PROBLEM IDENTIFICATION REPORT
YUBA RIVER LEFT BANK LEVEE
SPRR TO SIMPSON LANE
(APPROXIMATE PLM 0.9 TO 2.2)
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

August 29, 2005

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August 29, 2005
File: 51730

Mr. Ken Myers, PE
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Subject: Problem Identification Report
Yuba River Left Bank Levee
SPRR to Simpson Lane
(Approximate PLM 0.9 to 2.2)
Reclamation District 784
Yuba County, California

Dear Mr. Myers:

Kleinfelder is pleased to present the attached Problem Identification Report (PIR) describing the results of our evaluation of the Yuba River left bank levee within Reclamation District 784 (RD 784) in Yuba County, California. The portion of the levee evaluated extends from the Southern Pacific Railroad (SPRR) east to Simpson Lane, or approximate project levee mile (PLM) 0.9 to 2.2. The purpose of our investigation was to explore and evaluate levee and subsurface geotechnical conditions in accordance with Federal Emergency Management Agency (FEMA) guidelines for seepage and stability. The enclosed report contains a summary of our field explorations, laboratory testing, and engineering analyses together with our conclusions and preliminary recommendations.

In the attached report we have incorporated our responses to review comments on the draft PIR (June 14, 2005) provided by Mr. Henri Mulder of Sacramento District US Army Corps of Engineers and Mr. Peter Hradilek of HDR Engineering. Written comments and responses are included in the appendix of the attached report.

Based on available geotechnical data and the results of our field exploration, laboratory testing, and engineering analyses, it is our professional opinion the subject levee does not currently meet FEMA geotechnical certification requirements for seepage. However, based on our preliminary evaluation of alternatives it is our opinion the seepage conditions can be mitigated either by constructing a slurry cutoff wall or a new combination levee/berm set forward into the floodplain.
We appreciate the opportunity of providing our services for this project. If you have questions regarding this report or if we may be of further assistance, please contact us.

Sincerely,

KLEINFELDER, INC.

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Read the Full Report
Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors
Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client’s goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:
- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:
- the function of the proposed structure, as when it’s changed from a parking garage into office building, or from an oilfield plant to a refrigerated warehouse.
- elevation, configuration, location, orientation, or weight of the proposed structure.
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

Subsurface Conditions Can Change
A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions
Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Relaying the geotechnical engineer who developed your report to provide construction observation is the best method of managing the risks associated with unanticipated conditions.

A Report’s Recommendations Are Not Final
Do not overly rely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual
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1 INTRODUCTION

1.1. GENERAL

In this report we present the results of our geotechnical investigation and preliminary evaluation of the Yuba River left bank levee within Reclamation District 784 (RD 784) in Yuba County, California. The portion of the levee evaluated extends from the Southern Pacific Railroad (SPRR) east to Simpson Lane, or approximate project levee mile (PLM) 0.9 to 2.2. The site location relative to cities, rivers, and existing roadways is shown on Plate 1.

This report includes our preliminary recommendations related to the geotechnical aspects of project design and construction. Conclusions and recommendations presented in this report are based on the subsurface conditions encountered at the locations of our explorations and the provisions and requirements outlined in the LIMITATIONS section of this report. Recommendations presented herein should not be extrapolated to other areas or used for other projects without our prior review.

1.2. PURPOSE AND SCOPE OF SERVICES

The purpose of our investigation was to explore subsurface conditions and perform a feasibility level evaluation of site levee and subsurface geotechnical conditions in accordance with Federal Emergency Management Agency (FEMA) requirements for seepage and stability. We have not performed evaluations of either erosion or settlement conditions.

The scope of our services for PLM 1.2 to 2.2 was originally outlined in our proposal dated January 27, 2005. The scope of work was subsequently modified to include reevaluation of the reach from PLM 0.9 to 1.2. The drilling method was also modified from rotary to hollow stem auger. This change was in order to better facilitate drilling

1 Union Pacific currently operates the railroad at the downstream limit of the project area. In order to differentiate this railroad in this report from others near the project area it is identified by its previous name, Southern Pacific, as it appears on USGS maps.
penetration and recovery in the coarse grain, highly permeable, cohesionless gravels and cobbles underlying the study area. The modified scope included the following:

- A review of available subsurface information contained in our files and obtained from the US Army Corps of Engineers (USACE) pertinent to the project site;
- A geomorphic evaluation using historic topographic maps and geologic maps;
- Exploration of the site subsurface conditions utilizing 5 drilled borings;
- Limited laboratory testing of representative samples obtained during the field investigation to evaluate relevant engineering parameters of the subsurface soils;
- Engineering analyses on which to base our assessment of the levee stability and compliance of the levee with USACE and certain FEMA criteria;
- Preparation of this report which includes the following items:
  - A description of the proposed project;
  - A brief description of the site geology and geomorphology;
  - A description of the surface and subsurface site conditions encountered during our field investigation;
  - Preliminary recommendations concerning levee:
    - Stability
    - Seepage
    - Erosion potential
    - Mitigation alternatives
  - Appendices that include a summary of our field investigation and laboratory testing programs, a summary of our seepage and slope stability analyses performed, and photographs of select samples containing gravel collected during our field exploration.

1.3. PREVIOUS INVESTIGATIONS, REPORTS, AND CONSTRUCTION DRAWINGS

We have reviewed a number of previous reports that evaluated the subject levee with respect to erosion, seepage, and stability. The Sacramento District USACE prepared a report dated January 1990 entitled “Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Marysville/Yuba City Area.” This report includes a summary of findings and recommendations presented in the following two reports prepared for the USACE by The MARK Group: “Geotechnical Report for Subsurface Explorations, Levee Evaluations, Yuba County, California”, dated September 2, 1988,
and "Geotechnical Stability Assessments, Levee Evaluations, Yuba County, California", dated April 21, 1989. It also includes the USACE Sacramento District report dated October 1989 entitled "Office Report, Geotechnical Evaluation of Levees in Yuba, Sutter, and Butte Counties." The Yuba River left bank levee was evaluated as part of the studies and the breach that occurred on February 20, 1986 downstream of this levee reach is discussed.

We received levee subsurface profile drawings from the Sacramento District USACE that included simplified logs from 1988, 1991, 1997, 2001, and 2004 USACE explorations along the Yuba River left bank levee. These profile drawings also indicated the location and invert of a slurry cutoff wall completed in 1997 and the location and size of a landside berm-and-drain completed in 1998 within the subject levee reach. In addition, we received from the USACE detailed logs of several explorations performed in 1988, 1997, 2001, and 2004 within the subject levee reach. We reviewed these profile drawings and exploration logs and used them with exploration logs from the current study in our evaluation of the subject levee. The USACE levee subsurface profile drawings for the subject levee reach are included on Plate 4 of this report along with logs of explorations from the current study.

We received from the USACE a copy of seepage analysis computations and results for the Yuba River left bank levee dated May 2004. We reviewed these analysis results and incorporated them into our current evaluation of the subject levee reach.

From the USACE we also received contract drawings dated July 1996 for the Contract 2A-Site 6 slurry wall and as-built drawings dated June 1997 (some revisions noted in 2000) for the Contract 2B-Site 6 landside berm and toe drain, each of which were constructed along portions of the subject levee reach. We reviewed these contract and as-built drawings and used information in the drawing details in our evaluation of the levee.

We previously performed subsurface explorations along the Yuba River left bank levee between Highway 70 and the SPRR (approximate PLM 0.32 to 0.9) and prepared a Problem Identification Report for this adjacent reach. Subsequently, we also performed additional seepage analyses relative to the subject levee between just downstream of Highway 70 and the SPRR and between the SPRR and the downstream end of a slurry cutoff wall completed in 1997 (overall reach from approximate PLM 0.28 to 1.23) and
prepared two memoranda relative to this levee reach. These previous reports are as follows:

- "Problem Identification Report, Yuba River Left Bank Levee, Highway 70 to SPRR (Approximate PLM 0.32 TO 0.91), Reclamation District 784, Yuba County, California," dated June 11, 2004. File No. 43299, prepared for Three Rivers Levee Improvement Authority.
- "Technical Memorandum, Alternatives Assessment Yuba River Repair, Yuba County, California," dated September 23, 2004. File No. 46111, prepared for HDR Engineering, Inc. (Note: This report also addressed the subject levee upstream of the SPRR to the downstream end of the existing slurry cutoff wall near PLM 1.23).

We received and reviewed results of a pump test conducted in 1997 by the California Department of Water Resources (DWR) using an extraction well located northwest of the intersection of the Yuba River left bank levee and the Southern Pacific Railroad. Time-drawdown and time-recovery curves were developed by DWR for six observation wells and used to evaluate horizontal aquifer permeability. The calculated horizontal permeability varied from about 375 to 1278 feet per day with an average from six drawdown and five recovery curves equal to about 750 feet per day.

1.4. PROJECT VERTICAL DATUM

Elevation references in this report are in feet and are based on the National Geodetic Vertical Datum of 1929 (NGVD29). We understand this vertical datum is being used in project design and construction documents.

1.5. LEVEE TOPOGRAPHIC DRAWINGS AND LEVEE MILE REFERENCE

Existing topography on and adjacent to the subject levee alignment was provided to us in electronic drawings by MBK Engineers containing USACE August 2003 survey data. It is our understanding the vertical datum for this survey was NGVD29. We used these drawings and the 1997 USACE Comprehensive Study topographic drawings, also with a vertical datum of NGVD29, to produce landside and waterside ground surface profiles within the vicinity of the respective levee toes and included these profiles on Plate 4.
We also used these two drawings to produce transverse levee cross sections for use in seepage and slope stability analyses, and to estimate ground surface elevations at Borings KB-6 through KB-10 for the current study and Borings KB-4 and KB-5 and cone penetration test (CPT) soundings C-6 through C-8 explored during a previous investigation.

Levee subsurface profile drawings received from the USACE included a horizontal axis labeled "ALM" and "PLM". "ALM" was interpreted as "Actual Levee Mile" and is the levee mile system used by RD 784, separated into district units and denoted by levee mile markers along the levee. "PLM" was interpreted as "Project Levee Mile" and is the levee mile system typically used by the USACE along the subject levee. This system begins with 0.0 where the Yuba River left bank levee meets the Feather River left bank levee and extends upstream along the Yuba River left bank levee crown. The "PLM" levee mile system is referred to in preceding and subsequent sections of this report and is shown on the horizontal axis of Plate 4.

In this report we have chosen not to use the horizontal stationing used by HDR in the Yuba River levee Phase 2 contract drawings, since this stationing does not yet extend upstream to Simpson Lane.

1.6. YUBA RIVER DESIGN WATER SURFACE PROFILES

The following design water surfaces for the Yuba River left bank levee were provided to us by MBK Engineers and Tustinson Engineering on April 27, 2005:

- 1-in-100 annual exceedance probability (1/100 AEP) water surfaces corresponding to "with project" and "without project" conditions; and
- 1-in-200 annual exceedance probability (1/200 AEP) water surface corresponding to "with project" and "without project" conditions.

We understand the term "with project" indicates the condition where the proposed Bear River right bank levee setback and other proposed levee and channel improvements are completed, and "without project" simply indicates the condition with existing levees. According to our interpretation of the above water surface profiles, there is essentially no difference between the "with project" and "without project" water surface profiles along the Yuba River left bank levee, and thus we leave out these descriptors of the
water surface profiles in subsequent sections of this report. The 1/100 AEP and 1/200 AEP water surface profiles within the subject levee reach are presented on Plate 4. In general, the 1/100 AEP water surface for the subject levee is about Elevation 74.7 at Simpson Road and decreases to about Elevation 73.3 at the SPRR. The 1/200 AEP water surface for the subject levee is about Elevation 79.0 at Simpson Road and decreases to about Elevation 77.5 at the SPRR. For comparison purposes, the 1957 design water surface profile (which was used by the USACE during the 1990 Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Marysville/Yuba City Area) ranged from approximate Elevation 77.5 at Simpson Lane to 77.0 at the SPRR.

In this report where we describe a condition that either meets or does not meet the 1/100 AEP river stage condition, we are referring to the minimum acceptable geotechnical requirements for levees as contained in the USACE Levee Design Manual (EM 1110-2-1913), Technical Letter Design Guidance for Levee Underseepage (ETL 1110-2-569), and Standard Operating Procedure (SOP) Geotechnical Levee Practice (EDG-03). When referring to the 1/200 AEP river stage condition, we are also using the same geotechnical performance criteria. Both of these conditions consider steady state conditions for seepage and stability.
2 SITE CONDITIONS

2.1. GEOLOGIC SETTING

The subject site is located in the eastern portion of the Sacramento Valley, the northern portion of California's Great Central Valley. The Sacramento Valley contains thousands of feet of accumulated fluvial, overbank, and fan deposits resulting from erosion of the adjacent Sierra Nevada Mountains to the east and Northern Coast Range to the west. These deep alluvial deposits pinch out as the boundaries of the basin are approached. The site is underlain by Holocene alluvium. The contact with Pleistocene alluvium is located at the east end of the site near Simpson Lane. Pleistocene alluvial deposits extend about 10 miles east of the project site where Pliocene alluvium and fan deposits occur. Bedrock units of the Foothills Metamorphic Belt (FMB) and the crystalline terrain or basement complex of the Sierra Nevada Batholith are exposed another 2 miles to the east.

The project site has been mapped by a number of geologists at a regional scale, including Jennings (1991), Wagner (1981), and Helley and Harwood (Helley 1985). Jennings and Wagner are both compilation maps that reflect mapping by previous authors and thus show geologic interpretation similar to Helley. Helley’s mapping focused on Quaternary geologic units based on geomorphology and was performed at a scale of 1:62,500, making this mapping the most beneficial information relative to engineering properties of near-surface deposits. Helley maps several Quaternary earth units in the region shown including (from youngest to oldest):

- **Stream Channel Deposits (Qsc):** Recent and often Historic alluvial deposits generally consisting of unconsolidated sand, gravel, and silt contained primarily in active river and tributary channels. Includes material deposited from hydraulic mining activities.

- **Alluvium (Qa):** Pre-levee construction alluvium is mapped adjacent to the active river or tributary channels and consists of Holocene high energy fluvial deposits (i.e. sand and gravels) and overbank and fan deposits (i.e. sand, silt, and clay) that are also unconsolidated.
• Basin Deposits (Qb): Helley differentiates basin deposits from alluvium (Qa) on the basis of composition including only those deposits that are finer-grained and frequently organic-rich and suggests these deposits were distal deposits where energy conditions are much lower.

• Modesto Formation (Qm): Unconsolidated and older alluvium (i.e. pre-Holocene, Pleistocene estimated 12,000-42,000 years of age) is mapped along present day and ancestral tributaries of the Sacramento and Feather Rivers and their tributaries.

• Riverbank Formation (Qr): Semi-consolidated alluvial sand, silt, and clay with gravel are generally mapped throughout the area east of and upslope of the present-day Sacramento and tributary drainage systems. These deposits are estimated 130,000-450,000 years of age (mid-Pleistocene) deposits containing high pedogenic silt and clay content and reddish hues reflective of its relative age.

