HAMILTON CITY FLOOD DAMAGE REDUCTION AND

ECOSYSTEM RESTORATION

FEASIBILITY STUDY

APPENDIX C

ENGINEERING

February 2004

U.S. Army Corps of Engineers
Sacramento District

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BASIS OF DESIGN AND COST ESTIMATE

Hamilton City Flood Damage Reduction And Ecosystem Restoration Feasibility Study

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Hamilton City Flood Damage Reduction And Ecosystem Restoration Feasibility Study Appendix C1 - Basis of Design and Cost Estimate

I. Introduction

A. Purpose and Scope

The purpose of this appendix is to present preliminary level design and costs of six alternatives proposed in the Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study, which includes the identification of a recommended plan. The basis for the costs are a compilation of preliminary measures that were unique in providing specific goals or objectives such as reducing flood risk in the study area and provide a more ecosystem friendly river system. Setback levees at varying distances were included within each alternative except Alternative 3, which looked at a ring levee encompassing Hamilton City. Each alternative was also to ensure that there were no hydraulic impacts downstream of the study area. The individual alternatives are discussed in detail in the main report. All alternatives were evaluated at an equal level of detail. Preliminary cost estimates were developed for each of the alternatives with prepared template costs for basic features using typical M-CACES standards.

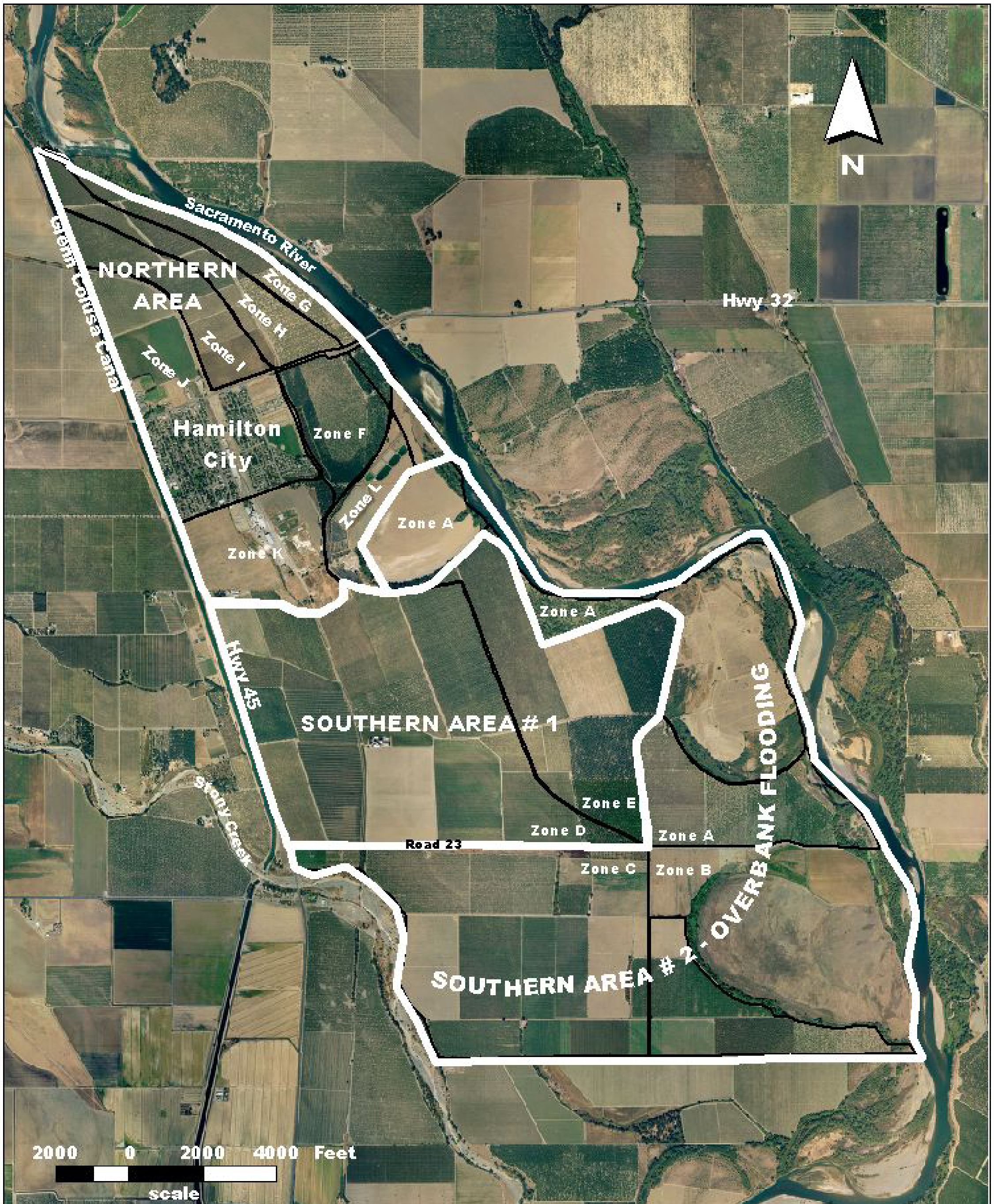
B Project Performance

Design alternatives included different levels of project performance within each alternative. Each ***intra***-design (Design Impact Area) would provide varying reliability of passing a particular event at 90-percent confidence relative to a specific *n*-year design. Figure C1-1 shows the boundaries of these proposed damage impact areas and include the following reliability criteria:

Table C1-1: Design Reliability

Damage Impact Area	*n*-Year Design	Frequency of Exceedance (90% Confidence)	Conditional Non-Exceedance					
			10 year flood	25 year flood	50 year flood	100 year flood	250 year flood	500 year flood
Northern Area	320	1 in 75	100	100	96	84	49	17
Southern Area #1	100	1 in 35	100	96	81	53	20	6
Southern Area #2	20	1 in 11	93	46	20	6	1	0

Figure C1-1
Damage Impact Areas and Analysis Zones



	Damage Impact Areas and Analysis Zones	**Hamilton City Flood Damage Reduction and Ecosystem Restoration, CA** *map created July 25, 2003*

C. Project Description

The regional and study area locations of the project are referenced in Figure C1-2 and Figure C1-3, respectively, and described in Chapter 2 of the main report.

Figure C1-2 Regional map of the Hamilton City area.

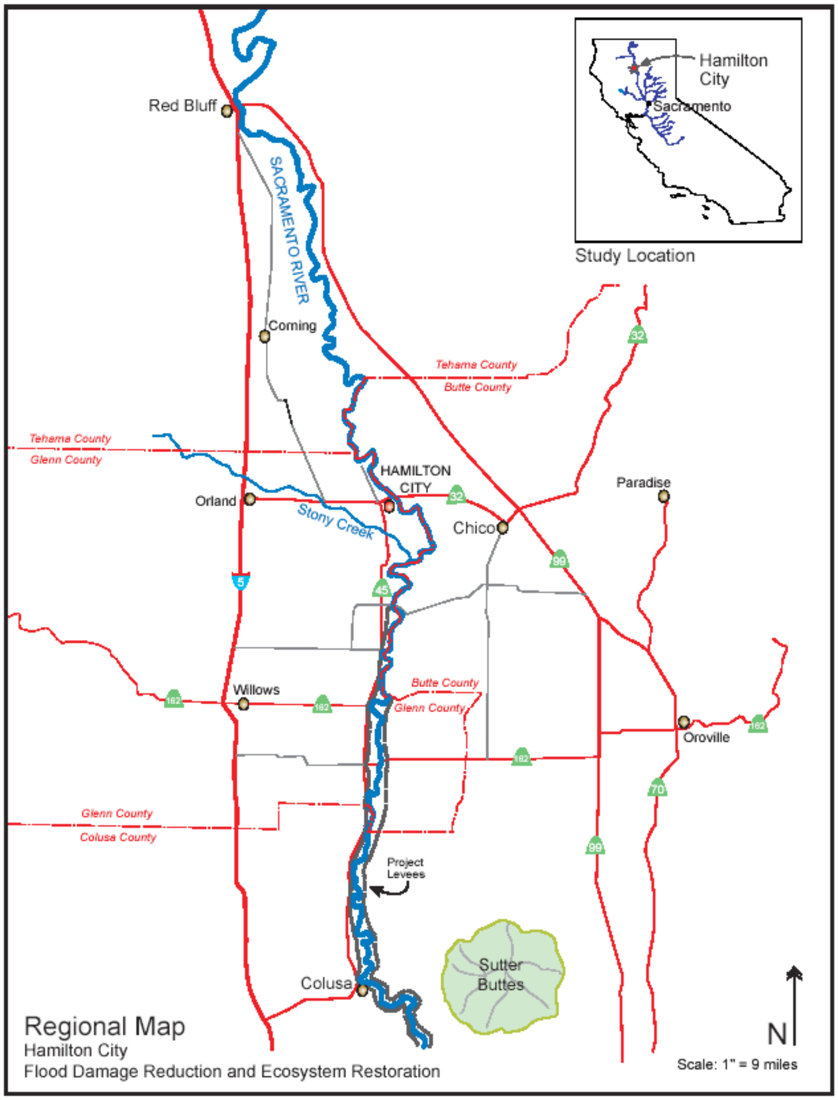
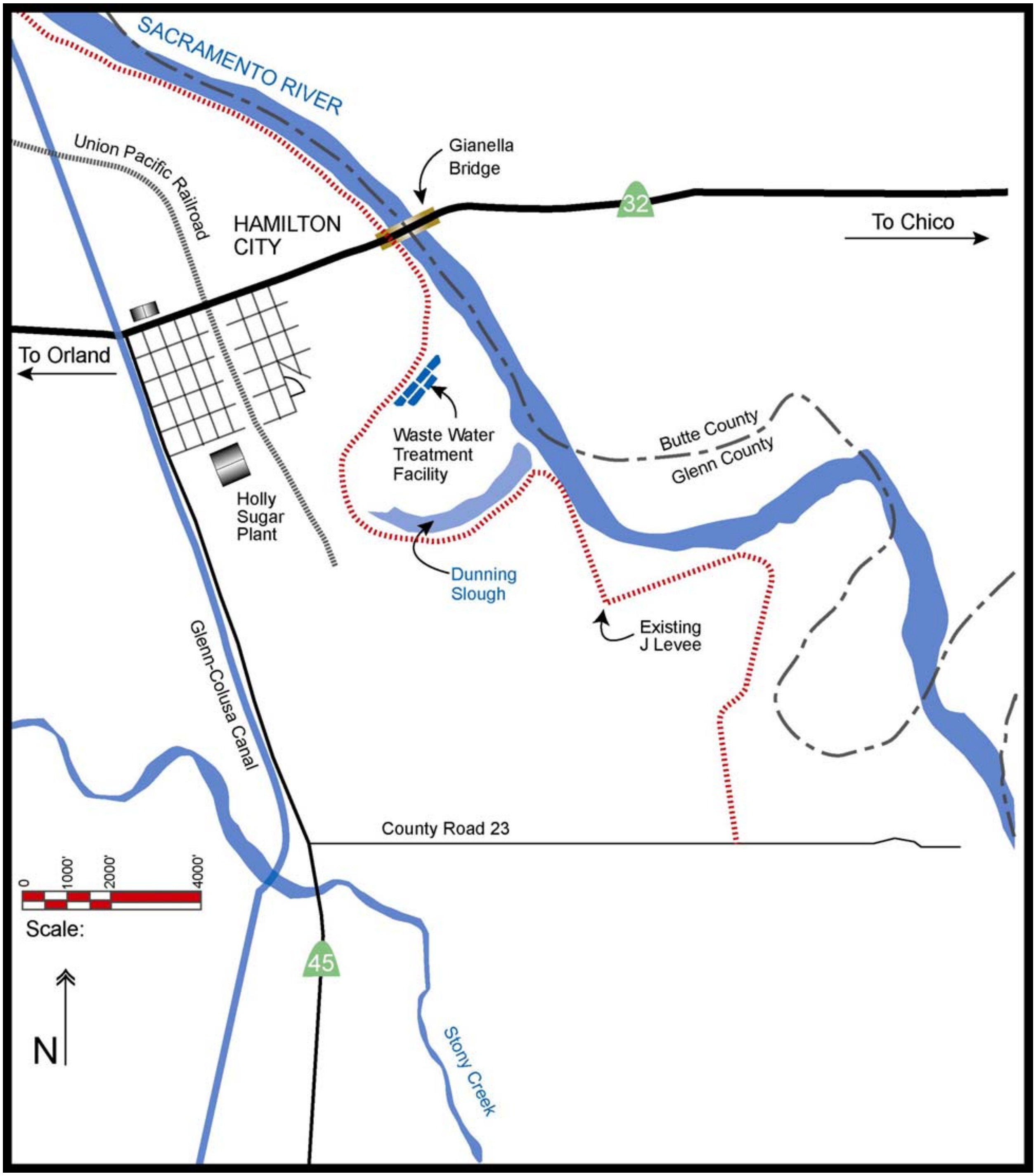


Figure C1-3 Study Area Map (Existing)



D. Description of Alternative Plans

The individual alternatives with Ecosystem Restoration (ER) and Flood Damage Reduction (FDR) benefits are briefly summarized below in Table C1-2 and are described in more detail in the main report.

Table C1-2 Alternatives and Major Features with Relative Benefits

Preliminary Combined Alternatives[2]	Increase in Habitat Units (AAHU)	Flood Damage Reduction Benefits[3] ($1,000)
1-Locally Developed Setback Levee with 500-yr FDR	783	676
2-Intermediate Setback Levee with 500-yr FDR	795	483
3-Ring Levee with 500-yr FDR	895	470
4-Locally Developed Setback Upstream of Dunning Slough, Intermediate Setback Levee Downstream of Dunning Slough with 500-yr FDR	642	493
5-Intermediate Setback Upstream of Dunning Slough, Locally Developed Setback Downstream of Dunning Slough with 500-yr FDR	937	666
6-Intermediate Setback Upstream of Highway 32, Locally Developed Setback Downstream of Highway 32 with 500-yr FDR	888	676

E. Recommended Plan

An M-CACES cost estimate current for the final report has been developed only for the recommended plan.

II. Design Considerations

A. Hydrology and Hydraulic Design

The hydrology report was completed and approved for use and is included as Appendix C2. That appendix provides a more detailed description of the work in developing the study hydrology and was influential in determining the necessary information used in this report.

The hydraulic modeling is used to describe how the flood flows developed by the hydrology and reservoir operations modeling move through the river system. This includes flow within the defined system of channels, weirs, and bypasses and flooding of the overbank areas due to potential levee breaks. The models compute flooding extent, stage, how the flood changes as it moves downstream. These models are used to identify current, baseline conditions and analyze the effects of various alternatives and measures. Appendix C3 provides a detailed description of the hydraulic models. Included with Appendix 3 are the sediment, scour, and geomorphic analyses.

B. Surveying and Mapping

Topography Data

Topography (above waterline) was developed using standard photogrammetric mapping techniques. For 2-foot contour mapping, aerial photos were taken at 5,000 feet above mean terrain (all new mapping and some existing Sacramento River mapping) and for 5-foot contour mapping (existing Sacramento River mapping only), aerial photos were taken at 12,000 feet above mean terrain. The survey techniques are similar to those described for the 1995 surveys.

Datum

The North American Datum of 1983 (NAD 83 1991.35), California Coordinate System of 1983 Zone 2 was used for horizontal control. The National Geodetic Vertical Datum of 1929 (NGVD29) was used to establish elevations. The NAD83 were obtained from the California Department of Transportation, North Region Surveys and are a part of the California Spatial Reference System – Horizontal (CSRS-H). The NGVD29 values were obtained in part from the National Geodetic Survey Control Database dated 1995, The California Department of Transportation and the County of Sacramento.

Bathymetric Data

Bathymetric (below waterline) data was collected with boats equipped with a dual frequency GPS receiver, Fathometer, and sonar transducer. Bathymetric survey data was collected along river cross-sections oriented generally perpendicular to the channel banks to detail the form of the river bottom. These cross-sections were spaced roughly at a distance equal to the channel top width.

C. Geotechnical

Introduction and Purpose

This report discusses the analysis and design of a new setback levee, risk-based evaluations of the existing J-levee, existing explorations and conclusions/recommendations. Upon completion of the feasibility report, additional subsurface explorations and engineering will be conducted during the Pre-construction Engineering and Design Phase (PED).

Because the alignments are relatively close to each other, foundation conditions are not expected to change significantly among the alternative alignments. For this reason, this initial geotechnical analysis is based upon a single cross section from river mile 199.5, which is several hundred feet upstream of Highway 32. This cross-section of the locally developed setback levee was chosen as the representative profile because of the levee's close proximity to the Sacramento River. For conservatism, the soil parameters chosen to use in the model were chosen such that they represent a worst-case scenario (i.e. high permeability and low shear strength). Appendix C4 provides a more detailed description of the geotechnical analysis.

D. Relocations

For discussion purposes, a portion of Highway 32 would need to be raised in alternative 1. Levee alignments in these two alternatives combined with the degrading of the existing J Levee would expose the current highway configuration to increased flooding.

The sewer treatment facility could be relocated in alternatives 1 and 2 from its current location inside of Dunning Slough. This would allow for the reconnection of Dunning Slough with the Sacramento River.

It is assumed that any of the alternatives may require the relocation or protection of various utilities such as power lines, gas lines, and possibly fiber optic cables. Some irrigation pumps may also need to be relocated.

The alternative carried forward for design and cost estimating purposes is the recommended plan (combination 6). This alternative offers an opportunity to provide dual-performance levees for urban and agriculture development, respectively. The alternative is also provides a high level of acceptance by the stakeholders and sponsors.

E. Minimize Impacts to Traffic Flows, Recreation, and Environment

Construction work will be designed and scheduled to allow public traffic to continue to use roads with minimum interruptions, especially during peak commuter times.

F. Operations and Maintenance

Creating a project levee system will typically increase annual costs for operation and maintenance. Specifically, any setback levee or realignment of existing levee structures will require the degrading, breaching or total removal of any existing private levee. Operation and maintenance of realigned or setback levees will require maintenance for wind and wave erosion during flood events. In addition, the recommended plan will include maintaining facilities such as roads and culverts, or water delivery systems associated with the realigned or setback levees.

III. Real Estate Requirements

The real estate work will include the evaluation, cost estimation and identification of relocation, land and acquisition requirements necessary to support development and assessment of the Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study.

Lands acquired for environmental mitigation, enhancement, and restoration purposes will, by regulation, be fee acquisitions. Lands acquired in support of levees, floodways or flowage areas will be easements, and lands acquired for temporary work areas in support of levee construction or improvement will be temporary work area easements. Additionally, there will be requirements for borrow sites and disposal areas. These acquisitions may be fee, easement or leasehold depending on the specific circumstances of the requirement. Real Estate relocations involving the replacement of existing public utilities or facilities (such as the boat ramp located immediately downstream of the Highway 32 bridge) may also be a real estate component cost.

At each study phase, the real estate requirements will be addressed in greater detail and refined. For this phase of the study measures and alternatives are general in nature, therefore, so are the real estate requirements. These requirements and land costs are identified by a range of values for types of land use by county. Based on an assessment of predominant land usage a reasonable mean land value can be identified through the use of price ranges as identified in the California Agricultural Property Information Exchange Guide and available records for recent comparable sales of properties. Temporary construction easements are more in the nature of a land rental and value is frequently established on such a basis. Acquisition for borrow and disposal is not addressed at this level, but should be recognized as a potential cost where material will be needed to build new levees raise existing levees and/or strengthen existing levees either by the use of berms or slurry walls. Currently, borrow will be select fill purchased from the Glenn County Irrigation District (GCID).

The recommended plan would require the acquisition of about 1,500 acres in fee title along with about 145 acres of permanent easements and about 28 acres of temporary work easements are required for the recommended plan. This consists of lands under and waterside of the proposed setback levee. The non-Federal sponsor would acquire these lands as part of the project.

Real estate acquisition for the recommended plan is split among 13 landowners. Relocations are estimated to be about $653,000 which would consist of raising County Road 203 about 1.5 feet to tie into the new levee, ramping County Road 23 over the new levee, as well as relocating affected utilities and irrigation ditches. Detail on relocations and costs can be found in Table C5-3, Appendix C5 Civil Design.

IV. Value Engineering

A value engineering (VE) study of the feasibility study was completed in late fall of 2003. A thorough VE study will be required at the 35 % design level (PED). The M-CACES estimate includes a cost for the VE study during PED. Design documents will be delivered to the Value Engineering Office (VEO) and shall include comprehensive estimates. Upon completion of the study, copies of the study will be provided to all interested parties. The Project Manager will make the final determination whether the VE is approved or disapproved.

V. Basis of Cost Estimate

A. First Costs

The detailed estimate of the first costs for the alternatives is based on October 2003 price levels for comparative purposes. For the recommended plan, a M-CACES cost estimate has been developed. The Real Estate Division furnished the estimated cost of lands. The unit prices used for construction items were based on adjustments of average bid prices received for comparable work in the same study area. An average 25 percent contingency allowance has been included in the estimates. Suitable allowances have been included for Engineering and Design and Supervision and Administration, based on costs experienced on similar construction work in the Sacramento District.

B. Annual Costs

The detailed estimate of annual costs for the recommended plan is calculated on the first cost. Costs for the alternative is based on October 2003 price levels at 5.628 %

interest rate and 50-year amortization period. Annual costs were determined in accordance with EM 1120-2-104. The costs for maintenance, operation, and major replacement were computed from a Sacramento District compilation of cost factors. Such costs were compiled from prior costs in the Sacramento District and elsewhere.

C. Summary of First and Annual Costs

The summary of first and annual costs for the recommended plan is shown in Tables C1- 3.

Table C1-3
First and Annual Costs Of
Recommended Plan[1] ($1,000)

Item	Cost
Investment Cost	
First Cost[2]	43,650
Interest During Construction	3,258
Total	46,908
Annual Cost	
Interest and Amortization	2,819
OMRR&R[3]	55
Subtotal	2,874
Annual Benefits	
Monetary (Flood Damage Reduction)	584
Non-monetary (Ecosystem Restoration)	888 AAHUs
Net Annual FDR Benefits	253
FDR Benefit-Cost Ratio	1.8 to 1

[1] Based on October 2003 price levels, 5 5/8 percent rate of interest, and a 50-year period of analysis.
[2] Excludes Cultural Resource Preservation.
[3] Operation, Maintenance, Repair, Replacement and Rehabilitation.

VI. Implementation

A. Features and Costs

Successful implementation of the recommended plan would include construction of the above-mentioned physical features and replacement, and any mitigation required.

The M-CACES costs for this alternative are summarized in Table C1-4 below.

Table C1-4
ESTIMATED COSTS OF RECOMMENDED PLAN[1] ($1,000)

MCACES Account[2]	Description	Total First Cost
01	Lands and Damages[3]	12,825
02	Relocations[4]	563
06	Fish and Wildlife[5]	24,097
11	Levees[6]	921
18	Cultural Resources[7]	170
30	Planning, Engineering, Design[8]	3,070
31	Construction Management[9]	2,174
	Total First Cost	43,820

1 Based on October 2003 price levels, 5 5/8 percent rate of interest, and a 50-year period of analysis.
2 MCACES (Micro Computer-Aided Cost Engineering System) is the software program and associated format used by the Corps in developing cost estimates. Costs are divided into various categories, identified as "accounts." Detailed costs estimates are presented in Appendix C, part 8, Cost Engineering.
3 Real Estate land costs. Includes no Damages.
4 Relocations include raising County Road 203, ramping County Road 23, and relocating affected utilities and irrigation ditches.
5 Includes habitat restoration, removal of "J" levee, levee costs allocated to restoration, plus 25 percent contingency.
6 Includes levee costs allocated to flood damage reduction and training dike, plus 25 percent contingency.
7 Assumes approximately 0.4 percent of project first cost.
8 12 percent of 02, 06, 08, 11, and 18 accounts. PED is cost shared 75 percent Federal and 25 percent non-Federal during PED, then adjusted as part of the total project cost sharing to 65 percent Federal and 35 percent non-Federal during construction.
9 8.5 percent of 02, 06, 08,11 and 18 accounts.

Appendix C2.

HYDROLOGIC

US ARMY CORPS
OF ENGINEERS
Sacramento District

Hamilton City Feasibility Study
Hamilton City, California

HYDROLOGY OFFICE REPORT
June 2003

HAMILTON CITY FEASIBILITY STUDY
HAMILTON CITY, CALIFORNIA

HYDROLOGY OFFICE REPORT
JUNE 2003

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HAMILTON CITY FEASIBILITY STUDY
HAMILTON CITY, CALIFORNIA

HYDROLOGY OFFICE REPORT
JUNE 2003

1. Purpose and Scope

This office report presents hydrologic data needed to develop floodplains for the Sacramento River near Hamilton City, Glenn County, California. The hydrologic analysis is part of a feasibility study conducted by the U.S. Army Corps of Engineers and the Reclamation Board of the State of California to develop and evaluate potential alternative plans to reduce flood damages and restore the ecosystem in this area.

The area covered by the hydrologic analysis includes the Sacramento River Valley from the headwaters upstream of Lake Shasta down to the Sacramento River at Hamilton City. The drainage area encompasses over 11,000 square miles, and includes contributions from Sacramento Valley "westside tributaries" (Clear, Cottonwood, Thomes, and Elder creeks) and "eastside tributaries" (Cow, Battle, Mill, and Deer creeks). The area evaluated includes headwater reservoirs and the Sacramento River tributaries north of Glenn County (Plate 1). This report includes newly-generated synthetic hydrology using headwater reservoir models for the study area.

Two sets of Sacramento River flow frequency curves for unregulated conditions were developed: one for the total Sacramento River flow at the Latitude of Hamilton City index point and the second for local flow at Hamilton City (minus any contribution upstream of Shasta Dam). The local flow frequency curves for Hamilton City included a peak flow curve. A Sacramento River flood centering series above Hamilton City, with concurrent floods above Shasta Dam, was developed, based on the two sets of frequency curves. The tributary hydrographs constructed for each frequency event were input into the reservoir system models to simulate regulated flows downstream. The hydrologic methods and reservoir system models used were created as part of the Sacramento and San Joaquin River Basins Comprehensive Study. Documentation of the methods and models are presented in References 2a and 2b, listed below.

2. References

Information from the references listed below was used in this study. References c, d, e, and f are previous flood studies in the vicinity of Hamilton City.

a. Sacramento and San Joaquin River Basins Comprehensive Study: Technical Studies Documentation, Appendix B, Synthetic Hydrology Technical Documentation. U.S. Army Corps of Engineers, Sacramento District, December 2002.

b. Sacramento and San Joaquin River Basins Comprehensive Study: Reservoir Simulation Model User's Guide. U.S. Army Corps of Engineers, Sacramento District, December 2002.

c. Hamilton City, California, Feasibility Investigation Office Report. U.S. Army Corps of Engineers, Sacramento District, July 1997.

d. Section 205 Reconnaissance Investigation, Sacramento River near Hamilton City, California. U.S. Army Corps of Engineers, Sacramento District, January 1991.

e. Design Memorandum No. 1, Cottonwood Creek, California, Hydrology Report. U.S. Army Corps of Engineers, Sacramento District, July 1977.

f. Reconnaissance Report on Flood Control on Sacramento River at Hamilton City, Glenn County, California. U.S. Army Corps of Engineers, Sacramento District, March 1975.

g. United States Average Annual Precipitation, 1961-1990, George Taylor, the Oregon Climate Service at Oregon State University, Corvallis, Oregon, September 2000. http://nationalatlas.gov/atlasftp.html.

h. Guidelines for Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Subcommittee, Interagency Advisory Committee on Water Data, U.S. Department of the Interior, Geological Survey, Office of Water Data Coordination, Reston, Virginia, revised September 1981, editorial corrections March 1982.

i. Flood Frequency Analysis, HEC-FFA, User's Manual. U.S. Army Corps of Engineers, Hydrologic Engineering Center, May 1992.

j. Regional Frequency Computation, REGFQ, User's Manual. U.S. Army Corps of Engineers, Hydrologic Engineering Center, July 1972.
k. HEC-5, Simulations of Flood Control and Conservation Systems, User's Manual, Version 8.0. U.S. Army Corps of Engineers, Hydrologic Engineering Center, October 1998.
l. HEC-RAS River Analysis System, User's Manual, Version 3.0. U.S. Army Corps of Engineers, Hydrologic Engineering Center, January 2001.

3. Descriptive Information

The Sacramento River originates in the northern part of California and flows southward through Lake Shasta to the Sacramento Valley. It enters the Sacramento Valley about 5 miles northeast of Red Bluff, then flows southward about 240 river miles to the Sacramento-San Joaquin Delta east of San Francisco.

Hamilton City is located about 60 miles south of Redding and 85 miles north of the City of Sacramento in the central part of northern California (see Plate 2). Hamilton City is located about 6,000 feet west of the Sacramento River, in Glenn County. The study area includes Hamilton City and the surrounding rural area. The area around Hamilton City is primarily agricultural with a variety of crops, including several types of orchards.

The Hamilton City climate is characterized by hot, dry summers and mild winters. Normal annual precipitation varies considerably throughout the basin, ranging from a low of 21 inches around Hamilton City to over 100 inches at Mount Lassen, to the northeast in the Sierra Nevada Mountains (Reference 2g). Precipitation occurs primarily during the period from November to April. During the late summer and early fall, precipitation is confined to occasional local thunderstorm activity, usually light in rainfall amounts.

Soils on the Sacramento Valley floor around Hamilton City are alluvial, composed of sediments derived from the surrounding mountains. Topography of the basin varies from flat valley areas and low rolling foothills, to steep mountainous terrain to the west (Coast Ranges), north (Cascade Range), and east (Sierra Nevada Mountains). The elevation is around 170 feet near Hamilton City, but rises to above 10,000 feet at Mount Lassen.

4. Flood Problems

4a. Storm Characteristics. Major flood-producing storms over central and northern California are generally associated with storm systems that originate about 30° to 50° north latitude and develop a moist air trajectory from about the latitude of the Hawaiian Islands. As the system approaches the coast, the trajectory is over cooler water, thus retarding release of the moisture until the air mass is borne inland, where the north-south coast ranges lift the air mass and cause condensation and release of moisture. This general flow pattern produces strong southwesterly or southerly winds up the Sacramento Valley that are lifted as they flow over the mountains at the north end of the valley. This lifting effect, combined with some convergence, accounts for the major portion of storm precipitation around Hamilton City.

Intense thunderstorms have occurred in the area around Hamilton City, but they do not cause high flows on the mainstem Sacramento River. Local storms may cause interior drainage flooding, which will become less of a problem due to alternatives being considered for the Hamilton City feasibility study. Also, interior drainage problems are not major, since Hamilton City is not an urban center and has existing drainage facilities and low lying areas to handle these flows as well as flows off the orchards and other agricultural areas north of the city. Areas south of the City drain south and eventually enter the Sacramento River downstream of Hamilton City. This hydrology report does not address interior drainage flooding. Hydraulic Design Section will cover that aspect of the study.

4b. Historic Flooding. Flooding along the Sacramento River occurs from midwinter to early spring and is usually due to a combination of rain and snowmelt conditions. Some of the more significant peak flows on the Sacramento River at the Latitude of Hamilton City occurred in February 1940 (350,000 cfs, before Shasta Dam was built), February 1958, December 1964, January 1969, January 1970, January 1974, February 1986, January 1995 (155,000 cfs), and January 1997 (155,000 cfs). The magnitudes of most of these peak flows are difficult to determine, since much of the flow occurs out-of-channel. Hamilton City was flooded during February 1940, prior to the completion of Shasta Dam. In January 1974 floodwaters inundated orchards and the lower eastern portion of Hamilton City, due to failure of the levee along Dunning Slough, southeast of Hamilton City. During the February 1986 event, sandbagging on the top of the levee prevented flooding in Hamilton City. Additionally, because a levee broke east of the river, pressure on the Hamilton City levee was reduced. During the storm of January 1997 the city was evacuated, but crews working on the levee were able to prevent flooding in the city. Flood fighting efforts also prevented Hamilton City from being flooded in 1983, 1995, and 1998.

5. Hydrologic Analysis Procedure

The hydrologic analysis was performed to generate 30-day flood hydrographs for the Sacramento River at Hamilton City index point for several synthetic exceedence frequency events, using Comprehensive Study methodology. Generating the hydrographs is a three-step process consisting of: (1) development of unregulated rain flood flow frequency curves, (2) creation of synthetic flood patterns and subsequent development of tributary and downstream mainstem flood hydrographs based on those patterns, and (3) input of the synthetic tributary hydrographs into the reservoir system models to produce regulated hydrographs at Hamilton City. A schematic diagram of the process is illustrated on Plate 3 (taken from the Reservoir Simulation Model User's Guide, Reference 2b).