The location of Holocene alluvium relative to the site is depicted on Plates 2A through 2D.

2.2. YUBA RIVER HISTORIC GEOMORPHOLOGY

The filling of the Sacramento Valley with sediments has significantly reduced the gradient of rivers (including the Yuba River) flowing down from the Sierra Mountains east of the site. This gradient reduction has caused the energy of these rivers to transition from erosional to graded. Graded rivers are characterized by erosion that is less dominant and directed toward side to side rather than down-cutting. The lateral energy of the river causes synchronous erosion and deposition in sweeping bands commonly referred to as meanders. The outside of the meander is a zone of erosion. Material removed from the river at this zone is then deposited downstream as point bars in zones of decreased velocity on the inside of other meanders. In this way the river migrates across the flood plain. Often this erosion is slowed where the river encounters more resistant portions of the flood plain. This allows the next closest upstream meander to catch up and gradually erode away the “neck” between the two meanders. Flooding often accelerates this process as the higher energy flows can more easily cut a new thalweg (base of the active channel). The result of the conjoining meanders is the straightening of the river at that point of intersection and the creation of an abandoned bend in the river commonly referred to as an oxbow lake.
Review and comparison of historic topographic maps with current topographic maps, aerial photographs, and geologic maps of the Yuba River in the project area reveal features indicative of graded rivers described above. A number of oxbow scars, channel remnants, and outside meander erosion scars can be identified south of the site and crossing beneath the existing levee system as shown on Plates 2A through 2D. These historical remnant river features are evidence the Yuba River has historically migrated across the flood plain creating and abandoning channels throughout the process. These abandoned channels are typically filled with loose granular sediments deposited by the river when it flowed through the channels. Heiley (1985) has mapped several abandoned channels at the site through evidence of these unconsolidated coarse sediments. However, often the coarse grained alluvium is "capped" by a relatively thin layer of silt and/or clay deposited from the river during more recent (post abandonment) flood stages. During these flood events the river overtops its current channels and carries with it finer grained materials that are deposited outside of the channels as the river recedes. Eventually these overbank deposits accumulate and can eliminate evidence of the older, abandoned river channels.

2.3. EXISTING SLURRY WALL AND LANDSLIDE TOE BERM AND DRAIN

According to the USACE Contract 2A contract drawings and Contract 2B as-built drawings along separate portions of the subject levee there is an existing slurry cutoff wall extending through the levee crown and a berm and drain located along the landslide toe. From our review of the above references we understand the existing slurry cutoff wall was constructed through the levee embankment to depths of about 40 to 45 feet below the levee crown between PLM 1.23 and 1.79. The slurry wall is at least 18 inches wide with an 18-inch thick compacted fill cap near the levee crown. Based on a conversation with USACE personnel, the seepage barrier was constructed as a soil-cement-bentonite (SCB) wall.

From our review of the above references we understand the landslide berm and toe drain were constructed between PLM 1.77 and 2.18, approximately between the upstream end of the slurry cutoff wall and Simpson Lane. In conjunction with construction of the berm and toe drain within this levee reach a landward portion of the landslide railroad spur embankment was removed and the levee crown was widened landward to produce an approximately 20-foot wide crown. The toe drain consists of an approximately 1-foot wide by 6½-foot deep trench filled with drain rock overlain with a 1-
foot thick layer of drain rock extending about 3 to 6 feet up the levee slope and out to the toe of the new berm. The rock filled trench was planned to be excavated 9 feet into foundation materials, but was shortened during construction. The drain rock is wrapped with a geotextile filter fabric. According to the Contract 2B as-built drawings, the new berm constructed on top of the toe drain is 10 feet wide at the top and 5 to 8 feet high, with the top at Elevation 71.5 to 73.0 on the drawings. However, on the USACE August 2003 topographic survey drawing, the top of the berm is shown at Elevation 73 to 75. Approximate extents of these existing construction features are shown in profile view on Plate 4.

2.4. EXISTING SURFACE CONDITIONS

2.4.1. Levee Alignment and Geometry

The Yuba River left bank levee under evaluation for this study is located near the southern end of Marysville in Yuba County, California. The levee reach relative to cities, rivers, existing roadways, and other adjacent surface features is shown on Plate 1 on a USGS topographic map and on Plate 3 on an aerial photograph from the 1997 USACE Comprehensive Study. The levee reach is located upstream of the confluence of the Yuba and Feather Rivers between the SPRR (approximate PLM 0.9) and Simpson Lane (approximate PLM 2.2). The levee is constructed of earth fill and is surfaced at the crown with a gravel patrol road.

Between the SPRR and approximately PLM 1.23, the levee is about 60 to 80 feet wide at the crest. We understand some of the waterward levee fill consists of sawdust/wood chips from a nearby timber processing facility. Between PLM 1.23 and Simpson Lane the levee is about 15 to 20 feet wide at the crest. The entire reach of levee between the SPRR and Simpson Lane was augmented by a landside embankment associated with a railroad easement. According to the USACE 2003 topographic drawing, the landside railroad embankment top elevation varies between about Elevation 75 and 77. Between the SPRR and about PLM 1.23 the landside embankment supports a railroad spur. As discussed previously in this report, from PLM 1.77 to 2.18 the landside railroad embankment was incorporated into the 1998 levee crown widening/toe berm construction, where the toe berm top elevation is about 73 to 75. Levee crown elevations generally vary between approximately 80 and 82 feet within the subject reach, with a lower crown elevation (about 75 to 76) occurring at the SPRR crossing.
Landside toe elevations of the levee range from about 62 to 68. Waterside toe elevations range from about 60 to 69, with the lowest areas occurring within a portion of the levee where there is a depression along the waterside toe, extending from about PLM 1.33 to 1.89. Existing waterside slopes are generally on the order of 3 horizontal(h):1 vertical(v). Landside slopes are generally on the order of 2(h) to 2.5(h):1(v).

2.4.2. Vegetation

Some trees exist near the waterward and landward slopes in several locations along the subject levee primarily associated with residential areas (landside) and orchards (waterside). Other existing vegetation along the levee slopes includes low-lying grasses and shrubs. On the waterside of the levee are agricultural fields and orchards and some riparian forested areas.

2.4.3. Additional Waterside Features

A former borrow pit is located approximately 1000 feet north or waterward of the levee between the SPRR and about PLM 1.6. The main Yuba River channel is located at least ½ mile from the subject levee within this reach; however, according to aerial photographs taken during relatively low river stage levels the former borrow pit is typically partially full of water. This may indicate a direct connection for groundwater between the main channel and the borrow pit through sand or gravel layers.

2.4.4. Existing Development

Existing developments near the landward slopes of the subject levee include a concrete batch plant near the SPRR as well as a residential area extending from about PLM 1.23 to 1.79.

2.5. **SUBSURFACE CONDITIONS ENCOUNTERED**

The subsurface conditions at the site were explored most recently by Kleinfelder between April 7 and April 13, 2005, by drilling 1 boring through the levee crown and 4 borings at the waterside levee toe. Previous explorations were performed by Kleinfelder between June 29 and July 2, 2004 by drilling 2 borings through the levee
crown and advancing 3 cone penetration test (CPT) soundings at the landside toe of the levee. The exploration depths ranged from 60 to 91½ feet through the levee crown, 66 to 76 feet below the waterside levee toe, and 30 to 42 feet below the landside levee toe. A discussion of the field investigation and laboratory testing programs is presented in Appendices A and B, respectively, of this report. Detailed descriptions of the subsurface conditions encountered during our field investigation are presented on the Logs of Borings, Plates A-3 through A-9, and CPT Test Logs, Plates A-10 through A-12 in Appendix A. Boring and CPT logs from current and previous investigations are shown on a levee profile presented on Plate 4.

Based on the geomorphology and geologic review, numerous oxbow scars, channel remnants, and outside meander erosion scars were located within the project boundaries. As stated in Section 2.2, these types of features commonly create highly variable subsurface conditions, which can be seen in our subsurface description to follow and on the levee profile shown on Plate 4.

In general, the levee fill encountered along the project reach consisted of silty sand to relatively “clean” sand (i.e. low percentage passing the No. 200 sieve). Levee crown elevations ranged from approximately 80 to 82 and the height of levee ranged from approximately 15 to 20 feet.

Subsurface materials encountered along the levee alignment have been divided into three units. These units include a near surface layer of highly variable braided alluvial deposits consisting of sand, silty sand, and sandy silt underlain by a layer of coarser grain soils including sands, gravels, and cobbles followed by a fine grained layer consisting predominately of silt and clay.

The upper layer consisted predominately of sandy silt, silty sand, and sand to elevations ranging from 20 to 45. Based on our laboratory testing the fines content of the poorly graded sand ranged from about 1 to 13 percent.

The second subsurface layer consisted predominately of sand and gravels with sand and cobbles. Based on our laboratory testing, these soils had a fines content ranging from about 1 to 12 percent. The top of the gravelly layer typically ranged from approximately Elevation 20 to 45 with a thickness of up to 30 feet. A maximum particle size of 6 inches was observed; however, larger cobbles and even boulders are
expected to be present but were not observable with the exploration methods employed. The coarse alluvial layer pinches out near Simpson Lane. Refer to Appendix D for photographs showing materials obtained during our field sampling using a 2.4-inch I.D. California Sampler.

Underlying this coarse sand and gravel layer, the third layer consisted predominately of very stiff to hard sandy silt and low to high plasticity clays and dense to very dense clayey sand and silty sand to the total depth explored (approximately Elevation -11).

2.6. PAST LEVEE PERFORMANCE

Based on accounts during previous flood events, a large boil was documented along the landside toe of the levee near PLM 2.2 in 1955 and numerous boils were observed between PLM 1.0 and 2.0 during the 1986 flooding.

2.7. GROUNDWATER

At the time of our field investigation free groundwater in our borings ranged between approximate Elevations 27 to 45.

DWR maintains a water data library on the Internet (http://well.water.ca.gov/) containing groundwater depth measurements from numerous monitoring wells throughout the State. Data for three wells located within 1.6 miles of the subject levee indicates groundwater elevations varied between approximately 64 and 2 between the years of 1963 and 2004.

It should be noted that groundwater and soil moisture conditions within the area will vary depending on Yuba River stage, rainfall, irrigation practices, and/or runoff conditions not apparent at the time of our field investigation.
3  ENGINEERING ANALYSES

3.1.  GENERAL


3.2.  EMBANKMENT PROTECTION

Evaluation of embankment protection was performed in accordance with FEMA requirements of Section 65.10 (b) Part (3) of the NFIP.

The main Yuba River channel, located over ½ mile from the subject levee is gently sinusoidal with flow essentially tangential to the levee embankment. The flood plain between the main channel and the levee is presently covered with a sparse to moderate growth of grasses, shrubs, and trees, including some orchards. The existing levee embankment consists primarily of sand and silty sand and is presently covered with a sparse growth of grasses.

Throughout a majority of the year, water depths within the channel are expected to remain relatively shallow and contained within the low-flow channel. Sandy soils observed at the ground surface near the waterside toe of the left bank levee and within the levee embankment appear to be erodible. However, erosion potential of these materials depends on the anticipated river velocities at design water surface elevations, which we do not know at this time. Based on EM 1110-2-1601 referenced above the suggested maximum permissible mean channel velocity for "earth channel material" consisting of sand and silty sand is 2.0 feet per second (fps). If the anticipated river velocities at design water surface elevations are greater than 2.0 fps, it is our opinion erosion protection such as rock slope treatment should be provided along the waterside.
slopes of the subject levee. We recommend a qualified hydraulic engineering consultant perform more thorough erosion potential analysis.

3.3. SEEPAGE ANALYSIS

3.3.1. General

Levee through seepage and underseepage were evaluated in accordance with FEMA requirements of Section 65.10 (b) Part (4) of the NFIP. Since the majority of soils encountered in our investigation were essentially non-plastic and assumed to be erodible, maximum vertical exit gradients were used for determining underseepage risk (as opposed to using average vertical gradients through a blanket layer). Based on recommendations made by the Levee Seepage Task Force (2003), a maximum vertical exit gradient of 0.5 was used as performance criterion for our analysis.

Based on observed subsurface conditions at the site, the existing levee embankment consists of sand and silty sand. These materials could provide a path for through seepage and resulting levee instability during elevated river stages. Some of these potential through seepage paths and corresponding levee materials have been cutoff by construction of a cutoff wall through the levee crown and into the levee foundation. In addition, the existing landslide berm and toe drain located upstream of the cutoff wall could intercept some through seepage during elevated river stages. In our opinion additional through seepage mitigation is needed within the subject levee reach, likely in the form of additional cutoff walls through the levee embankment, partial levee fill replacement with impervious fill along the waterside slope, or raising the existing landslide stability berm to at least the 1/100 AEP (or conservatively the 1/200 AEP) water surface elevation. These through seepage mitigation alternatives could be incorporated into the underseepage mitigation alternatives modeled and discussed below.

Following in this report section we provide an explanation of seepage analysis cross sections and a table of analysis results. Refer to Appendix C for a detailed description of the methods used in analyzing underseepage potential of the chosen cross sections, soil parameters used in our analysis, and computer model printouts of our seepage analysis results.
3.3.2. Sections Analyzed

Underseepage analyses were performed at 2 cross sections using 3 soil profiles representing subsurface conditions along the levee. Cross sections for these analyses were determined after reviewing boring and CPT logs for this project reach and identifying locations with stratigraphy associated with different degrees of underseepage potential. Analysis Sections G-G' and H-H' along the levee were projected perpendicular to the levee about 50 feet upstream of Boring KB-8 and about 200 feet downstream of Boring KB-10, respectively. Section G-G' was analyzed using Borings 2F-97-5 and 2F-97-6, and Section H-H' was analyzed using Boring 2F-01-15. In addition the bottom portion of the stratigraphy for the analysis cross sections was based on deeper borings in the vicinity. Locations of these analysis cross sections are shown on Plate 3.

Subsurface conditions associated with the analysis cross sections were modeled based on the information obtained by Kleinfelder during our site investigation and subsequent laboratory testing performed for the project, as well as using subsurface data from previous explorations by USACE and others. The three subsurface profiles analyzed represented perceived critical case seepage conditions based on the levee and channel geometry and/or subsurface profile.

The levee cross sections were determined using the USACE 2003 topographic drawing. The cross sections were extended approximately 300 feet to the waterside of the levee and 500 feet to the landside of the levee. Elevations of these portions of the cross section were taken to be the lowest elevation within 200 feet of the levee toe and set at a constant elevation from the levee to the edges of the model. These elevations do not necessarily reflect the toe elevations that are shown on the levee profile on Plate 4. An existing slurry cutoff wall 2-feet wide by 45-feet deep was modeled through the center of the levee in Section G-G', and the existing railroad and stability berms were modeled as depicted on the topographic drawing.

In Section G-G' the silt foundation layer directly beneath the levee fill was modeled as being continuous under the levee and beyond the landside levee toe but nonexistent looking waterward from the waterside toe. This foundation/blanket condition was used based on observation of sand materials adjacent to the waterside toe during our field exploration.
Two mitigation alternatives were analyzed in order to assess their effectiveness in reducing the vertical exit gradients. These included a 2-foot wide fully penetrating slurry cutoff wall and a 300-foot wide seepage berm (maximum berm). In the seepage models the cutoff wall was extended from the centerline of the levee through the embankment fill for Section H-H' and extended from the waterside toe in Section G-G'. Both cutoff wall models typically keyed 5 feet into an underlying lower-permeability material. Depths of the cutoff wall ranged from about 50 to 60 feet below the waterside toe in Section G-G' and approximately 40 to 80 feet below the top of the levee in Section H-H'. In Section G-G' the waterside cutoff wall model included additional impervious levee fill constructed over the cutoff wall to the full height of the existing levee.

Simplified berm geometry was used for feasibility analysis. For the seepage berm alternative the berm was modeled as 14-feet thick in Section G-G' and 11-feet thick in Section H-H'. The top of the seepage berms coincides with the 1/100 AEP water surface elevation of approximately 74. Due to an existing residential development on the landside adjacent to Section G-G', for this cross section the berm was modeled on the waterside of the levee along with a new set-forward levee constructed on the waterside of the berm. The set-forward levee was modeled with side slopes of 3(h) to 1(v) waterside, 2(h) to 1(v) landside, a crown width of 20 feet, and crown elevation approximately equal to that of the existing levee (approximate Elevation 80).

The cross sections were analyzed for steady-state seepage with the Yuba River at a 1/100 AEP water surface elevation modeled with the existing conditions. The sections were then modeled using the 1/200 AEP water surface elevation with the mitigation alternatives in place.

3.3.3. Analysis Results

The data obtained from our analysis (both average and maximum vertical gradient) were compared to the performance criterion of 0.5 for existing levees with no past distress. In the case of cross section H-H' with a landside seepage berm added to the project levee, the analysis results were compared to the maximum calculated exit gradient of 0.8 at the end of the berm, as given in the Sacramento District USACE Standard Operating Procedure (SOP) EDG-03 "Geotechnical Levee Practice".
Results of the analyses are presented in Table 3.1 below. Graphical presentations of the seepage analyses presenting contours of vertical gradients at 0.1 intervals and total head at 1-foot intervals are presented in Appendix C for the three subsurface analysis sections evaluated.

### Table 3.1
Calculated Vertical Gradients

<table>
<thead>
<tr>
<th>SECTION</th>
<th>Yuba River 1/100 AEP Water Surface Elevation</th>
<th>Yuba River 1/200 AEP Water Surface Elevation</th>
<th>Average Gradient at Landslide Toe¹</th>
<th>Maximum Exit Gradient Through Landslide Blanket¹</th>
<th>Maximum Allowable Exit Gradient</th>
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<tr>
<td><strong>G-G'</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>2F-97-5</td>
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<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
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<td>Cutoff Wall</td>
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<td>0.1</td>
<td>0.5</td>
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<td></td>
<td>Waterside Berm and Levee</td>
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<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
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<td>-</td>
<td>0.8</td>
<td>0.9</td>
<td>0.5</td>
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<td></td>
<td>Cutoff Wall</td>
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<td>0.2</td>
<td>0.5</td>
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<tr>
<td></td>
<td>Waterside Berm and Levee</td>
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<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>H-H'</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2F-01-15</td>
<td>Existing Conditions: 74.6</td>
<td>-</td>
<td>0.8</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Cutoff Wall</td>
<td>78.8</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Landside Seepage Berm</td>
<td>78.8</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

¹ Gradients in bold reflect the value greater than the allowable exit gradient.
3.4. EMBANKMENT AND FOUNDATION STABILITY

Landside levee topography consists of two slopes, one above and one below the railroad grade. Individually the slopes are near 2 horizontal (h) to 1 vertical (v) (2h:1v). In combination with the bench the composite slopes are flatter than 2h:1v. Stability analysis performed for the adjacent reach downstream of SPRR on 2h:1v slopes composed of cohesionless silty sand indicate a factor of safety greater than 1.5 under steady state seepage conditions. On the subject reach, the presence of the railroad grade, slurry wall, and drained stability berm should result in a stability factor of safety greater than the calculated 1.5.

Waterside levee slopes are equal to or flatter than 3h:1v along this reach except near cross-section H-H' where the slope is slightly steeper than 3h:1v. Stability analysis performed for the adjacent reach downstream of SPRR on 3h:1v slopes composed of silty sand and sandy silt indicate a factor of safety between 1.0 and 1.1 under rapid drawdown conditions. The presence of a slurry cutoff wall in the levee generally decreases the factor of safety under rapid drawdown conditions since the piezometric surface before drawdown is usually higher than a condition without the slurry wall. In practice cohesionless soils which would be most susceptible to surface sloughing are also the most likely to drain during drawdown conditions which are moderated by dam controlled release operations upstream of the subject reach. Surface sloughing due to drawdown may be difficult to distinguish from wave erosion and in fact may be due to a combination of factors. In conclusion, some combination of surface sloughing and wave erosion may occur but is not expected to compromise the integrity or freeboard of the levee. Maintenance of cohesionless waterside slopes should be addressed in the levee operations and maintenance plan.
4.2. SEEPAGE CUTOFF BARRIER

4.2.1. General

In our opinion, the most positive means of implementing underseepage mitigation would involve construction of a seepage cutoff barrier which completely penetrates underlying permeable strata. The presence of the coarse grain foundation soils impact the penetration resistance and slurry retention of several methods.

Of importance in the evaluation of a seepage barrier is the certainty of continuity of treatment. Some of the methods described below involve single and or multiple penetrations/injections to create the barrier. The diameter of the treated zone along with ability to maintain verticality will be important in assessment of each alternative.

4.2.2. Slurry Wall

Conventional soil/cement/bentonite (SCB) or soil bentonite (SB) slurry walls have been used successfully in the Sacramento River Valley. A 3-foot wide (SCB) or 5-foot wide (SB) wall penetrating up to 80 feet below the existing levee crown is recommended. The coarse grain soils present at this site may preclude this alternative at this location. The coarse materials will be difficult to penetrate, the sidewalls may cave/slough, and the slurry may flow into the particle voids. We encountered each of these conditions during drilling of our small diameter test borings. Before implementation of this alternative is considered further, we recommend at least one test section be constructed to further evaluate construction feasibility. The test section(s) should be excavated in the vicinity of the waterside levee toe and should be planned to fully penetrate the coarse grain soil layer. The trench should be filled with a water/bentonite slurry during excavation.

4.2.3. Jet Grouting

The use of jet grouting methods have been shown to be effective in coarse grain soils at locations outside the Sacramento River Valley. We are not aware of their use in similar conditions in this area. The construction of a fully penetrating jet grout cutoff wall from the top of the levee down to an underlying fine grain soil layer is likely cost prohibitive. However, we do believe there is merit in considering jet grouting only those
permeable layers extending below the existing slurry wall along this reach. The tie in
details/overlap would need to be developed but for cost estimating purposes, we expect
it would need to be on the order of about 10 feet. Triple fluid construction methods
should be anticipated. A pilot hole may be needed at each jet grout column location.

4.2.4. Deep Soil Mixing

Deep soil mixing techniques have been used successfully in the area for seepage
mitigation. However, the coarse grain soils may inhibit mixing auger penetration.
Advance pilot drilling may enable this method to be used. Before this alternative is
considered further, we recommend a test shaft be drilled (with casing) in order to
retrieve representative samples for particle size confirmation.

4.2.5. Drilled Secant Pile Wall

We are aware of secant pile walls being used successfully as seepage barriers in
coarse grain soil locations (Las Vegas, Nevada). An outer casing is used to penetrate
the coarse grain soils and prevent caving. Special mixes may be needed to prohibit
loss of SCB or SB slurry. If this method appears feasible, we recommend at least one
test location to evaluate construction conditions.

4.2.6. Steel Sheet Piles

Driven steel sheet piles have been successfully used for seepage barriers. However, it
is not known whether the piles can fully penetrate the dense, coarse grain soils and
maintain an interlock. If this alternative appears cost effective, a test program should
also be considered. A corrosion mitigation system consisting of sacrificial
anodes/cathodes may have to be constructed to extend service for a 50-year design
life.

4.2.7. Shored Excavation

Exotic methods of sheet piling and/or ground freezing could be used to stabilize the
trench sidewalls such that a conventional trench excavation could occur. We do not
believe these alternatives would be cost effective but present them for completeness of
method consideration.
4.3. RELIEF WELLS

The use of relief wells was considered downstream of this location. It was not selected due to the relatively close spacing of wells and high quantities of groundwater which would need to be collected/disposed. In the limited area of the existing development, this system may have merit. The existing railroad berm would need to be relocated along the waterside of the levee. After berm removal, partially penetrating relief wells 50 to 60 feet deep spaced 25 to 50 feet apart could be constructed. A maximum discharge of about 150 to 300 gallons per minute (gpm) should be anticipated from each relief well. The relief wells should discharge above grade for monitoring purposes. Maintenance should be performed on each well at 2 to 5 year intervals.

4.4. SEEPAGE BERM

Due to the elevated seepage gradients at this location the maximum width seepage berm (300 to 400 feet) should be constructed. We recommend this landside berm be constructed with pervious materials similar in thickness and shape as the berm recommended for construction downstream of this location. Because of end effects, we recommend the existing slurry wall located upstream of Simpson Lane be extended downstream (across Simpson Lane) at least 500 feet.

An alternative to berm construction landside of the existing levee would be a new combination levee/berm along the waterside. The resulting configuration should be a maximum 300-foot wide berm utilizing the existing levee embankment. Removal of the reported wood chip material along the waterside slope of the downstream reach of levee would be required prior to berm construction. The new levee should be constructed according to California Title 23 standards. The berm material should be considered impervious.
5 LIMITATIONS

Recommendations contained in this report are based on our field observations and subsurface explorations, laboratory tests, and our present knowledge of the proposed construction. It is possible that soil conditions could vary between or beyond the points explored.

We have prepared this report in substantial accordance with the generally accepted geotechnical engineering practice as it exists in the site area at the time of our study. No warranty is expressed or implied.

This report may be used only by the Client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on site and off site), or other factors may change over time and additional work may be required with the passage of time. Any party other than the Client who wishes to use this report shall notify Kleinfelder of such intended use. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the Client or anyone else will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party.
6 REFERENCES


Cedergren (1967), "Seepage, Drainage, and Flow Nets".

DWR (1997), State of California Department of Water Resources, "Results of Pump Test of Left Bank Levee of Yuba River near the SPRR."


Freeze and Cherry (1979), "Groundwater".


USGS (1911), Yuba City Quadrangle, California – 7.5 Minute Series (Topographic), Edition of July 1911, US Geological Survey, obtained from the Meriam Library at California State University, Chico.


Yuba County (1887), "Official Map, Yuba County, State of California," compiled and drawn by J.M. Doyle, approved by the Yuba County Board of Supervisors in November 1887, obtained from the Meriam Library at California State University, Chico.
PLATES
APPENDIX A
APPENDIX A

FIELD INVESTIGATION

FIELD INVESTIGATION

The subsurface conditions at the site were explored most recently by Kleinfelder between April 7 and April 13, 2005, by drilling 1 boring through the levee crown and 4 borings at the waterside levee toe. These explorations included Borings KB-6 through KB-10. Previous explorations were performed by Kleinfelder between June 29 and July 2, 2004 by drilling 2 borings through the levee crown and advancing 3 cone penetration test (CPT) soundings at the landside toe of the levee. These earlier explorations included Borings KB-4 and KB-5 and CPT soundings C-6 through C-8. The ten exploration depths ranged from 60 to 91½ feet through the levee crown, 66 to 76 feet below the waterside levee toe, and 30 to 42 feet below the landside levee toe. The borings were drilled either by Western Strata Exploration of Clarksburg, California using a Mobile Drill B-61 truck mounted drill rig equipped with 8-inch diameter hollow stem auger or by Spectrum Exploration of Stockton, California using a CME 85 truck-mounted drill rig equipped with a 8-inch diameter hollow stem auger and 4- to 5-inch-diameter rotary wash drill bit. Casing was also advanced when drilling fluid circulation was not possible due to clean, coarse gravel layers encountered at depth. The cone penetration tests were performed by Fugro Geosciences of Oakland, California.

Upon completion of explorations, locations were recorded using a handheld Global Positioning System (GPS) unit with a horizontal accuracy of 10 to 50 feet. Latitude and longitude coordinates of boring locations were converted to northing and easting coordinates based on the California Coordinate System Zone II (1983 North American Datum). Ground surface elevations (NGVD29 datum) at exploration locations were estimated from available project topographic drawings. Northing and easting coordinates and approximate ground surface elevations for Borings KB-4 through KB-10 are shown on the boring logs included in this appendix. Plan locations of explorations are shown on Plate 3 of this report or an aerial photograph from the 1997 USACE Comprehensive Study.
Our engineer and geologist maintained logs of the borings, visually identified and classified soils encountered in general accordance with ASTM Standard Practice D 2488 and the Unified Soil Classification System (see Plate A-1), and obtained disturbed and relatively undisturbed samples of the subsurface materials. Upon completion of laboratory testing, soil classifications were evaluated in general accordance with ASTM Standard Practice D 2487 and are presented on the Logs of Borings. Soil parameters were derived from the CPT data using known relationships between the measured tip resistance and the side friction. Fugro Geosciences used proprietary computer programs to derive the soil behavior type and equivalent Standard Penetration Test blow count for the various soil layers encountered. Interpreted soil parameters were compared to nearby soil borings to evaluate the accuracy of the interpretations. A key to the Logs of Borings is presented on Plate A-2. Logs of Borings are presented on Plates A-3 through A-9. Graphical logs of CPT soundings are presented with interpreted soil parameters on Plates A-10 through A-12. Boring and interpreted CPT logs are also shown on a levee profile on Plate 4.