6. Analysis for Unregulated Flow Frequency Curves

Unregulated flow frequency curves were created using procedures defined in Bulletin 17B, Guidelines for Determining Flood Flow Frequency, Reference 2h, for key index locations where a systematic record of natural flow data exists or could be computed. Bulletin 17B requires the use of a Pearson Type III distribution with log transformation of the data as the method to analyze flood flow frequency. The mean, standard deviation, and skew of the log-transformed data are computed for the flows at the stream gage or index point. The data are screened for high and low outliers and, if found, adjustments to the statistics are computed as outlined in Bulletin 17B. The statistics may be further adjusted or smoothed to account for sampling error differences among the various durations, or after comparison with similar gages in the area. Sets of unregulated frequency curves of primary significance to this analysis are those for Sacramento River at Shasta Dam, at Bend Bridge, and at the Latitude of Ord Ferry index points. These existing frequency curves (in Reference 2a), developed as part of the Comprehensive Study, cover durations from 1 day to 30 days and are presented here on Plates 4 through 6.

Two new sets of unregulated flow frequency curves were developed specifically for the mainstem of the Sacramento River at Hamilton City: one for the total Sacramento River flow at the Latitude of Hamilton City, and the other for the Sacramento River local flows between Shasta Dam and Hamilton City, for the 1-, 3-, 7-, 15- and 30-day durations. Also, a peak flow frequency curve was developed for the Sacramento River local flow at Hamilton City. The sets of flow frequency curves for Hamilton City are presented in Plates 7 and 8 and their development is discussed below.

6a. Frequency Curves for Sacramento River at the Latitude of Hamilton City. Comprehensive Study methodology, described in Reference 2a, Chapter III, pages 3 - 4, was used to develop the unregulated rain flood frequency curves for the total Sacramento River flow at Latitude of Hamilton City index point. "Latitude of Hamilton City" includes any and all diverted or channelized flows that pass Hamilton City's geographic latitude. The flow frequency curves reflect this assumption. The procedures described below were used to route the upstream hydrographs down the Sacramento River to combine them at Hamilton City for a "Latitude of Hamilton City" hydrograph. When the hydrographs are routed through the floodplain using a dynamic routing model, such as the HEC-RAS River Analysis System (Reference 2l), the peaks and volumes will be different.

River routings were simulated assuming infinite channel capacity with no flow lost to overbank areas. The daily natural flow data for 1922 to 1997 for the mainstem Sacramento River at Bend Bridge were routed downstream to Hamilton City using the Muskingum routing method. The adjustments made to develop unregulated flows at Shasta Dam and Bend Bridge and for downstream Valley tributaries are listed in Reference 2a, Attachment B.1, Table 1. The observed or adjusted daily flows at the four tributary streamflow gaging stations, for Elder Creek near Paskenta, Mill Creek near Los Molinos, Thomes Creek at Paskenta, and Deer Creek near Vina, were routed, using Muskingum routing parameters, to Hamilton City and then added to the Sacramento River mainstem flows plus an estimate for local flow contribution from smaller, ungaged tributaries. The estimate used for local flow contribution was 55 percent of the combined gaged daily flows for the tributaries, Elder, Mill, Thomes, and Deer creeks, plus 48 percent of the gaged flow for Big Chico Creek near Chico. The estimate for local flow, developed for the Comprehensive Study, is based on historic flow records at Bend Bridge, at Ord

Ferry, and for the 5 gaged unregulated tributaries between Bend Bridge and Ord Ferry, Elder, Thomes, Mill, Deer, and Big Chico creeks. The data sets for the unregulated Sacramento River flows at Bend Bridge and for the tributary gaging stations were developed for the Comprehensive Study. The annual historic routed and combined flows at Hamilton City were plotted using moving averages of the daily time series for 1-, 3-, 7-, 15-, and 30-day duration natural flow data. Statistics were computed for the samples of annual flows, using statistical analysis tools (FFA and REGFQ computer programs, References 2i and 2j). As with the unregulated frequency curves for Bend Bridge and Latitude of Ord Ferry, water year 1977 was excluded as a low outlier for Hamilton City. The sample skews were adjusted to match those at the downstream Latitude of Ord Ferry frequency curves. The unregulated flow frequency curves for total Sacramento River flow at the Latitude of Hamilton City, with their statistics, are presented in Plate 7. Table 1 lists the Muskingum routing parameters.

TABLE 1
MUSKINGUM ROUTING PARAMETERS FOR SACRAMENTO RIVER BASIN INDEX POINTS

Source	From	To	Travel Time (Hours)	Muskingum Coefficient
Sacramento River	Shasta Dam	Keswick	2	0.4
Sacramento River	Keswick	Clear Creek	3	0.4
Clear Creek	Whiskeytown Dam	Mouth	2	0.4
Sacramento River	Clear Creek	Cow Creek	2	0.1
Cow Creek	Gage near Millville	Mouth	1	0.2
Battle Creek	Gage below Coleman F.H.	Mouth	1	0.2
Sacramento River	Battle Creek	Bend-Bridge	3	0.1
Sacramento River	Bend-Bridge	Hamilton City	17	0.2
Mill Creek	Gage near Los Molinos	Hamilton City	14	0.2
Elder Creek	Gage near Paskenta	Hamilton City	19	0.2
Deer Creek	Gage near Vina	Hamilton City	13	0.2
Thomes Creek	Gage at Paskenta	Hamilton City	19	0.2

Note: Cottonwood Creek contributions were included, but the gage is so close to the Sacramento River, that no Muskingum routing of Cottonwood Creek flows was performed. (Source: Reference 2a.)

6b. Unregulated Frequency Curves for Local Flow at Hamilton City. The local flow at Hamilton City is the streamflow from the Sacramento River tributaries between Shasta Dam and Hamilton City, excluding any contribution upstream of Shasta Dam. Frequency curves for unregulated local flow between Shasta Dam and Hamilton City were needed for the development of a Sacramento River flood centering series above Hamilton City, with concurrent floods above Shasta Dam. Such a Hamilton City flood centering series is needed to test the potential for flooding at Hamilton City when Shasta Dam controls flood flows on the upper Sacramento River basin. Development of the flow frequency curves was similar to that of the frequency curves at the Latitude of Hamilton City, except that the daily flows for Sacramento River upstream of Shasta Dam were removed from the routed and combined Sacramento River flows. The unregulated daily flow record for Sacramento River at Shasta Dam (prior to 1943, Sacramento River at Kennett) was developed for the Comprehensive Study for water years 1932 to 1997. The unregulated daily flows at Shasta Dam were routed downstream to Bend Bridge using Muskingum routing parameters (Table 1), and were then subtracted from the unregulated daily flows for Sacramento River at Bend Bridge for the period 1932 to 1997. The remaining flows were the Bend Bridge local flows, unregulated runoff from the local drainage area between Shasta Dam and Bend Bridge. The Bend Bridge daily local flows were routed down to Hamilton City and added to the routed flows from the four gaged tributaries plus an estimate for local ungaged drainage.

The annual flows for the 1-, 3-, 7-, 15-, and 30-day durations for 1932-1997 were plotted and statistics computed using the FFA and REGFQ computer programs. Water year 1977 was excluded as a low outlier. The unregulated flow frequency curves for Sacramento River Local Flow at Hamilton City, with their statistics, are presented in Plate 8.

6c. Unregulated Peak Flow Frequency Curve for Local Flow at Hamilton City. Comprehensive Study methodology did not include a procedure to develop peak flow frequency curves for the mainstem Sacramento River index points (at the Latitudes of Ord Ferry, Verona and Sacramento). A peak flow frequency curve was needed at Hamilton City, because the peak flow overtops the levee and causes the flood damage. A record of unregulated peak flows is not available for the Sacramento River downstream of Bend Bridge. The development of the unregulated peak flow curve was based upon the relationship of regulated peak and one-day flows for the Sacramento River at Hamilton City, using streamflow records from the California Department of Water Resources gage at that location. Records for the Hamilton City gage (regulated conditions) began in 1945. The mean logarithms for the regulated peak and one-day annual flows at Hamilton City were computed. The difference between the peak flow mean log and the one-day flow mean log (for regulated conditions) was added to the mean log of the one-day flow frequency curve for unregulated conditions for Hamilton City Local Flow (Plate 8), to estimate the mean log of the unregulated peak flow frequency curve. The peak flow frequency curve also has the same standard deviation and skew as the one day curve. The relationship between regulated peak and one-day flows on the Sacramento River was verified by a check of the records at Bend Bridge for regulated conditions. Since it was built, Shasta Dam has controlled all inflows from the drainage area above it. All the differences between the peak and 1-day flows along the Sacramento River from Shasta Dam to Hamilton City are due to tributary flow below Shasta Dam. It is assumed that, for the period of record, 1945 to present, the contribution from above Shasta Dam to the peak flow at Hamilton City is the same as the one-day flow. The unregulated peak flow frequency curve for Hamilton City local flow was added to the set of flow frequency curves on Plate 8.

6d. Regulated Peak Flow Frequency Curve for Bend Bridge and Hamilton City.
Graphical curves of regulated peak and one-day flows were drawn for Bend Bridge and Hamilton City (shown on Plates 12 and 13, respectively) for the purpose of comparison with hypothetical results. Since high flows at Hamilton City bypass the gage, recorded flows at the gage do not reflect total flows at the Latitude of Hamilton City. At Bend Bridge all flows remain in-channel and are recorded at the gage. The relationship of the central tendency of the flows at Hamilton City is similar to that shown at Bend Bridge. Therefore, the relationship between peak and one-day flows at Bend Bridge was applied in construction of the graphical curves for Hamilton City to better estimate the total flows at the Latitude of Hamilton City.

7. Development of Flood Centering Series Patterns above Hamilton City

Comprehensive Study methodology was used to develop the combination of patterns for seven synthetic flood events (the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence events) with 30-day hydrographs, to generate the synthetic flood hydrographs for simulated regulated conditions at Hamilton City. The development of the flood centering series for mainstem Sacramento River index points is described in Reference 2a, Chapter III, pages 11 to 13.

7a. Ord Ferry Flood Centering Series. The patterns for the flood centering series for the Sacramento River at Latitude of Ord Ferry are tabulated in Table 2 (from Reference 2a). The unregulated flow frequency curves (for 1-, 3-, 7-, 15-, and 30-day durations) for the Latitude of Ord Ferry index point are displayed on Plate 6. The tributary hydrographs constructed from the Ord Ferry flood centering series, when routed and combined at the Ord Ferry index point, were roughly equal to the hypothetical volumes specified by the Latitude of Ord Ferry flow frequency curves. As a test of the frequency curves for the Latitude of Hamilton City index point, the tributary hydrographs for the Ord Ferry flood centering series were routed and combined at the Hamilton City index point. Tributary hydrographs for Stony and Big Chico Creeks were not included, as they enter the Sacramento River downstream of Hamilton City. The flood volumes of the seven synthetic hydrographs at the Hamilton City index point were roughly equal to the hypothetical volumes from the Hamilton City mainstem frequency curves. Table 3 presents a comparison of the volumes routed to Hamilton City (Ord Ferry centering series) with the hypothetical volumes from the Hamilton City mainstem frequency curves, for the seven floods, for the 1-, 3-, 7-, 15-, and 30-day durations. The flood volumes in Table 3 were developed using the Muskingum routing procedure. Actual in-channel flows may differ due to limited channel capacities and overbank flows. The Latitude of Ord Ferry flood centering series meets the guidelines for a mainstem centering series at Hamilton City as well. The Latitude of Ord Ferry flood centering patterns are tabulated on Table 2.

TABLE 2 **Synthetic Flood Centerings for** **Sacramento River Total Flow at Latitude of Ord Ferry**							
Index Point	Percent Chance Exceedence						
	50%	10%	4%	2%	1%	0.50%	0.20%
Sacramento River at Shasta	82.08	16.91	5.71	2.41	1.25	0.65	0.28
Clear Creek at Whiskeytown	61.56	15.04	9.03	5.61	2.92	1.52	0.65
Cow Creek nr Millville	61.56	13.53	8.02	3.89	2.02	1.05	0.45
Cottonwood Creek nr Cottonwood	61.56	15.04	9.03	5.61	2.92	1.52	0.65
Battle Creek below Coleman FH	61.56	13.53	8.02	3.89	2.02	1.05	0.45
Mill Creek near Los Molinos	87.94	15.03	7.22	5.94	3.10	1.61	0.69
Elder Creek near Paskenta	87.94	19.33	12.50	10.10	5.26	2.74	1.17
Thomes Creek at Paskenta	87.94	19.33	12.50	10.10	5.26	2.74	1.17
Deer Creek near Vina	87.94	15.03	7.22	5.94	3.01	1.61	0.69
Big Chico Creek near Chico	87.94	15.03	7.22	5.94	3.01	1.61	0.69
Stony Creek at Black Butte	87.94	19.33	12.50	10.10	5.26	2.74	1.17
Butte Creek near Chico	87.94	15.03	10.20	8.42	4.39	2.28	0.97
Feather River at Oroville	87.94	19.33	9.62	8.42	4.39	2.28	0.97
Yuba River at New Bullards Bar	87.94	19.33	11.76	9.18	4.78	2.49	1.06
Yuba River at Englebright	87.94	19.33	11.76	9.18	4.78	2.49	1.06
Deer Creek near Smartsville	87.94	19.33	11.76	9.18	4.78	2.49	1.06
Bear River near Wheatland	87.94	19.33	12.03	10.10	5.26	2.74	1.17
Cache Creek at Clear Lake	87.94	19.33	18.05	12.63	6.58	3.42	1.46
North Fork Cache Creek at Indian Valley	87.94	19.33	18.05	12.63	6.58	3.42	1.46
American River at Folsom	87.94	19.33	14.29	12.63	6.58	3.42	1.46
Putah Creek at Berryessa	87.94	19.33	18.05	12.63	6.58	3.42	1.46
Note: The numbers in Table 2 are percent chance exceedence floods. The (x) percent chance exceedence flood is defined as having one chance in 100/x of being exceeded in any future 1-year period.							

TABLE 3
Unregulated Volume Comparison
Hamilton City Flow Frequency Curves
Versus Routed Flows at Hamilton City

	Frequency Curves Hamilton City Target Volumes Average flow in Day cfs	Hamilton City Flood Series at Hamilton City Average flow in Day cfs	Ord Ferry Flood Series at Hamilton City Average flow in Day cfs
Duration	**50% Flood**	**50% Flood**	**50% Flood**
1-day	97,500	105,000	100,000
3-day	81,300	89,600	85,600
7-day	60,300	61,500	59,300
15-day	45,800	46,000	44,600
30-day	34,900	35,800	34,800
Duration	**10% Flood**	**10% Flood**	**10% Flood**
1-day	214,000	227,000	223,000
3-day	181,000	192,000	190,000
7-day	132,000	128,000	128,000
15-day	94,000	91,600	92,300
30-day	69,800	68,400	69,000
Duration	**4% Flood**	**4% Flood**	**4% Flood**
1-day	286,000	306,000	295,000
3-day	242,000	259,000	252,000
7-day	174,000	171,000	168,000
15-day	119,000	121,000	120,000
30-day	87,900	88,900	88,400
Duration	**2% Flood**	**2% Flood**	**2% Flood**
1-day	345,000	366,000	349,000
3-day	293,000	310,000	298,000
7-day	208,000	204,000	198,000
15-day	139,000	143,000	141,000
30-day	102,000	104,000	103,000
Duration	**1% Flood**	**1% Flood**	**1% Flood**
1-day	408,000	430,000	411,000
3-day	347,000	365,000	350,000
7-day	244,000	238,000	231,000
15-day	158,000	166,000	163,000
30-day	115,000	120,000	118,000
Duration	**0.5% Flood**	**0.5% Flood**	**0.5% Flood**
1-day	475,000	494,000	474,000
3-day	406,000	419,000	404,000
7-day	281,000	273,000	265,000
15-day	177,000	189,000	186,000
30-day	128,000	135,000	133,000
Duration	**0.2% Flood**	**0.2% Flood**	**0.2% Flood**
1-day	572,000	592,000	560,000
3-day	490,000	501,000	476,000
7-day	334,000	325,000	310,000
15-day	202,000	224,000	215,000
30-day	146,000	158,000	153,000

Notes: (1) Volumes in day cfs represent flows routed using the Muskingum method, not a dynamic routing into or through the floodplains. (2) The routed volumes for the Hamilton City flood series had to match within 10 percent the target volumes from the frequency curves for the Latitude of Hamilton City.

7b. Strategy for a Hamilton City Flood Centering Series. While the Ord Ferry flood centering series meets the criteria for the Hamilton City flood centering series, a centering series was needed that would test the potential for flooding at Hamilton City when Shasta Dam is controlling high flows on the upper Sacramento River, and determine at what point Shasta Dam loses control. Such a flood centering series was developed using both sets of Hamilton City flow frequency curves, the mainstem frequency curves and the local frequency curves. A flood centering series was developed specifically for the local drainage area between Shasta Dam and Hamilton City, with concurrent flood above Shasta. The tributary hydrographs constructed from the centering patterns were routed and combined at Hamilton City, and the synthetic flood volumes of the Hamilton City hydrographs were compared with the hypothetical volumes from the Hamilton City local flow frequency curves. The local flood patterns were adjusted until the routed hydrographs at Hamilton City roughly matched the hypothetical volumes from the Hamilton City local flow frequency curves. A series of concurrent flood centerings was then developed for Sacramento River above Shasta Dam and adjusted until the following condition was met: when the unregulated concurrent flood hydrographs above Shasta Dam were routed to Hamilton City and combined with the local flows, the combined hydrograph volumes roughly matched the hypothetical volumes from the Latitude of Hamilton City flow frequency curves.

7c. Flood Centering Series for Shasta Dam to Hamilton City. The seven Hamilton City flood centering patterns for the Sacramento tributaries between Shasta Dam and Hamilton City follow the general trends for the tributaries in the historic flood centering matrices for the Sacramento Basin, Reference 2a, Attachment B.3, Table B.3, Historic Flood Event Matrices. For the larger, less frequent mainstem floods, the flows from the eastside tributaries are usually more rare than those on the westside, with the least frequent flows on the eastside tributaries south of Bend Bridge: Mill Creek, Deer Creek, Big Chico Creek (south of Deer Creek). For the more frequent flood events, orographic effects are more pronounced and the flow frequencies are usually more evenly distributed between eastside and westside tributaries. The Hamilton City flood centering series patterns, tabulated on Table 4, are based on historic trends. For each hypothetical centering flood pattern, hydrographs were constructed for the major tributaries between Shasta Dam and Hamilton City: Clear Creek (for unregulated conditions), Cottonwood, Elder and Thomes creeks on the west side; Cow, Battle, Mill and Deer creeks on the east side. The tributary hydrographs were routed down to Hamilton City using the Muskingum routing parameters listed in Table 1. An estimate for local flow downstream of the gaged tributaries was not added during the routing procedure for the synthetic floods; the local flow estimate was added in the process of constructing the tributary hydrographs themselves, a procedure developed for the Comprehensive Study.

TABLE 4
Synthetic Flood Centerings for
Sacramento River Total Flow at Latitude of Hamilton City

Index Point	Percent Chance Exceedence						
	50%	10%	4%	2%	1%	0.50%	0.20%
Sacramento River at Shasta	117.65	26.14	11.76	5.88	2.61	1.11	0.33
Clear Creek at Whiskeytown	51.28	11.76	5.83	3.56	2.06	1.23	0.56
Cow Creek nr Millville	51.28	10.53	4.50	2.34	1.32	0.79	0.36
Cottonwood Creek nr Cottonwood	51.28	11.76	5.83	3.56	2.06	1.23	0.56
Battle Creek below Coleman FH	51.28	10.53	4.50	2.34	1.32	0.79	0.36
Mill Creek near Los Molinos	50.51	10.10	4.08	2.11	1.16	0.69	0.31
Elder Creek near Paskenta	50.51	10.31	4.89	3.12	1.85	1.11	0.50
Thomes Creek at Paskenta	50.51	10.31	4.89	3.12	1.85	1.11	0.50
Deer Creek near Vina	50.51	10.10	4.08	2.11	1.16	0.69	0.31
Big Chico Creek near Chico	50.51	10.10	4.08	2.11	1.16	0.69	0.31
Stony Creek at Black Butte	50.51	10.31	4.89	3.12	1.85	1.11	0.50
Butte Creek near Chico	71.94	18.35	7.55	3.82	2.07	1.22	0.54
Feather River at Oroville	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Yuba River at New Bullards Bar	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Yuba River at Englebright	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Deer Creek near Smartsville	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Bear River near Wheatland	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Cache Creek at Clear Lake	125.00	100.00	50.00	20.00	10.00	5.00	2.00
North Fork Cache Creek at Indian Valley	125.00	100.00	50.00	20.00	10.00	5.00	2.00
American River at Folsom	125.00	100.00	50.00	20.00	10.00	5.00	2.00
Putah Creek at Berryessa	125.00	100.00	50.00	20.00	10.00	5.00	2.00

Note: The numbers in Table 4 are percent chance exceedence floods. The (x) percent chance exceedence flood is defined as having one chance in 100/x of being exceeded in any future 1-year period.

7d. Concurrent Flood Patterns above Shasta Dam. A flood series concurrent to the specific centering series above Hamilton City (7c above) was developed for the drainage basin upstream of Shasta Dam. The patterns for the concurrent floods above Shasta Dam are listed on Table 4. For the Hamilton City flood centering patterns, concurrent Shasta flows are more frequent than the westside and eastside tributary flows (except for the 0.5% and 0.2% floods). This pattern has been observed historically: the floods of February 1958, January-February

1983, and January-February 1998 were centered on the westside tributaries; the flood of January 1974 targeted Cow and Battle creeks; the floods of December 1964 and February 1986 were centered south of Bend Bridge. The 0.2% flood pattern is similar to that of January 1997, with the Shasta percent exceedence flood almost the same as that for the eastside tributaries south of Bend Bridge.

7e. Hamilton City Synthetic Flood Volumes. The unregulated flow hydrographs at Shasta Dam and on the westside and eastside tributaries constructed from the flood centering series (Table 4) were routed and combined at Hamilton City. Table 3 presents a comparison of the volumes from the routed hydrographs at Hamilton City for the Hamilton City flood series, the Ord Ferry flood series (at Hamilton City), and the hypothetical volumes from the Hamilton City mainstem frequency curves, for the seven floods, for the 1-, 3-, 7-, 15- and 30-day durations. The flood volumes for the Hamilton City flood series are, in general, slightly higher than those for the Ord Ferry flood series routed to Hamilton City.

8. Reservoir Simulation Model (HEC-5) Routing

The Hydrologic Engineering Center's HEC-5 software (Simulation of Flood Control and Conservation Systems), Version 8.0 (October 1998, Reference 2k), was used to route the synthetic tributary flood hydrographs through the reservoir system on the Sacramento River Basin for analysis of floodplain and channel hydraulics. The Reservoir Simulation Model User's Guide, Reference 2b, documents the reservoir model assumptions and methodology for routing the flood hydrographs through two reservoir system models, the headwater reservoirs model, and the lower basin reservoirs model. The reservoir system models routed tributary flows for the entire Sacramento basin; however, the only hydrographs needed for this study are those upstream of and at Hamilton City. The synthetic unregulated hydrographs constructed for Shasta Dam and Valley tributary locations from the Hamilton City flood centering series were input to the reservoir system models to simulate regulated hydrographs at mainstem points on the Sacramento River, including Hamilton City. The Shasta Dam hydrographs were routed through the HEC-5 headwater reservoirs model, to simulate results from regulation by reservoirs upstream of Shasta Dam for the synthetic flood series. The headwater reservoirs are listed on Table 5, and their relative locations shown in the schematic on Plate 9. The simulated regulated inflow hydrographs to Lake Shasta and the downstream tributary hydrographs were then input to the lower basins reservoir model. The only reservoirs upstream of Hamilton City that are in the lower basins reservoir model are Shasta and Whiskeytown. The schematic on Plate 10 shows the relationship of the reservoirs and the east- and westside tributaries downstream on the Sacramento River. Ord Ferry is "JUNC-SAC+STO." Hamilton City is not shown as an index point on Plate 10; it is neither a junction of the Sacramento River with any tributaries nor a hydrograph input point to the HEC-RAS routing model. Plates 9 and 10 are from Reference 2b.

TABLE 5
LIST OF RESERVOIRS IN THE
SACRAMENTO RIVER BASIN ABOVE ORD FERRY

Reservoir	Drainage	Owner	Gross Pool Storage (ac-ft)	Drainage Area (sq.mi.)	Began Operation	Purpose
Britton	Pit River	Pac Gas & Electric Co	34,600	4700	1925	Water Supply
(Pit No. 3)						Hydropower
Pit No. 6	Pit River	Pac Gas & Electric Co	15,700	5020	1965	Water Supply
						Hydropower
Pit No. 7	Pit River	Pac Gas & Electric Co	34,000	5170	1965	Water Supply
						Hydropower
McCloud	McCloud River	Pac Gas & Electric Co	35,300	380	1965	Hydropower
Shasta	Sacramento, McCloud & Pit	US Bureau of Reclamation	4,552,000	6665	1945	Flood Management
Whiskeytown	Clear Creek	US Bureau of Reclamation	241,100	201	1963	Water Supply
East Park	Little Stony Creek	US Bureau of Reclamation	51,000	102	1910	Water Supply
Stony Gorge	Stony Creek	US Bureau of Reclamation	50,350	735	1928	Water Supply
Black Butte	Stony Creek	USACE	143,700	741	1963	Flood Management

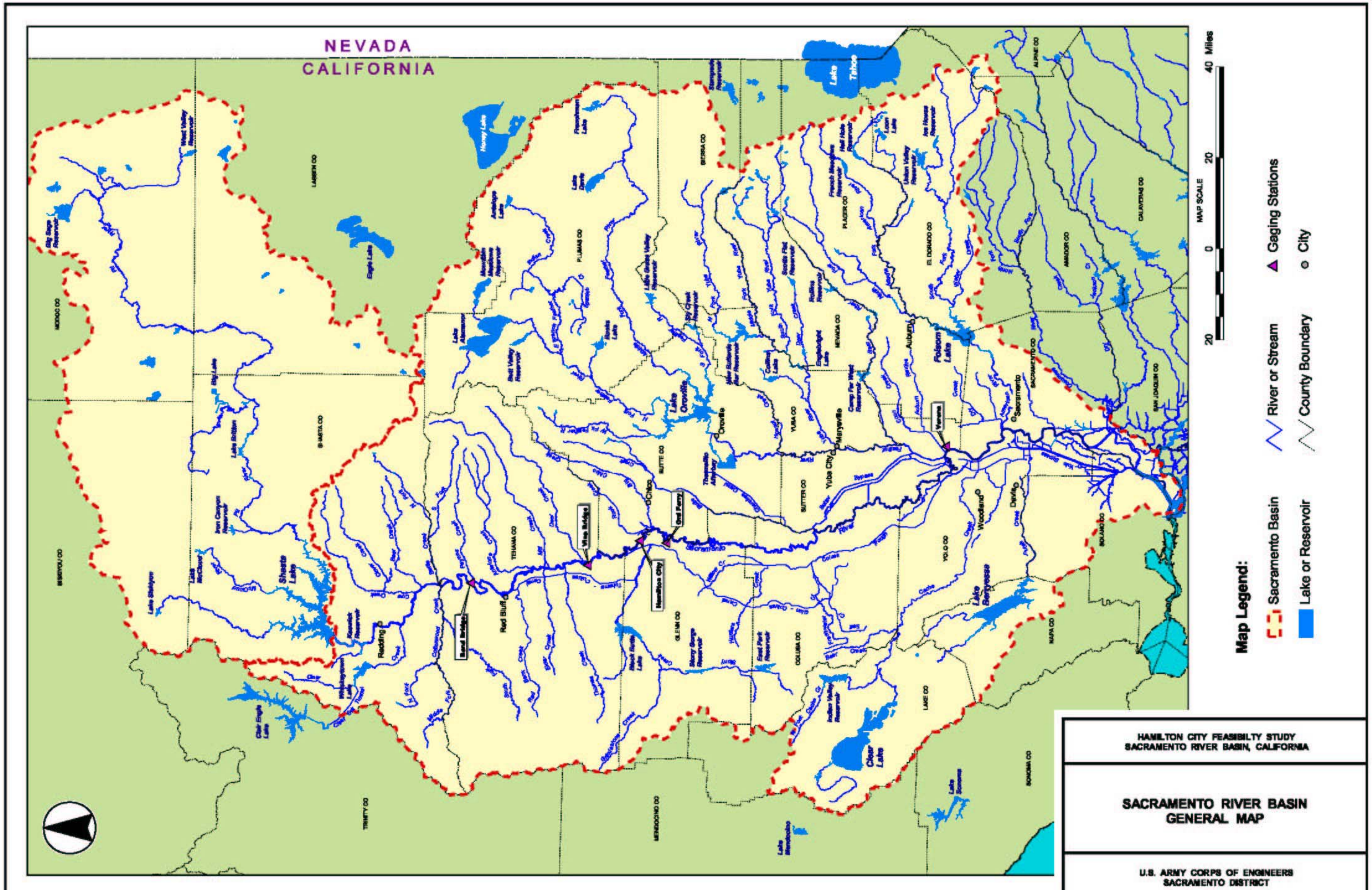
9. Results

Output from the lower basins reservoir model includes simulated regulated flood hydrographs at the "UNET-VINA BR" (Sacramento River at Vina Bridge downstream of Deer Creek) location for the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence events. These hydrographs are presented on Plate 11. Hydraulic Design Section uses a dynamic routing model, HEC-RAS, to route the regulated flow hydrographs from Vina Bridge downstream, for use in developing floodplains at Hamilton City. The flows and volumes at Hamilton City used to develop the Hamilton City floodplains are slightly different from the flows and volumes at Hamilton City listed on Table 4 for the Hamilton City flood series, due to the differences in routing methods.

Peak flow output from the HEC-RAS model (representing total regulated flow at the Latitude of Hamilton City) was plotted against the regulated peak flow frequency curve at Hamilton City (Plate 13). The model results matched well with the graphical peak flow curve.

10. Conclusions

The hydrology for Hamilton City and vicinity has been reanalyzed: new methodologies were used to develop a set of natural flow records for Sacramento River at Hamilton City; a regional flow frequency analysis was made, using observed streamflow records on nearby tributaries south of Shasta Dam; and unregulated flow frequency curves were developed for both Latitude of Hamilton City and local flows above Hamilton City. A methodology was developed to compute peak flow frequency curves for unregulated conditions on the Sacramento River downstream of Bend Bridge. As a result, synthetic flood hydrographs were developed for Sacramento River at the Latitude of Hamilton City. As a validation check, the synthetic regulated peak flows at Hamilton City were compared to the graphical peak flow curve presented on Plate 13. Good agreement between the synthetic peak flows and graphical peak flow curve further supports the methodology used in the development of the regulated flood hydrographs at Hamilton City for the 50, 10, 4, 2, 1, 0.5, and 0.2 percent chance exceedence events. It is believed that the hydrology presented in this office report is acceptable for a feasibility level analysis of flood protection alternatives.