Soil samples were obtained using California samplers driven 18 inches (unless otherwise noted) into undisturbed soil using a 30-inch drop of a 140-pound automatic hammer, with the exception of Boring KB-10 in which some samples were obtained using the automatic hammer and some were obtained with a 140-pound downhole hammer attached to a wireline. Blow counts were recorded at 6-inch intervals for each sample attempt and are reported on the logs in terms of blows-per-foot for the last foot of penetration. Bulk soil samples were obtained from the drill cuttings in the upper fine grained soils to depths ranging from 32 to 55 feet to aid in soil classification in place of drive samples for Borings KB-6 through KB-10. Soil samples obtained from the borings were packaged and sealed in the field to reduce moisture loss and disturbance, and returned to our Sacramento laboratory for further testing. After borings and CPTs were completed, they were backfilled with cement grout in accordance with County of Yuba criteria. Excess cuttings and drilling fluid were left spread-out onsite.
LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

<table>
<thead>
<tr>
<th>Plate A-1</th>
<th>Unified Soil Classification System</th>
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<tbody>
<tr>
<td>Plate A-2</td>
<td>Log Key</td>
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<tr>
<td>Plate A-3</td>
<td>Log of Boring KB-4</td>
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<td>Plate A-4</td>
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<td>CPT Test Log C-7</td>
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<tr>
<td>Plate A-12</td>
<td>CPT Test Log C-8</td>
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# Unified Soil Classification System

## Major Divisions

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<thead>
<tr>
<th>Coarse Grained Soils</th>
<th>Typical Descriptions</th>
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<tr>
<td>Gravels (More than half of coarse fraction is larger than the #4 sieve)</td>
<td>Clean Gravels with Little or No Fines</td>
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<tr>
<td>GM</td>
<td>Silty Gravels, Gravel-Silt-Sand Mixtures</td>
</tr>
<tr>
<td>GC</td>
<td>Clayey Gravels, Gravel-Sand-Clay Mixtures</td>
</tr>
<tr>
<td>SANDS (More than half of coarse fraction is smaller than the #4 sieve)</td>
<td>Clean Sands with Little or No Fines</td>
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<td>SW</td>
<td>Well-Graded Sands, Sand-Gravel Mixtures with Little or No Fines</td>
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<tr>
<td>SP</td>
<td>Poorly-Graded Sands, Sand-Gravel Mixtures with Little or No Fines</td>
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<td>SM</td>
<td>Silty Sands, Sand-Gravel-Silt Mixtures</td>
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<td>SC</td>
<td>Clayey Sands, Sand-Gravel-Clay Mixtures</td>
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<td>Silts and Clays (Liquid limit less than 50)</td>
<td>Inorganic Silts &amp; Very Fine Sands, Silty or Clayey Fine Sands, Clayey Silts with slight plasticity</td>
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<tr>
<td>CL</td>
<td>Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays</td>
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<td>Organic Silts &amp; Organic Silty Clays of Low Plasticity</td>
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<tr>
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<td>MH</td>
<td>Inorganic Clays of High Plasticity, Fat Clays</td>
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<tr>
<td>CH</td>
<td>Organic Clays &amp; Organic Silts of Medium-to-High Plasticity</td>
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<tr>
<td>OH</td>
<td>Peat, Humus, Swamp Soils with high organic content</td>
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**KLEINFELDER**

**UNIFIED SOIL CLASSIFICATION SYSTEM**

**PLATE** A-1

**Drafted By:** D. Anderson  **Project No.:** 51730-yuba3  **Date:** 6/7/2005  **File Number:** 51730 yuba3

**TRLIA PHASE 2**  **YUBA RIVER LEFT BANK LEVEE**  **RECLAMATION DISTRICT 784**  **YUBA COUNTY, CALIFORNIA**
### LOG SYMBOLS

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<tr>
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<td>LIQUID LIMIT (ASTM Test Method D 4318)</td>
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<td>PLASTICITY INDEX (ASTM Test Method D 4318)</td>
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<tr>
<td><img src="symbol" alt="CONTINUOUS CORE" /></td>
<td>CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (EM 1110.1-1906)</td>
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<tr>
<td><img src="symbol" alt="SHELBY TUBE" /></td>
<td>EXPANSION INDEX (UBC STANDARD 18-2)</td>
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<td><img src="symbol" alt="ROCK CORE" /></td>
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<td><img src="symbol" alt="WATER LEVEL" /></td>
<td>MOISTURE CONTENT (ASTM Test Method D 2216)</td>
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### GENERAL NOTES

1. Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual.

2. No warranty is provided as to the continuity of soil conditions between individual sample locations.

3. Logs represent general soil conditions observed at the point of exploration on the date indicated.

4. In general, Unified Soil Classification System designations presented on the logs were evaluated by visual methods. Where laboratory tests were performed, the designations reflect the laboratory test results.
### Field Data

<table>
<thead>
<tr>
<th>Elevation (ft.)</th>
<th>Depth (ft.)</th>
<th>Sample Type</th>
<th>Blows/ft</th>
<th>Pocketrometer (ft)</th>
<th>Permeability</th>
<th>Moisture Content (%)</th>
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### Laboratory Data

- **Silty SAND** (SM): Olive-brown to gray-brown, moist, medium dense, fine grained, mottled, approximately 20 to 40% silt (Levee Fill)
- Trace organics, some visible mica
- Some interbedded gray-brown silt layers
- Approximately 20 to 30% silt
- Some iron oxidation in interbedded silt layers brown to gray-brown
- Gray-brown to yellow-brown, some silt seams and poorly graded sand lenses
- Some medium sand

### Soil Description

- **Sandy SILT** (ML): Gray-brown to red-brown, moist, stiff, fine sand, low plasticity (Native)
- **SILT** (ML): Gray, moist, very stiff, some fine sand, low plasticity, some organics
- **Silty SAND/Sandy SILT** (SM/ML): Red-brown to gray-brown, moist, medium dense to very stiff, fine sand, low plasticity, interbedded, trace organics
- Red-gray to light gray, mottled, loose/stiff, some mica visible
- **Sandy SILT** (ML): Gray-brown, moist, stiff, fine sand, low plasticity, visible mica, approximately 30 to 40% sand
<table>
<thead>
<tr>
<th>Elevation (ft. MSL)</th>
<th>Depth (feet)</th>
<th>Sample No.</th>
<th>Blow'sft</th>
<th>Pocket penetrometer (kPa)</th>
<th>Dry density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
<th>Passing #4 sieve (%)</th>
<th>Passing #200 sieve (%)</th>
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<td>Poorly Graded SAND with silt (SP-3M): Light gray to gray-brown, some black motting, dry to moist, loose, fine grained, 5 to 10% silt</td>
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<td>SILT (ML): Dark brown, wet, medium stiff, low plasticity, trace fine sand</td>
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<td>Sandy SILT (ML): Dark brown, wet, soft, fine sand, low plasticity, approximately 40% sand</td>
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<td>Poorly Graded SAND (SP): Gray, wet, dense, fine grained, &lt;5% silt</td>
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<td>Well Graded GRAVEL with silt and sand (GW-GM): Gray, wet, medium dense, fine to coarse gravel to 1-1/2 inches diameter, fine to coarse sand, approximately 5% silt, some silt seams (some loss of drilling fluid to formation, some heaving sand)</td>
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<td>refusal to rotary wash drilling</td>
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LOG OF BORING KB-4

TRLIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

Boring terminated at a depth of approximately 80 feet below existing site grade due to refusal to rotary wash drilling.

Drafted By: D. Anderson  Project No.: 51730-yuba3  Date: 8/25/2005  File Number: 51730 yuba3

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**LOG OF BORING KB-5**

**TRLIA PHASE 2**
**YUBA RIVER LEFT BANK LEVEE**
**RECLAMATION DISTRICT 784**
**YUBA COUNTY, CALIFORNIA**

<table>
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<tr>
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<th>Sample Type</th>
<th>Borehole</th>
<th>Sample No.</th>
<th>Blowsft</th>
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<td>Silty SAND (SM): Gray-brown, with orange</td>
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**Date Completed:** 8/30/2004

**Logged By:** B. Honea

**Total Depth:** 62 feet

**Boring Diameter:** 8 inch and 4-1/2 inch

**Approximate Elevation:** 81 feet (msl)

**Approximate Northing:** 2173485 feet

**Approximate Easting:** 6683348 feet

---

**KLEINFELDER**

**Drafted By:** D. Anderson
**Project No.:** 51730-yuba3
**Date:** 8/25/2005
**File Number:** 51730_yuba3

**Copyright KLEINFELDER, Inc. 2004**
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<tr>
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<th>Sample No.</th>
<th>Blow/ft</th>
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<th>Density (pcf)</th>
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<th>Plastics Index</th>
<th>#4 Sieve (%)</th>
<th>#200 Sieve (%)</th>
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<td>Poorly Graded SAND with silt and gravel (SP-SM): Brown, wet, dense to very dense, fine to coarse sand, approximately 10% fines</td>
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**LOG OF BORING KB-5**

**TRLIA PHASE 2**
**YUBA RIVER LEFT BANK LEVEE**
**RECLAMATION DISTRICT 784**
**YUBA COUNTY, CALIFORNIA**
<table>
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<tr>
<th>Sample Type</th>
<th>cat. 22</th>
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<tbody>
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<td>Blows/ft</td>
<td></td>
</tr>
<tr>
<td>Pocket Penetrometer (tsf)</td>
<td></td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td></td>
</tr>
<tr>
<td>Dry Density (pcf)</td>
<td></td>
</tr>
<tr>
<td>Liquid Limit</td>
<td></td>
</tr>
<tr>
<td>Plasticity Index</td>
<td></td>
</tr>
<tr>
<td>Passing #4 Sieve (%)</td>
<td></td>
</tr>
<tr>
<td>Passing #200 Sieve (%)</td>
<td></td>
</tr>
<tr>
<td>Other Tests</td>
<td></td>
</tr>
</tbody>
</table>

**Sample No.**

**Description**

- COBBLES and GRAVEL: Very difficult drilling.
- Boring terminated at depth of approximately 130 ft. below existing site grade due to refusal to rotary wash drilling.

**Graphic Log**

- logo

**LOG OF BORING KG-5**

**TRUIA PHASE 2**

**YUBA RIVER LEFT BANK LEVEE**

**RECLAMATION DISTRICT 784**

**YUBA COUNTY, CALIFORNIA**

**PLATE**

- 3 of 3

**Elevation (ft., msl)**

**Depth (feet)**

---

**Date:** 8/25/2005

**Dated By:** D. Anderson

**Project No.:** 51730-yuba4

**File Number:** 51730-yuba4
**Surface Conditions:** Levee crown, gravel surface

**Groundwater:** Groundwater initially encountered at a depth of approximately 50 feet below existing site grade and finally at a depth of 42 feet.

**Method:** Hollow Stem Auger

**Equipment:** Mobile Drill B-61 with 140lb, Automatic Hammer

**Date Completed:** 4/13/2005

**Logged By:** T. Sayre

**Total Depth:** 91-1/2 feet

**Boring Diameter:** 8 inches

<table>
<thead>
<tr>
<th>Field Drill B-61</th>
<th>Laboratory Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample No.</td>
<td>Sample No.</td>
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<tr>
<td>Elevation (ft. msl)</td>
<td>Elevation (ft. msl)</td>
</tr>
<tr>
<td>Depth (ft)</td>
<td>Depth (ft)</td>
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<tr>
<td>Sample Type</td>
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<tr>
<td>Blowsift</td>
<td>Blowsift</td>
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<tr>
<td>Pocket penetrometer (ft)</td>
<td>Pocket penetrometer (ft)</td>
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<td>Dry Density (pdc)</td>
<td>Dry Density (pdc)</td>
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<td>Moisture Content (%)</td>
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<tr>
<td>Plasticity Index</td>
<td>Plasticity Index</td>
</tr>
<tr>
<td>Passing No. 4 sieve (%)</td>
<td>Passing No. 4 sieve (%)</td>
</tr>
<tr>
<td>Passing No. 200 sieve (%)</td>
<td>Passing No. 200 sieve (%)</td>
</tr>
<tr>
<td>Other Tests</td>
<td>Other Tests</td>
</tr>
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</table>

**Approximate Elevation:** 80 feet (msl)

**Approximate Northing:** 2173550 feet

**Approximate Easting:** 6662720 feet

**DESCRIPTION**

**Silty SAND (SM):** Brown, moist, fine grained, approximately 40% silt, trace fine to coarse gravel to 1-1/2 inches diameter

(sand descriptions based on auger cuttings samples, 0 to 55 feet)

- Approximately 25% silt, some clay
- Approximately 35% silt, no gravel
- Approximately 25% silt
- Gray-brown, approximately 45% silt, some clay
- Sandy SILT (ML): Gray-brown, moist, approximately 30% fine sand, some clay

**LOG OF BORING KB-6**

**TRILIA PHASE 2**

**YUBA RIVER LEFT BANK LEVEE**

**RECLAMATION DISTRICT 784**

**YUBA COUNTY, CALIFORNIA**

**PLATE**

1 of 3

**A-5**
### FIELD

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Sample No.</th>
<th>Blowsilt</th>
<th>Pocket Magnetometer (ft)</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
<th>Passing #4 Sieve (%)</th>
<th>Passing #200 Sieve (%)</th>
<th>Other Tests</th>
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</table>

#### LABORATORY

<table>
<thead>
<tr>
<th>Elevation (ft.)</th>
<th>Description</th>
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<tbody>
<tr>
<td>30</td>
<td>SILT with sand (ML): Gray-brown, moist, approximately 20% fine sand, some clay</td>
</tr>
<tr>
<td>40</td>
<td>Sandy SILT (ML): Brown, moist, approximately 30% fine sand, some clay</td>
</tr>
<tr>
<td>50</td>
<td>SILT (ML): Dark brown, moist, low plasticity, approximately 10% fine sand, some clay</td>
</tr>
<tr>
<td>55</td>
<td>SILT with sand (ML): Dark brown, moist, approximately 20% fine sand, some clay</td>
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<tr>
<td>60</td>
<td>Grain Size; see Plate B-3</td>
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<tr>
<td>70</td>
<td>Poorly Graded SAND (SP): Gray, wet, medium dense, fine to medium grained, trace fine gravel</td>
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<tr>
<td>80</td>
<td>Well Graded GRAVEL with silt and sand (GW-GM): Gray, wet, medium dense, fine to coarse gravel to 1-1/2 inches diameter, approximately 40% fine to coarse sand, approximately 10% silt</td>
</tr>
<tr>
<td>90</td>
<td>Poorly Graded SAND (SP): Gray, wet, very dense, fine to medium grained, trace fine gravel, trace silt</td>
</tr>
</tbody>
</table>

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**LOG OF BORING KB-6**

**YUBA RIVER LEFT BANK LEVEE**

**RECLAMATION DISTRICT 784**

**YUBA COUNTY, CALIFORNIA**

**PLATE**

2 of 3

**A-5**
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Elevation (ft)</th>
<th>Depth (ft)</th>
<th>Grain Size</th>
<th>Other Tests</th>
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<tbody>
<tr>
<td>6</td>
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<td>6</td>
<td>50/8</td>
<td>Grain Size; see Plate B-3</td>
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<tr>
<td>7</td>
<td>10</td>
<td>8</td>
<td>50/5&quot;</td>
<td>Grain Size; see Plate B-3</td>
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<tr>
<td>8</td>
<td>8</td>
<td>24</td>
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<td>Silty SAND (SM); Gray, moist, hard, fine to medium grained, trace fine gravel</td>
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<tr>
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<td>7</td>
<td>50/5&quot;</td>
<td>99</td>
<td>25</td>
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<tr>
<td>10</td>
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<td>50/5&quot;</td>
<td>100</td>
<td>51</td>
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<tr>
<td>11</td>
<td>5</td>
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<td>Sandy SILT (ML); Gray, moist, hard, fine to medium grained, approximately 40% fine to medium sand</td>
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<tr>
<td>12</td>
<td>50/5&quot;</td>
<td>53</td>
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<td>Silty SAND (SM); Gray, moist, hard, fine to medium grained, approximately 40% fine to medium sand</td>
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<tr>
<td>13</td>
<td>45</td>
<td>79</td>
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<td>22</td>
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<tr>
<td>14</td>
<td>35</td>
<td>79</td>
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<td>Silty SAND (SM); Gray, wet, dense, fine to coarse sand, approximately 10% silt</td>
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<tr>
<td>15</td>
<td>30</td>
<td>84</td>
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<td>Well Graded GRAVEL with silt and sand (GW-GM); Gray, wet, dense, fine to coarse gravel to 1-1/2 inches diameter, approximately 40% fine to coarse sand, approximately 10% silt</td>
</tr>
</tbody>
</table>

Boring completed at a depth of approximately 91-1/2 feet below existing site grade.
**Surface Conditions:** Dirt road at waterside levee toe.

**Groundwater:** Groundwater encountered at a depth of approximately 39 feet below existing site grade.

**Method:** Hollow Stem Auger

**Equipment:** Mobile Drill B-61 with 140/lb. Automatic Hammer

**Date Completed:** 4/12/2005

**Logged By:** T. Sayre

**Total Depth:** 75-1/2 feet

**Boring Diameter:** 8 inches

---

**FIELD**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Pocket Shear (ft)</th>
<th>Density (g/cc)</th>
<th>Moisture Content (%)</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
<th>#200 Silt (%)</th>
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**LABORATORY**

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<th>Sample No.</th>
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<td>Cut 2</td>
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<td>Cut 3</td>
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<td>Cut 4</td>
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<tr>
<td>Cut 5</td>
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</tr>
</tbody>
</table>

**Graphic Log**

- Sandy Silt (ML): Dark brown, moist, approximately 50% fine sand, trace fine gravel
- (soil descriptions based on auger cuttings samples, 0 to 32 feet)
- Brown
- Approximately 30% fine sand

---

**LOG OF BORING KB-7**

TRLIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA
<table>
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<th>Pocket penetrometer (lbf)</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Liquid Limit (%)</th>
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<tr>
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<td>Grain Size; see Plate B-3</td>
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<td>8</td>
<td>43</td>
<td>12</td>
<td>Grain Size; see Plate B-3</td>
<td></td>
<td></td>
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</tbody>
</table>

**Description of Materials**

- **Silty SAND (SM):** Dark brown, moist, fine grained, approximately 25% silt
- **SILT with sand (ML):** Gray, moist, stiff, low plasticity, approximately 20% fine sand, trace fine gravel, some sand lenses, some clay, some organics
- **Poorly Graded GRAVEL with silt and sand (GP-GM):** Brown, wet, medium dense, fine to coarse gravel to 2 inches diameter, approximately 30% fine to coarse sand, approximately 10% silt (cobbles approximately 3 inches dimension observed in sampler shoe)
- **Silty SAND with gravel (SM):** Gray, wet, medium dense, fine to coarse sand, approximately 40% fine to coarse gravel to 1-1/2 inches diameter, approximately 15% silt, some interbedded sandy clay
- **Poorly Graded SAND with silt (SP-SM):** Gray, wet, medium dense, fine to coarse grained, approximately 10% silt

**(easier drilling)**

- **Fat CLAY (CH):** Gray, moist, hard, high plasticity, approximately 5% fine sand, some silt,
<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Sample No.</th>
<th>Blows/ft</th>
<th>Pocket Penetrometer (ft)</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
<th>Passing #4 Sieve (%)</th>
<th>Passing #200 Sieve (%)</th>
<th>Other Tests</th>
<th>Graphic Log</th>
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<tr>
<td>13</td>
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</tbody>
</table>

**Description**

- **5'-1/2 feet below existing site grade:**
  - Brown to gray, very dense, fine to medium sand, interbedded with gray, fine to medium sand, and fine to medium sand, interspersed with gray, fine to medium sand, and fine to medium sand.

- **5'-1/2 feet below existing site grade:**
  - 5'-1/2 feet below existing site grade.

- **5'-1/2 feet below existing site grade:**
  - 5'-1/2 feet below existing site grade.

- **5'-1/2 feet below existing site grade:**
  - 5'-1/2 feet below existing site grade.

- **5'-1/2 feet below existing site grade:**
  - 5'-1/2 feet below existing site grade.
**LOG OF BORING KB-8**

**TRLIA PHASE 2**

**YUBA RIVER LEFT BANK LEVEE**

**RECLAMATION DISTRICT 784**

**YUBA COUNTY, CALIFORNIA**

---

**Surface Conditions:** Dirt road at waterside levee toe.

**Groundwater:** Groundwater encountered at a depth of approximately 22-1/2 feet below existing site grade.

**Method:** Hollow Stem Auger

**Equipment:** Mobile Drill B-61 with 140lb. Automatic Hammer

**Date Completed:** 4/12/2005

**Logged By:** T. Sayre

**Total Depth:** 66-1/2 feet

**Boring Diameter:** 8 inches

---

**Elevation (ft. msl)** | **Sample No.** | **Sample Type** | **Soil Description**
---|---|---|---
68 | Cut 1 | Silty SAND (SM) | Brown, moist, fine to medium grained, approximately 15% silt
50 | Cut 2 | Sandy SILT (ML) | Brown, moist, approximately 30% fine sand, some clay
48 | Cut 3 | Silty SAND (SM) | Brown, moist, fine grained, approximately 25% silt
30 | Cut 4 | red-brown | Approximately 20% silt
26 | Cut 5 | | Approximately 30% silt
26 | Cut 6 | |
**Surface Conditions:** Dirt road at waterside levee toe.

**Groundwater:** Groundwater encountered at a depth of approximately 34 feet below existing site grade.

**Method:** Hollow Stem Auger

**Equipment:** Mobile Drill B-51 with 140 lb. Automatic Hammer

---

**Elevation (ft, msl)**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Cut 1</th>
<th>Cut 2</th>
<th>Cut 3</th>
<th>Cut 4</th>
<th>Cut 5</th>
<th>Cut 6</th>
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<tbody>
<tr>
<td>Depth (feet)</td>
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<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
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</tbody>
</table>

---

**DESCRIPTION**

- **Silty SAND (SM):** Brown, moist, fine grained, approximately 15% silt
- (Soil descriptions based on auger cuttings samples, 0 to 40 feet)
- approximately 35% silt, slight increase in moisture
- **Silt with sand (ML):** Brown, moist, approximately 20% fine sand, some clay
- increasing clay
- **Silty SAND (SM):** Brown, moist, fine grained, approximately 35% silt
- trace coarse gravel, approximately 45% silt
<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Sample Type</th>
<th>Sample No.</th>
<th>Elevation (ft.)</th>
<th>Eniwsft.</th>
<th>Pocket penetrometer (ft)</th>
<th>Opt. Density (pct)</th>
<th>Moisture Content (%)</th>
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<th>Plastidity Index</th>
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</tbody>
</table>

**DESCRIPTION**

- **10-12 feet**: Moist to wet, very stiff, approximately 45% fine sand, trace coarse gravel.
- **13-15 feet**: Silty sand (SM): Gray, moist to wet, dense, fine grained, trace fine gravel, approximately 25% silt.
- **16-17 feet**: Poorly Graded SAH with gravel (SP): Gray, wet, very dense, fine to medium sand, fine to coarse gravel.
- **18-19 feet**: Well Graded GRAVEL with sand (GV): Gray, very dense, fine to subangular gravel, fine to coarse sand.

- **Graphic Log**: Booring completed at a depth of approximately 75 feet below existing site grade.
**LOG OF BORING KB-10**

**TRILIA PHASE 2**

**YUBA RIVER LEFT BANK LEVEE**

**RECLAMATION DISTRICT 784**

**YUBA COUNTY, CALIFORNIA**

---

**Surface Conditions:** Dirt road at waterside levee toe.

**Groundwater:** Groundwater encountered at a depth of approximately 39 feet below existing site grade.

**Method:** Hollow Stem Auger

**Equipment:** Mobile Drill B-51 with 140 lb. Downhole and Automatic Hammers

**Date Completed:** 4/7/2005

**Logged By:** T. Sayre

**Total Depth:** 66 feet

**Boring Diameter:** 8 inches

---

<table>
<thead>
<tr>
<th>Elevation (ft, msl)</th>
<th>Sample Type</th>
<th>Blows/ft</th>
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**Approximate Elevation:** 68 feet (msl)

**Approximate Northing:** 2174016 feet

**Approximate Easting:** 6687710 feet

**DESCRIPTION**

- Silty SAND (SM): Brown, moist, fine to medium grained, approximately 15% silt

  (soil descriptions based on auger cuttings samples, 0 to 36 feet)

- Some perched groundwater at approximately 6 to 6-1/2 feet

- Increase in drilling resistance, observed silt lenses in auger cuttings

- Approximately 30% silt

- Dark brown

- Approximately 40% silt
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**DESCRIPTION**

- **Sandy SILT/Sandy Lean CLAY (ML/CL):** Dark brown, moist, low plasticity, approximately 35% fine sand.
- **Poorly Graded GRAVEL with sand (GP):** Brown, wet, very dense, fine subrounded gravel, fine to medium sand. Fine to coarse gravel to 1-1/2 inches diameter observed on center plug prior to sampling.
- **Silty SAND (SM):** Gray-brown, wet, loose, fine to coarse sand, trace fine gravel, approximately 15% silt.
- **Lean CLAY (CL):** Gray-brown, moist, hard, moderate plasticity, some silt.
- **Lean CLAY with sand (CL):** Gray-brown, moist, hard, moderate plasticity, approximately 25% fine sand.

**LOG OF BORING KB-10**

TRILIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

**PLATE**

A-9
## CPT DATA

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<th>Local Friction Fs TSF</th>
<th>Tip Resistance Qt TSF</th>
<th>SPT N* 60% Hammer</th>
<th>Soil Behavior Type</th>
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1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sand to silty sand
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)
APPENDIX B
APPENDIX B

LABORATORY TESTING

LABORATORY TESTING

General

Laboratory tests were performed on selected samples to aid in soil classification and to evaluate physical properties of the soils that may affect the geotechnical aspects of project design and construction. A description of the laboratory testing program is presented below. A summary of all laboratory tests performed is presented on the Summary of Laboratory Tests, Plate B-1.

Moisture Content and Dry Unit Weight

Moisture content and dry unit weight tests were performed to evaluate soil overburden pressures and relative soil strength and compressibility. Moisture content was evaluated in general accordance with ASTM Test Method D 2216; dry unit weight was evaluated using procedures similar to ASTM Test Method D 2937. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests.

Particle-size Analyses

Particle-size analyses were performed using sieves and hydrometers to evaluate the gradational characteristics of the material and to aid in soil classification. Tests were performed in general accordance with ASTM Test Method D 422. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests. In addition particle-size distribution curves for the majority of these samples are presented on Plates B-2 and B-3.

Atterberg Limits

Atterberg Limits tests were performed to aid in soil classification and to evaluate the plasticity characteristics of the material. Tests were performed in general accordance
with ASTM Test Method D 4318. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests. In addition, plasticity charts summarizing the results of these tests are presented on Plate B-4.

LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

Plate B-1  Summary of Laboratory Tests
Plate B-2  Sieve Analyses
Plate B-3  Grain Size Analyses
Plate B-4  Plasticity Charts
<table>
<thead>
<tr>
<th>BORING NO.</th>
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<th>MOISTURE CONTENT (% of dry weight)</th>
<th>PARTICLE SIZE SIEVE SIZE (percent passing)</th>
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**SUMMARY OF LABORATORY TESTS**

TRILIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

Plate 1 of 2

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<th>DRY UNIT WEIGHT (pcf)</th>
<th>MOISTURE CONTENT (% of dry weight)</th>
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SIEVE ANALYSIS
TRULIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

KLEINFELDER

Drafted By: D. Anderson  Project No.: 51739-yuba3
Date: 5/5/2005  File Number: 51730-yuba3

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<th>SAND (%)</th>
<th>FINES (%)</th>
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<th>D10 (mm)</th>
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<th>Cc</th>
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PERCENT PASSING
SIEVE SIZE
PARTICLE SIZE IN MILLIMETERS
COBBLE  GRAVEL  SAND

PLATE 1 of 4
B-2
### Sieve Analysis

#### Legend:

<table>
<thead>
<tr>
<th>Source</th>
<th>Depth (ft)</th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Fines (%)</th>
<th>D60 (mm)</th>
<th>D10 (mm)</th>
<th>Cu</th>
<th>Gc</th>
<th>Description</th>
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</table>
SIEVE ANALYSIS

KLEINFELDER

TRLIA PHASE 2
YUBA RIVER LEFT BANK LEVEE
RECLAMATION DISTRICT 784
YUBA COUNTY, CALIFORNIA

PLATE
4 of 4

B-2
<table>
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<tr>
<th>GRAVEL</th>
<th>SAND</th>
<th>SILT</th>
<th>CLAY</th>
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<td>medium</td>
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**LEGEND:**

- **SOURCE:**
  - KB-7
  - KB-7
  - KB-7
  - KB-8

- **DEPTH (ft):**
  - 33.0
  - 41.0
  - 56.0
  - 33.0

- **GRAVEL (%)**
  - 57
  - 43
  - 0
  - 42

- **SAND (%)**
  - 32
  - 44
  - 6
  - 52

- **FINES (%)**
  - 12
  - 13
  - 94
  - 6

- **D_60 (mm)**
  - 0.14
  - 0.33
  - 0.01
  - 5.28

- **D_10 (mm)**
  - 0.06
  - 0.03
  - 0.16
  - 0.16

- **Cu**
  - 145
  - 19
  - 32

- **Cc**
  - 10
  - 6
  - 1

**DESCRIPTION:**

- Poorly Graded GRAVEL with silt and sand (GP-GM)
- Silty SAND with gravel (SM)
- Fat CLAY (CH)
- Poorly Graded SAND with silt and gravel (SP-SM)
## Sieve Analysis

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<thead>
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<th>GRAVEL</th>
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<th>SILT</th>
<th>CLAY</th>
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<table>
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<th>SAND (%)</th>
<th>FINES (%)</th>
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<td>5</td>
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Explaination:

GROUP
ML
CL
CH
OH
ML-CL
ML or OL

SYMBOL
Q
M
C
O
M
L

UNIFIED SOIL CLASSIFICATION
FINE GRAINED SOIL GROUPS

Organic silts and organic silty clays of low plasticity
Inorganic clayey silts to very fine sands of slight plasticity
Inorganic clays of low to moderate plasticity
Organic clays of moderate to high plasticity, organic silts
Inorganic silts and clayey silts
Inorganic clays of high plasticity

PLASTICITY INDEX (PI)

LIQUID LIMIT (LL)

LEGEND:

○ KB-7 56.0 57 24 33 Fat CLAY (CH)

KB-7 70.5 NP NP NP Silty SAND (SM)

△ KB-8 51.0 40 21 19 Lean CLAY (CL)

KB-8 56.0 34 20 14 Lean CLAY with sand (CL)

○ KB-9 49.0 36 23 13 Lean CLAY (CL)
APPENDIX C
APPENDIX C
SEEPAGE ANALYSIS

SEEPAGE ANALYSIS

In this appendix we provide an explanation of methods and soil parameters used in our analysis of seepage potential of the subject levee, as well as computer model printouts of our seepage analysis results. An explanation of analysis cross sections and a table of analysis results is included in the main report text.