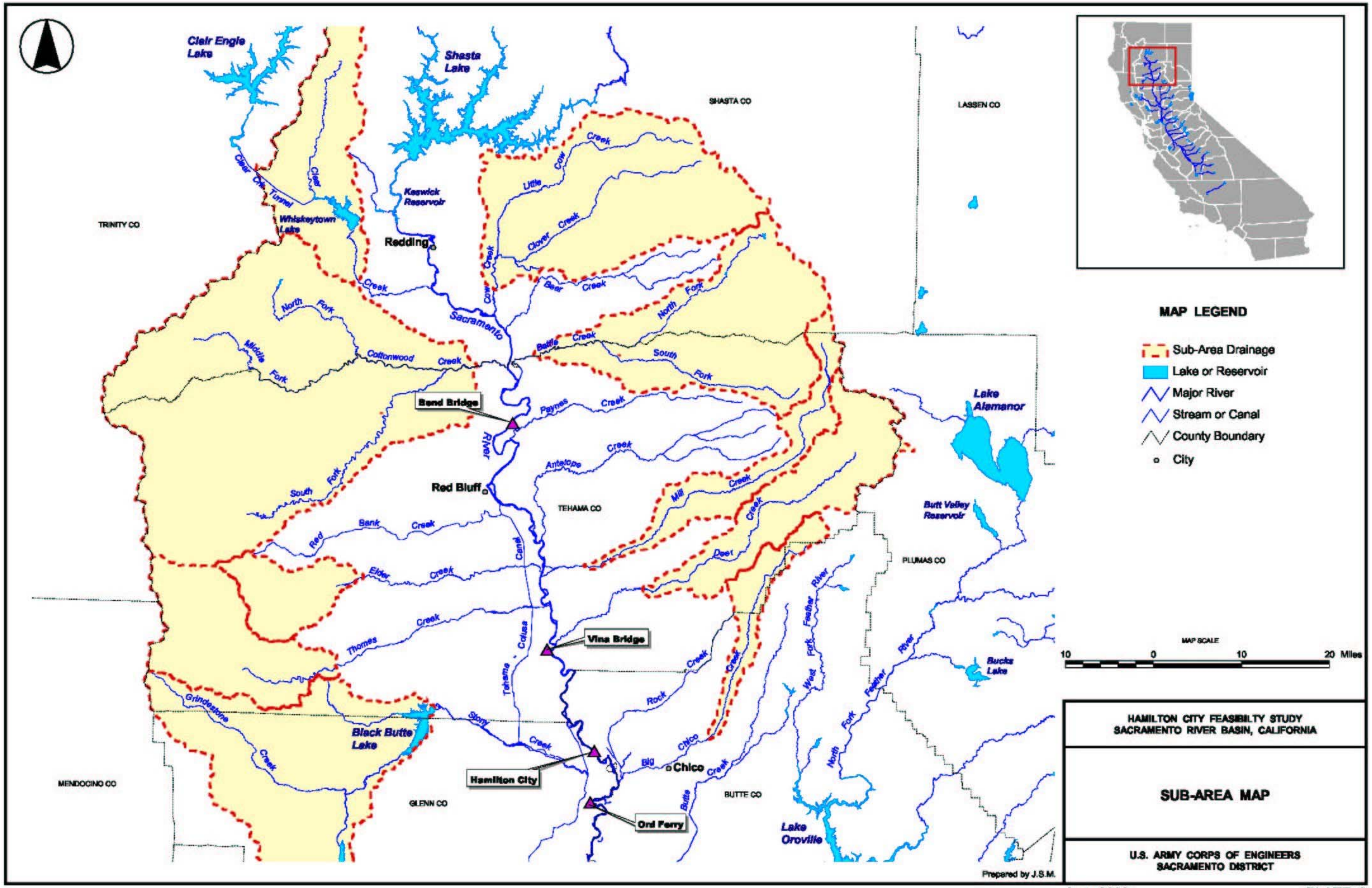


HAMILTON CITY FEASIBILTY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

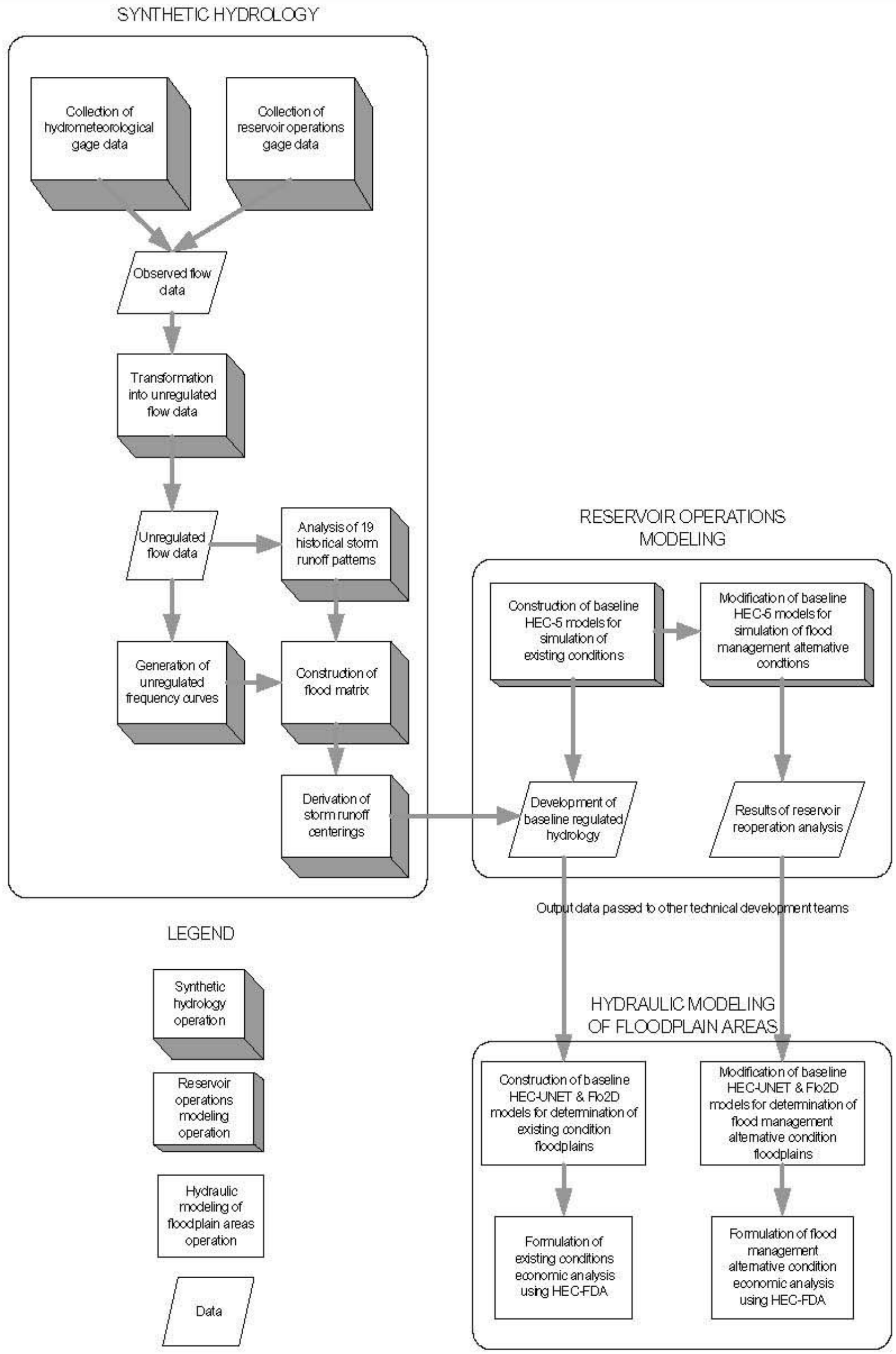
**SACRAMENTO RIVER BASIN
GENERAL MAP**

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 1

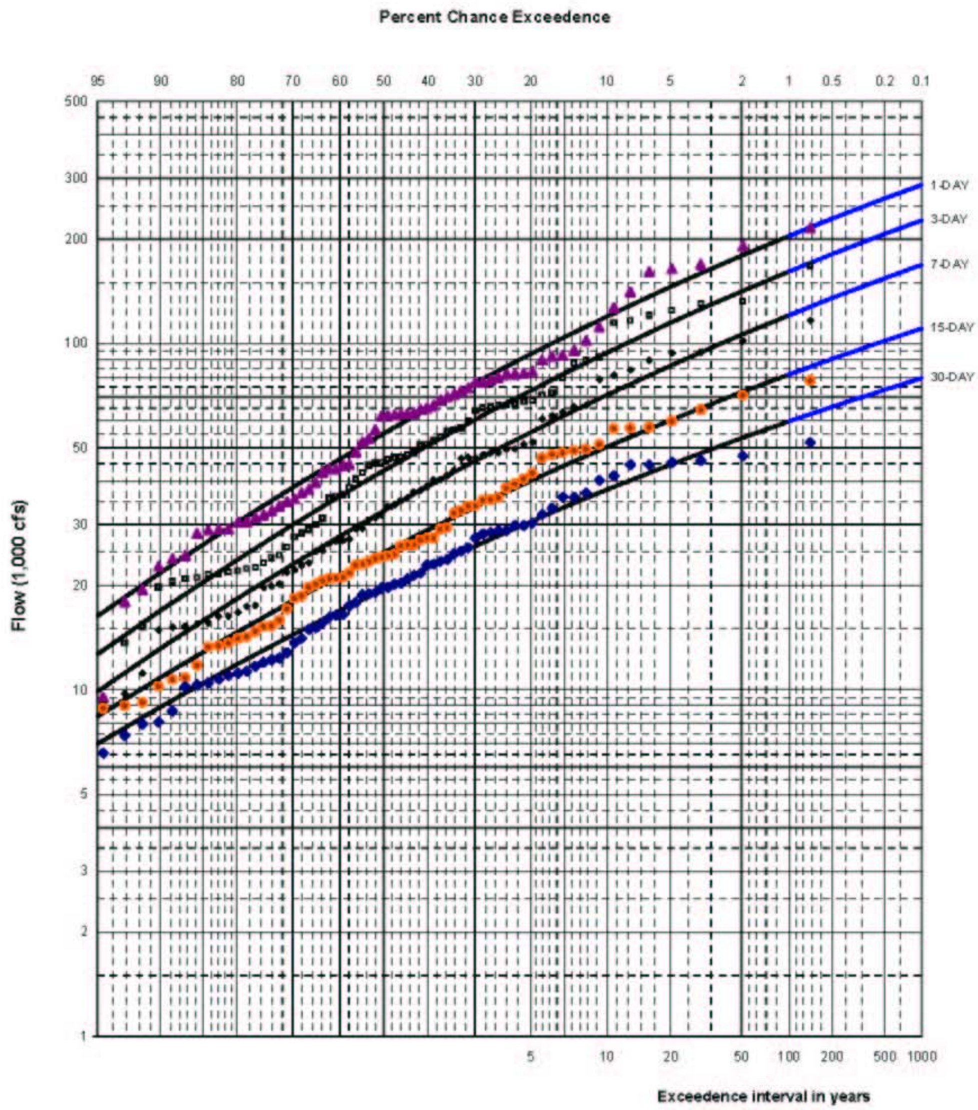


June 2003 PLATE 2



HAMILTON CITY FEASIBILITY STUDY **SACRAMENTO RIVER BASIN, CALIFORNIA**
HYDROLOGY AND MODELING **DEVELOPMENT PROCESS SCHEMATIC**
U.S ARMY CORPS OF ENGINEERS **SACRAMENTO DISTRICT**

June 2003 PLATE 3



ADOPTED STATISTICS:

	Mean	Std Dev	Skew
1-day	4.721	0.290	-0.4
3-day	4.614	0.292	-0.4
7-day	4.498	0.287	-0.4
15-day	4.380	0.261	-0.4
30-day	4.275	0.246	-0.4

NOTES:

1. Equivalent years of record after correlation with Bend Bridge (1892-1998) is 98 years.
2. Adjusted USGS gage 11370000 to account for daily change in storage at upstream reservoirs (potential channel, out-of-channel, or storage losses neglected).
3. Median plotting positions.
4. Drainage area: 6,421 sq. mi.
5. Period of record: 1932-1998.

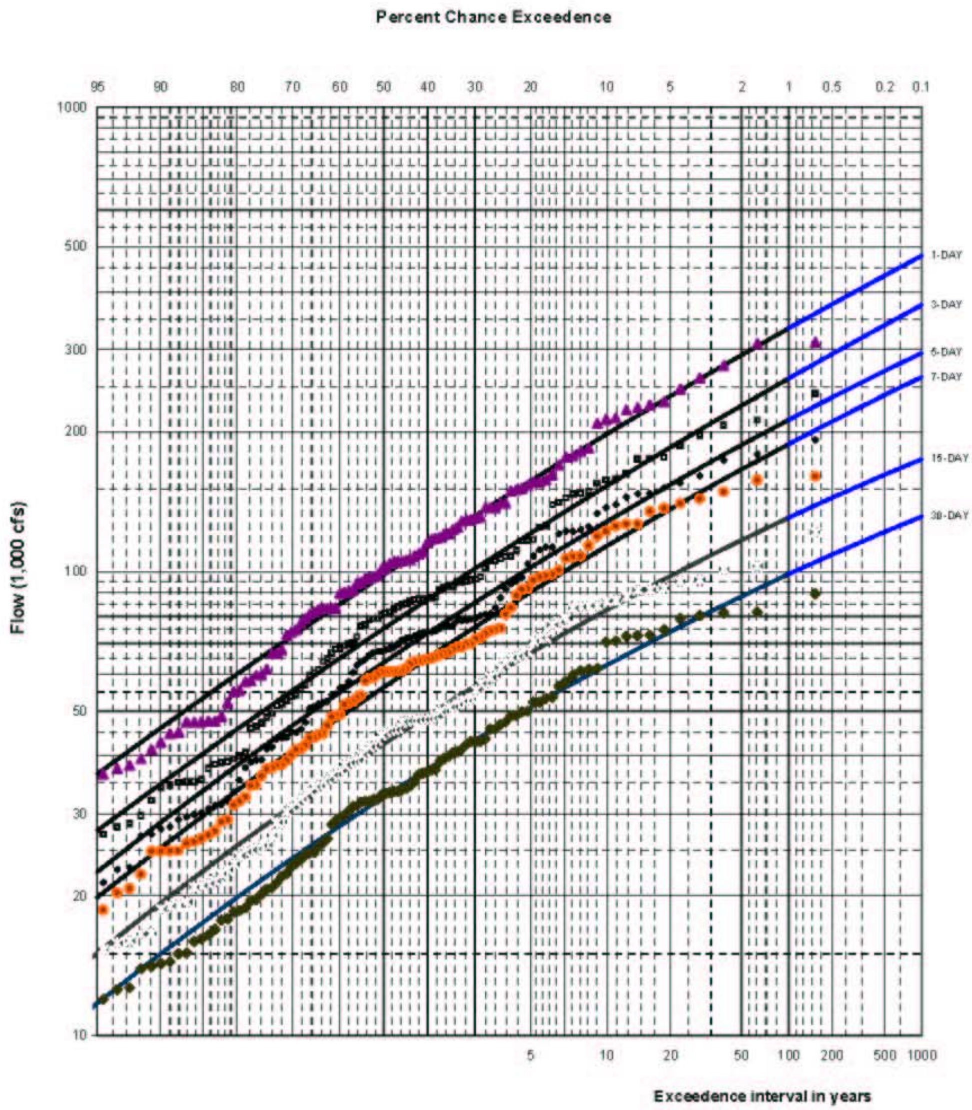
HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
SACRAMENTO RIVER AT SHASTA DAM
UNREGULATED CONDITIONS

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003

PLATE 4



ADOPTED STATISTICS:

	Mean	Std Dev.	Skew
1-day	4.984	0.247	-0.2
3-day	4.868	0.251	-0.2
5-day	4.791	0.254	-0.3
7-day	4.738	0.255	-0.3
15-day	4.612	0.248	-0.4
30-day	4.498	0.244	-0.4

NOTES:

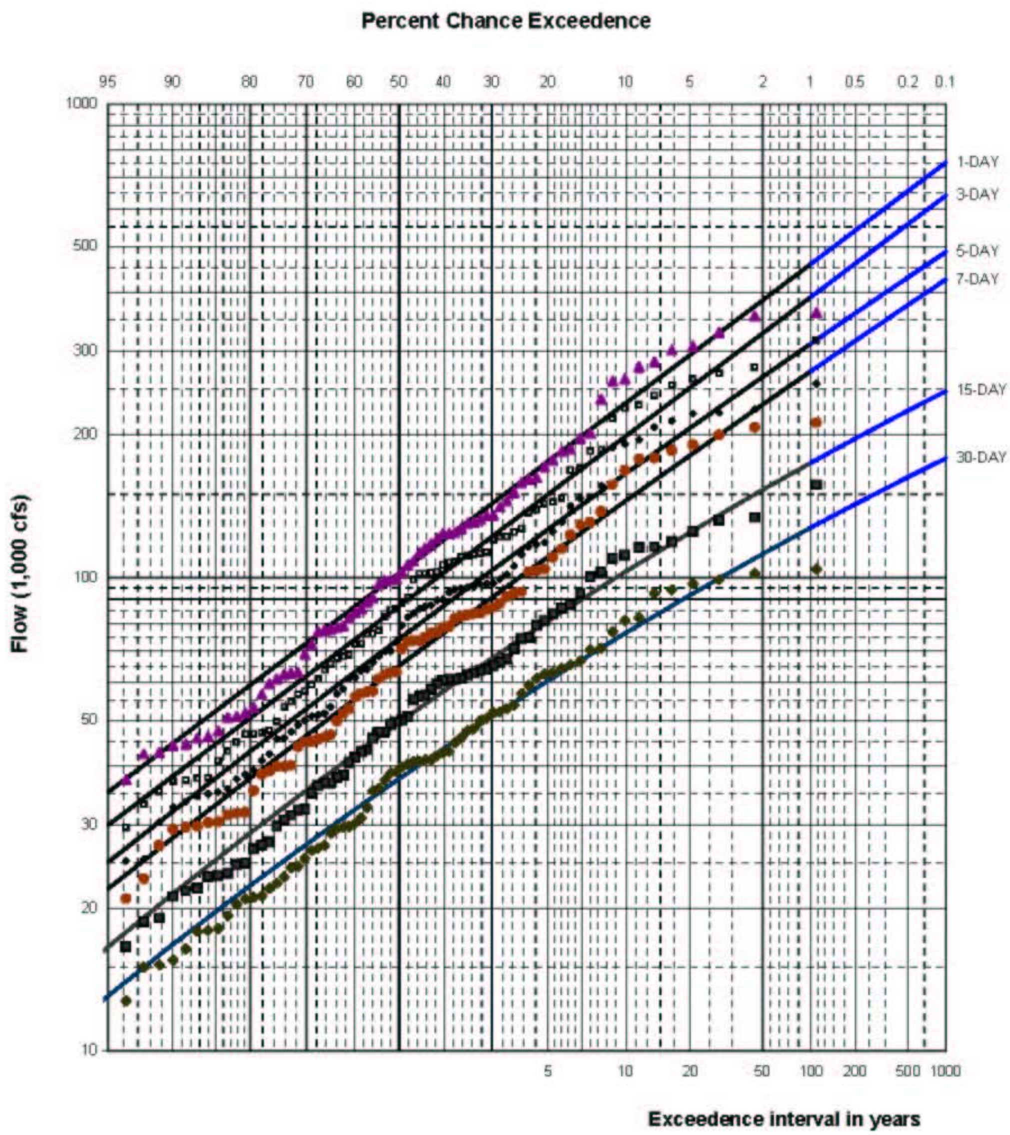
1. Adjusted USGS gage 11377100 to account for daily change in storage at Shasta Lake and Whiskeytown Reservoir (potential channel, out-of-channel, or storage losses neglected).
2. WY 1977 censored as low outlier.
3. Median plotting positions.
4. Drainage area: 8,900 sq. mi.
5. Period of record: 1893-1998.

HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
SACRAMENTO RIVER AT BEND BRIDGE
UNREGULATED CONDITIONS

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 5



ADOPTED STATISTICS:

	Mean	Std Dev.	Skew
1-day	5.009	0.281	0.0
3-day	4.939	0.281	0.0
5-day	4.866	0.279	-0.1
7-day	4.809	0.278	-0.1
15-day	4.680	0.267	-0.3
30-day	4.562	0.258	-0.3

NOTES:

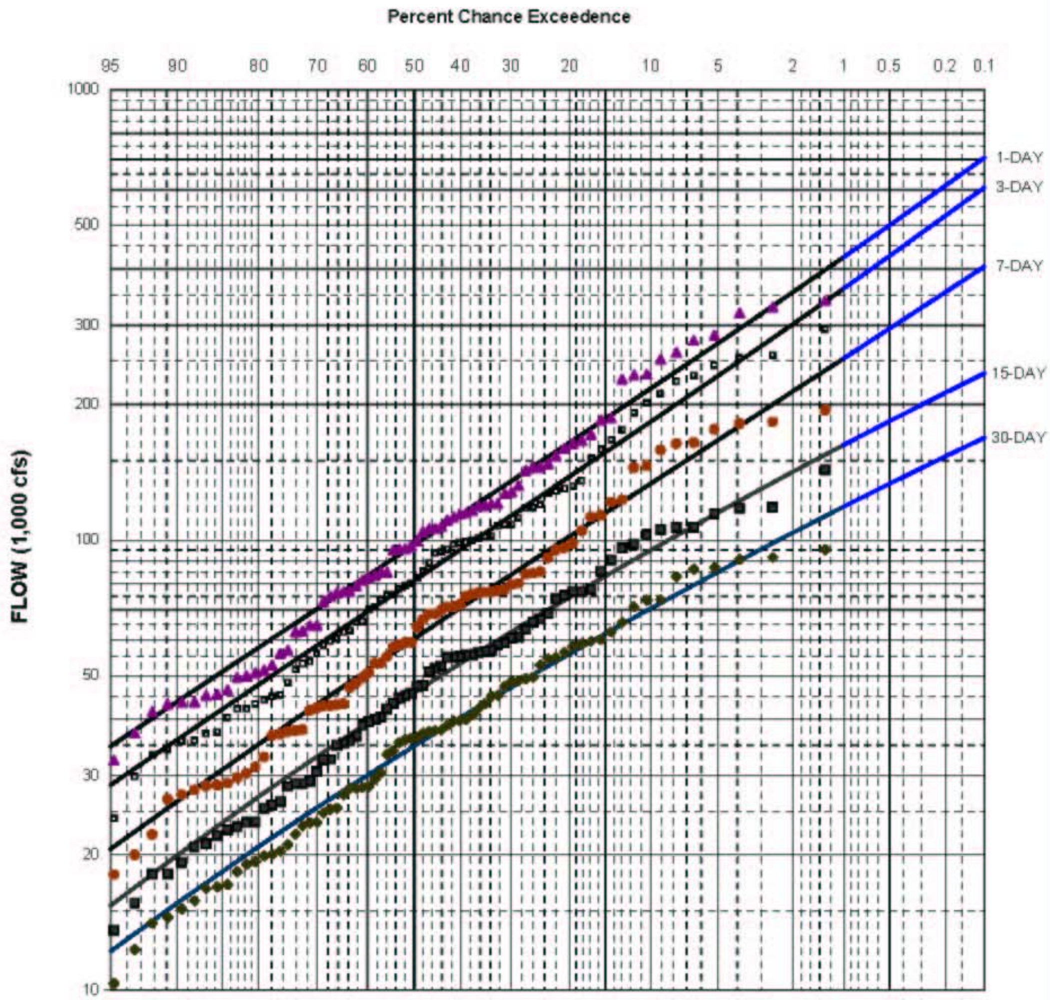
1. Adjusted USGS gage 11388700 to account for daily change in storage at upstream reservoirs (potential channel, out-of-channel, or storage losses neglected).
2. WY 1977 censored as low outlier.
3. Median plotting positions.
4. Drainage area: approx. 12,050 sq. mi.
5. Period of record: 1922-1997.

HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
SACRAMENTO RIVER AT ORD FERRY (LATITUDE)
UNREGULATED CONDITIONS

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 6



ADOPTED STATISTICS:

	Mean	Std Dev.	Skew
1-day	4.989	0.267	0.0
3-day	4.910	0.271	0.0
7-day	4.776	0.271	-0.1
15-day	4.648	0.261	-0.3
30-day	4.530	0.252	-0.3

NOTES:

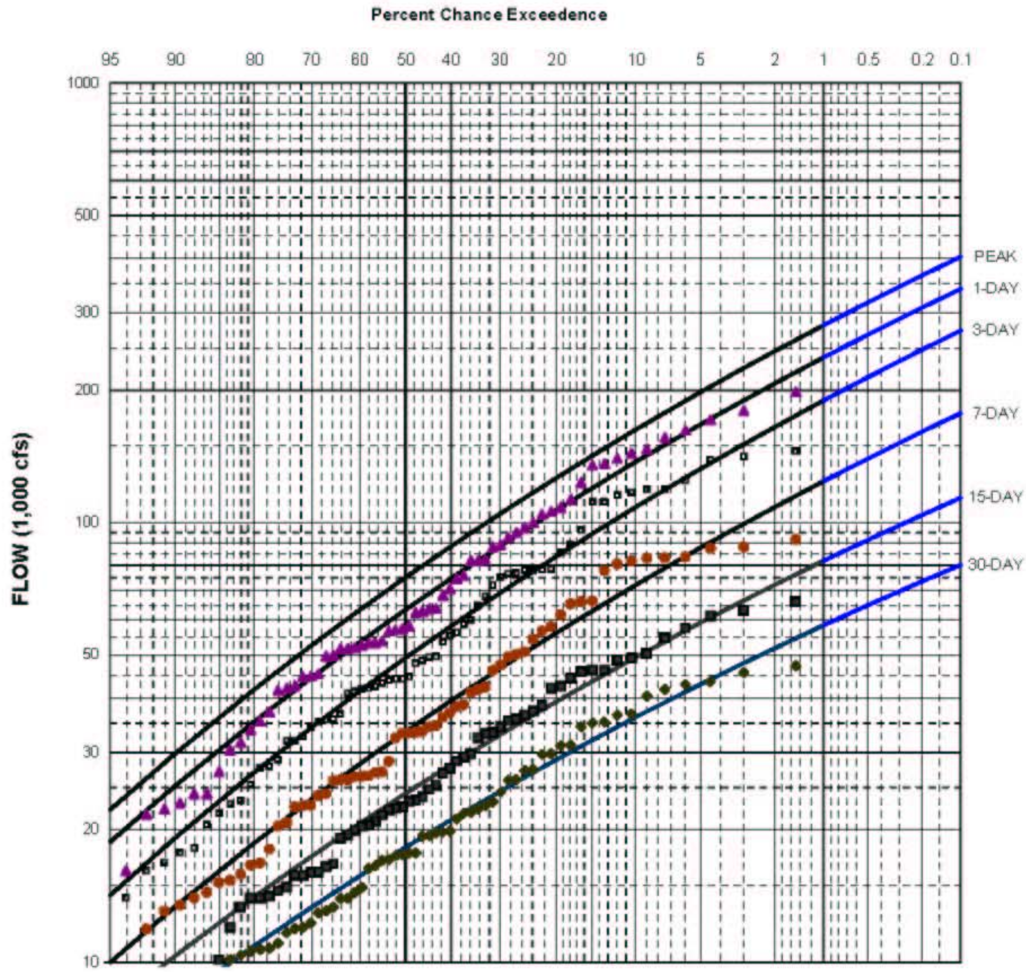
1. Median plotting positions
2. Change in storage from upstream reservoirs routed and combined at Hamilton City without regard for chanel, out of channel, or storage losses.
3. Period of record 1922-1997
4. Drainage area: approx. 11,040 sq. mi.
5. 1977 censored a low outlier

HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
SACRAMENTO RIVER AT HAMILTON CITY (LATITUDE)
UNREGULATED CONDITIONS

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 7



ADOPTED STATISTICS:

	Mean	Std Dev	Skew
Peak	4.857	0.284	-0.4
1-day	4.784	0.284	-0.4
3-day	4.673	0.290	-0.4
7-day	4.506	0.282	-0.4
15-day	4.367	0.262	-0.4
30-day	4.245	0.250	-0.4

NOTES:

1. Median plotting positions
2. Change in storage from upstream reservoirs routed and combined at Ord Ferry without regard for chanel, out of channel, or storage losses.
3. Period of record 1932-1997
4. Drainage area: approx. 4,620 sq. mi.
5. 1977 censored a a low outlier

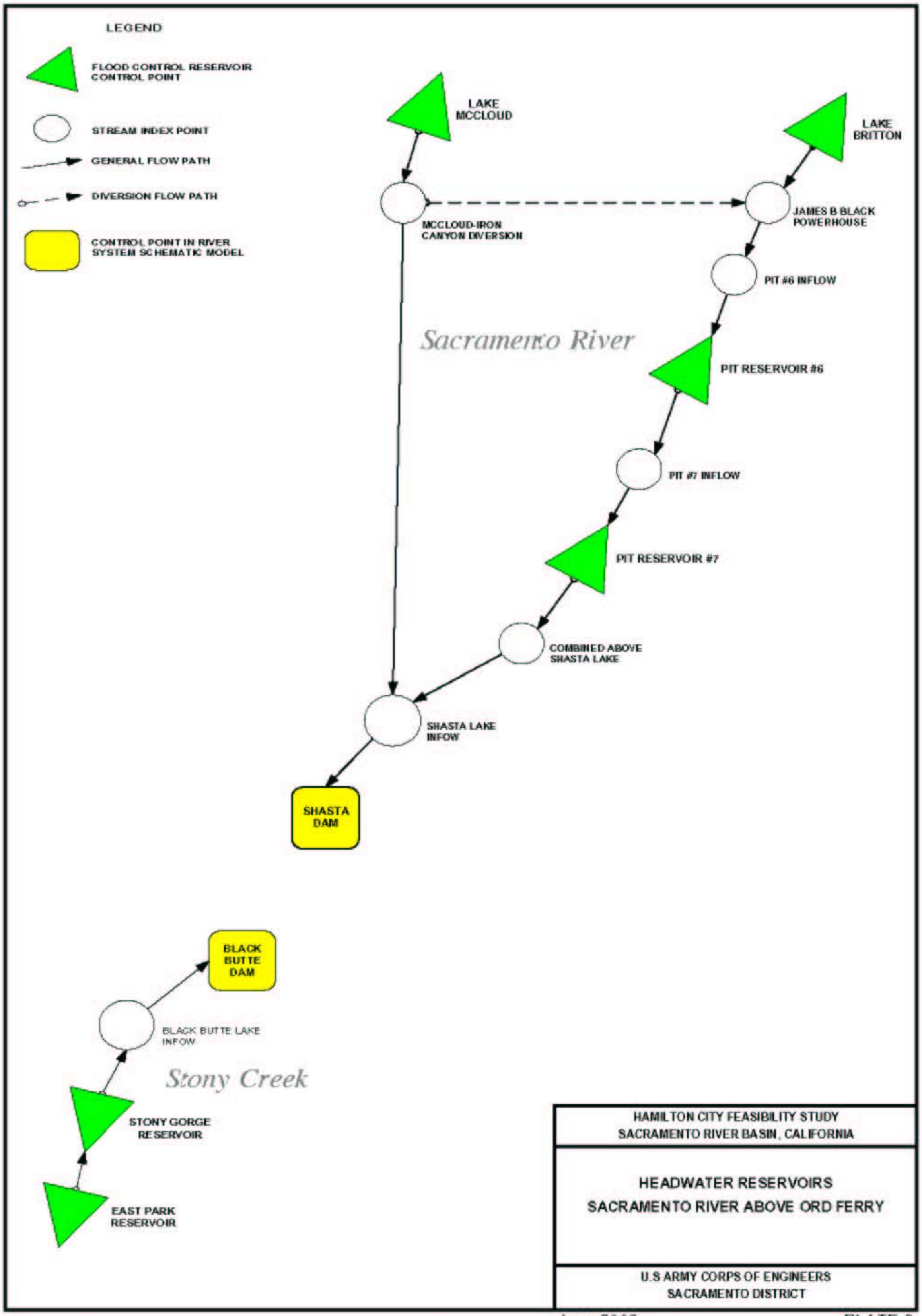
HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAINFLOOD FREQUENCY CURVES
LOCAL FLOW ABOVE HAMILTON CITY
UNREGULATED CONDITIONS

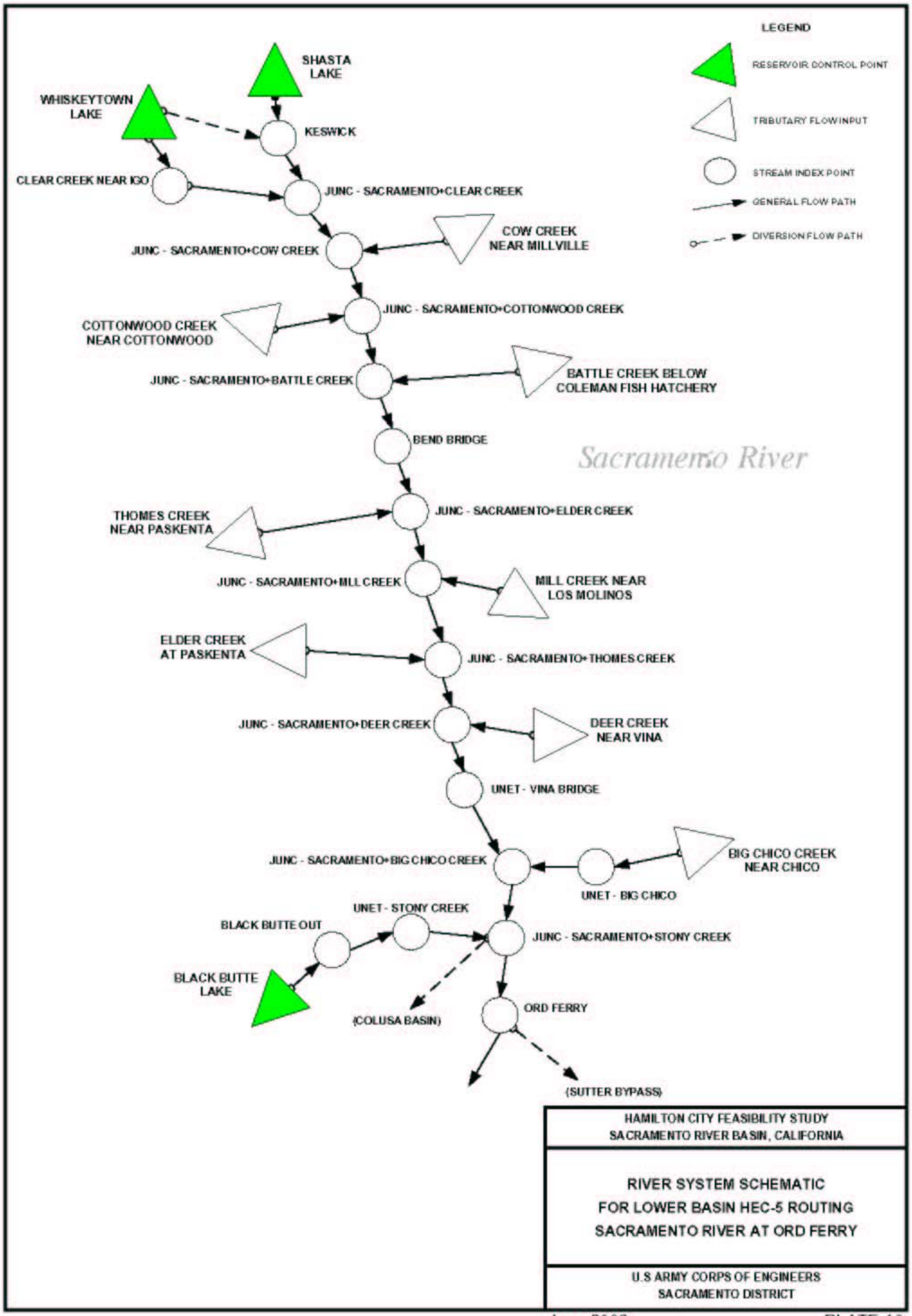
U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003