Analysis Methods

Seepage analyses were performed using steady-state analysis procedures of the finite element program SEEP/W version 4.24. This software was developed by GEO-SLOPE International, Ltd (2001) and can analyze two-dimensional planar or axi-symmetrical problems with isoparametric and higher-order finite elements. The program is able to work with multiple soil types having anisotropic hydraulic conductivity characteristics. Boundary conditions in steady-state analyses can be modeled as constant head, no-flow, constant flow, or variable based on head condition. Infinite elements can also be included in the profile to model a semi-infinite condition at the edge of the model.

A fixed-head boundary condition set to the 1/100 AEP or 1/200 AEP water surface elevation was used along the vertical waterside edge, the boundary nodes of the river bottom and waterside slope of the levee. Along the vertical landslide edge of the model the nodes have been assigned a fixed head boundary condition with a value equal to the ground surface elevation. The vertical elements along the landslide edge of the model have been designated as infinite elements, thus modeling a uniform infinite half-space along this edge. The nodes along the bottom of the model were modeled with a no-flow boundary condition. The elements on the top of the model extending from the high water line on the waterside to the landslide levee toe are modeled with a variable boundary condition (elevation head). These nodes are assigned a no flow boundary condition that is automatically adjusted by the computer program to a constant head boundary based on the iterative results of successive finite element runs. After each successive iteration the calculated head at each node is compared to the elevation
head of the boundary nodes. If the elevation head at the node is higher than the elevation, the node becomes a constant head node with head equal to the ground surface elevation, thus, allowing groundwater to seep from the surface. The nodes located along the top of the model on the landside of the levee were assigned a fixed head boundary condition with a value equal to the ground surface elevation. This reflects a worse case scenario of groundwater being at the ground surface.

No-flow boundary conditions are represented by a solid triangle, boundary conditions adjusted by elevation are represented by an open triangle, and a solid circle represents fixed head boundary conditions.

Soil Parameters Used in Analysis

Hydraulic conductivity (also known as coefficient of permeability or simply permeability) values for the various soils in the analysis cross sections were selected using published empirical relationships between the soil type and the hydraulic conductivity such as those presented by Terzaghi and Peck (1967), Freeze and Cherry (1979), and Cedergren (1967). Correlation relationships based on grain size distribution as described in EM-1110-2-1913 (USACE 2000) and in NAVFAC DM-7.01 (NAVFAC 1986) were also utilized. Adjustments were made to the hydraulic conductivity of the sandy materials based on the percentage of fines (material passing No. 200 sieve) utilizing the Kozeny-Carman equation (Carrier 2003). Adjustments were made to the hydraulic conductivity of the gravelly material based on pump test data provided by DWR (1997). Values from the ranges provided by those referenced above were assigned to the various zones as shown in Table C.1 below. The construction and compaction effort of the levee fill material are not known and thus the anisotropy of this material was assumed. The analyses were performed using a soil anisotropy ratio (kv/kh) of 0.1 or 0.25 for all naturally deposited layers and 0.125 or 1.0 for all engineered/fill layers (cutoff wall, seepage berm, levee fill).

The seepage analysis models attempt to represent a combination of adverse topography (tall levee with steep sides and narrow waterside bank) and adverse subsurface conditions that may (based on our interpretation) occur together. The bottom portion of the stratigraphy for the analysis cross sections is partially based on deeper borings in the vicinity of borings chosen with adverse subsurface conditions.
### Table C.1
Hydraulic Conductivity Values for Holocene Alluvium And Levee Fill within Reclamation District 784

| Material Type | Additional Description | Selected Horizontal Hydraulic Conductivity Values | Selected Vertical Hydraulic Conductivity Values | Selected Anisotropy Ratio | USACE Yuba/Feather Seepage Analysis 2004 (horizontal) | Terzaghi and Peck (horizontal ranges)
|---------------|------------------------|-------------------------------------------------|---------------------------------------------|--------------------------|--------------------------------------------------|---------------------------------------------|
|               |                        | cm/sec                                          | m/day                                       |                           | cm/sec                                          | com/sec                                      | 10⁻⁶ 
| Clay          | Clay cone              | 10⁻⁴                                           | 0.0028                                      | 10⁻⁶                     | 0.0028                                          | 10⁻⁸ 
|               | Fill, mechanically     | 10⁻⁴                                           | 0.0028                                      | 10⁻⁶                     | 0.0028                                          | -                                            |
|               | placed                 |                                                 |                                             |                          |                                                 | -                                            |
|               | Fill, hydrolastic      | 10⁻⁴                                           | 0.028                                       | 10⁻⁶                     | 0.0035                                          | 0.025                                        |
|               | weathered blanket 3 ft | 10⁻⁴                                           | 0.28                                        | 10⁻⁶                     | 0.028                                           | 10⁻⁴                                         | 2.05                                         |
|               | thick                  |                                                 |                                             |                          |                                                 | -                                            |
|               | Weathered blanket 4 ft | 10⁻⁴                                           | 0.28                                        | 10⁻⁴                     | 0.28                                            | 10⁻⁴                                         | 0.66                                         |
|               | thick                  |                                                 |                                             |                          |                                                 | -                                            |
|               | Weathered blanket 6 ft | 10⁻⁴                                           | 0.112                                       | 10⁻⁴                     | 0.28                                            | 10⁻⁴                                         | 4.05                                         |
|               | thick                  |                                                 |                                             |                          |                                                 | -                                            |
|               | Unweathered flat       | 10⁻⁴                                           | 0.0112                                      | 10⁻⁴                     | 0.028                                           | 10⁻⁴                                         | 0.0112                                      |
| Silt          | Fill, mechanically     | 10⁻⁴                                           | 0.28                                        | 10⁻⁴                     | 0.28                                            | 10⁻⁴                                         | 0.28                                        |
|               | placed                 |                                                 |                                             |                          |                                                 | -                                            |
|               | Fill, hydrolastic      | 8x10⁻⁴                                         | 10⁻⁴                                        | 0.28                     | 10⁻⁴                                            | 0.28                                         |
|               | 20 to 100% fines       | 4x10⁻⁴                                         | 10⁻⁴                                        | 0.28                     | 10⁻⁴                                            | 0.28                                         |
|               | Silt with sand 70 to   | 4x10⁻⁴                                         | 10⁻⁴                                        | 0.28                     | 10⁻⁴                                            | 0.28                                         |
|               | 85% fines              |                                                 |                                             |                          |                                                 | -                                            |
|               | Sandy silt, 50 to 70%  | 4x10⁻⁴                                         | 10⁻⁴                                        | 0.28                     | 10⁻⁴                                            | 0.28                                         |
| Sand and Silty Sand | Fill, mechanically     | 10⁻⁴                                           | 0.28                                        | 10⁻⁴                     | 0.28                                            | 10⁻⁴                                         | 2.3                                          |
|               | placed                 |                                                 |                                             |                          |                                                 | -                                            |
|               | Fill, hydrolastic      | use anisotropy ratio to calc                    | see values below                           | 0.125                    | 1.5x10⁻⁴                                        | 1.5x10⁻⁴                                    |
|               | coarse                 | use anisotropy ratio to calc                    | see values below                           | 0.125                    | 1.5x10⁻⁴                                        | 1.5x10⁻⁴                                    |
|               | 0 to 2% silt           | 10⁻⁴                                           | 28                                           | 2.5x10⁻⁴                 | 7                                               |
|               | 2 to 7% silt           | 5x10⁻⁴                                         | 14                                           | 1.2x10⁻⁴                 | 3.5                                             |
|               | 8 to 12% silt          | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 13 to 27% silt         | 10⁻⁴                                           | 2.3                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 28 to 49% silt         | 10⁻⁴                                           | 1.12                                         | 10⁻⁴                     | 0.28                                            |
| Sand and Clayey Sand | Fill, mechanically     | 10⁻⁴                                           | 0.28                                        | 10⁻⁴                     | 0.28                                            | 10⁻⁴                                         |
|               | placed                 |                                                 |                                             |                          |                                                 | -                                            |
|               | Fill, hydrolastic      | use anisotropy ratio to calc                    | see values below                           | 0.125                    | 1.5x10⁻⁴                                        | 1.5x10⁻⁴                                    |
|               | coarse                 | use anisotropy ratio to calc                    | see values below                           | 0.125                    | 1.5x10⁻⁴                                        | 1.5x10⁻⁴                                    |
|               | 0 to 2% clay           | 5x10⁻⁴                                         | 14                                           | 1.2x10⁻⁴                 | 3.5                                             |
|               | 2 to 7% clay           | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 8 to 12% clay          | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 13 to 37% clay         | 10⁻⁴                                           | 1.12                                         | 10⁻⁴                     | 0.28                                            |
|               | 38 to 49% clay         | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 40 to 49% clay         | 10⁻⁴                                           | 1.12                                         | 10⁻⁴                     | 0.28                                            |
| Gravel        | 0 to 2% fines          | 2.5x10⁻⁴                                       | 70                                           | 2.5x10⁻⁴                 | 0.7                                             |
|               | 3 to 7% fines          | 2.5x10⁻⁴                                       | 70                                           | 2.5x10⁻⁴                 | 0.7                                             |
|               | 8 to 12% fines         | 1.2x10⁻⁴                                       | 35                                           | 1.2x10⁻⁴                 | 0.7                                             |
|               | 13 to 17% fines        | 8x10⁻⁴                                         | 18                                           | 8x10⁻⁴                   | 0.7                                             |
|               | 18 to 27% fines        | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 28 to 49% fines        | 10⁻⁴                                           | 1.12                                         | 10⁻⁴                     | 0.28                                            |
| Gravel with Cobble and Sand | 0 to 2% fines          | 2x10⁻⁴                                         | 50                                           | 2x10⁻⁴                   | 0.7                                             |
|               | 3 to 7% fines          | 2x10⁻⁴                                         | 50                                           | 2x10⁻⁴                   | 0.7                                             |
|               | 8 to 12% fines         | 10⁻⁴                                           | 280                                          | 10⁻⁴                     | 0.7                                             |
|               | 13 to 17% fines        | 10⁻⁴                                           | 28                                           | 10⁻⁴                     | 0.7                                             |
|               | 18 to 27% fines        | 10⁻⁴                                           | 2.8                                          | 2.5x10⁻⁴                 | 0.7                                             |
|               | 28 to 49% fines        | 4x10⁻⁴                                         | 1.12                                         | 10⁻⁴                     | 0.28                                            |
| Slurry Cut-off Wall | soil-cement-bonded or | 10⁻⁴                                           | 0.0028                                      | 10⁻⁴                     | 0.0028                                          |
|               | soil-bentonite         |                                                 |                                             |                          |                                                 | -                                            |

2. Cedergren (1967), "Seepage, Drainage, and Flow Nets"; values associated with drainage characteristics of soils and assumed to represent horizontal hydraulic conductivity.
3. Freeze and Cherry (1979), "Groundwater"; values assumed to represent horizontal hydraulic conductivity.
LIST OF ATTACHMENTS

The following plates are attached as part of this appendix and include graphical presentations of the seepage analyses with contours of vertical gradients at 0.1 intervals and total head at 1-foot intervals for the sections evaluated:

Plate C-1  Section G-G', 2F-97-5, Existing Conditions, 1/100 AEP Water Surface, Total Head Contours
Plate C-2  Section G-G', 2F-97-5, Existing Conditions, 1/100 AEP Water Surface, Vertical Gradient Contours
Plate C-3  Section G-G', 2F-97-5, Cutoff Wall, 1/200 AEP Water Surface, Total Head Contours
Plate C-4  Section G-G', 2F-97-5, Cutoff Wall, 1/200 AEP Water Surface, Vertical Gradient Contours
Plate C-5  Section G-G', 2F-97-5, Seepage Berm, 1/200 AEP Water Surface, Total Head Contours
Plate C-6  Section G-G', 2F-97-5, Seepage Berm, 1/200 AEP Water Surface, Vertical Gradient Contours
Plate C-7  Section G-G', 2F-97-6, Existing Conditions, 1/100 AEP Water Surface, Total Head Contours
Plate C-8  Section G-G', 2F-97-6, Existing Conditions, 1/100 AEP Water Surface, Vertical Gradient Contours
Plate C-9  Section G-G', 2F-97-6, Cutoff Wall, 1/200 AEP Water Surface, Total Head Contours
Plate C-10 Section G-G', 2F-97-6, Cutoff Wall, 1/200 AEP Water Surface, Vertical Gradient Contours
Plate C-11 Section G-G', 2F-97-6, Seepage Berm, 1/200 AEP Water Surface, Total Head Contours
Plate C-12 Section G-G', 2F-97-6, Seepage Berm, 1/200 AEP Water Surface, Vertical Gradient Contours
Plate C-13 Section H-H', 2F-01-15, Existing Conditions, 1/100 AEP Water Surface, Total Head Contours
Plate C-14 Section H-H', 2F-01-15, Existing Conditions, 1/100 AEP Water Surface, Vertical Gradient Contours
Plate C-15 Section H-H', 2F-01-15, Cutoff Wall, 1/200 AEP Water Surface, Total Head Contours
Plate C-16  Section H-H', 2F-01-15, Cutoff Wall, 1/200 AEP Water Surface, Vertical Gradient Contours
Plate C-17  Section H-H', 2F-01-15, Seepage Berm, 1/200 AEP Water Surface, Total Head Contours
Plate C-18  Section H-H', 2F-01-15, Seepage Berm, 1/200 AEP Water Surface, Vertical Gradient Contours
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-5
File Name: Yuba River 2F-97-5 v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 8:34:19 AM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
5) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
6) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

TOTAL HEAD CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-5
File Name: Yuba River 2F-97-5 v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 8:34:19 AM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
5) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
6) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-5 with Cutoff Wall at WS toe
File Name: Yuba River G-G' 2F-97-5 Cutoff v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 5:30:10 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 112 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
5) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
6) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
8) Additional Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

TOTAL HEAD CONTOURS

Seepage Analysis G-G'
2F-97-5
Yuba River – Phase 2
Reclamation District 784
Yuba County, California
Description: Yuba River Cross Section G-G'  
Comments: Subsurface - 2F-97-5 with Cutoff Wall at WS toe  
File Name: Yuba River G-G' 2F-97-5 Cutoff v2.sep  
Last Saved Date: 8/24/2005  
Last Saved Time: 6:20:16 PM  
Analysis Type: Steady-State  
Analysis View: 2-D  

**Horizontal Hydraulic Conductivity**  
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V  
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V  
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V  
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V  
5) GP with cobble - 280 ft/day (10^-1 cm/s), 10H:1V  
6) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V  
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V  
8) Additional Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V  

**VERTICAL GRADIENT CONTOURS**
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-5 with WS Berm and Setforward Levee
File Name: Yuba River G-G' 2F-97-5 Berm v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 6:29:10 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
5) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
6) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
8) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V
9) New Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

TOTAL HEAD CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-5 with WS Berm and Selfforward Levee
File Name: Yuba River G-G'2F-97-5 Berm v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 6:31:00 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SM - 2.8 ft/day (10^-3 cm/s), 4H:1V
4) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
5) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
6) CL - 0.0112 ft/day (4 x 10^-5 cm/s), 4H:1V
7) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
8) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V
9) New Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6
File Name: Yuba River 2F-97-6 v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 7:18:29 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

TOTAL HEAD CONTOURS

KLEINFELDER
Graphic By: D. Stevens
Project No. 51730
Date: 8-24-05
File: Y3rev.ppt

Seepage Analysis G-G'
2F-97-6
Yuba River - Phase 2
Reclamation District 784
Yuba County, California

PLATE
C-7
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6
File Name: Yuba River 2F-97-6 v2.sep
Last Saved Date: 8/24/2005
Last Saved Time: 7:21:33 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6 with Cutoff Wall at WS toe
File Name: Yuba River G-G' 2F-97-6 Cutoff v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 10:12:02 AM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
7) Additional Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

TOTAL HEAD CONTOURS

Seepage Analysis G-G'
2F-97-6
Yuba River – Phase 2
Reclamation District 784
Yuba County, California
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6 with Cutoff Wall at WS toe
File Name: Yuba River G-G' 2F-97-6 Cutoff v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 10:15:33 AM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
7) Additional Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

Elevation (feet)

Horizontal Distance (feet) (x 1000)

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6 with WS Berm and Setforward Levee
File Name: Yuba River G-G' 2F-97-6 Berm v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 12:32:30 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
7) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V
8) New Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

TOTAL HEAD CONTOURS
Description: Yuba River Cross Section G-G'
Comments: Subsurface - 2F-97-6 with WS Berm and Setforward Levee
File Name: Yuba River G-G' 2F-97-6 Berm v2.xep
Last Saved Date: 8/25/2005
Last Saved Time: 12:34:18 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivity
1) Levee Fill (SP) - 14 ft/day (5 x 10^-3 cm/s), 8H:1V
2) ML - 1.12 ft/day (4 x 10^-4 cm/s), 4H:1V
3) SP - 14 ft/day (5 x 10^-3 cm/s), 4H:1V
4) GP with cobbles - 280 ft/day (10^-1 cm/s), 10H:1V
5) CL - 0.0112 ft/day (4 x 10^-6 cm/s), 4H:1V
6) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V
7) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V
8) New Levee Fill - ML - 0.28 ft/day (10^-4 cm/s), 1H:1V

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section H-H'
Comments: Subsurface - 2F-01-15
File Name: Yuba River 2F-01-15 v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 2:10:43 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivities:
1) Levee Fill (SM) - 2.8 ft/day (10^3 cm/sec), 8H:1V
2) SC - 1.12 ft/day (4 x 10^4 cm/sec), 4H:1V
3) GP with cobbles - 280 ft/day (10^1 cm/sec), 10H:1V
4) CL - 0.0112 ft/day (4 x 10^6 cm/sec), 4H:1V

TOTAL HEAD CONTOURS
Horizontal Hydraulic Conductivities:

1) Levee Fill (SM) - 2.8 ft/day \( (10^{-3} \text{ cm/sec}) \), 8H:1V
2) SC - 1.12 ft/day \( (4 \times 10^{-4} \text{ cm/sec}) \), 4H:1V
3) GP with cobbles - 280 ft/day \( (10^{-1} \text{ cm/sec}) \), 10H:1V
4) CL - 0.0112 ft/day \( (4 \times 10^{-6} \text{ cm/sec}) \), 4H:1V
Description: Yuba River Cross Section H-H'
Comments: Subsurface - 2F-01-15
File Name: Yuba River 2F-01-15 Cutoff v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 3:00:08 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivities:
1) Levee Fill (SM) - 2.8 ft/day (10^-3 cm/sec), 8H:1V
2) SC - 1.12 ft/day (4 x 10^-4 cm/sec), 4H:1V
3) GP with cobbles - 280 ft/day (10^-1 cm/sec), 10H:1V
4) CL - 0.0112 ft/day (4 x 10^-6 cm/sec), 4H:1V
5) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

TOTAL HEAD CONTOURS
Horizontal Hydraulic Conductivities:

1) Levee Fill (SM) - 2.8 ft/day (10^-3 cm/sec), 8H:1V
2) SC - 1.12 ft/day (4 x 10^-4 cm/sec), 4H:1V
3) GP with cobbles - 280 ft/day (10^-1 cm/sec), 10H:1V
4) CL - 0.0112 ft/day (4 x 10^-6 cm/sec), 4H:1V
5) Cutoff Wall - 0.0028 ft/day (10^-6 cm/s), 1H:1V

Description: Yuba River Cross Section H-H'
Comments: Subsurface - 2F-01-15
File Name: Yuba River 2F-01-15 Cutoff v2.sep
Last Saved Date: 8/25/2005
Last Saved Time: 2:50:34 PM
Analysis Type: Steady-State
Analysis View: 2-D

VERTICAL GRADIENT CONTOURS
Description: Yuba River Cross Section H-H'
Comments: Subsurface - 2F-01-15 with 300' Landside Berm
File Name: Yuba River 2F-01-15 Berm v2 11ft rbp.sep
Last Saved Date: 8/25/2005
Last Saved Time: 5:35:11 PM
Analysis Type: Steady-State
Analysis View: 2-D

Horizontal Hydraulic Conductivities:
1) Levee Fill (SM) - 2.8 ft/day (10^-3 cm/sec), 8H:1V
2) SC - 1.12 ft/day (4 x 10^-4 cm/sec), 4H:1V
3) GP with cobbles - 280 ft/day (10^-1 cm/sec), 10H:1V
4) CL - 0.0112 ft/day (4 x 10^-6 cm/sec), 4H:1V
5) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V

TOTAL HEAD CONTOURS

KLEINFELDER
Seepage Analysis H-H'
2F-01-15
Yuba River -- Phase 2
Reclamation District 784
Yuba County, California

Graphic By: D. Stevens
Project No. 51730
Date: 8-24-05
File: Y3rev.ppt

PLATE
C-17
Horizontal Hydraulic Conductivities:

1) Levee Fill (SM) - 2.8 ft/day (10^-3 cm/sec), 8H:1V
2) SC - 1.12 ft/day (4 x 10^-4 cm/sec), 4H:1V
3) GP with cobbles - 280 ft/day (10^-1 cm/sec), 10H:1V
4) CL - 0.0112 ft/day (4 x 10^-5 cm/sec), 4H:1V
5) Seepage Berm - ML - 2.24 ft/day (8 x 10^-4 cm/s), 8H:1V
APPENDIX D

GRAVEL SAMPLE PHOTOS

This appendix includes photographs of select samples obtained from the current study that contained gravel. Plate D-1 shows relatively undisturbed samples in sample liners prior to extruding for laboratory testing. Plates D-2 through D-4 show samples in pans after extrusion from liners and prior to drying in the laboratory oven.

LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

Plate D-1       Photo: Boring KB-7, Samples S-2, S-3, S-4, at Depths of 33 to 41 feet
Plate D-2       Photos: Boring KB-6, Sample S-3, 56 Foot Depth;
                  Boring KB-6, Sample S-6, 66 Foot Depth
Plate D-3       Photos: Boring KB-7, Sample S-2, 33 Foot Depth;
                  Boring KB-7, Sample S-4, 41 Foot Depth
Plate D-4       Photos: Boring KB-8, Sample S-2, 40.5 Foot Depth;
                  Boring KB-8, Sample S-3, 41 Foot Depth
Note: Sample liners have inside diameter of 2.4 inches and are 6 inches tall.

Boring KB-7, Samples S-2, S-3, S-4, at Depths of 33 to 41 feet
Note: While notecard is 3.5 inches long by 2 inches wide.
Boring KB-7, Sample S-2, 33 Foot Depth

Boring KB-7, Sample S-4, 41 Foot Depth

Note: White notecard is 3.5 inches long by 2 inches wide.
Boring KB-8, Sample S-2, 40.5 Foot Depth

Note: White notecard is 3.5 inches long by 2 inches wide.

Boring KB-8, Sample S-3, 41 Foot Depth
APPENDIX E
APPENDIX E

DRAFT PIR REVIEW COMMENTS BY USACE AND KLEINFELDER'S RESPONSES

27 July 2005

TRLIA - Phase 2B, PIR Yuba River Left Bank Levee SPRR to Simpson Lane (Draft)
Corps of Engineers, Soil Design Section Review
Review conducted by Henri Mulder, PE, Soil Design Section

Responses by Ray Costa, PE of Kleinfelder, Inc., August 26, 2005

1. Based on a review of Kleinfelder's PIR, independent seepage analysis conducted by
the Corps, poor past performance in the area, variable surface conditions, and
global geomorphology of the area, the Corps concurs with Kleinfelder that there are adverse
underseepage conditions between SPRR and Simpson Lane (PLM 0.9 to 2.18) that
require mitigation prior to FEMA Certification of the levee.

Kleinfelder: For information only.

2. The Corps conducted an independent seepage analysis at the three Kleinfelder
analysis sections. The Corps selected its own permeability values, layer thickness,
riverbank blanket lengths, and topography. The Corps calculated gradients ranging from
30% to 50% lower than Kleinfelder. At section G-G' (2F-97-5), Kleinfelder calculated a
gradient of 1.0, while the Corps calculated a gradient of 0.5 to 0.6. At section G-G' (2F-
97-6), Kleinfelder calculated a gradient of 1.25, while the Corps calculated gradients of
0.55 to 0.64. Finally, at section H-H', Kleinfelder calculated a gradient of 0.67, while the
Corps calculated gradients of 0.4 to 0.5. All the gradients listed are at the 1/AEP=100
water surface. The reason the Corps and Kleinfelder calculated different gradients is
due to the selection of foundation and blanket permeabilities, differences in the length
of the riverbank blanket, and differences in landside levee toe and ground elevations.
Specific items noted by the reviewer are listed below. The items listed are
considerations for Kleinfelder's use rather than comments.

a. The foundation to blanket permeability ratios used by Kleinfelder for sections
G-G' and H-H' are very high for thin, fine-grained blankets. Kleinfelder
assigned a foundation to blanket permeability ratio of 4,000 for the 5-foot thick
silt blanket at section G-G' (2F-97-5). Turnbull and Mansur recommends a
foundation to blanket permeability ratio of 300, while Kansas City District
recommends a foundation to blanket permeability ratio of 200 to 400. The
Corps used foundation to blanket permeability ratio of 800 to 2,000 in their
analysis.

51730/SAC5R575
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Page E-1
August 29, 2005
Kleinfelder: We agree that the use of a foundation to blanket permeability ratio of 4,000 is higher than normally used in this type of analysis. This value represents a relatively low permeability blanket layer compared to the actual pump test result from the 1986 Yuba River levee break investigation. As described by the Reviewer, the use of a lower permeability ratio still generally indicates seepage gradients greater than the USACE recommended maximum. During final design, additional seepage modeling should be performed to evaluate the sensitivity of this ratio. Additionally, the final seepage remediation treatment may be affected by the recalculation.

b. Kleinfelder set the length of riverside blanket at section G-G’ at zero. This appears overly conservative given that borings along the waterside levee toe in vicinity of section G-G’ (KB-8 & KB-9) encountered fine-grained material above the coarse-grained aquifer.

Kleinfelder: In the vicinity of Borings 2F-97-5 and 2F-97-6 there exists a waterside borrow area excavated to about Elevation +60. We expect this excavation penetrates the water side lower permeability blanket and results in free access to the clean sand layer underlying the levee. Kleinfelder modeled this excavation as being at least 300 feet in width. According to available topographic information, it is more likely on the order of 150 feet in width. Since we have not reviewed any river flow velocity information along this reach, we feel it is appropriate at this time to consider the overlying blanket to be removed at the G-G’ cross section. Subsequent analysis of this feature can be performed during final design. Section H-H’ was modeled with the waterside blanket layer intact.

c. Kleinfelder set the landside levee toe and ground at an elevation of 2 feet lower than the Corps topography survey indicates. The report indicates that landside ground elevations used in the seepage models were based on the lowest ground elevation within 200 feet of the levee. This may be considered too conservative especially with the very thin blankets. Recommend modeling actual landside ground topography in the finite-element model.

Kleinfelder: Concur. Final design should include analyses with actual measured topography to evaluate the accuracy of the Kleinfelder seepage model.

3. Kleinfelder has concluded that levee instability from through-levee seepage is an issue along the study reach. The Corps concurs with Kleinfelder that through-levee seepage must be addressed between PLM 0.9 (SPRR) to 1.23 for the Corps to FEMA certify the levee. However, the Corps does not concur at this time with Kleinfelder on the through-levee seepage concern between PLM 1.23 and 2.18. The Corps constructed a slurry cutoff wall and stability berm with internal drain between PLM 1.23 and 2.18 as part of the Phase II system evaluation project to guard against through-
levee seepage. Kleinfelder's report does not include sufficient evidence to show to the Corps that the slurry wall and stability berm with drain are defective against through-levee seepage.

Kleinfelder: As described on Page 9 of the text, the existing seepage/stability berm from the reach between PLM 1.77 to 2.18 has a top elevation documented as between Elevations +71.5 to +75. The 1/100 AEP water surface along this reach is about Elevation +75. Only one (1) boring drilled through the levee along this reach (Boring 2F-01-16) encountered relatively clean sand (SP-SM) within the embankment. However, immediately downstream of this reach, several borings encountered clean sand in the levee embankment and were remediated using a slurry cutoff wall. We recommend additional borings be completed during final design along this reach. Additionally, accurate ground surface topography of the berm should be performed. Based on the results of this additional work, a final assessment of the need for additional through seepage remediation can be made. If a slurry cutoff wall along this reach is chosen for underseepage remediation, it would also serve to remediate the potential through seepage concern.

4. Given the relatively high fines content of the sand and gravel layers (i.e., fines from 5% to 12%) and the photos provided in Appendix E showing gravel samples with a sandy matrix, a slurry cutoff wall constructed by the open-slurry trench method appears feasible. The Corps concurs that multiple test sections should be excavated to test the feasibility of constructing a slurry cutoff wall by the open trench method.

Kleinfelder: Concur. We recommend a test section program be implemented to evaluate the constructability of a conventional SCB slurry cutoff wall along this reach.