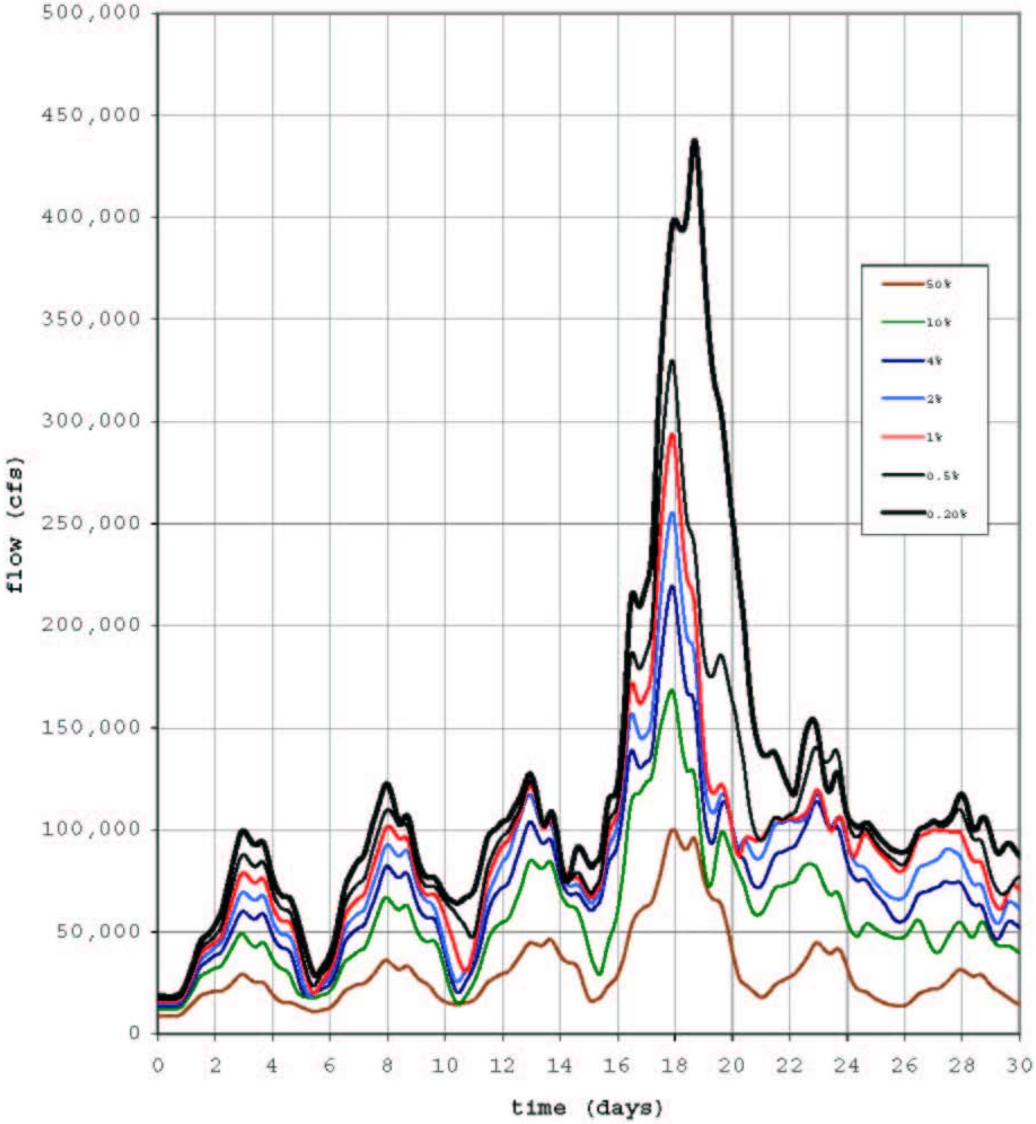
PLATE 8



June 2003 PLATE 9



June 2003 PLATE 10

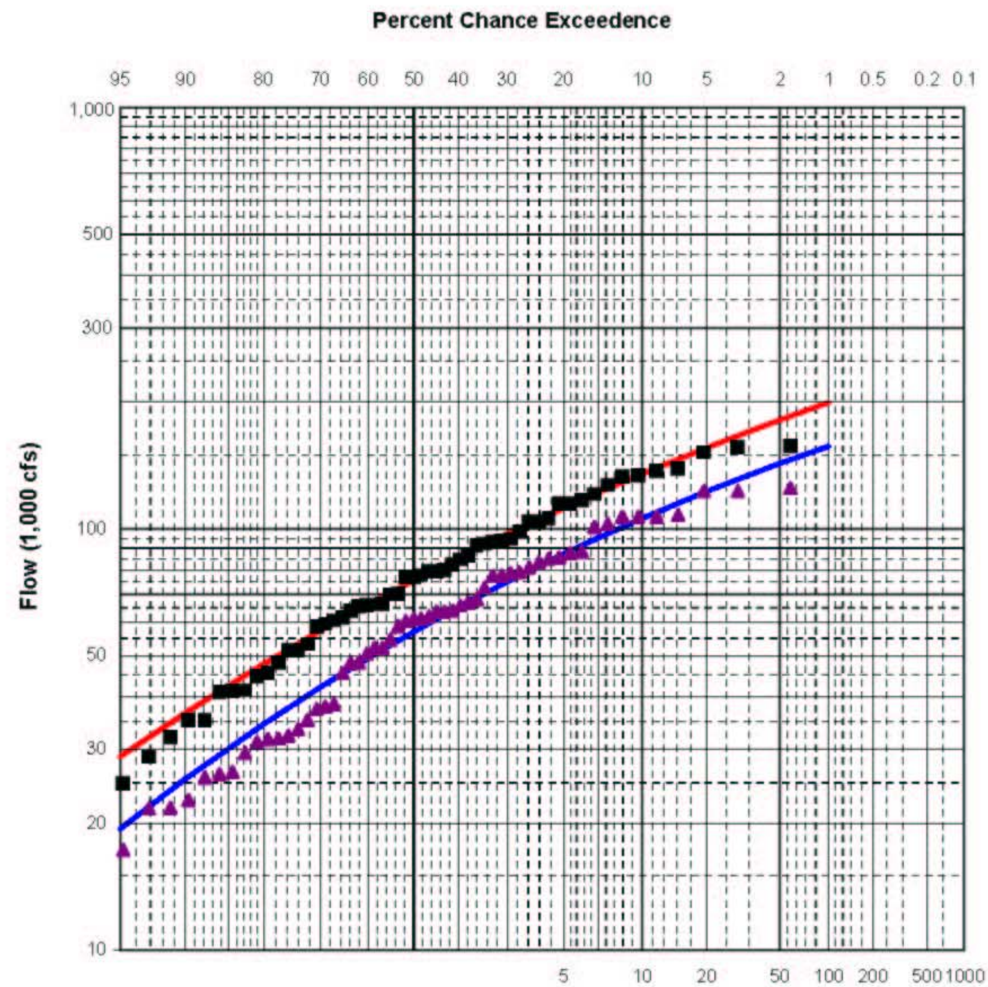


HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

HAMILTON CITY FLOOD CENTERING
REGULATED HYDROGRAPHS
SACRAMENTO RIVER AT VINA BRIDGE

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 11



NOTES:

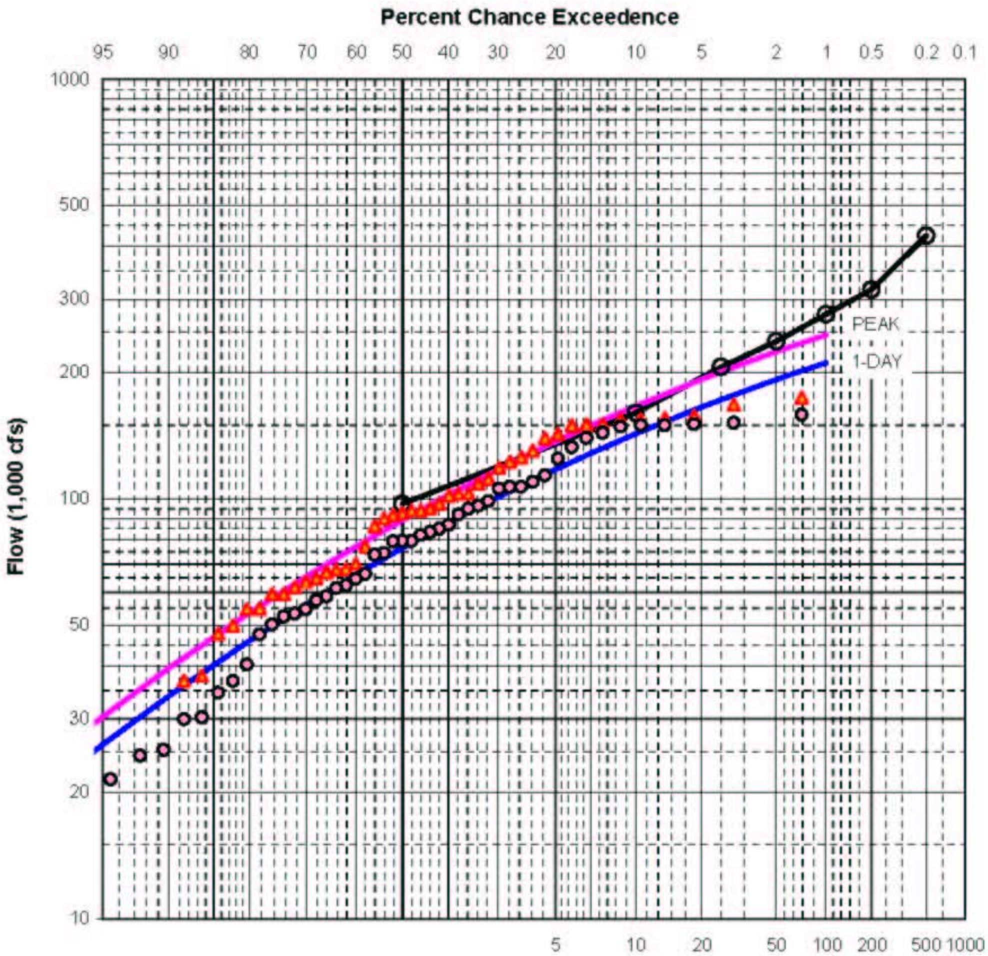
1. Period of Record 1945-2001
2. All flows in referenced period of record have remained in channel; no flows have bypassed the gage.
3. Uncontrolled relases from Shasta have not occurred during referenced period of record.
4. Median plotting positions.
5. Drainage Area 8,900 sq. mi.

HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CA

REGULATED PEAK & 1-DAY RAIN FLOOD FREQUENCY CURVES SACRAMENTO RIVER AT BEND BRIDGE

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 PLATE 12



NOTES:

1. Open circles represent hypothetical values from HEC-RAS model
2. Hypothetical values represent total regulated flow at the latitude of Hamilton City
3. During large floods, flows outside the main channel are not recorded by the Hamilton City gage (DWR station # AO-2630)
4. Median plotting positions
5. Drainage area: approx 11,040 sq. mi.
6. 49 years of record (1945-1998) where peak & 1-day data were available

HAMILTON CITY FEASIBILITY STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

REGULATED PEAK & 1-DAY RAINFLOOD FREQUENCY CURVES SACRAMENTO RIVER AT HAMILTON CITY

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

June 2003 **PLATE 13**

Sacramento & San Joaquin River Basins Comprehensive Study
Initial Project, Hamilton City

Flood Damage Reduction and Ecosystem Restoration Feasibility Study, California

Appendix C3
Hydraulic Design Document Report

June 2004

U.S. Army Corps of Engineers, Sacramento, California

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Appendix C3. Hydraulics

C3.1. Project Description

C3.1.1. Background

The U.S. Army Corps of Engineers and The Reclamation Board of the State of California conducted a feasibility study to develop and evaluate potential alternative plans to reduce flood damages and restore the ecosystem along the Sacramento River near Hamilton City. The goal of the study is to identify a cost effective, technically feasible, and locally acceptable project that best meets the dual objectives of reducing flood damages and restoring the ecosystem and is in compliance with all Federal, State, and local laws and regulations. The study will culminate in an integrated feasibility report and environmental impact statement/environmental impact report (EIS/EIR) documenting the study findings. The intent is to submit the report to Congress for consideration for Federal authorization to implement the project. The costs to conduct the study and implement a project are shared between Federal, State, and local interests. State and/or local interests would be responsible for operation and maintenance of a project if implemented.

C3.1.2. Study Area Description

Hamilton City is located in Glenn County, California, along the right bank of the Sacramento River, about 85 miles north of the City of Sacramento. The study area includes Hamilton City and the surrounding rural area. The study area is bounded by the Sacramento River to the east and the Glenn Colusa Canal to the west and extends about two miles north and six miles south of Hamilton City. Hamilton City has a population of about 2,000 people. Surrounding land use is agricultural with fruit and nut orchards being the primary crops.

An existing private levee, constructed by landowners in about 1904 and known as the "J" levee, provides some flood protection to the town and surrounding area. The "J" levee, however, is not constructed to any formal engineering standards and is largely made of silty sand soil. It is extremely susceptible to erosion and flood fighting is necessary to prevent levee failure and flooding when river levels rise. Since the construction of Shasta Dam in 1945, flooding in Hamilton City due to failure of the "J" levee has occurred once (1974). In addition, extensive flood fighting has been necessary to avoid flooding in 1983, 1986, 1995, 1997, and 1998. Currently, the Sacramento River is actively eroding into the toe of the levee at the northern end of the study area. Glenn County has built a backup levee, about 1,000 feet in length, to protect the community in the event the toe erosion causes failure at the northern end of the "J" levee.

Native habitat and natural river function in the study area have been altered by construction of the "J" levee and conversion of the floodplain to agriculture and rural development. Construction of the "J" levee and hardening of the river bank and levee in several locations through the years (typically with rock) have constrained the ability of the river to meander and overflow its banks and promote propagation and succession of native vegetation. Conversion of the floodplain to agriculture and rural development has reduced the extent of native habitat to remnant patches along the river and in historic oxbows. These alterations to the ecosystem have greatly diminished the abundance, richness, and complexity of riparian, wetland, and floodplain habitat in the study area and the species dependent upon that habitat.

River miles as noted in this report are U.S. Geological Survey river miles, unless noted otherwise.

C3.1.3. Authority

In response to concerns primarily raised by the 1997 flood, the Governor of California formed the Flood Emergency Action Team (FEAT). In its May 1997 report, the FEAT recommended developing a "new master plan for improved flood control in the Central Valley" of California. The California State Legislature (September 1997) and U.S. Congress (1998) subsequently authorized the Sacramento and San Joaquin River Basins Comprehensive Study. The House Report 105-190, accompanying the 1998 Energy and Water Development Appropriations Act, Public Law (PL) 105-62 called for "development and formulation of comprehensive plans **for flood control and environmental restoration** purposes."

The U.S. House Report 108-357, which is the conference report accompanying the Energy and Water Development Appropriations Act, 2004, P.L. 108-137, urged the Secretary of the Army to include in the study an area extending from 2 miles due north to four miles due south of State Highway 32, and extending at least 1.2 miles due south of County Road 23.

C3.2. Surveys

C3.2.1. Source of Data

Survey data used to develop the hydraulic model geometry for this study was developed from two surveys, one in 1995 for the Sacramento River Bank Protection Project, Sacramento River and Tributaries, Breach at Road 29 near RM 188, Glenn County, California and one in 1998 as part of the Sacramento and San Joaquin River Basins Comprehensive Study (Comp Study). **Figure 1**, page 4, shows the 2-foot contour mapping area in the darker shading and the 5-foot contour mapping in the lighter shading. The upper line of the 2-foot contour mapping separates the two sources of survey data. The 1998 survey area is the 5-foot contour area above the 2-foot contour mapping.

C3.2.2. Surveys in 1995

Horizontal and vertical ground control for photogrammetric mapping was established using Global Positioning System (GPS) survey techniques. Aerial photographs were taken at scales of 1:10,000 for 2-foot contour mapping and 1:24,000 for 5-foot contour mapping on July 31, 1995. Northings and Eastings were defined in California State Plane Coordinates (NAD 83). Above the waterline, topography was developed using standard photogrammetric mapping techniques. For 2-foot contour mapping, aerial photos were taken at 5,000 feet in elevation (all new mapping and some existing Sacramento River mapping) and for 5-foot contour mapping (existing Sacramento River mapping only), aerial photos were taken at 12,000 feet. All photos are in black and white, and some are digital. Mapping is complete for the riverine corridor (300 feet landward of banks and levees.) Under the waterline, hydrosurvey data was collected with boats equipped with a dual frequency GPS receiver, fathometer, and sonar transducer. Hydrographic survey data was collected along river cross-sections oriented generally perpendicular to the channel banks to detail the form of the river bottom. These cross-sections were spaced roughly at a distance equal to the channel topwidth. These surveys were originally developed in metric and were later converted to feet for the Comprehensive Study.

C3.2.3. Surveys in 1998

Surveys in 1998 are part of the Sacramento and San Joaquin River Basins Comprehensive Study. The area surveyed is the 5-foot contour area above the upper limit of the 2-foot contours as described above and shown in **Figure 1**, page 4. The survey techniques are similar to those described for the 1995 surveys.

C3.2.4. Datum

The North American Datum of 1983 (NAD 83 1991.35), California Coordinate System of 1983 Zone 2 was used for horizontal control. The National Geodetic Vertical Datum of 1929 (NGVD29) was used to establish elevations. The NAD83 were obtained from the California Department of Transportation, North Region Surveys and are a part of the California Spatial Reference System – Horizontal (CSRS-H). The NGVD29 values were obtained in part from the National Geodetic Survey Control Database dated 1995, The California Department of Transportation and the County of Sacramento.

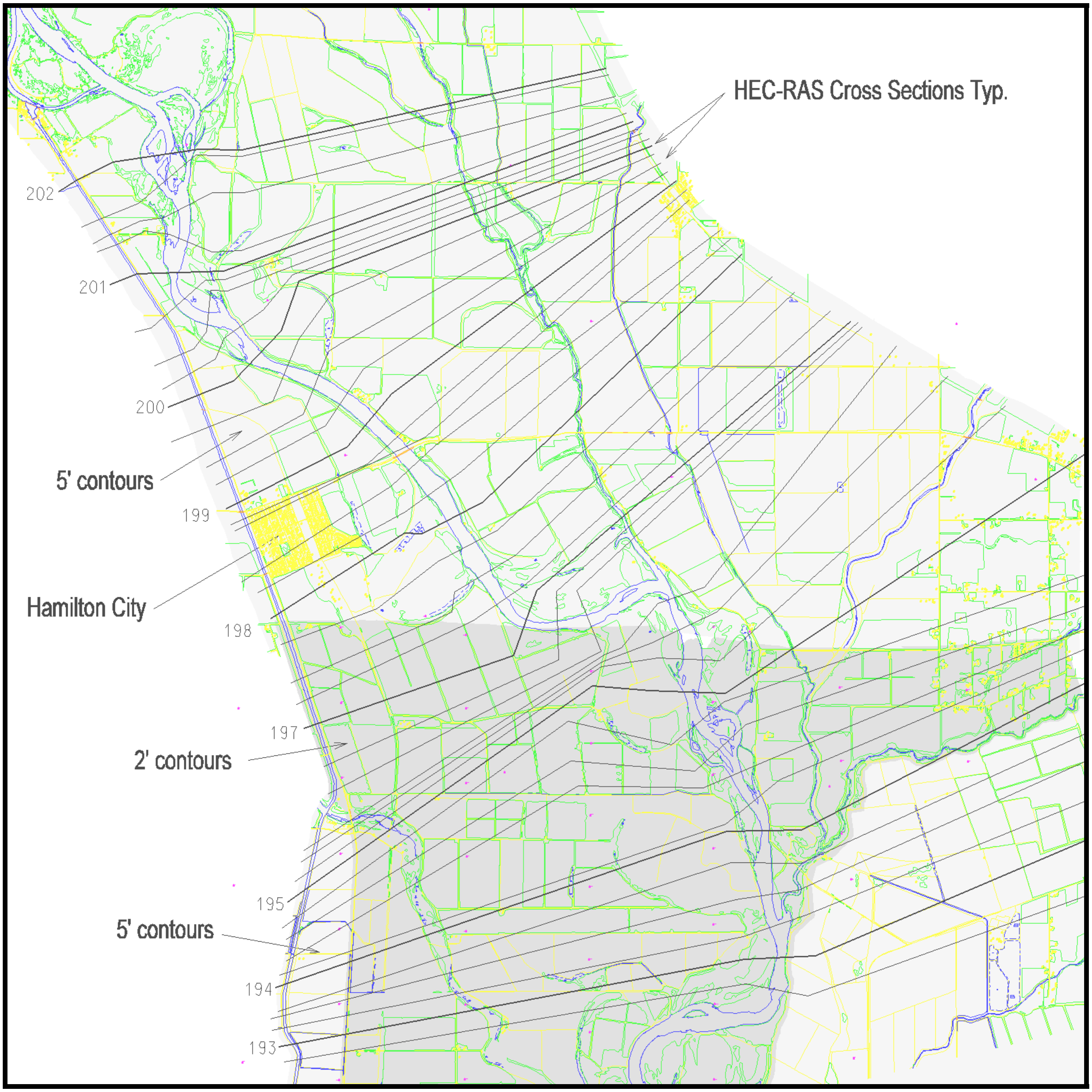


Figure 1. Survey Area and Cross Section Layout for Hydraulic Model.

C3.3. Design Tools

C3.3.1. Drafting

The Bentley software MicroStation was used as the primary drafting package for vector and raster file viewing and editing.

C3.3.2. Civil Design

The Intergraph software InRoads SelectCAD was used to produce hydraulic model cross sections and levee designs. A set of alignments, plans, profiles, and cross sections are developed for the proposed levee alignments, see Appendix C5, Civil Design.

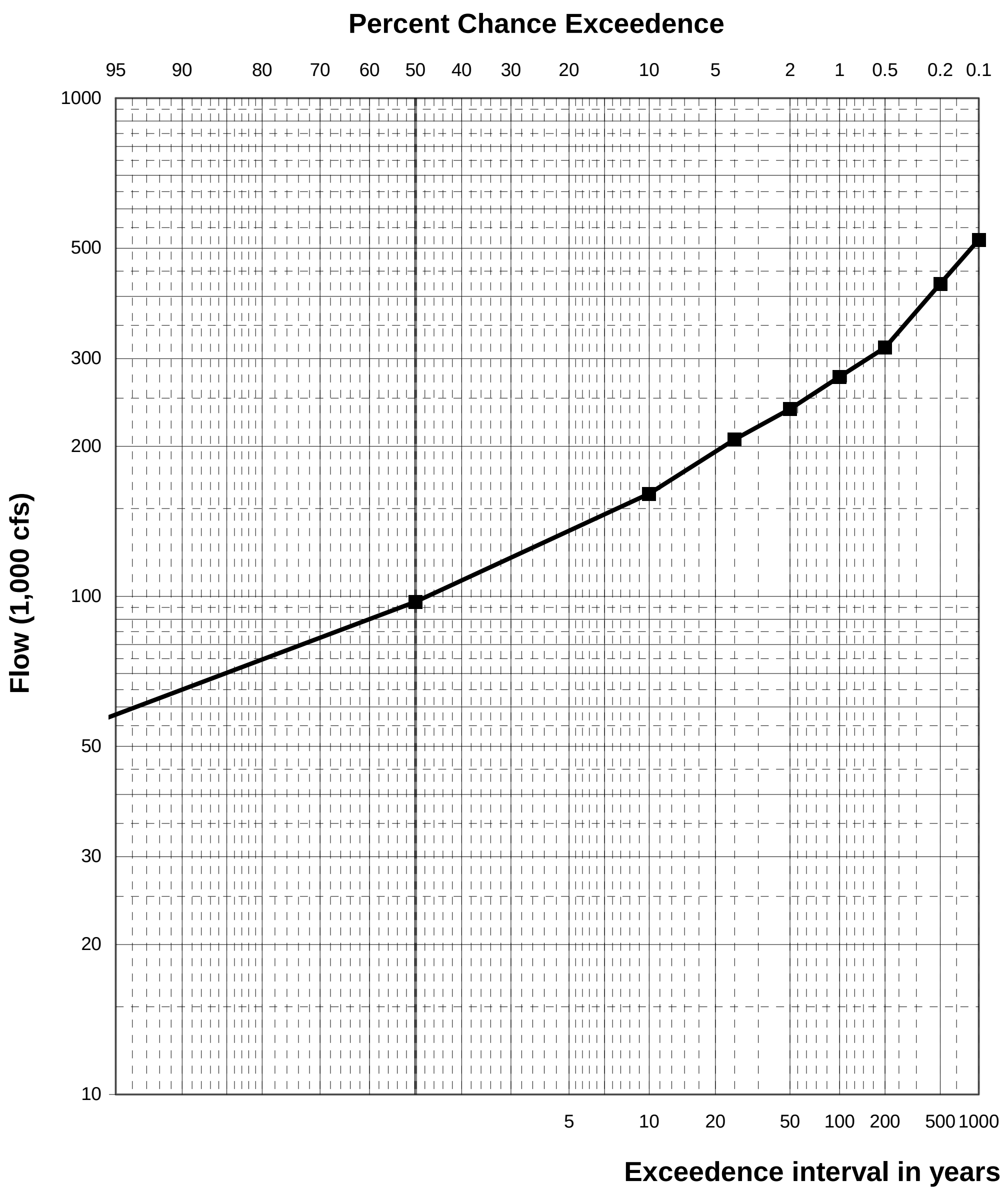
C3.3.3. Hydraulic Design

HEC-RAS Version 3.0.1, March 2001, was used for the hydraulic analysis. Hydraulic analysis used steady state, one-dimensional, standard step backwater techniques based on the following:

- The peak flow has a long duration.
- Storage area for flood flow is very small compared to the flood hydrographs
- The Sacramento River along Hamilton City is contained by high ground on each side of the floodplains.

C3.4. Hydrology

Hydrographs for the 2-year through 500-year flood events were obtained from a refinement of the Comprehensive Study Hydrology. See the hydrology documentation for this study (see Appendix C2, Hydrologic Engineering). The HEC-RAS hydraulic model for this study was extended upstream to the Comprehensive Study handoff point at Vina Bridge. The DSS file hamcity.dss was used for the 2-year event through the 500-year event. To develop the floodplains and analyze alternatives, HEC-RAS was run in the steady state mode. The peak flows for Hamilton City used for all three index points can be seen in **Table 1**, page 7. The flow values were taken from the unsteady HEC-RAS runs at RM 198.61. This study area is near the handoff point at Vina Bridge; changes in peak flows based on the channel routings have been insignificant. Peak flows used for this study are the same throughout the study reach of the river.



Pecent Exceed.	Exceed. Years	Discharge c.f.s.
0.10	1,000	520,000
0.20	500	424,511
0.50	200	315,965
1.00	100	275,910
2.00	50	237,829
4.00	25	206,575
10.00	10	160,634
50.00	2	97,524
99.99	1	30,000

SACRAMENTO-SAN JOAQUIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
HAMILTON CITY
2003 HEC-RAS Model Results

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

1-Sep-00

Figure 2. Peak Flow Frequency Curve.

Table 1. Index Points at Hamilton City.

			Peak Stage (feet NGVD) @ River Mile (RM)		
Percent (Exceed.)	Exceed. (Years)	Discharge (cfs)	198.25 (feet)	197.25 (feet)	194.25 (feet)
0.10	1,000	520,000	153.89	150.45	143.83
0.20	500	424,511	152.30	149.08	142.09
0.31	320	342,580	150.75	147.80	140.42
0.50	200	315,965	150.39	147.93	139.81
1.00	100	275,910	149.53	147.06	138.86
2.00	50	237,829	148.37	145.94	137.86
4.00	25	206,575	147.85	144.87	136.98
10.00	10	160,634	145.73	143.18	135.40
50.00	2	97,524	141.22	138.99	132.34
99.99	1	30,000	131.27	128.95	121.79

C3.5. Project Description

Hamilton City is on the right bank of the Sacramento River. An existing levee known as the "J" levee, so named for its alphabetical relationships to other levees in the area, lies between the Sacramento River and Hamilton City. The floodplain along this reach of the river is bordered by the foothills of the Coast Range to the west and the Sierras to the east. Seven proposed plans were considered. A description of each preliminary alternative plan can be found in Chapter 3 (paragraph 3.5) of the main report.

C3.6. Hydraulic Analysis

C3.6.1. Model Description

A one-dimensional steady state HEC-RAS hydraulic model was used for this study. It was made using the original cross sections defined for the Comp Study Sac River Basin UNET one-dimensional unsteady model. A UNET model and a FLO-2D model had been used for the Comprehensive Study for the Hamilton City Reach. The cross sections from the UNET model were extended across the floodplain so one hydraulic model could be used for this study. This study was able to use a single model because the flow split into the Butte Basin was not considered.

The cross sections are shown in plan view on **Figure 1**, page 4. The cross sections extend across the valley floor to essentially contain the 500-year flood event. Cross sections are spaced about one-quarter mile apart.

Existing levees present along the east bank of the Sacramento River and Pine Creek in Butte County were included in the hydraulic model. Based on historical accounts and experience in the area the levees were allowed to fail between the water surface profiles of the January 1997 event and the 50-year peak flood event water surface profile, where the larger event is the 50-year event.

C3.6.2. Boundary Conditions

Peak flood flows entering the upstream boundary RM 202 are described above in section 4. Hydrology. **Table 1**, page 7, shows the discharges in cubic feet per second that were run in the model.

At the downstream end of the model (RM 192.75) a normal depth-rating curve was developed. The rating curve development considered stage discharge information from the Comprehensive Study UNET results and from a RMA-2V two-dimensional hydrodynamic model developed by Ayres Associates to model the Butte Basin flow splits based on the 1995 survey data described above. **Figure 3**, page 9, shows a comparison of the three stage discharge relationships. To compute normal depth a slope of 0.0006 was used. The Manning's roughness coefficients used were 0.025 for the channel and 0.10 for the overbanks.

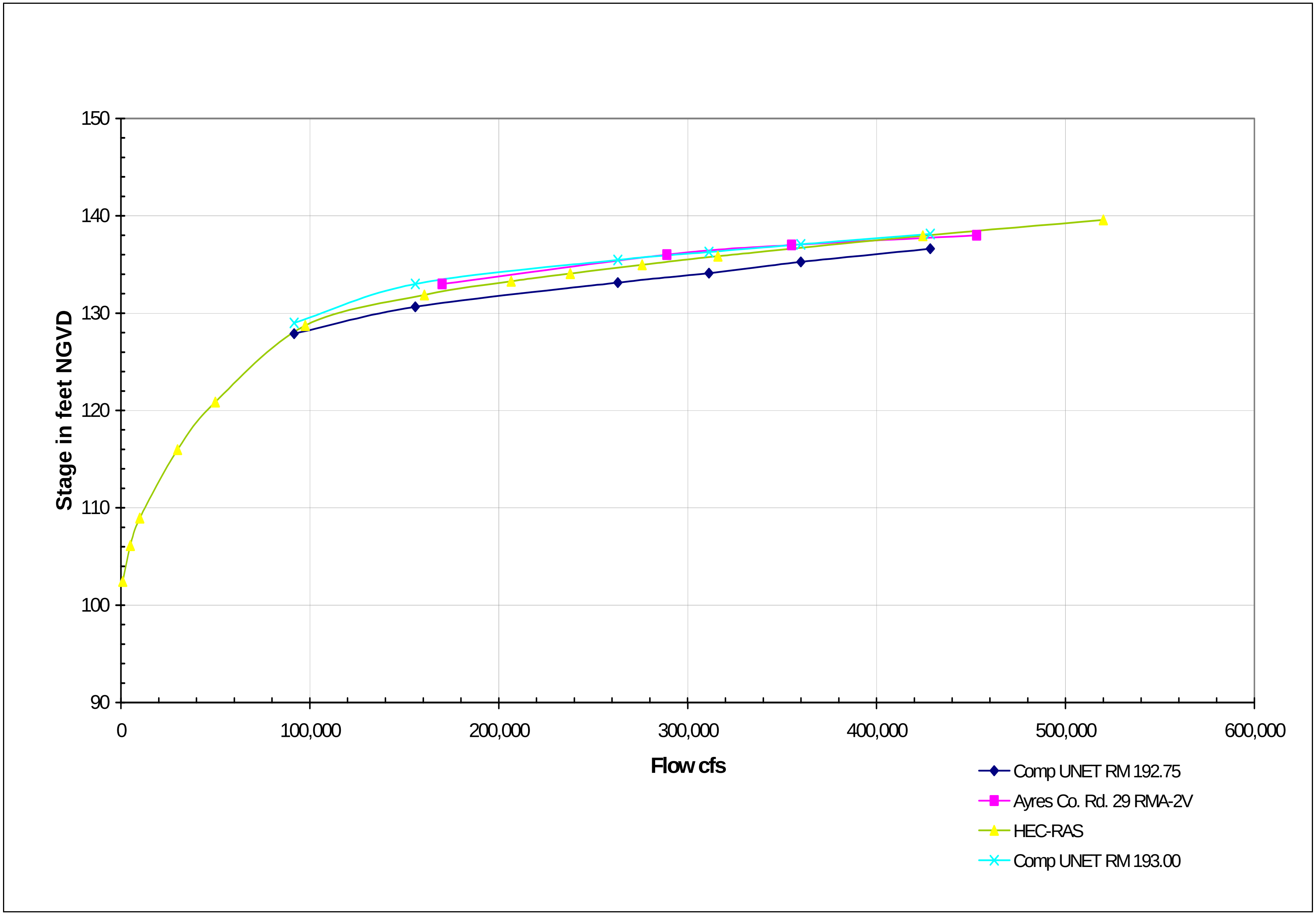


Figure 3. Rating Curve Sacramento River, RM 192.75.

C3.6.3. Manning's Roughness Coefficients

Manning's roughness coefficients were estimated considering values used in the Comprehensive Study, previous multi-dimensional studies by Ayres Associates, and matching the water surface elevations from the USGS gage rating at Gianella Bridge River Mile ~198.67 (1997 UNET river miles). Manning's roughness coefficients used for this study are listed below in **Table 2**, page 10. Form Loss coefficients of 0.1 for contraction and 0.3 for expansion was used throughout the model.

Table 2. Manning's Roughness Coefficients.

	N	N	N
River	Left	Main	Right
Mile	Overbank	Channel	Overbank
220.00	0.15	0.027	0.15
198.63	0.15	0.027	0.15
198.71	0.15	0.026	0.15
193.00	0.15	0.025	0.15
192.75	0.10	0.025	0.10

C3.6.4. Bridge Analysis and Form Loss Coefficients

The Gianella Bridge crosses the Sacramento River adjacent to Hamilton City. There are no other bridges within the study reach. The low cord (elevation 158.26 feet NGVD) on the bridge is well above the water surface for all the flood events. Flood flows can go around the bridge on both ends. The standard step energy method was used to model the bridge. Pressure and weir flow do not occur for the range of flows analyzed.

C3.6.5. Junctions, Transitions, and Bifurcations

There are no junctions or bifurcations within this study reach. All transitions were modeled using form loss and roughness coefficients.

C3.6.6. Calibration/Verification

Very little data was available to calibrate the hydraulic model. The hydraulic model results were compared to one 1997 high water mark and the DWR Hamilton City Gage rating curve (HMC rating). The gage is just upstream of the Gianella Bridge. **Figure 4**, page 11, shows the comparisons.

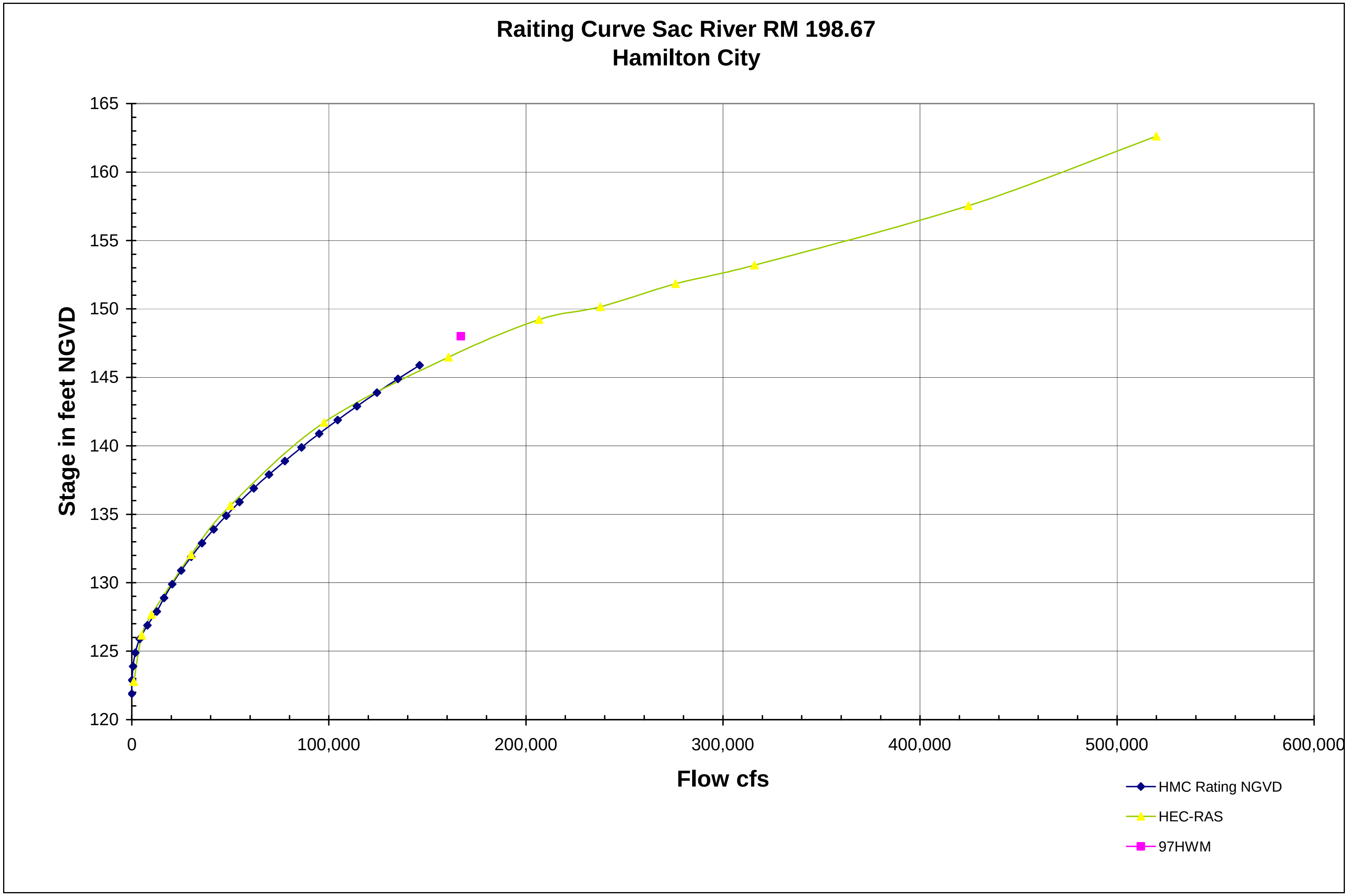


Figure 4. Hamilton City Rating Curve Sacramento River, RM 198.67.

C3.6.7. Superelevation

Superelevation of the river's water surface was not considered significant in this study because flow is in the sub-critical regime, and the river does not experience any significant bends in the study area.

C3.6.8. Wind Setup and Wave Runup

This analysis was conducted to determine the magnitude of wind-induced wave action against the proposed west-side (right bank) setback levee on the Sacramento River east of Hamilton City, California. The Stillwater Level used for the analysis is the 100-year floodplain elevation of the Sacramento River at the latitude of Hamilton City, about 152 feet.

Wind data used in the analysis are from the records at Sacramento Executive Airport, for the months of November through April, for the period of record, 1950-1986. The maximum monthly windspeeds were tabulated, in miles per hour, to find the maximum recorded 1-minute and 60-minute windspeeds for eight directions. The 60-minute windspeeds were estimated by dividing the 1-minute windspeeds by 1.24. This relationship of 1-minute to 60-minute wind speed is based on records for airport wind gages in the Central Valley. The 1- and 60-minute overland windspeeds are tabulated below, on **Table 3**, page 12.

Table 3. Sacramento Maximum Wind Speeds.

Wind Direction	1-Minute Wind (mph)	60-Minute Wind (mph)
N	48	39
NE	32	26
E	22	17
SE	62	50
S	59	47
SW	50	40
W	36	29
NW	38	31

The wind direction is the direction from which the wind is blowing. The Sacramento Valley with its southeast-northwest orientation has stronger winds coming from the north, south, and southeast. Maximum windspeeds may be somewhat less at Hamilton City, so the computed wave runup values computed for this location will be conservative.

The northeast, east, and southeast wind directions were investigated for wave action against the setback levee. The northeast wind action was evaluated against a stretch of proposed levee slightly north and west of the Gianella Bridge (Fetch #2). Wind action for the east wind was evaluated for two locations, one north (Fetch #1) and the other south (Fetch #3) of the bridge. The southeast wind-wave action was evaluated for two locations south of Gianella Bridge. One southeast wind location (Fetch #4) has a somewhat limited fetch, due to the presence at the end of the fetch of roads just below the surface of the 100-year floodplain. These roads would dissipate most of the wave energy along a longer fetch. The other, longer southeast wind fetch (Fetch #5) passes south of the sub-surface roads. A north wind fetch was not considered, due to the existence of a sub-surface levee road along the west side of the Sacramento River that would dissipate the energy of a north-facing fetch.

The **Effective Fetch Length, Fe**, is the horizontal distance in miles, in the direction of the wind, over which the wind generates waves or creates a wind setup. The effective fetch, Fe, is the average length of 9 radials, at 3-degree intervals, centered on the wind direction against the levee. For two fetch locations (Fetches #1 and #5), a single fetch, rather than an average of 9 fetch radials, was considered.

The **Average Fetch Depth, D**, is the predominant depth of water, in feet, averaged for the 9 fetch lengths (or along a single fetch) for each wind direction, and is different for each wind direction considered.

The average fetch lengths and depths for the three wind directions and five fetches were estimated using the most recent Hamilton City 100-year Floodplain Map.

The Effective Fetch Length, Average Fetch Depth, and other parameters discussed below that are associated with wave runup for the three wind directions are listed on **Table 4**, page 16.

The design windspeed over the Effective Fetch for each wind direction was developed using Figures 5.34 to 5.37 in EM 1110-2-1414, "Engineering and Design – Water Levels and Wave Heights for Coastal Engineering Design," dated 5 July 1989. The design wind is that which will generate the largest significant wave for the fetch. The following windspeed adjustments were made. The overland windspeeds were already assumed to be measured at the Standard Level of 33 feet (10 meters) above ground. The overland windspeeds were corrected to overwater windspeeds, using ratios presented in Chapter 15-2 of EM 1110-2-1420, "Hydrologic Engineering Requirements for Reservoirs," dated 31 October 1997. The boundary layer condition is assumed to be neutral.

Significant wave characteristics were developed based upon the effective fetch length (Fe), design windspeed and wind duration (the time in which the wind will generate the largest significant wave for the fetch). The significant wave characteristics are:

Significant wave height, Hs - the average height in feet of the highest one-third waves of a given wave group; height is measured as vertical distance between crest and preceding trough;

Wavelength - the horizontal distance in feet between similar points on two successive waves; **Wave period, Ts** - the time in seconds for a wave crest to travel a distance equal to one wavelength;

Deepwater wavelength, Lo - measure in feet, equals 5.12

times the wave period (Ts) squared:

$$Lo = 5.12xTs^2$$

Wavelength type - deepwater or shallow-water.

If the average water depth, D, over the fetch length, F, is less than half the deepwater wavelength, Lo, then the wave growth is affected by the bottom, and the computed design windspeed and fetch length are used to predict the significant **shallow-water wave** height and period. If the wave growth over the fetch is not affected by the bottom (deepwater conditions are in effect), the significant wave height, Hs, is predicted by the **deepwater wavelength**. The waves from the northeast, east, and southeast are all shallow-water waves, since they are less than one-half of their respective deepwater wavelengths. The shallow-water wave characteristics for each wave were computed by interpolating values from Figures 5.35 through 5.37, for constant depths of 5, 10, and 15 feet.

Theta and **cotangent Theta**: Theta is the angle of the levee embankment relative to horizontal. Cotangent theta is the slope of the levee embankment, or the ratio of horizontal distance to vertical rise. The embankment slope, cotangent theta, is 3.0 for the proposed setback levee. Other information used for computing wave runup included the **depth at toe**, ds, of the levee, estimated from the 100-year floodplain map.

Computation of Wave Runup on Sloping Embankment: The above information was used to compute the vertical height of runup, R, against a smooth, impermeable sloped embankment. Figure 7-11 in the 1984 edition of the Shore Protection Manual was used to compute the runup, R, for the Southeast wind fetches (Fetches #4 and #5), for which the ratio of the toe depth to the Significant Wave Height is greater than one and less than three. For the Northeast and East direction fetches (Fetches #1 to #3), the ratio of toe depth to Significant Wave Height is greater than three; Runup R is computed using Figure 7-12 in the 1984 Shore Protection Manual. The computed runup values were adjusted for scale effects by using Figure 7-13 in the 1984 Shore Protection Manual. The scale correction factor for all three directions is 1.12.

Slope Roughness Factor: The wave runup values above are for smooth, impermeable slopes. A roughness and porosity correction factor, r, was applied to the wave runup to account for the effects of other structure slope characteristics. Two other slope conditions were evaluated, in addition to the smooth impermeable levee slope. In one case, grass is assumed to be growing on the levee at the 100-year floodplain level. The roughness coefficient factor for grass is 85 percent of the smooth impermeable levee slope runup. The other condition is a levee with riprap placement, assuming random quarrystone, with a roughness coefficient between 60 and 66 percent of the smooth levee runup. The roughness coefficient used is dependent on the ratio of the toe depth (ds) to the Significant Wave Height (Hs), as well as the ratio of the Significant Wave Height to the product of the Wave Period, (Ts) squared and the gravitational constant.

Maximum Runup: Thirteen percent of the waves will be higher than the Significant Wave Height. For design purposes, a Maximum Runup is used that is 150 percent of the Significant Wave Runup.

Wind setup is determined by EM 1110-2-1420, formula 15-1, and is defined as the **wind tide (set-up, caused by the design wind on the water surface)**, the vertical rise in feet above the Stillwater level that would prevail with zero wind action. Formula 15-1 to determine the wind setup is:

$$S = \frac{U^2 x F}{1400 x D}$$

where:

S is setup in feet above the Stillwater level,

U is the design wind speed in miles per hour.

F is the single fetch length in miles per hour,

D is the average water depth in feet over the fetch.

F used for the southeast wind Fetch #4 is twice the effective fetch length used for computing the wave runup. For the northeast and east wind directions, Fetches #2 and #3, the averaged fetch lengths and depths were almost the same as if a single fetch were used. For those directions, the effective fetch length was used. For the two single fetches (east and southeast, Fetches #1 and #5), the single fetch length, F, was used in the above equation.

The Maximum Wave Runup and Wind Setup were combined for the each of the five fetches. This sum of wave runup plus wind setup was then adjusted for the wave angle (angle adjustment factor).

Angle Adjustment Factor: The wave energy is reduced when the wave hits the shoreline at an angle, instead of straight on ("shore normal"). The reduction in wave energy is considered insignificant when the wave hits the shoreline at an angle less than 30° from "shore normal". For an angle greater than 30°, a wave reduction ratio, Rh, is applied. The southeast wind (at Fetches #4 and #5) impacts against the proposed setback levee at an angle of 75°, for which a wave reduction ratio of 78 percent has been applied.

Wave Runup Plus Wind Setup: The total water level increase (wave runup plus wind setup) against the proposed setback levee, for each of the five fetches, for grassy slope and riprap, is listed on **Table 4**, page 16. North of the Gianella Bridge, the wave runup would be highest from the northeast direction. South of the Gianella Bridge, a southeast wind would produce the highest total water level increase. A barrier of trees and thick underbrush in front of the levee can deflect much of the wave energy along the fetch.

Table 4. Wind-wave runup analysis results for proposed setback levee, westside Sacramento River at Hamilton City, California.

Levee Description	Proposed Hamilton City Westside Setback Levee						
	Symbol	Units	Fetch 1	Fetch 2	Fetch 3	Fetch 4	Fetch 5
Wind Direction			East	Northeast	East	Southeast	Southeast
Embankment Description, in relation to Gianelli Bridge			north end of levee	3,000 ft WNW	3,000 ft SE	3,000 ft SE	8,000 ft SSE
Stillwater Level is 100-Yr Flood Stage Elev. (approx.)		(feet)	152	152	152	152	152
Effective Fetch Length	Fe	(mi)	4.7	3.5	3.3	1.91	3.3
Average Fetch Depth	D	(ft)	10.4	11.6	9.5	13.6	9.1
Depth at Toe (from floodplain map)	ds	(ft)	8	8	5	5	5
Overland Wind (Using Sac Exec AP)	Ul						
Elevation above ground (assumed)	s	(ft)	33	33	33	33	33
1-Minute Wind	Us	(mph)	22	32	22	62	62
60-Minute Wind	Us	(mph)	17.7	25.8	17.7	36.0	36.0
Overwater Wind Relationship to Overland Wind			=1.29*Us	=1.27*Us	=1.26*Us	=1.2*Us	=1.26*Us
1-Minute Wind	Uw	(mph)	28.4	40.6	27.8	74.4	78.1
60-Minute Wind	Uw	(mph)	22.9	32.8	22.4	60.0	63.0
Design Wind Speed (Velocity)	U	(mph)	22.0	32.5	22.0	63.7	61.0
Wind Duration	t	(min)	90	65	75	36	53
Significant Wave Height	Hs	(ft)	1.75	2.50	1.50	4.00	5.00
Wave Period	Ts	(sec)	2.80	3.00	2.50	3.20	3.75
Deepwater Wave Length: Lo = 5.12 x Ts ^2	Lo	(ft)	40.1	46.1	32.0	52.4	72.0
Half Deepwater Wave Length	0.5 * Lo	(ft)	20.1	23.0	16.0	26.2	36.0
Wave Test: D > (0.5 x Lo)?	Ratio		0.52	0.50	0.59	0.52	0.25
Ratio: D / (0.5 x Lo) > 1?	>1?		No	No	No	No	No
Wave Type: Deep or Shallow			Shallow	Shallow	Shallow	Shallow	Shallow
Computation of Shallow-Water Wave Characteristics			Fetch 1	Fetch 2	Fetch 3	Fetch 4	Fetch 5
Wind Duration	t	(min)	55	37	45	17	22
Significant Wave Height	Hs	(ft)	1.40	1.99	1.23	3.42	3.19
Wave Period	Ts	(sec)	2.40	2.63	2.19	3.00	3.25
Cotangent Theta (Slope)	cot O	(ft/ft)	3	3	3	3	3
ds/Hs	ds/Hs		5.7	4.0	4.1	1.5	1.6
Hs / (g*Ts^2)			0.0075	0.0089	0.0080	0.0118	0.0094
R/Hs for Relationship: (ds/Hs)	(ds/Hs)	Relationship	>3	>3	>3	=2	=2
R/Hs on smooth impermeable slope	interpolated		1.50	1.41	1.47	1.14	1.30
Runup (not corrected for scale effects)	R	(ft)	2.10	2.81	1.81	3.89	4.15
Scale correction factor	k		1.12	1.12	1.12	1.12	1.12
Wave Runup on smooth impermeable surface	R*k	(ft)	2.35	3.15	2.03	4.36	4.65
Roughness coefficient for Grassy Slope	Ratio r =	0.85	0.85	0.85	0.85	0.85	0.85
Significant Runup on Grassy Slope	Rs=r*R*k	(ft)	2.00	2.68	1.72	3.71	3.95
Maximum Runup on Grassy Slope	Rmax=1.5*Rs	(ft)	3.00	4.01	2.58	5.56	5.93
Roughness coefficient for riprap (random quarrystone)	Ratio r	0.6 to 0.65	0.60	0.62	0.61	0.66	0.65
Significant Runup on Riprap	Rs=r*R*k	(ft)	1.41	1.95	1.24	2.88	3.02
Maximum Runup on Riprap	Rmax=1.5*Rs	(ft)	2.12	2.93	1.85	4.32	4.53
WIND SETUP:			Fetch 1	Fetch 2	Fetch 3	Fetch 4	Fetch 5
Fetch Length	F	(mi.)	4.7	3.5	3.3	3.8	3.3
Design Wind Speed	U	(mph)	22.0	32.5	22.0	63.7	61.0
Avg Fetch Depth	D	(ft)	10.4	11.6	9.5	13.6	9.1
Wind Setup S = (Fe*U^2)/(1400*D)	S	(ft)	0.16	0.23	0.12	0.81	0.96
Combined Wind+Wave for Grassy Slope	Rmax+S	(ft)	3.16	4.24	2.70	6.38	6.89
Combined Wind+Wave for Riprap	Rmax+S	(ft)	2.27	3.15	1.97	5.13	5.50
Angular Spread (from Shore Normal)		(degrees)	0	0	30	75	75
Wave Reduction Ratio	Rh	(Ratio)	1.00	1.00	1.00	0.78	0.78
Fetch Location Number			Fetch 1	Fetch 2	Fetch 3	Fetch 4	Fetch 5
Wind Direction			E	NE	E	SE	SE
Wave Runup + Wind Setup After Angular Adjustment							
Final Wave Runup & Wind Setup for Grassy Slope	Rh*Rmax+S	(ft)	3.16	4.24	2.70	4.97	5.38
Final Wave Runup & Wind Setup for Riprap	Rh*Rmax+S	(ft)	2.27	3.15	1.97	4.00	4.29

This spreadsheet for Hamilton City Project Setback Levee wave runup uses the latest criteria, EM 1110-2-1420, dated 31 Oct 1997

C3.6.9. Wind Wave Protection

The recommended minimum width suggested by the SCS in Technical Release No. 56, December 12, 1974, A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments, The minimum width is 20 feet. The width is based on x / y = z where:

x = the width of the berm (vegetation zone)

y = the difference in potential water elevations against the levee

z = (from 10 to 15) depending on the fetch, in this case it would be adequate to use 10, this is a levee not a dam

Data taken from HEC-RAS along the training dike the depth of the 100-year flood is from about 5 to 8 feet. When the water is below 2 feet the waves should not be an issue. The vegetation then would protect for a variation of depth ranging from 3 to 6 feet.

Using an average variation of water stage of say 4.5 feet then the width would be 4.5 x 10 or 45 feet.

The planting density would vary depending on how wide the vegetation zone is. Using only a 20-foot width the vegetation would need to form a solid wall along the levee and would require a high level of maintenance. However, using a wider zone with the same number of plants the maintenance should be much less and the cost would be similar, especially if the plants are self seeding, rhizomatous or stoloniferous and will fill in the gaps.

If the area out from the levee will be riparian, it should offer sufficient protection without additional vegetation. If it is Oak Savannah then the levee will need additional protection.

C3.6.10. Superiority

Levee overtopping has not been fully addressed at this time. In general, the levee design is expected to provide initial overtopping at the least hazardous location for initial inundation of the interior. The least hazardous location is thought to be at the downstream end of the project, since the end of the levee is open to backwater.

C3.6.11. Breaching/Removing J-Levee

Initially it was felt that the J-Levee would be breached at appropriate locations to induce flooding in the proposed ecosystem restoration locations. After additional modeling with RMA2, a two-dimensional model, it was determined that the majority of the J-Levee would need to be removed to reduce localized water surface increases in the study area. Modeling to date for the selected alternative has taken into account the removal of the J-Levee.

C3.6.12. Project Performance

Modeling efforts by Ayres Associates with RMA2, a two-dimensional model, have identified locations of localized stage increases, see attached memorandum. Two locations exist where localized stage increases were observed within the study reach. First, upstream of Gianella Bridge (HWY 32) an increase in water surface is observed in the 2-dimensional model, east of this location a decrease in the water surface is observed in Butte County suggesting that additional flow is being conveyed through the Sacramento River. The bridge at HWY 32 acts as a control in this case, causing an increase in water surface to push flow under the bridge. Second, an increase in water surface elevation is observed in the 2-D model at the most southerly portion of the proposed setback levee at high, infrequent flows, such as the 320-year hydrologic flood frequency. By comparing the Annual Exceedance Probability (AEP) for with and without the project, the big picture can be seen. Without the project the AEP is 9%, meaning that the probability of getting flooded in any given year is twenty-four percent annually. With the project the AEP is 1%, meaning that the probability of getting flooded in any given year is five percent annually. The southern end of the project protects against the more frequent flood events, even though a localized stage increase is observed at the less frequent, more significant flows, a significant flood reduction benefit exists at the most southerly portion of the proposed setback levee.

Flows from Stony Creek were taken into account in RMA2 model runs.

C3.6.13. Results

The results of this hydraulic analysis did not reveal any unexpected results. A basic standard step backwater method was used. Water surface profiles for the full range of discharges analyzed are shown below in **Figure 5**, page 19.

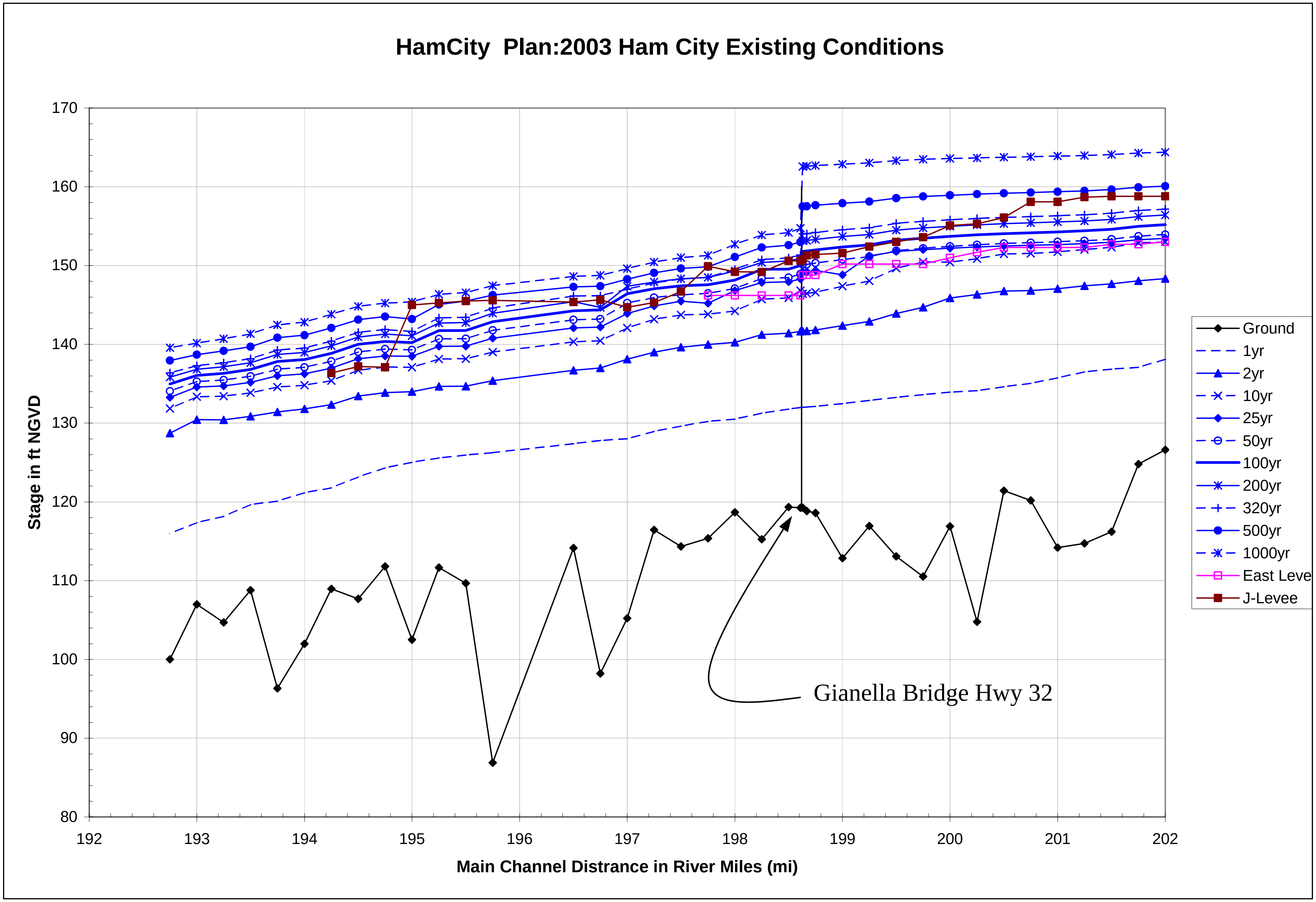


Figure 5. Water Surface Profiles in feet NGVD29.

C3.7. Floodplain Delineation (2-,10-,25-,50-,100-,200-,500-year events)

Floodplains have been developed for this study based on present and future with and without project hydrology being the same. Floodplain depths for the 2-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year are shown on Plates 2 through 8.

C3.8. Sedimentation and Dynamic Stability Analysis

Sedimentation and channel stability are not thought to be significant issues at this time. The preliminary results of the Sediment Analysis Model (SAM) do not indicate significant new information from the previous studies done in the area (Corps, Larson 2002). A more in-depth study may be needed during Planning, Engineering and Design (PED) phase of the project. The Modesto Formation and the Tahema Formation (an alluvial deposit that is more resistant to erosion than the more prevalent Modesto Formation) have historically limited the Sacramento River migration to some extent and would improve sedimentation and channel stability projections.

C3.8.1. Meander Migration Rates

Historic data presented by Eric Larsen (2002), see **Figure 6**, page 20, suggests that River Miles 201-198 since 1904 has been characterized by channel stability, and that there has been little to no shift in the channel since 1904. In 1978 riprap was installed between RM 201-198. **Figure 7**, page 21, shows the average historical rate of migration in the study areas of the report in meters/year; for River mile 201-198 (Zone 1) the minimum, maximum, and average rate of migration are 0.16, 41.0, and 11.5 feet/year (0.05, 12.5, and 3.5 meters/year) respectively.

The report calculates a predicted average rate of migration into the future. Two main scenarios are of interest. Scenario 1 represents existing conditions at river mile 201-198 the predicted average rate of migration is 2.3 feet/year (0.7 meters/year). Scenario 2 represents conditions where all the riprap is removed. Average rates of migration for river mile 201-198 are predicted to be 3.6 feet/year (1.1 meters/year).

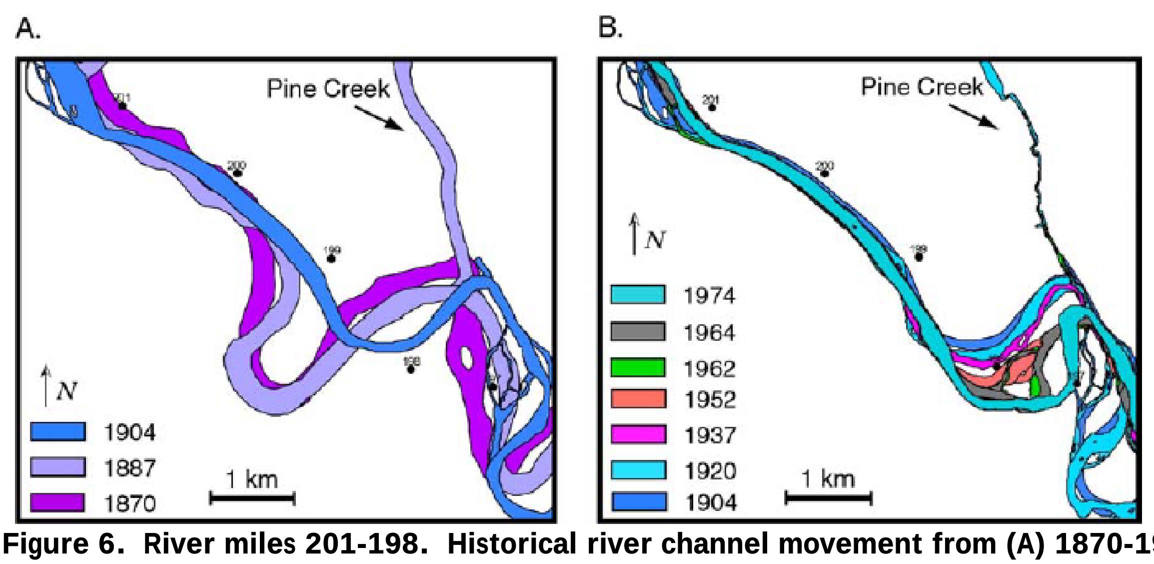


Figure 6. River miles 201-198. Historical river channel movement from (A) 1870-1904 and (B) 1904-1974 (Larsen 2002).