5. The Corps advises against the use of relief wells to remediate the adverse foundation seepage conditions because (1) a high number of wells are required, which will require a large maintenance budget from R.D. 784; (2) the wells will discharge a large amount of water and will require an elaborate collector system and pump station(s); (3) there is a lack of room along the landside levee toe behind the subdivision to properly install relief wells, collector system, and maintenance access.

Kleinfelder: Concur. The alternative was presented in order to be complete in our preliminary analysis.
APPENDIX F

DRAFT PIR REVIEW COMMENTS BY HDR AND KLEINFELDER'S RESPONSES

Problem Identification Report
Yuba River Left Bank Levee
SPRR to Simpson Lane
(Draft)
QC Review by Peter Hradilek, PE (HDR)

Responses by Ray Costa, PE, Rick Stauber, PE,
and David Stevens, PE of Kleinfelder, Inc., August 26, 2005

1. Sec. 1.6, Yuba River Design Water Surface Profiles, last paragraph. – The text references the geotechnical requirements of the USACE Engineer Manual EM 1110-2-1913 "Design and Construction of Levees"; the 2003 CESPK Levee Task Force report “Recommendations for Seepage Design Criteria, Evaluation and Design Practices” should also be referenced.

Kleinfelder: Concur. Since the USACE has published ETL 1110-2-569 Design Guidance for Levee Underseepage, which appears to incorporate many of the recommendations of the 2003 CESPK Levee Task Force report, we have chosen to insert that reference.

2. Sec. 2.2, Yuba River Historic Geomorphology, 1st paragraph, next-to-last sentence. – The correct spelling is “thalweg” (not “thalwag”; although the misspelling is widely used, including in federal regulations).

Kleinfelder: Concur. Spelling corrected.

3. Sec. 3.3.1, General, 1st paragraph. – According to the text, “[b]ased on recommendations made by the Levee Seepage Taskforce (2003), a maximum vertical gradient of 0.5 was used as performance criterion” for the analyses. However, note that the task force report lists a number of conditions (subsurface explorations, past flood performance, maintenance, flood fighting plans, unit weights) that must be met to allow design to this gradient (rather than the 0.3 gradient usually applicable).

Kleinfelder: Concur. Agree that in order to use the 0.5 gradient criterion, ETL 1110-2-569 lists several conditions which need to be implemented. These conditions include such factors as additional explorations, review of past performance histories, piezometer installation/monitoring, etc. It is expected that these criteria will be achieved during final design analyses.

4. Sec. 3.3.3, Analysis Results, 1st paragraph. – According to the text, the analysis results were compared to “the performance criterion of 0.5 for existing levees with no past distress.” Note, however, that in Sec. 2.5 “Past Levee Performance”
it was noted that numerous boils were observed in the project area during the 1986 flooding; i.e., there was “past distress.”

*Kleinfelder: Concur. Will be evaluated as described in Response 3, above.*

5. Sec. 3.3.3, Table 3.1, Calculated Vertical Gradients. – (a) For G-G' the 1/200 AEP water surface elevation is shown as 77.5 ft; this is inconsistent with Sec. 1.6 which states it to range from 79.0 ft to 77.6 ft in the project area. (b) Note that an allowable exit gradient of 0.5 is only applicable under certain conditions (see Observation 3 above) which are not all met at the present time (see Observations 11 and 12 which follow). A maximum allowable exit gradient of 0.3 would be more appropriate for this analysis, especially since this is a Problem Identification Report. If the future design is to be based on an allowable exit gradient of 0.5, more investigations would be needed.

*Kleinfelder: Concur. a) Text changed to reflect a range between 79.0 feet to 77.5 feet. b) Calculated exit gradients by Kleinfelder and USACE are all in excess of 0.5. Agree that all recommendations for remediation construction should include an evaluation of the appropriate after project seepage gradient.*

6. Sec. 3.4, Embankment and Foundation Stability. – The text states that the levee will meet slope stability acceptance criteria; do these criteria include earthquake loading? EM 1110-2-1913 stipulates that in some cases, depending on the severity of the earthquake and the importance of the levee) seismic analyses may be required (note that these would include also foundation stability including liquefaction). Since these levees protect housing developments (instead of the traditional agricultural lands) I believe they are important; I anticipate the design earthquake loading to be high also. I am not so much concerned with the simultaneous occurrence of an earthquake and a flood, but rather with whether if a major earthquake were to occur, the resulting damage could be repaired prior to the next flood season.

*Kleinfelder: The evaluation of earthquake loading is not proposed to be included in this PIR. It has been our previous experience in levee evaluations within the Sacramento Valley that the non-flood stage impact of a major seismic event is a general settlement of the embankment. Loss of freeboard is generally less than about 1 foot. In general, the SCB slurry cutoff walls generally used within the USACE Sacramento District are compatible with this magnitude of settlement. This concern can be further addressed during final design.*

7. Sec. 4.2, Seepage Cutoff Barrier. – For a number of the methods the report recommends at least one test section or shaft. Note that in Sec. 2.5 it is stated that “numerous oxbow scars, channel remnants, and outside meander erosion scars were located within the project boundaries.” Given these highly variable subsurface conditions (corroborated by the field investigation logs), I find it doubtful that if one test proves successful, that result could be extrapolated for the rest of the reach.

*Kleinfelder: Concur. Kleinfelder agrees that each additional test section or shaft would further increase the confidence of a particular remediation method.*
8. Sec. 4.2.6, Steel Sheet Piles. – The problem is not only whether or not the piles can be driven to penetrate the dense, coarse grained soils, but additionally whether or not the piles can be so driven while maintaining interlock; sheet piles are only effective against seepage if they maintain interlock.

Kleinfelder: Concur. Agree that interlock must be maintained in order to create a seepage barrier. Predrilling may be required in order to provide better assurance interlock will be maintained. Text modified to include importance of interlock.

9. Plate 2B, Historic Stream Channels. – Historic stream channels are only shown for the extreme westernmost portion of the site, and they end abruptly. Is the fact that they are not shown for the rest of the project area an indication of their absence in 1860, or was that area not covered in the 1860 mapping? I presume the map is based on the reference: Yuba River Channels (1860) titled “Survey of a Tract of Land South of Marysville Yuba County California.”

Kleinfelder: The referenced 1860 map does not cover areas upstream from that shown on Plate 2B.

10. Appendix A, Field Investigation, 1st paragraph. – Note that the subsurface explorations detailed here do not meet the minima needed to meet the requirements for the use of an exit gradient of 0.5 (see Observation 3 above). The task force recommendations are that in order to use a 0.5 gradient for design, the subsurface investigation must include, as a minimum, three borings/soundings (riverside, crown and landside) every 1000 ft. If future designs are to be based on an allowable exit gradient of 0.5, more subsurface explorations will need to be conducted.

Kleinfelder: Concur.

11. Appendix B, Laboratory Testing, Plate B-1. – The sample of KB-7 taken at a depth of 56.0 ft had a dry unit weight of 81 pcf and a moisture content of 33%. Since Plate A-6 shows that for KB-7 the water table was at a depth of 39 ft to 40 ft, the sample can be assumed to have been saturated. If so, the saturated unit weight comes out to be slightly below 108 pcf. Note that this is below the minimum needed to meet the requirements for the use of an exit gradient of 0.5 (see Observation 3 above). The task force recommendations are that in order to use a 0.5 gradient for design, the saturated unit weights of the soils must be at or above 110 pcf. However, if this is the only sample failing to meet the criterion, possibly an exception can be made.

Kleinfelder: Concur. It is of critical importance that the blanket layer soils have a moist/saturated unit weight greater than 110 pcf for the 0.5 gradient criteria to be valid.

12. Appendix C, Seepage Analysis, Analysis Methods, 2nd paragraph. – (a) The fixed-head boundary condition along the boundary nodes of the river bottom and waterside slope of the levee are intuitive; however, this is not so for the vertical waterside edge. The reason for this (i.e., connection to deep river channel, top layer pinching out, etc.) should be explained. (b) From a mathematical
standpoint the usage of the term "half-space" is not rigorously correct for describing the condition along the landslide (right) edge of the model. What is modeled is at best a quarter-space; actually semi-infinite layers are modeled.

Kleinfelder: a) This is a simple conservative approach that accounts for direct recharge through the sandy waterside bank or future sand and gravel pits. b) We will correct the text.

13. Appendix C, Seepage Analysis, Soil Parameters Used in Analysis. – (a) The values selected for the various layers of the Cross Sections G-G’ and H-H’ should be presented and discussed. The values used in the analyses do not always agree with the values presented in Table C.1; for example, in Cross Section G-G’ 14 ft/day was used for the permeability for "Levee Fill (SP)"; the tabulated value for "Sand Fill" is 28 ft/day. (b) What is completely missing is a description of how the system of soil layers used in the analysis was arrived at. No correlations or comparisons between boring logs and adopted layer parameters (depth, thickness, soil type, etc.) are presented; no idealized cross section based on nearby borings is shown.

Kleinfelder: a) We were in the process of developing the permeability table at the time we were running the models. The discrepancies will be removed in the final runs. b) Stratigraphy is based on a specific boring log, which is referenced in the comments on each plate. The bottom portion of the stratigraphy is based on deeper borings in the vicinity.

14. Appendix C, Plates C-1 through C-12, Cross Section G-G’. – (a) Plate 3 in the body of the report shows that Cross Section G-G’ was cut near boring KB-8; that boring extends down to about elevation -6. Plates C-1 through C-4 reference boring 2F-97-5; Plates C-5 through C-12 reference boring 2F-97-6. These borings only penetrate to about elevation 30 and 25, respectively. However, for the analyses, the cross section was modeled down to elevation -30; no discussion on how that was done is presented. (b) The upper layering on Plates C-1 through C-4 differs from that presented on Plates C-5 through C-13; however, both sets are labeled "Cross Section G-G’"; this should be explained here (it is mentioned in Sec. 3.3.2 of the main report; however the text there refers to Appendix C for details).

Kleinfelder: a) Topography and subsurface conditions vary independently of each other. Borings are spaced at roughly even intervals and may not be located at critical topographic sections. The models attempt to represent a combination of adverse topography (tall levee with steep sides and narrow waterside bank) and adverse subsurface conditions that may (based on our interpretation) occur together. A deep boring is placed about every 5000 feet to locate the bottom of the aquifer (usually a hard fine-grained layer of mid Pleistocene age) and the approximate depth of the layer is used to define the bottom of the model. In this case USACE Boring 2F-04-17 within the study reach extends to about Elevation -30 and was used in the stratigraphy. b) We will attempt to explain this process more clearly in Appendix C.
15. Appendix C, Plates C-3 through C-6 and C-9 through C-12, Seepage Analysis G-G'. The water surface elevation is shown as 77.5 ft; this is too high to be the 1/100 AEP water surface and too low to be the 1/200 AEP anywhere in this reach — Sec. 1.6 shows them to range form 74.7 ft to 73.3 ft and 79.0 ft to 77.6 ft, respectively.

Kleinfelder: The 77.5 ft value represents the 1/200 AEP water surface elevation for these analysis cross sections. The report text regarding the approximate 1/200 AEP water surface profile range will be changed to 79.0 to 77.5 feet.

16. Appendix C, Plates C-3 and C-4, Cross Section G-G' with Proposed Wall. The numbering of the features on the model is off (for example according to the table the symbol for the cutoff walls is “7”; however the model uses “6”).

Kleinfelder: The numbering will be corrected in the final model runs.

17. Appendix C, Plates C-3, C-4, C-9 and C-10, Cross Section G-G' with Proposed Wall. (a) Why was the proposed wall located at the waterside toe of the levee? The levee fill was modeled with a high hydraulic conductivity — 14 ft/day; the waterside slope is a ready point of entry for seepage which can bypass the proposed wall. The seepage would have to pass through the ML layer confined between the old and new wall, and possibly another layer of ML levee fill placed on the upstream face (mentioned in Sec. 3.3.2, but not clearly indicated on the plates — see Observation 17); however, these layers have a hydraulic conductivity 1000 times that of the cutoff walls. Also, wouldn’t construction on the crown be easier? (b) The existing wall is noted as 2 ft x 45 ft; in Sec. 2.3 it is stated that the existing wall has a minimum thickness of 18 in and is 40 to 45 ft deep. (c) The proposed wall is noted as 2 ft wide; the thicknesses stated in Sec. 4.2.2 are 3 ft (SCB) and 5 ft (SB).

Kleinfelder: a) Within the levee reach represented by analysis cross section G-G' an existing cutoff wall is located approximately along the levee centerline and extends through the levee fill and into foundation layers. A new wall is proposed near the waterside toe, a location that would avoid the existing wall and degrading the levee and allow for more practical depths of wall construction. The new silt (ML) layer along the waterside slope of the levee would act as a seepage barrier along with the new wall. b) The wall thickness in the seepage models was chosen as the thickness of typical elements (2 feet) in the finite element mesh. Changing this thickness in the models by a few inches would not significantly change the computed results as long as the hydraulic conductivities of the wall and adjacent soil layers were not changed. The existing slurry wall reportedly varies between 40 and 45 feet deep but in the vicinity of cross section G-G' the wall is about 45 feet deep. c) See previous response.

18. Appendix C, Plate C-3, Cross Section G-G' with Proposed Wall. Note that the shown exit gradient of 0.33 is above the maximum allowable unless additional investigations are conducted (see Observation 11 above).

Kleinfelder: See previous response regarding maximum allowable exit gradient. Updated seepage model for this case indicates gradients on the order of 0.1.
19. Appendix C, Plates C-5 and C-6, Cross Section G-G' with Waterside Berm and Setforward Levee. – Apparently the symbols for Seepage Berm ("8") and Levee Fill ("9") were switched between the table and the model.

Kleinfeld: The numbering will be corrected in the final model runs.

20. Appendix C, Plates C-5, C-6, C-11 and C-12, Cross Section G-G' with Waterside Berm and Setforward Levee. – The potential benefits of this solution are partially negated by the assumption of the fixed-head boundary condition set along the vertical waterside edge of the model.

Kleinfeld: Gradients at the landside toe of the existing levee remain elevated in this case but due to the presence of the "maximum berm" it is expected flood fighting personnel would have time to monitor and repair seepage damage to the berm before the levee would be affected.

21. Appendix C, Plate C-11, Cross Section G-G' with Waterside Berm and Setforward Levee. – The value of the average gradient at the landside toe is not noted on the plate.

Kleinfeld: The value will be added in the final model runs.

22. Appendix C, Plate C-15, Cross Section H-H' with Proposed Wall. – The value of the average gradient at the landslide toe is not noted on the plate.

Kleinfeld: The value will be added in the final model runs.

23. Appendix C, Plate C-16, Cross Section H-H' with Proposed Wall. – The value of the exit gradient is not noted on the plate.

Kleinfeld: The value will be added in the final model runs.

24. Appendix D, Slope Stability Analysis. – At the time of this review, the only entry was the word "PENDING".

Kleinfeld: Additional discussion of slope stability will be included in the final report.