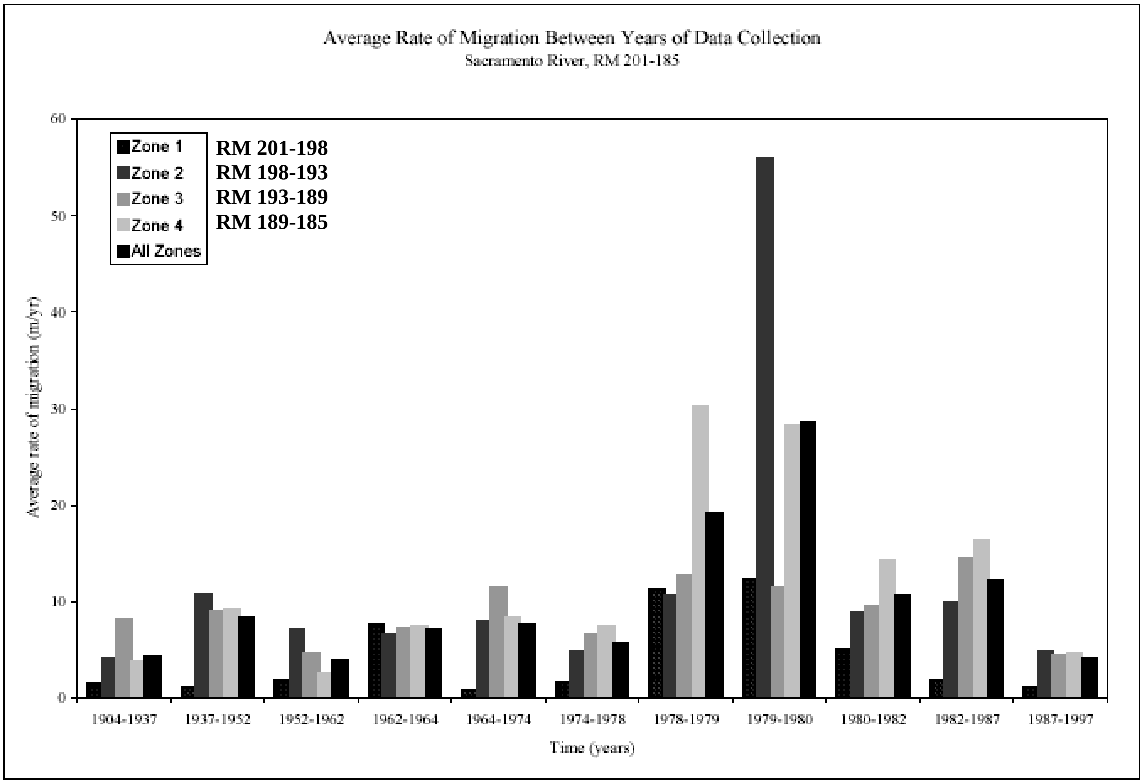


Figure 7. Average rate of migration (meters/year) (Larsen 2002).

Migration rates reported for the Sacramento River (USACE 1990) for historical period during 1908 to 1986 are summarized below. River mile 204 has a predicted 5-year migration rate of 90 feet/year; while river mile 196 has a predicted 5-year migration rate of 102 feet/year. The migration rate for river mile 201.8 for years 1981-1986 was 102 feet/year (USACE 1999).

C3.9. Channel Stabilization Features

Ayres Associates has performed an analysis on channel migration rates, sediment transport capacity and channel stabilization features. Based on this work, riprap bank protection will be placed in areas that are anticipated to have a higher risk of erosion. Entrenched rock protection will be placed at areas that are currently exhibiting high river migration rates (e.g. RM 200.7). Such locations have been noted in **Figure 8**, page 25.

C3.9.1. Current Bank Protection

In the project area on the west side of the Sacramento River, on the right bank, approximately 1,600 feet of concrete rubble and 5,000 feet of rock riprap are located south of Dunning Slough on the waterside of the existing J-Levee. The bank protection at approximately River Mile 197 to 198 was placed in 1975-76 during the Chico Landing to Red Bluff Project. In addition, south of Dunning Slough there is 500 feet of abandoned rock riprap located in the middle of the Sacramento River due to erosion and river migration that has removed part of the riprap placed in 1975-76. Near the Gianella Bridge approximately 450 feet of rock riprap was added on the bank at the J-Levee during the 1997 emergency flood fight. This emergency revetment covered about 11,250 square feet (450 feet long by about 25 feet high; greater than 20 inch diameter rock). The rock was placed in 1997 because the existing J levee is of poor quality and subject to erosion.

On the east bank of the Sacramento River, within the project study area, there is bank protection placed by the Chico to Red Bluff Project at River Mile 201 (about 1,800 feet). Also on the east bank there is privately placed revetment at River Mile 200-199.5 (2,500 feet) and privately placed rubble at River Mile 196-195.5 (about 2,200 feet) just south of Pine Creek's confluence.

C3.9.2. Rock Removal

Rock removal is not a viable option along the Sacramento River between River Mile 195 and River Mile 197.5.

The rock along the lower portion of the Hamilton City project was placed in 1976 is 26 years old. It is reaching the end of its design life. This rock was placed without scour considerations as was common during that period. As such the rock riprap bank protection usually lasts about 50-years with significant deterioration starting about 20-years from its time of placement. About 20% - 25% of the riprap cover has already eroded from the bank.

Although there is a high uncertainty in any bank erosion and/or channel migration estimate the rock riprap bank protection does not last indefinitely and will have less and less impact into the future. Removing the rock and leaving the bank (unprotected) in a bare newly disturbed condition will make the bank highly susceptible to erosion. This could easily cause a channel evolution in the area that may have undesirable hydraulic and geomorphic impacts upstream and downstream. If the rock on the channel bank is not periodically replenished; it will not stop channel migration, it will only slow it down (albeit significant initially).

C3.9.3. Project Bank Protection

Placement of rock (entrenched and revetment) is necessary at some points along the replacement levee to ensure the stability of the levee. **Figure 8**, page 25, shows the location of the proposed project bank protection.

Initially removal of the existing bank protection was considered. In consideration of public safety, risk, legal liabilities, and potential benefits it was determined that the rock riprap was to remain because of unknown hydraulic impacts both upstream and downstream that could occur. Over time, fluvial processes will remove the existing riprap and restore the river's dynamic meandering processes. If maintenance and replacement are required, then existing agreements and authorities would be used.

At Highway 32 around Gianella Bridge the replacement levee is setback from the existing J-Levee. This exposes the northern bridge abutment to direct flows, which it is not currently exposed, creating the possibility that scour could occur around the abutment. In order to ensure that bridge is not compromised by the potential project, 1,000 feet of rock riprap would be placed on and around the abutment. In addition, 100 feet of rock would be placed under the Gianella Bridge at Highway 32 specifically to protect the bridge from higher velocities as a result of passing higher flows with the tentatively selected plan. Grouted rock riprap, lining the bridge and other alternatives will be looked at in more detail in final design.

At the north and south ends of Dunning Slough a bend in the replacement levee would be exposed to overland flows, which could cause erosion on the replacement levee. In order to ensure that the replacement levee is not subject to this erosion, 1,400 feet of rock riprap would be placed along the levee at the bend.

At the southernmost extent no bank protection is anticipated assuming that the Chico Landing to Red Bluff Project (local site constructed in 1975-1976) would remain. It is felt that erosion control at the end of the levee can be controlled with vegetation (about 20 feet or so from the levee toe) to reduce velocities at the levee. No rock is anticipated in this area.

Additional rock volume may be required as the levee height increases to account for concentrated velocities and possible toe scour at the Highway 32 Bridge. Using CHANLPRO with conservative velocity estimates from HEC-RAS, **Table 5**, page 24, was developed. This shows the thickness and the percent increase based from the 100-year flood frequency flow. It was determined that an additional 29% rock by volume will be required for protecting from the 320-yr flood frequency, and a 57% increase will be required for protecting from the 500-year flood frequency based on the 100-yr flood frequency rock volume estimates. Additional analysis, including velocity change results from the 2-dimensional hydrodynamic model; RMA2 (USACE 1996) will be used for further refinement. Other alternatives to reduce costs while providing the same protection will be looked at in final design.

Table 5. Additional Rock Volume at Gianella Bridge based on 100-year Hydrologic Flood Frequency.

Hydrologic Flood Frequency	Calculated Rock Thickness		Max % Increase from 100-yr Flood
	u/s Gianella Bridge (in)	d/s Ginaella Bridge (in)	
50	24.8	42	0%
100	24	42	-
320	30	54	29%
500	36	66	57%

C3.9.4. Launchable Rock Riprap

In areas where erosion is expected or possible a launchable rock riprap will be placed to protect the levee in the event that the river starts to migrate in that general direction. Launchable rock riprap is where rock is buried in a trench below the ground, when the river erodes away the bank at the location of the trench the rock falls and armors the bank inhibiting erosion beyond that point. A detailed schematic can be seen in Plate 1.

There is potential for the river to migrate near the replacement levee at the most northern end where it ties in to County Road 45, 1,500 feet of entrenched rock would be placed from County Road 203 along the replacement levee (the portion that parallels County Road 203). An alternate approach would be to provide launchable rock riprap a between the existing setback levee and the river. This would allow the existing setback levee to act as a training dike and guide the river away from the new project levee.

South of Dunning Slough, 1,500 feet of entrenched rock would be placed to protect the new levee from erosion and river migration.

As mentioned in the previous paragraph, an additional amount of rock volume is expected to be required as protection against higher flood frequency increases. **Table 5**, page 24, has values that the rock volume is expected to increase by based on the volume of rock needed for the 100-year flood frequency.

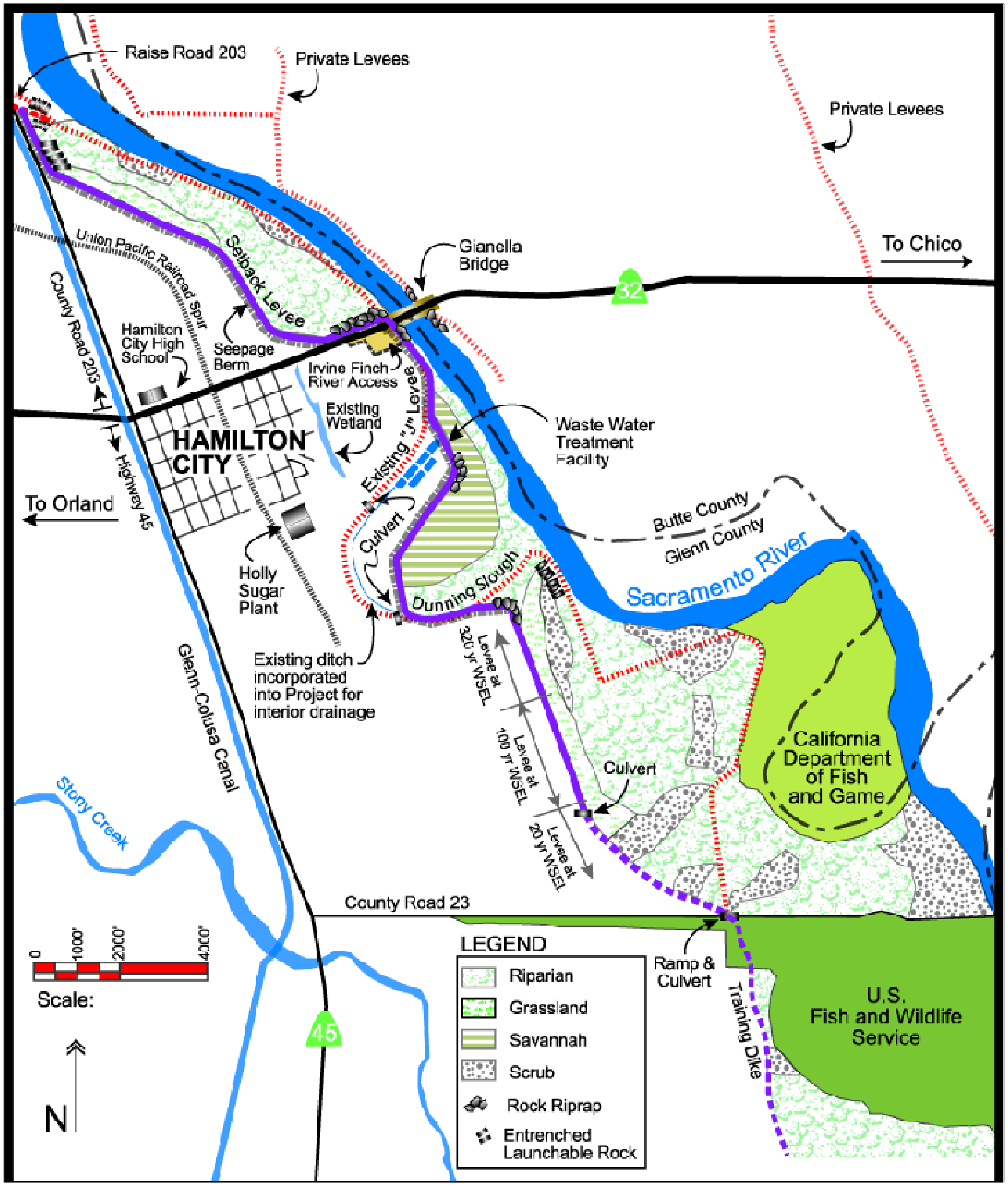


Figure 8. Tentatively Selected Plan.

C3.10. Interior Flooding Analysis

Interior flooding has not been included in this study. If levee alignment number 2, 3, or 4 is selected as the preferred alternative an interior drainage assessment will be required.

C3.11. Risk Analysis

Figure 9, page 26, shows the conditional non-exceedance probability (CNP) for various frequency flood events for top of levee of elevation 150.8 feet at index point 198.25. The CNP describes the probability of a given flood being successfully conveyed without flooding. The figure shows the flood event with the corresponding CNP. As the water surface elevation increases, the chance of flooding increases, which is to be expected. The levee height required to achieve 90% CNP of passing the 100-year event considered necessary to meet the requirements FEMA top of levee purposes is shown on **Figure 9**, page 26. The CNP for index points 197.25 and 194.25 are shown in **Figures 10 and 11**, page 27, respectively. The top of levee for each of the index points is different, which changes the CNP of passing the corresponding hydrologic flood frequency event. The height of the existing J-Levee is shown as a reference at each of the index points.

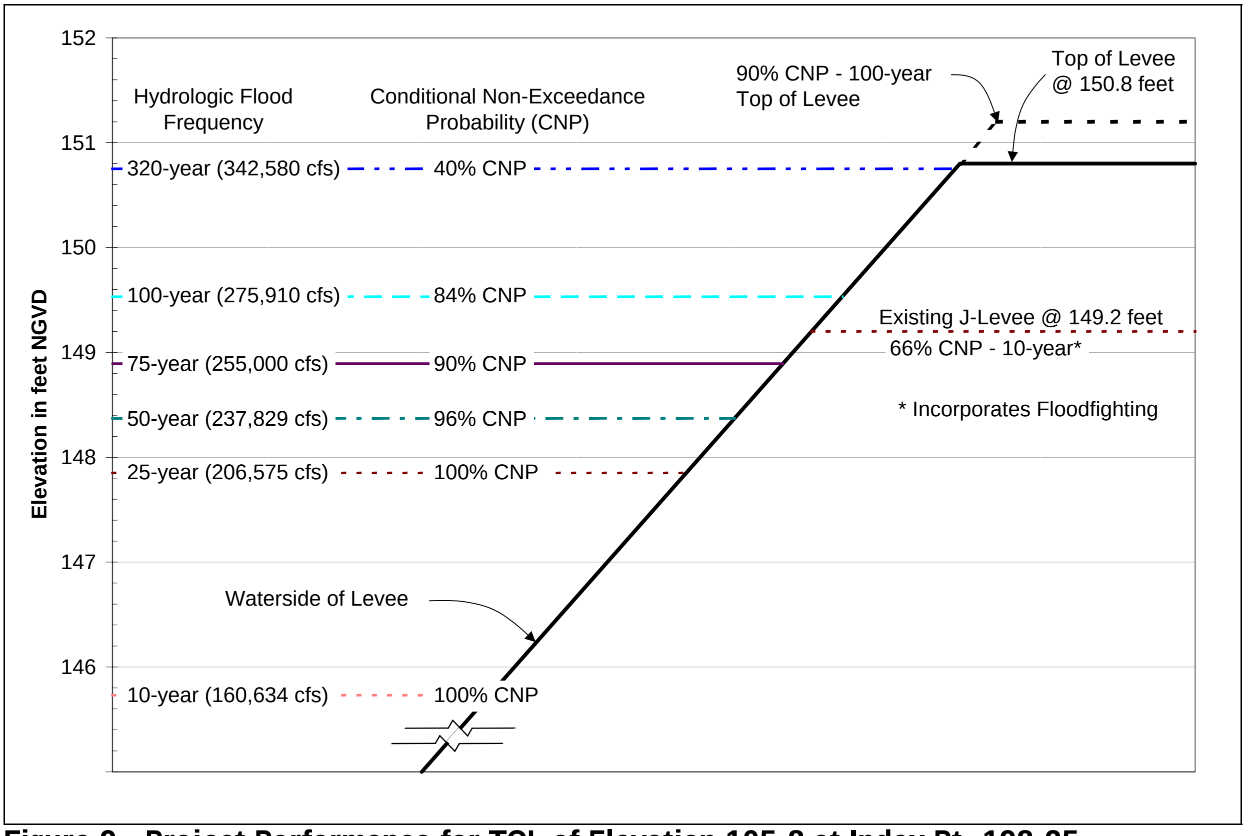


Figure 9. Project Performance for TOL of Elevation 105.8 at Index Pt. 198.25.

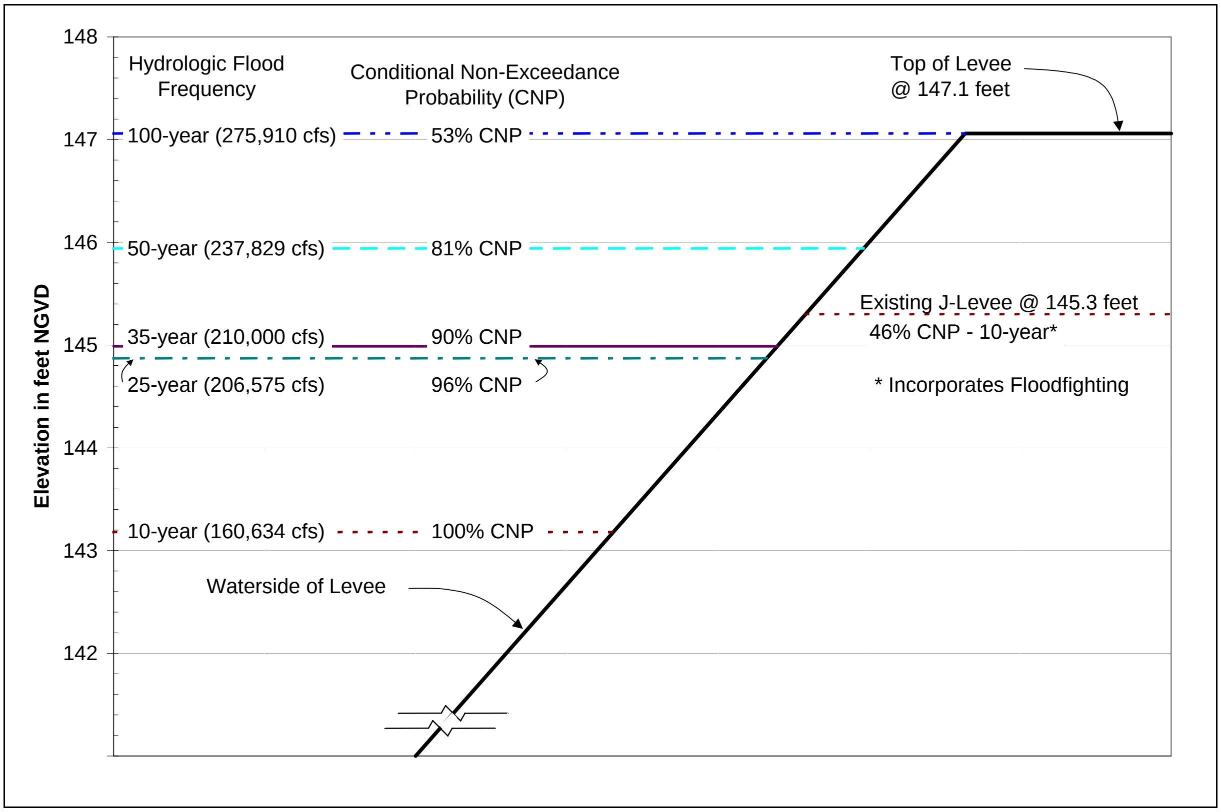


Figure 10. Project Performance for TOL of Elevation 147.1 at Index Pt. 197.25.

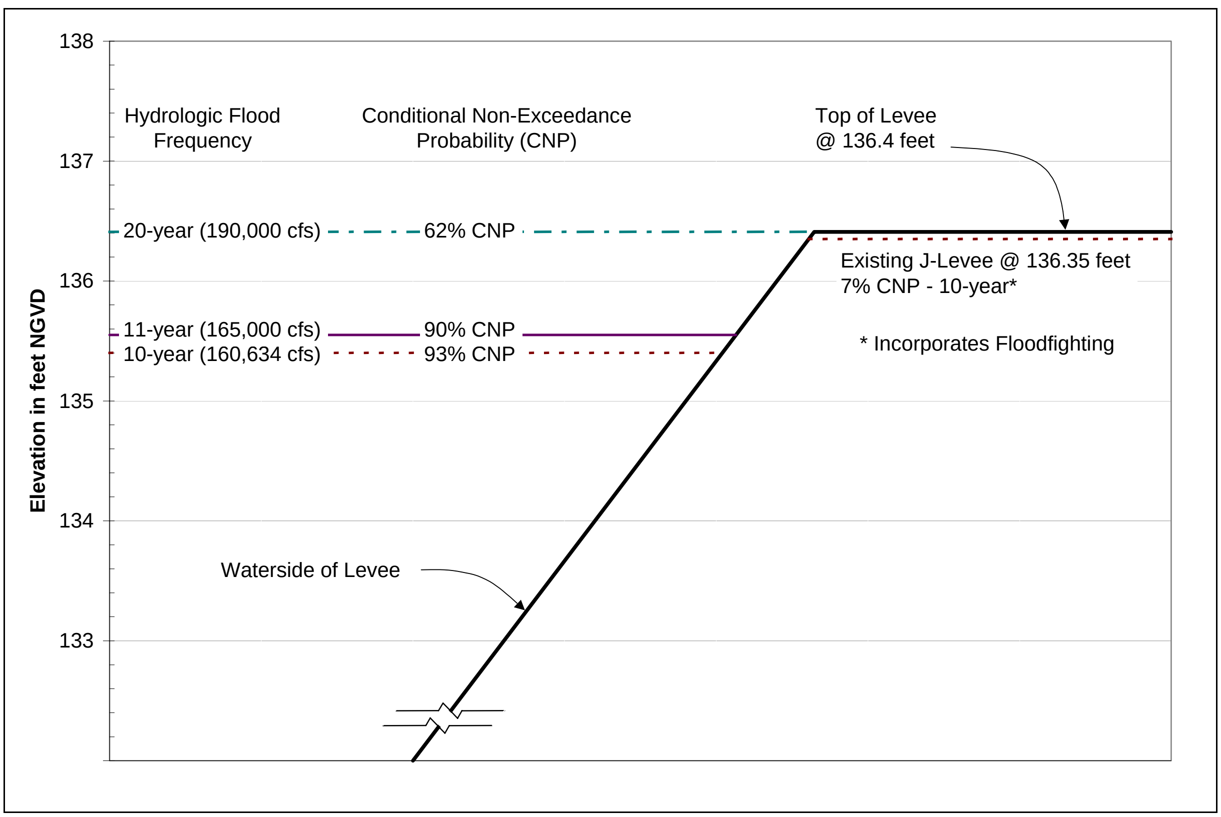


Figure 11. Project Performance for TOL of Elevation 136.4 at Index Pt. 194.25.

C3.11.1. Index Points

There were three index points selected for this study. The relationship between discharge/frequency, discharge/stage, and stage/damage is well represented within the study area by three index points. With and without project discharge/stage relationships remain constant. A sensitivity analysis was made comparing the no levee water surface to the most restrictive levee water surface. For the 100-year event there was about a one-foot difference at the worst location.

C3.11.2. Stage Uncertainty

A standard deviation of 1-foot was selected based on experience and Table 5-2 in EM 1110-2-1619; Risk Based Analysis for Flood Damage Reduction Studies. The HEC-RAS has a "fair" reliability meaning that the model has good calibration with a limited high-water mark data that was available at Gianella Bridge.

C3.11.3. Stage Discharge Curves

Stage discharges at the index points are shown on **Table 1**, page 7.

C3.11.4. Bank Migration

Bank Migration was estimated for specific exceedance intervals based on peak flood flows and stream power. Stream power was calculated using reach-averaged results from the HEC-RAS steady state model and existing conditions. It is not expected that with project potential migration rates would be significantly different. Preliminary annual bank migration rates provided by Ayres Associates were used. The maximum migration rate was related to a 50-year peak flood event based on peak flood frequency and the historical period of maximum migration. It should be noted that much of the average yearly migration occurs during the more frequent flood event years. Stream power for some of the reaches does not increase with discharge, such as in reaches where backwater controls the channel hydraulics. **Tables 6 through 8**, page 29 through 31, show the results for three selected bends within the study area. The second part of the table shows the erosion rate associated with the exceedance probability. Stream power was selected as a good representation of the river's ability to do work. The values are annual and represent a duration of one-year. As can be seen from the migration rates associated with specific periods the actual migration values can cover a wide range. The migration in feet values shown on the lower tables should be taken as upper values.

Table 6. Meander Bend at River Mile 196 to 198.

Period	Years	Migration Distance (ft)	Migration Rate (ft/yr)
1896-1923	27	1202	44.5
1923-1937	14	43	3.1
1937-1946	9	1122	**124.7**
1946-1955	9	584	64.9
1955-1960	5	258	51.6
1960-1969	9	444	49.3
1969-1972	3	623	**207.7**
*1972-1981	9	797	88.6
1981-1984	3	355	**118.3**
1984-1986	2	0	0.0
1986-1991	5	0	0.0
1991-1999	8	28	3.5
1999-2002	3	30	10.0
1896-2002	106	5486	51.8
1946-2002	56	3119	55.7
1960-1981	**21**	**1864**	**88.8**
1981-2002	21	413	19.7

*** Neck cutoff of tightly compressed meander bend between RM 196 and RM 197 occurred during this period**

Flow (cfs)	Stream Power (lb/ft s)	Migration (feet)	Exceedance Interval (years)	Percent Chance Exceedance
520,000	14.29	344	1000.00	0.10
424,511	11.88	286	500.00	0.20
315,965	9.83	237	200.00	0.50
275,910	8.99	217	100.00	1.00
237,829	8.30	200	50.00	2.00
206,575	8.27	199	25.00	4.00
160,634	7.04	170	10.00	10.00
97,524	3.89	94	2.00	50.00
30,000	1.33	32	1.00	99.99

Table 7. Meander Bend at River Mile 201 to 202.

Period	Years	Migration Distance (ft)	Migration Rate (ft/yr)
1896-1923	27	0	0.0
1923-1937	14	51	3.6
1937-1946	9	119	13.2
1946-1955	9	0	0.0
1955-1960	5	0	0.0
1960-1969	9	-251	-27.9
1969-1972	3	36	12.0
1972-1981	9	-272	-30.2
1981-1984	3	224	74.7
1984-1986	2	278	**139.0**
1986-1991	5	-83	-16.6
1991-1997	6	679	**113.2**
1997-1999	2	391	**195.5**
1999-2002	3	158	52.7
1896-2002	106	1330	12.5
1946-2002	56	1160	20.7
1960-1981	21	-487	-23.2
1981-2002	**21**	**1647**	**78.4**
Note: Negative distance and rate indicates movement to the east, positive numbers indicate movement to the west.			

Flow (cfs)	Stream Power (lb/ft s)	Migration (feet)	Exceedance Interval (years)	Percent Chance Exceedance
520,000	0.86	188	1000.00	0.10
424,511	1.06	233	500.00	0.20
315,965	1.03	228	200.00	0.50
275,910	0.96	211	100.00	1.00
237,829	0.89	195	50.00	2.00
206,575	0.66	145	25.00	4.00
160,634	0.88	194	10.00	10.00
97,524	0.64	141	2.00	50.00
30,000	0.81	178	1.00	99.99

Table 8. Meander Bend at River Mile 202 to 203.

Period	Years	Migration Distance (ft)	Migration Rate (ft/yr)
1896-1923	27	-312	-11.6
1923-1937	14	0	0.0
1937-1946	9	0	0.0
1946-1955	9	0	0.0
1955-1960	5	0	0.0
1960-1969	9	22	2.4
1969-1972	3	69	23.0
1972-1981	9	560	62.2
1981-1984	3	205	68.3
1984-1986	2	141	**70.5**
1986-1991	5	128	25.6
1991-1997	6	422	**70.3**
1997-2002	5	234	46.8
1896-2002	106	1469	13.9
1946-2002	56	1781	31.8
1960-1981	21	651	31.0
1981-2002	**21**	**1130**	**53.8**

Note: Negative distance and rate indicates movement to the east, positive numbers indicate movement to the west.

Flow (cfs)	Stream Power (lb/ft s)	Migration (feet)	Exceedance Interval (years)	Percent Chance Exceedance
520,000	1.49	45	1000.00	0.10
424,511	2.01	61	500.00	0.20
315,965	2.22	67	200.00	0.50
275,910	2.32	70	100.00	1.00
237,829	2.32	70	50.00	2.00
206,575	3.37	102	25.00	4.00
160,634	1.87	56	10.00	10.00
97,524	1.98	60	2.00	50.00
30,000	0.94	28	1.00	99.99

C3.12. Operation and Maintenance

The operation and maintenance of the levees will be looked at in more detail in future studies.

C3.13. References

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The Shore Protection Manual (SPM), 1984 Edition, Chapter 7 – Structural Design: Physical Factors.

FINAL REPORT

CHANNEL MIGRATION, SEDIMENTATION, AND CHANNEL STABILITY ANALYSIS HAMILTON CITY INITIAL PROJECT

Flood Damage Reduction and Ecosystem Restoration Feasibility Study

Sacramento and San Joaquin River Basins Comprehensive Study

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Flood Damage Reduction and Ecosystem Restoration Feasibility Study

Sacramento and San Joaquin River Basins Comprehensive Study

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1. INTRODUCTION

The Sacramento River system plays an integral role in the economy and ecosystem of California's northern central valley. Flood protection is provided to adjacent communities and lands by various levees, reservoirs, flood control structures, and overflow channels. Despite the presence of these features, the river system has experienced frequent severe flooding due to a variety of factors. These include insufficient channel and levee capacity, unreliable facilities, poor maintenance practices, lack of a coordinated management system for upstream flood control reservoirs, and urban and agricultural encroachment on the floodplain. In addition, environmental resources within the basin have been significantly altered by human development and flood management activities. The results are substantial loss of habitat and species diversity, loss of historic natural hydrologic and geomorphic processes, exotic species invasion, and other ecosystem problems.

As part of the Sacramento and San Joaquin River Basins Comprehensive Study, the Sacramento District of the U.S. Army Corps of Engineers (Corps) conducted system-wide hydrologic, hydraulic, and sediment engineering analyses as well as a geomorphic assessment of the basin. During these comprehensive analyses, potential projects were identified that would improve conditions within the basin, as measured against a list of objectives produced by the study. A handful of these "initial" projects generated significant stakeholder interest, such as this project, which involves the development and evaluation of various alternatives to restore the ecosystem and reduce flood damages along the river in the vicinity of Hamilton City.

The goal of the Hamilton City initial project is to identify a cost effective, technically feasible, and locally acceptable project that meets the dual objectives of restoring the ecosystem and reducing flood damages and is in compliance with all federal, state, and local laws and regulations. This report describes the analysis of a proposed setback levee alignment intended to facilitate these objectives.

The Draft of this document included a section for the hydraulic analysis conducted for this project, including discussion of the modeling procedures and scenarios as well as the presentation of hydraulic model results. This section has been removed from the report and is now being provided separately as a Hydraulic Modeling Memo. This report provides a discussion of the sedimentation and channel stability conditions in the project reach and the potential impacts associated with the proposed project.

2. PROJECT DESCRIPTION

2.1 Project Setting

The project is located on the Sacramento River in the vicinity of Hamilton City, near River Mile (RM) 199. The project reach extends from roughly RM 204 downstream to RM 193 as shown in **Figure 2.1**. The floodplain is restricted on the west side of the river by the Glenn-Colusa Irrigation District (GCID) Canal and is relatively unrestricted on the east side of the river.

Levees are present in floodplains on both sides of the river and influence the distribution of flow in the overbanks during flood events. On the east side, a locally developed (Butte County) levee extends from approximately RM 204 to below the HWY 32 bridge crossing. As shown on Figure 2.1, the Butte County levee closely follows the left bank of the channel through most of the project reach.

On the west side there is an existing private levee, constructed by landowners in about 1904. Known as the "J" levee, this feature provides some flood protection to the town and surrounding area. This levee, however, is not constructed to any formal engineering standards and is largely made of silty sand. As a result, the levee is susceptible to erosion and flood fighting is necessary to prevent flanking when river levels rise. Since the construction of Shasta Dam in 1945, flooding in Hamilton City due to failure of the "J" levee has occurred once (1974). Extensive flood fighting has been required in several subsequent years (1983, 1986, 1995, 1997, and 1998) to prevent similar flooding.

Native habitat and natural river function in the study area have been altered by the presence of the "J" levee and conversion of the floodplain to agriculture and rural development. The ability of the river to meander has been constrained by the levee itself as well as the placement of bank protection features throughout the years. Native habitat has been reduced to remnant patches along the river and in historic oxbows. These alterations to the ecosystem have diminished the abundance, richness, and complexity of riparian, wetland, and floodplain habitat in the study area and the species dependent upon that habitat.

2.2 Hydrology

As shown in Figure 2.1, several creeks contribute flow to the Sacramento River within the project reach, including the Big Chico Creek, Mud Creek, Pine Creek, and Stony Creek. During flood events, Pine Creek receives flow from the Sacramento River where it breaks into the overbank upstream (between RM 208 and RM 215) and returns it to the main channel within the project reach (RM 196). With the exception of Stony Creek, the inflows from these tributaries are insignificant relative to the Sacramento River flood flow. Consequently, only Stony Creek inflows were considered in the hydraulic modeling. The GCID diverts water at its Hamilton City Pumping Plant just upstream of the project reach. GCID diversions are as high as 3,000 cfs during summer low-flow months.

Flows for various return intervals for the Sacramento River and Stony Creek are shown in **Table 2.1**. These are peak flows taken from recent hydrologic and unsteady hydraulic flow modeling conducted by the Sacramento District for the Comprehensive Study. These peak flow values are from the same storm centering used in the hydrologic analysis, but do not occur at the same time. Therefore, combining these flows in the hydraulic analysis of this project is slightly conservative.

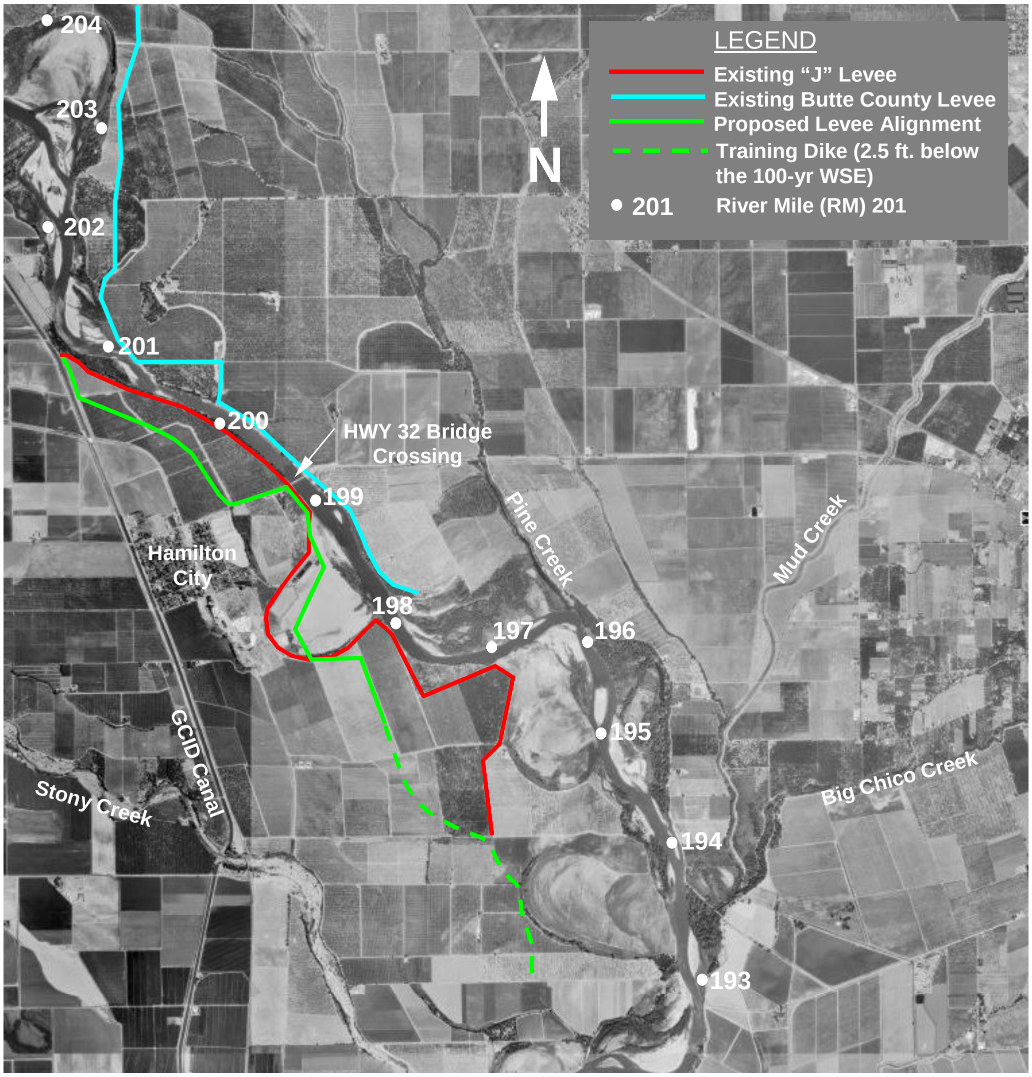

Figure 2.1. Plan view of project reach showing existing and proposed project features.

Table 2.1. Peak Flows on the Sacramento River and Stony Creek for Various Return Interval Flood Events.		
Flood Event	Sacramento River Peak Flow at Hamilton City (cfs)	Stony Creek Peak Flow (cfs)
50-year	237,829	15,000
100-year	275,910	27,400
200-year	315,965	48,500
320-year	342,000	52,000
500-year	424,511	62,330

2.3 Project Alternatives

During the planning phases of this project several alternative levee alignments were proposed to replace the "J" levee. The concept of the proposed alternative integrates a setback levee that will contain major flood flows and be aligned in such a way as to increase land within the active floodplain and cause no impact on flood-flow characteristics through the project reach. The land within the setback levee alignment will be converted to native riparian habitat. The tentatively selected plan, referred to as "Alignment 6" in earlier stages of the project, is shown in Figure 2.1. The levee transitions to a training dike as shown in Figure 2.1. The elevation of the training dike is 2.5 feet below the 100-year water surface elevation.

2.4 Study Objectives

The objective of this feasibility-level study is to analyze the impacts associated with implementing the proposed levee alignment. Investigations conducted for this project include:

- Channel migration analysis to investigate historic bankline locations and determine channel migration rates for assessing the need for erosion countermeasures
- Sediment analysis to determine the impact of the proposed levee alignment on the river's sediment transport capacity and associated impacts on channel stability
- Scour analysis to estimate scour and channel response
- Channel stability assessment and the development of three conceptual channel stabilization measures

This report summarizes each of these investigations, including the procedures and assumptions used in the analyses.

3. CHANNEL MIGRATION ANALYSIS

3.1 Historic Bankline Data

Historic bankline alignments through the project reach were collected for a number of years as shown in **Table 3.1**. This data came from a variety of sources. Most of the older alignments were previously assembled by the Department of Water Resources (DWR) as a part of their Middle Sacramento River Spawning Gravel Study (DWR 1984). The appendix to this study is in the form of a river atlas, including bankline alignments that were digitized for this analysis. Most of the more recent banklines were from aerial photography and/or survey data. All data sets were digitized into a CADD environment and registered to a common coordinate system. Sample historic banklines throughout the entire reach are provided in **Appendix A**.

Table 3.1. Bankline Data used in the Migration Analysis.

Date of Bankline	Source of Bankline Data
1896	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1908	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1923	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1935	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1937	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1946	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1955	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1960	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1964	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1969	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1972	DWR
1981	Appendix of Middle Sacramento River Spawning Gravel Study (1984)
1984	1"=500’ blueline aerials, Colusa to Red Bluff (DWR) – flown May 1984
1986	DWR / WET geomorphic investigation of Sacramento River
1991	Sacramento River Atlas (from Corps) – flown July 1991
1997	Sacramento River hydrographic survey
1999	DWR 1999 Sacramento River Atlas (RM 143-243) – flown May 1999
2002	Color aerials from Sacramento District, from erosion site atlas

3.2 Meander Migration Analysis

Once all of the historic bankline locations were registered in a common coordinate system within the CADD environment, the migration distance and migration rate for each time period were measured. The measurements were based on the migration of the outside bankline of the bend. **Figures 3.1 and 3.2** illustrate the migration patterns for the bends at RM 197 and RM 201, by presenting historic bankline locations for select years. **Tables 3.2 and 3.3** provide a tabulation of the migration distance and migration rate for all data sets for those same bends.

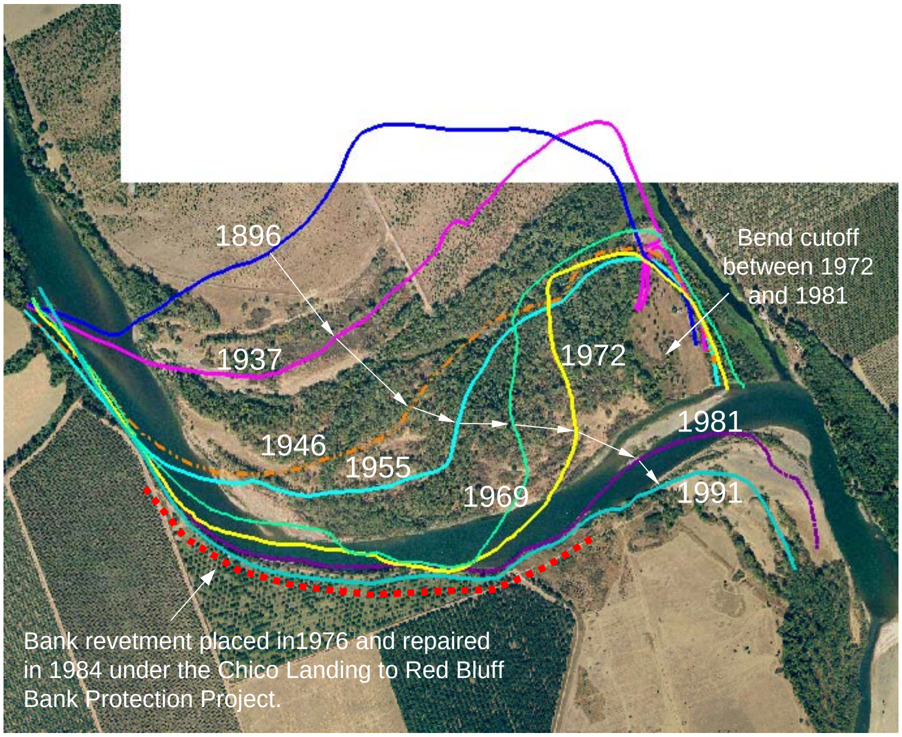

Figure 3.1. Select historic bankline locations for the bend at RM 197.

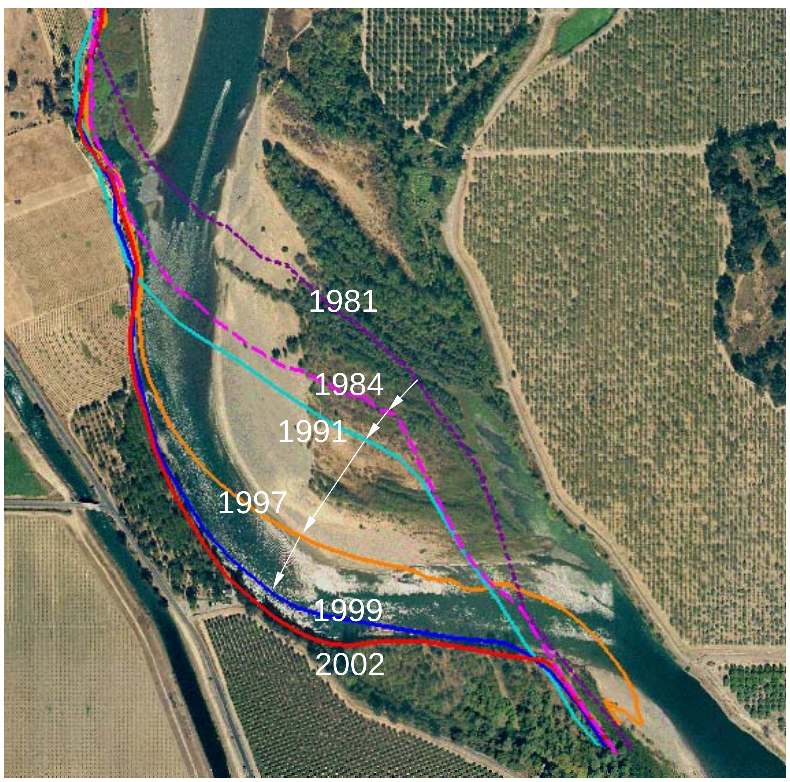

Figure 3.2. Select historic bankline locations for the bend at RM 201.

Table 3.2. Historic Migration Rates for the Meander Bend at RM 197.			
Period	Years	Migration Distance (ft)	Migration Rate (ft/yr)
1896-1923	27	1202	44.5
1923-1937	14	43	3.1
1937-1946	9	1122	**124.7**
1946-1955	9	584	64.9
1955-1960	5	258	51.6
1960-1969	9	444	49.3
1969-1972	3	623	**207.7**
*1972-1981	9	797	88.6
1981-1984	3	355	**118.3**
1984-1986	2	0	0.0
1986-1991	5	0	0.0
1991-1999	8	28	3.5
1999-2002	3	30	10.0
--------------------------------------- SUMMARY -------------------------------------			
1896-2002	106	5486	51.8
1946-2002	56	3119	55.7
1960-1981	**21**	**1864**	**88.8**
1981-2002	21	413	19.7
*Neck cutoff of tightly compressed meander bend between RM 196 and RM 197 occurred during this period.			

Table 3.3. Historic Migration Rates for the Meander Bend at RM 201.			
Period	Years	Migration Distance (ft)	Migration Rate (ft/yr)
1896-1923	27	0	0.0
1923-1937	14	51	3.6
1937-1946	9	119	13.2
1946-1955	9	0	0.0
1955-1960	5	0	0.0
1960-1969	9	-251	-27.9
1969-1972	3	36	12.0
1972-1981	9	-272	-30.2
1981-1984	3	224	74.7
1984-1986	2	278	**139.0**
1986-1991	5	-83	-16.6
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--------------------------------------- SUMMARY -------------------------------------			
1896-2002	106	1330	12.5
1946-2002	56	1160	20.7
1960-1981	21	-487	-23.2
1981-2002	**21**	**1647**	**78.4**
Negative distance and rate indicates movement to the east, positive numbers indicate movement to the west.			

As shown in Table 3.2, the most significant movement of the bend at RM 197 occurred prior to the 1980s. Between 1896 and the mid-1970s, the entire bend was moving to the south and east. As it migrated, the bend became gradually tighter until a cutoff occurred (shown in Figure 3.1). In 1976, 6,500 lineal feet of stone protection was placed on the outside of the bend (right bank) under the Chico Landing to Red Bluff Bank Protection Project (USACE 1981). The alignment of the bend, especially the upper portion, has been relatively fixed since that time. Prior to the placement of the bank protection, the average annual migration rate was roughly 63 ft/yr based on the period from 1896 to 1976. Migration rates, as shown in Table 3.2, have dropped significantly. However, the downstream end of the revetment has failed and the channel at this location has continued to migrate. According to records for the Chico Landing to Red Bluff project, the revetment placed in 1976 was repaired twice in 1984 (USACE 1981). Extrapolating the migration rates and directions indicates that the "J" levee requires protection from channel migration of the bend at RM 197. The proposed levee alignment could also be threatened by future channel migration.

As shown in Table 3.3, the bend at RM 201 began to actively migrate toward its current location in the 1980s. The banklines shown in Figure 3.2 are from this time period. The average annual rate during that time period was 78.4 ft/yr. In the 1990s, the average annual migration rate was as high as 200 ft/yr. Migration of the bend at RM 201 threatens the adjacent "J" levee and could potentially threaten a short segment of the GCID canal. The proposed levee alignment could also be threatened by future channel migration.

Although channel migration could pose a threat to the proposed levee alignment, the threat is much lower than to portions of the "J" levee due to the setback. It appears that at RM 197 and 201, the channel has migrated up to the Modesto Formation. Depending on the geotechnical properties of the Modesto Formation in this area, migration rates and directions could be significantly different than recent observations.

4. SEDIMENT ENGINEERING ANALYSIS

4.1 General

A sedimentation analysis was conducted to assess possible impacts of proposed levee realignment. The sediment analysis was conducted using the SAM software package developed by the U.S. Army Corps of Engineers (USACE 2002). SAM computes sediment transport capacity using average channel hydraulic data for the project reach. Since the sedimentation analysis is solely focused on identifying incremental impacts of the proposed project condition, the results of the analysis only show the differences relative to the current condition and were not calibrated to measured data. Consequently, although data representative of the project were used, the results should be considered qualitative rather than quantitative. The relative difference between conditions provides a qualitative understanding of how sedimentation characteristics vary between conditions without the project and conditions with the project.

4.2 Hydraulic Data

The sediment transport capacity of the river at any given location is dependent on the hydraulic conditions of the channel. Sediment transport capacity is generally determined for "reaches" of the river rather than at specific locations. The determination of a reach is based upon the consistency of hydraulic conditions within the reach. For this analysis, the project reach was divided into five sediment-modeling reaches as shown in **Figure 4.1**. These reaches were determined by reviewing main channel velocities from the various hydraulic modeling results.

Sediment transport capacity calculations are based on main channel hydraulic conditions since the majority of sediment transport occurs within the limits of the main channel where flow is concentrated. Transport in the channel overbank areas is relatively minor. Hydraulic data for this analysis were taken from the 2-dimensional hydraulic models developed for this project. The results of the 2-dimensional modeling are presented in detail in the Hydraulic Modeling Memo, submitted under separate cover. The hydraulic data for each reach were taken from cross sections representative of the overall conditions prevalent within that reach.

Since sediment transport capacity is based upon main channel hydraulics, the analysis was only conducted for flood conditions where flows break out of the main channel and into the overbanks. For any condition less than bank-full the proposed levee alignment will have no impact on hydraulic conditions. Bank-full flow for the project reach is approximately 90,000 cfs.

4.3 Sediment Transport Capacity Analysis

Using the SAM.sed module of the SAM package, the sediment transport capacity was calculated for each reach for the 50-, 100-, 320-, and 500-year flood events. The bed material data used in the analysis came from previous geomorphic and hydraulic modeling investigations of this reach, conducted by the Corps (WET 1990). Using sub-armor gradation data from samples taken at RM 191.6, RM 195.2, RM 197.7, and RM 221.1, an average gradation curve was created as shown in **Figure 4.2**. The curve was extended up to the 100 percent passing and down to the 10 percent passing to create a full data set to enter into the model. The sub-armor data was used since it is most representative of the material that dominates the sediment transport conditions at high flow. Any armor layer that might be covering the subarmor will be disrupted by 2-year flows exposing the material underneath.

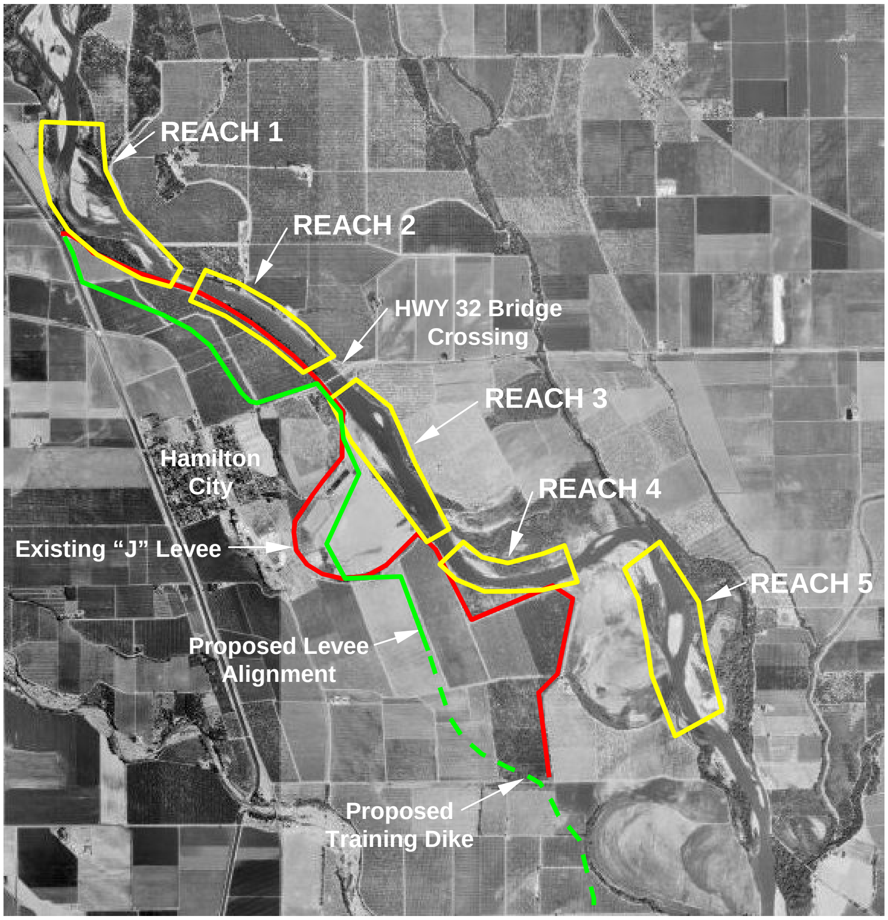

Figure 4.1. Plan view of project reach showing the sediment modeling sub-reaches.

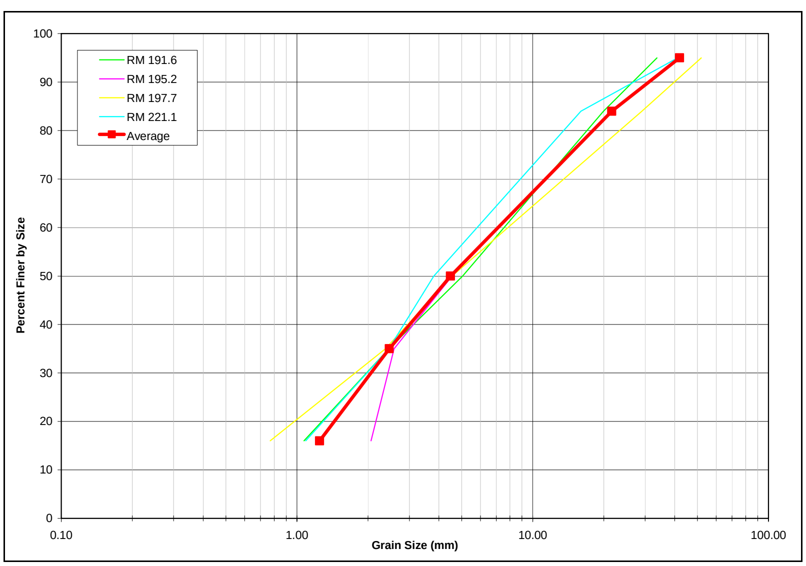

Figure 4.2. Bed material gradation used in the sediment modeling.

Several transport functions were reviewed in the analysis to determine which would provide the most reasonable results including the size of the sediment used in the analysis (D_{50} ~ 4.5 mm, D_{100} ~ 50 mm) and a comparison of all the equations. These variables indicate that Yang's transport function was the most appropriate.

The resulting sediment discharge rating curves for each reach for the without-project condition are presented in **Figure 4.3**. This curve illustrates that the overall project reach is not currently in a state of equilibrium in terms of its ability to transport sediment. Reach 2 has the highest sediment transport capacity. This is because it is well-confined with levees located on both banks. Reach 1 has the lowest transport capacity. The Butte County levee is set back from the channel in this reach, forcing less flow into the main channel than in Reach 2. As a result, it has lower transport capacity. The reach has a depositional tendency as evident by the point bars present within the reach. Reaches 3 and 4 also have less transport capacity than Reach 2. This is because the Butte County levee disappears along the left bank allowing flow into the eastern floodplain. This provides relief to the amount of flow remaining in the channel. Reach 5 is relatively unconfined with wide floodplains on both banks. This reach is characterized by active meandering and has a depositional tendency.

The sediment discharge rating curves were also developed for the proposed levee alignment. **Figure 4.4** presents a comparison in sediment transport capacity for each reach between the without-project and with-project conditions. The comparison is presented as a ratio. Values above 1 represent an increase in sediment transport capacity between the two with-project and without-project. Values below 1 represent a decrease.

The change in sediment transport capacity for each reach after the project is built is summarized below:

- Reach 1 – The sediment transport capacity increases in this reach with the addition of the proposed project. Due to downstream effects, slightly more flow is retained in the main channel by the Butte County levee. This increase in discharge and resulting increase in velocity cause an increase in sediment transport capacity.
- Reach 2 – Because the levee is set back under proposed conditions in this reach, flow breaks out of the main channel and into the west overbank between RM 201 and the HWY 32 bridge. Under existing conditions, the J levee on the west bank and the Butte County levee on the east bank keep most of the flow confined to the main channel. The relief provided by the proposed setback reduces the flow and resultant velocities in the reach, which reduce the sediment transport capacity of the reach.
- Reach 3 – The sediment transport capacity of Reach 3 increases with the proposed project. Under existing conditions the J levee breaks away from the channel following the old oxbow but then returns to the channel margin at RM 198. For lesser flood conditions (50- and 100-year), the water that flows into this local setback area is returned to the channel. For the greater flood flows, water that breaks into this area overtops the J levee and flows southward toward Stony Creek. The proposed project levee is slightly set back from the main channel in comparison to the J levee. The proposed levee is also higher, which prevents flow from overtopping and providing relief to the main channel. The net result is that the proposed levee alignment does not significantly change the amount of flow in the channel. The water surface elevation through this reach is slightly lower under project conditions due to the more significant setback downstream. As a result, main channel velocities increase slightly between with-project and without-project conditions, which increases the sediment transport capacity of the reach.

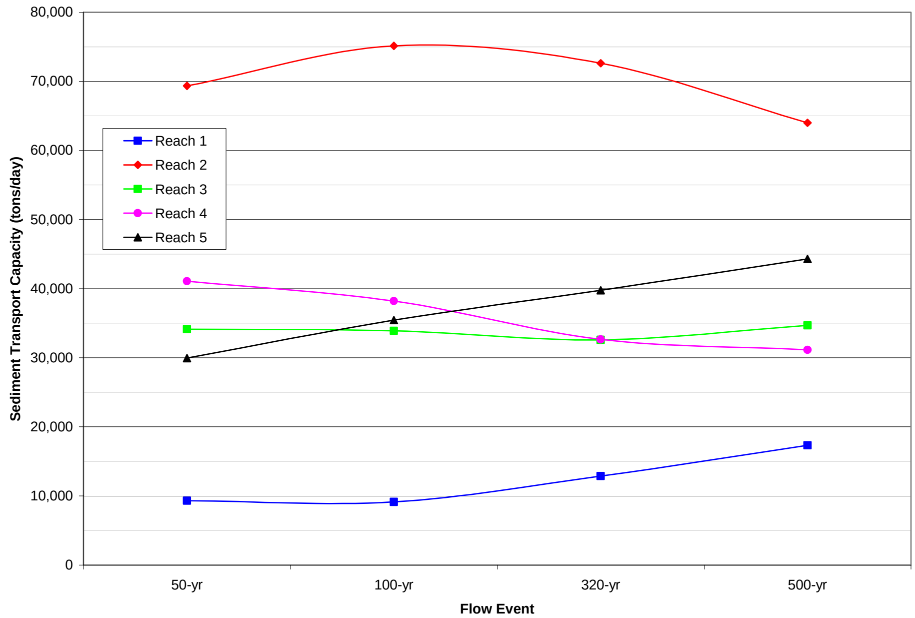

Figure 4.3. Sediment discharge rating curves for each reach for the without-project condition.

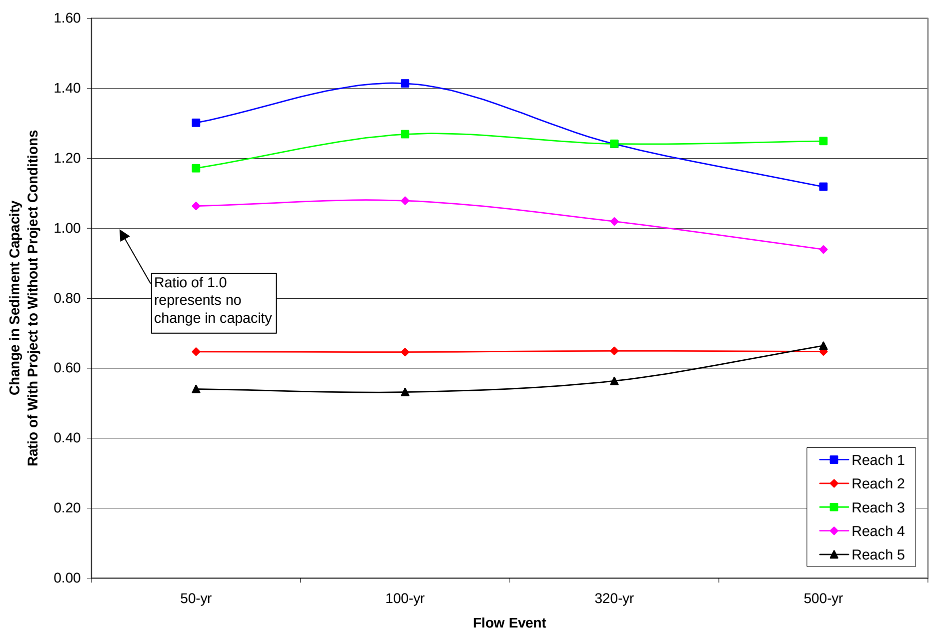

Figure 4.4. Comparison of sediment transport capacity, ratio of with-project to without-project conditions.

- Reach 4 – This reach experiences a slight increase in sediment transport capacity, primarily due to downstream effects from the proposed setback. The degree of setback provided with the proposed alignment is greatest in this area. This setback provides relief to the flow causing a slight decrease in water surface elevation that propagates upstream. Within the bend centered at RM 197 (Reach 4), the lower water surface elevation results in an increase in main channel velocity through the bend. This causes a slight increase in sediment transport capacity.
- Reach 5 – The proposed setback opens up a significant amount of floodplain within this reach, allowing more flow to leave the main channel than under existing conditions. As a result, the sediment transport capacity decreases in this reach.

4.4 Discussion

The results of the SAM analysis indicate that the proposed levee alignment will cause some changes in the river's ability to carry sediment. The extent of these changes is difficult to quantify without more detailed sediment transport modeling. As illustrated by Figure 4.3, the overall project reach is not in a state of equilibrium in terms of its ability to carry sediment. This conclusion is supported by the bar development in reaches 1 and 5. There is a significant degree of variability between the sub-reaches modeled. This variability remains with the proposed project, although there are some adjustments within each reach.

It is important to note that this sedimentation analysis was only conducted for flood flows (50-year and above). In reality, flood flows do not dominate sediment transport capacity in terms of affecting changes to channel geometry. The majority of sediment transport through the reach occurs at flows that are at or below bank-full conditions. This is illustrated in **Figure 4.5**, which shows the annual flow duration curve for the Hamilton City gage located at the HWY 32 bridge crossing. This curve was taken from work previously completed by the Sacramento District in a report titled, Draft Office Report, Streamflow Characteristics of the Sacramento River Floodways Hydrology (USACE 1990). This report was prepared by the hydrology section and includes stage/discharge rating curves and flow duration curves for most of the system. The flow duration curve at Hamilton City was based on daily historical data from 1947 to 1981 (12,626 days).

Figure 4.5 shows that flows exceed bank-full conditions (greater than 90,000) less than 1 percent of the time. For flows below bank-full, the proposed project will have no impact on the river's ability to carry sediment.

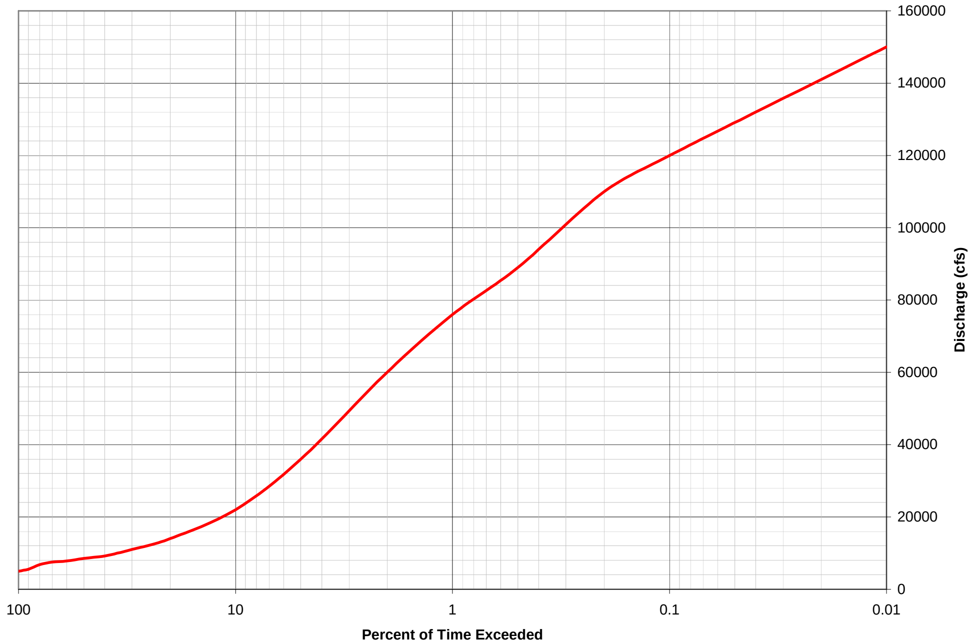

Figure 4.5. Annual flow duration curve for the Sacramento River at the Hamilton City gage.

5. CHANNEL SCOUR ANALYSIS

5.1 General

Analyses were conducted to assess anticipated changes in the stability of the channel within the project reach due to implementing either of the proposed levee alignments. These analyses are summarized in the following sections. Supporting calculations for the scour estimates are provided in **Appendix B**.

5.2 Scour Analysis at the Highway 32 Crossing

A scour analysis was conducted at the HWY 32 bridge crossing to estimate the impact of the proposed project on the bed elevation at the bridge opening. The most common form of general scour is contraction scour. Contraction scour typically occurs when the bridge opening is smaller than the flow area of the upstream channel and floodplain.

Contraction scour was estimated for both without-project and project conditions at the Highway 32 bridge crossing using the methodologies outlined in HEC-18 (FHWA 2001). To determine if the scour is live-bed or clear-water, the critical velocity of the bed material was compared to the mean velocity of the flow in the channel approaching the bridge. In all cases, the flow approaching the bridge is carrying sediment, and as a result, live-bed scour methods were used.

Contraction scour is estimated by comparing hydraulic conditions in the upstream (approach) channel with hydraulic conditions at the contracted cross section at the bridge. Hydraulic results from the 2-dimensional modeling were used to compute scour for without-project and project conditions for the 50-, 100-, 320-, and 500-year events. Scour estimates from this analysis are shown in **Table 5.1**.

Table 5.1. Contraction Scour Summary for Existing and Project Conditions at the Highway 32 Bridge Crossing.

Flow Condition	Without Project	With Project
50-year	1.6 ft	5.1 ft
100-year	1.5 ft	5.8 ft
320-year	0.9 ft	5.4 ft
500-year	0.8 ft	5.1 ft

Under existing conditions the J levee (on the right bank) and the Butte County levee (on the left bank) keep flood flows relatively confined to the main channel. This results in a relatively minor amount of constriction as the flow approaches the bridge. With the local setback on the right bank associated with the proposed levee alignment, the amount of constriction imposed on the flow as it approaches the bridge is increased. Since the new levee allows flow into the right overbank, there is less flow in the approach section than at the bridge where the overbank flow is forced to return to the channel. As such, the ability of the channel to carry sediment increases locally at the bridge because of the returning flow. These conditions will cause scour through the bridge section.

5.3 Bendway Scour

The migration analysis presented in Section 3 indicates that continued migration should be expected at the bends centered at RM 197 and RM 201, even though some bank protection measures exist at each site. If those features fail to arrest ongoing bank erosion, the channel could migrate toward the proposed levee setback although the proposed levee is less threatened than the J levee. Stabilizing the banks, either by repairing existing revetment or by constructing new features, may be necessary to prevent future flanking of the levees. Section 6 presents possible bank revetment alternatives for accomplishing this.

Whenever a migrating river bend is fixed in place by revetment, some sort of channel response is to be anticipated, typically in the form of vertical scour. This is due to the fact that stabilizing the bankline reduces or eliminates the supply of sediment in the bend from bank erosion, causing the channel to narrow or deepen. While riprap provides good protection for the river bank, it also causes scour along the toe. The riprap surface usually provides a more efficient hydraulic section than a vegetated, natural bank, attracting more flow and causing higher velocities along the toe of the riprap.

Estimates were made of the potential scour that could occur if additional efforts are made to stabilize the bends. This information will be used in the design of specific bank protection measures to determine how far the rock will need to be keyed into the river bed to protect against future scour.

Thorne et al. (1995) presents the following empirical equation for estimating scour depth in meander bends based on data from several rivers of various size:

$$d_{max} = \left[2.07 - 0.19 \log\left(\frac{R_c}{W} - 2\right) \right] d_{mnc}$$

Where:

d_{max} = Maximum depth in bend due to scour
d_{mnc} = Depth of the approach channel at the crossing upstream of the bend
R_c = Radius of curvature of the centerline of the channel in the bend
W = Width of channel at the upstream crossing

The predicted scour depth at each of the sites using this method is presented in **Table 5.2**. This empirical equation is applicable for values of R/W greater than 2. The depth values used in the analysis are from a bank-full flow condition.

Table 5.2. Bend Scour Summary for the Bends at RM 197 and RM 201.

Bend Location	R_c/W	Average Depth (ft) Upstream of Bend (D_{mnc})	Calculated Max. Depth (ft) in Bend (D_{mxb})	Existing Max. Depth (ft) in Bend	Max. Potential Scour in Bend (ft)
RM 197	8.60	23	44	40	**4.0**
RM 201	3.77	22	44.5	37	**7.5**

5.4 Channel Stability

Aggradation and degradation are streambed elevation changes due to natural or human-induced causes that can affect the reach of the river under investigation. Aggradation involves the deposition of material eroded from the channel or watershed upstream of the reach. Degradation involves the lowering or scouring of the streambed due to a deficit in sediment supply from upstream or local changes in the sediment transport capacity of the reach.

As described in Section 4, a sedimentation analysis was conducted to assess changes in the sediment transport characteristics of the reach that would result from implementing the proposed levee alignment. This analysis looked at sediment transport capacity for a range of flood flows. As described previously, there were no data available for calibrating the sedimentation analysis. As such, the results should be considered qualitative rather than quantitative in understanding how the proposed levee alignment will influence sediment conditions within the reach. A quantitative understanding of the actual sediment supply from the reach upstream of the project would be beneficial in placing the transport capacity of the project reach in context.

The analysis indicated that for flood flow conditions, the project would increase sediment transport capacity for three of the five sub-reaches modeled (Figure 4.1). Sediment transport capacity would decrease for the other two reaches. For flows that are most dominant in transporting sediment and affecting channel geometry (bank-full and below), the project will have no impact on sediment transport capacity.

Some estimation can be made of potential channel response due to the change in sediment transport capacity between without-project and project conditions. By assuming that discharge remains constant, the resulting change in channel area can be estimated using the continuity equation. If it is assumed that all adjustments to channel geometry happen vertically, an estimation can be made of the amount of aggradation or degradation required to respond to the new sediment transport capacity conditions (those predicted for project conditions). These estimates of vertical channel response are presented in **Table 5.3**.

Table 5.3. Estimated Vertical Channel Response Due to Change in Sediment Transport Capacity for Flood Flows.

Reach	Potential Change in Bed Elevation
1	-1 to -2.5 ft
2	+2.5 to +3 ft
3	-1 to -1.5 ft
4	-0.5 to +0.5 ft
5	+2.5 to +3.5 ft

This estimate of aggradation/degradation is simplification in several ways. First, it assumes that as the channel geometry changes due to new sediment transport capacity conditions, the discharge in the channel will stay the same. In reality, the amount of flow in the channel will change along with the channel geometry. Second, it assumes that all channel adjustment will occur in the vertical. In reality, channel adjustment will occur laterally (through bank erosion or bar deposition) as well as vertically. Last, it assumes that the proposed condition channel would revert to the transport conditions of the existing channel, even though it is apparent that the existing channel is not in an equilibrium state of sediment transport. As such, the numbers presented in Table 5.3 provide a conservative estimate of how the channel might respond during flood flows. It should also be emphasized that no change is expected for flow less than the bankfull flow.

6. BANK PROTECTION MEASURES

6.1 General

The reach of the Sacramento River upstream of Colusa (RM 145) is relatively unconfined. Sacramento River Flood Control Project (SRFCP) levees are somewhat set back from the active channel between Colusa and their upstream limit near Ord Ferry (RM 180). Upstream of Ord Ferry, local levees are intermittent and the river is free to meander within the floodplain. As described previously, the bends at RM 197 and RM 201 continue to migrate, although migration is limited at both bends due to the presence of bank protection measures.

Active channel meandering is a natural process and is beneficial for ecosystem function and health. One of the objectives of this project is to restore natural river function and enhance existing ecosystem conditions. Allowing these river bends to continue to erode and migrate will aid in accomplishing that objective. On the other hand, the project is also intended to reduce flood damages by providing flood protection. Maintenance of the proposed levee throughout the life of the project will be required to provide ongoing flood protection. One threat to constructing a new levee is the potential that it could be flanked by the continued migration of a river bend. This section presents conceptual alternatives for stabilizing the bends in the reach, should it be necessary to protect the proposed levee alignments over the life of the project.

The bend at RM 201 has experienced significant erosion over the last two decades, averaging roughly 50 feet per year since 1981. The current location of the bankline is up against the existing J levee for a distance of roughly 400 feet, and is only 310 feet away from the toe of the levee/road next to the GCID canal, which is the location of the proposed levee alignment. If erosion continues at current rates, the upstream limit of the proposed levee alignment could be threatened in 5 to 10 years. As such, some type of bank protection will be needed to protect the bend at this site.

The bend at RM 197 experienced most of its erosion prior to the last couple of decades. Bank protection was installed along most of the bank in 1976 under the Chico Landing to Red Bluff Project as described in Section 4. This revetment has kept the alignment of the bend relatively fixed. Like much of the revetment installed under the Chico Landing to Red Bluff Project, it is beginning to deteriorate. Erosion along the toe is leading to local failures of the riprap and portions of the upper bank are also caving in. The distance between the existing bank and the proposed levee alignment is roughly 1,500 feet. In the estimated direction of migration, the distance between the river bank and the levee alignment increases to as much as 6,000 feet.

One possibility at RM 197 is to remove the existing revetment and allow the bend to meander. This would allow the bend to move southward toward the proposed levee alignment, which may require intervention in the future to protect the levee. Migration rates prior to the placement of riprap at this site in 1976 were as high as 210 feet per year. One alternative for providing future protection of the proposed levee would be to install buried revetment, offset from the levee some distance, that would arrest channel migration before it reached the levee. The other alternative at RM 197 would be to maintain the current revetment. Without repair, the existing revetment is not likely sufficient to protect the levee over the life of the project. At a minimum, maintaining the existing revetment would require installing a rock toe along the entire site and repairing areas where the existing revetment has failed or is in poor condition.

Due to the proximity of the current alignment of the bend at RM 201 to existing infrastructure as well as the proposed levee alignment, it is recommended that the bank be stabilized in its current location. Full riprap bank revetment is proposed at this site. Some type of flow alteration, such as using spur dikes or bendway weirs, is not recommended due to potential realignment of the channel downstream that could affect the local Butte County levee on the opposite bank. If the existing infrastructure, such as the private residence and orchard, as well as the J levee, does not need protection, then some type of buried revetment may be installed along the toe of the proposed levee to provide protection for the new levee.

6.2 Riprap Toe (Repair Existing Revetment)

The instability of the existing riprap at the RM 197 bend appears to be due to the absence of sufficient toe protection. Scour along the toe of the bankline has resulted in local failures in the revetment and the loss of rock below the waterline. It may be possible and more cost effective to repair the existing revetment than replace it with new revetment. This alternative is illustrated in **Figure 6.1**.

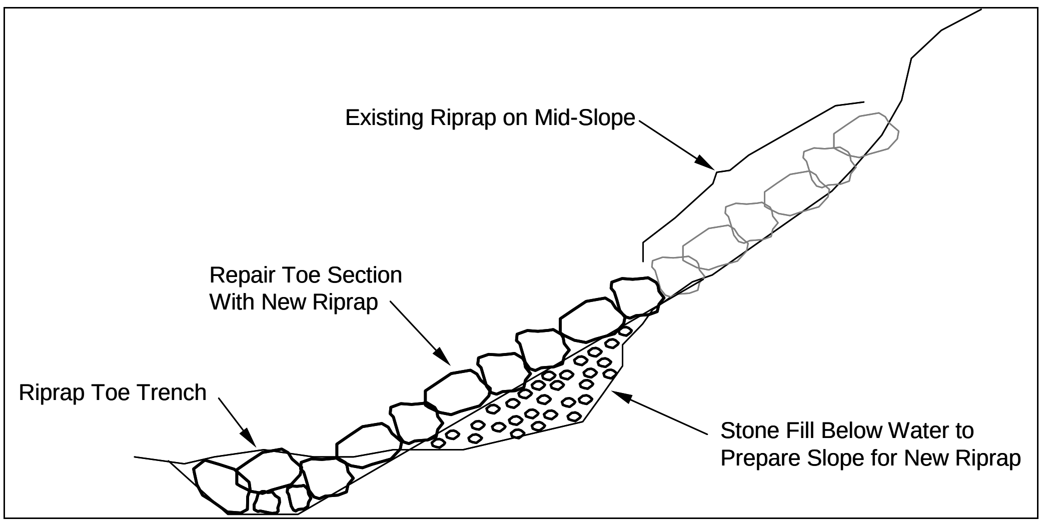

Figure 6.1. Typical cross section of riprap toe and revetment repair.

6.3 Riprap Bank Revetment

This alternative is illustrated in **Figure 6.2** and involves re-grading and reshaping the existing bank to prepare the slope for the placement of riprap. Design slopes are typically 2H:1V or flatter. When fill is required to shape the bank slope, stone fill is typically used below the low water level and embankment material above. An excavated riprap trench is placed along the toe to protect against further scour of the channel bed. Riprap is placed on the prepared slope up to the top of the bank.

The upper bank slope can be planted with woody riparian shrub species to create near-shore aquatic cover and the top of bank can be planted with cottonwoods and other trees. To further enhance aquatic conditions along the revetted bank, trees with large root masses can be anchored below the low water level.

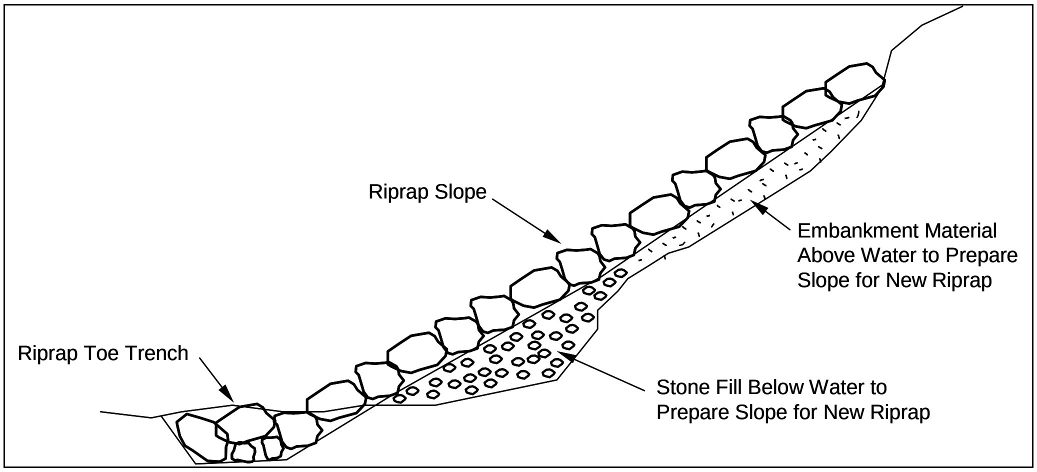

Figure 6.2. Typical cross section of riprap bank protection.

6.4 Buried (Setback) Revetment

Buried revetment consists of a mass of rock placed in a trench that is intended to launch into a bank configuration when intersected by an eroding bankline as shown in **Figure 6.3**. The trench is offset some distance from the toe of the levee alignment that is being protected. Enough rock is included in the trench to launch to a configuration similar to that shown for the riprap bank protection in Figure 6.2. The backslope of the trench is set to the desired slope of the bank protection. The deeper the mass of rock is buried, the better the likelihood that it will launch to the desired configuration.

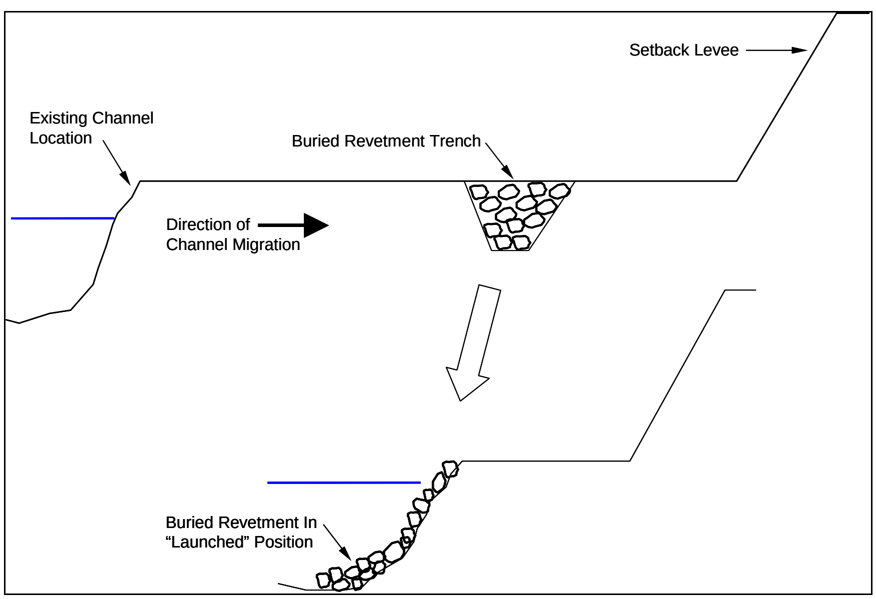

Figure 6.3. Typical cross section and plan view of buried revetment.

6.5 Riprap Sizing

Riprap requirements for the conceptual bank protection alternatives were evaluated using the procedure outlined in EM 1110-2-1601, Hydraulic Design of Flood Control Channels (USACE 1991). This procedure requires data describing the bank slope, channel morphology, angle of repose and specific gravity of the rock, design velocity conditions, flow depth, safety factors, and other information. The velocity required is the depth-averaged local velocity at the eroding bank located at a point 20 percent up the bank slope from the toe.

The hydraulic results from the 2-dimensional modeling described previously were used to obtain the velocity and depth data required to size the riprap for the 100-year event. The riprap size was also checked against results from the HEC-RAS model for the 2-year event.

For the bend at RM 197, the design D_{30} was determined to be 0.5 foot while the D_{30} was 0.3 foot for the bend at RM 201. For both of these conditions, the standard 200-pound gradation used by the Corps and shown in **Figure 6.4** is adequate. This gradation has been used extensively for riprap banks constructed under the Sacramento River Bank Protection Project (SRBPP). The layer thickness for this gradation is 18 inches.

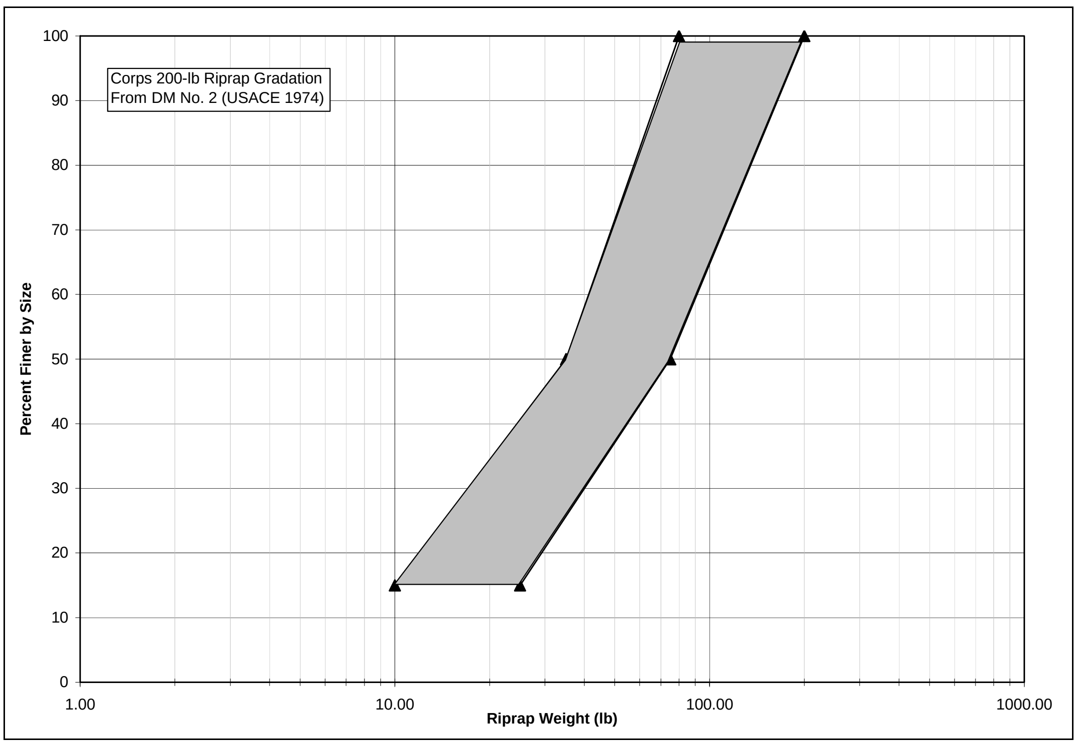

Figure 6.4. Gradation for standard Corps 200-pound gradation (from Design Memorandum No. 2).

7. SUMMARY

The analyses completed for this project provide a basis for comparing the without-project and project conditions for two alternative levee alignments (6 and 6a). Following is a brief summary of the hydraulic, sedimentation, and channel migration analysis.

- The bend centered at RM 197 has been relatively fixed since the mid-1970s when revetment was placed along the bank. The condition of that revetment, however, is poor and continued migration should be expected. In contrast, the bend centered at RM 201 has been most active in the last 20 years. Further erosion of the bank threatens the "J" levee and other infrastructure. It is roughly only 300 feet from the toe of the levee/road next to the GCID canal, which is the location of the proposed levee alignment.

- The proposed levee alignment will have no impact on the sediment transport capacity of the river for flows below the bank-full condition. The proposed project will impact the sediment transport capacity of the river under flood flow conditions, although these changes will result in only minor adjustments to channel.

- The proposed levee alignment will not exacerbate local bridge scour or reach-wide aggradational or degradational trends in comparison to existing conditions for flows below the bank-full condition. For flood flows, the contraction scour potential at the HWY 32 bridge increases from roughly 1 to 1.5 feet of scour for without-project conditions to 5 to 6 feet of scour for with-project conditions. Minor adjustment to channel geometry in the form of aggradation or degradation can be expected during flood events due to changes in sediment transport capacity associated with the project levee alignment.

- The potential vertical adjustment in the form of toe scour will need to be considered when designing bank protection at RMs 197 and 201, if the bends are to be fixed in places.

- Three conceptual bank protection alternatives are presented for stabilizing the bends at RM 197 and RM 201 in order to protect the proposed levee alignment from flanking in the future. These include repairing existing revetment (RM 197), full bank revetment, and buried (setback) revetment.

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AYRES ASSOCIATES

MEMORANDUM

To: Nathan Cox – U.S. Army Corps of Engineers, Sacramento District

From: Scott Hogan and Jason McConahy

Date: May 28, 2004

Re: Hydraulic Modeling Memo for Public Review – Hamilton City Initial Project, Flood Damage Reduction and Ecosystem Restoration Feasibility Study

This memo describes the hydraulic modeling Ayres Associates completed to evaluate potential impacts associated with the proposed project levee alignment and ecological restoration near Hamilton City, California. The main project goals were to determine a levee alignment and configuration that will meet the ecological restoration objectives while providing improved flood protection without adverse hydraulic impacts. Given the complexity of hydraulic conditions through the project reach and the need for detailed hydraulic results, the 2-dimensional hydrodynamic model, RMA-2 (USACE 1996) was used for this analysis.

This memo summarizes the hydraulic model runs for the tentatively selected plan. Graphics summarizing the model results are included in the Attachments.

Model Development

A 2-dimensional model, previously developed for The Nature Conservancy (TNC) (Ayres 2002), was used in the development of the model for this hydraulic analysis. The SMS program, developed by Brigham Young University, was used to modify the geometric finite element mesh that represents the topographic and bathymetric data through the project reach. The TNC model was originally developed to analyze impacts of flows less than the 50-year event. Since the analysis for this project includes higher flows (up to the 500-year event), the mesh was expanded to incorporate the inundation limits for these flows. The TNC model, the HEC-RAS model provided by the Sacramento District, existing mapping data for the Sacramento River (Ayres 1999), and USGS quadrangle maps were all used to help develop the new finite element mesh.

The representation of the project reach was based on 1995 and 1997 topographic conditions. Extensive 2-foot contour mapping of the Sacramento River system was developed by the USACE from hydrographic and aerial photogrammetric surveys. Upstream of RM 194, the mapping data was derived from aerial and hydrographic surveys conducted in 1997. Downstream of RM 194 the mapping was derived from aerial and hydrographic surveys conducted in 1995. The horizontal datum for the survey data is the North American Datum of 1983 (NAD83), State Plane Coordinates. The vertical datum is the National Geodetic Vertical Datum of 1929 (NGVD29). The 2-foot contour mapping covered the limits of the 2-dimensional model.

The without-project condition finite element mesh developed for this project is shown in **Figure 1**. The limits of the modeling analysis extended from RM 212 downstream to RM 191. The proposed levee alignment was integrated into the mesh after the without-project condition mesh was completed.

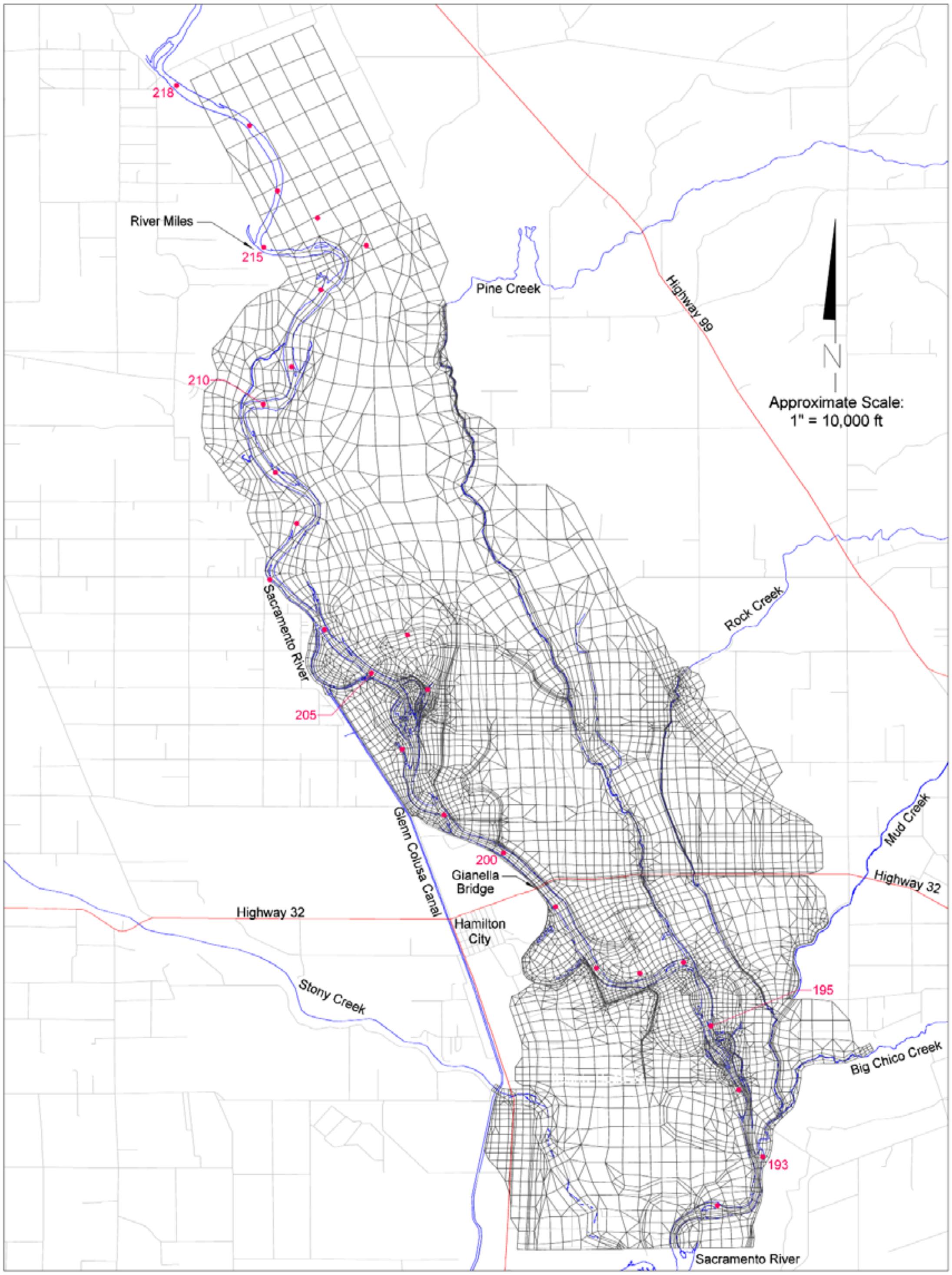

Figure 1. Without-project condition finite element mesh.

The Manning's n roughness values used in the TNC model were preserved in the without-project conditions model for this analysis. Revised n-values for the project condition models, which represent ecological restoration along the river corridor, were provided by the Sacramento District and the DWR. A complete list of the n-values used in the modeling is provided in **Table 1**. The distribution of element types for both the without-project and project models are provided in the attachments. Manning n values for "areas of turbulent flow" are set high to maintain model stability where extreme flow conditions occur in the model, such as at levee crests.

Table 1. Roughness Coefficients used in the 2-Dimensional Model.

Element Type	Land Use	n value
1	Main channel	0.035
2	Forest/Riparian	0.16
3	Orchard	0.15
4	Cultivated field	0.035
5	Sand/gravel	0.04
6	Stony creek bed	0.04
7	Pasture/grassland	0.035
8	Creek bed	0.035
9	Levee/road	0.025
10	Pine creek bed	0.035
11	Buildings	0.20
12	Area of turbulent flow	0.20
13	Area of turbulent flow (Without-Project)	0.50
	Scrub (Project)	0.10
14	Savannah (Project)	0.05
15	Area of turbulent flow (Project)	0.50

Modeling Scenarios

Without-Project Condition. The without-project model was run for various return period flows to provide a baseline for comparison with the hydraulic results of the project conditions. For the without-project condition, the existing J-levee was assumed to contain flows up to the 100-year event, as indicated by flood fighting reports and agreements from the local Hamilton City landowners. The flood fighting efforts extend along the J-levee from its upper terminus, downstream to the limit shown on **Figure 2**, which is just north of County Road 23. For events greater than the 100-year flow, the J levee was modeled with a crest elevation equal to the 100-year water surface elevation.

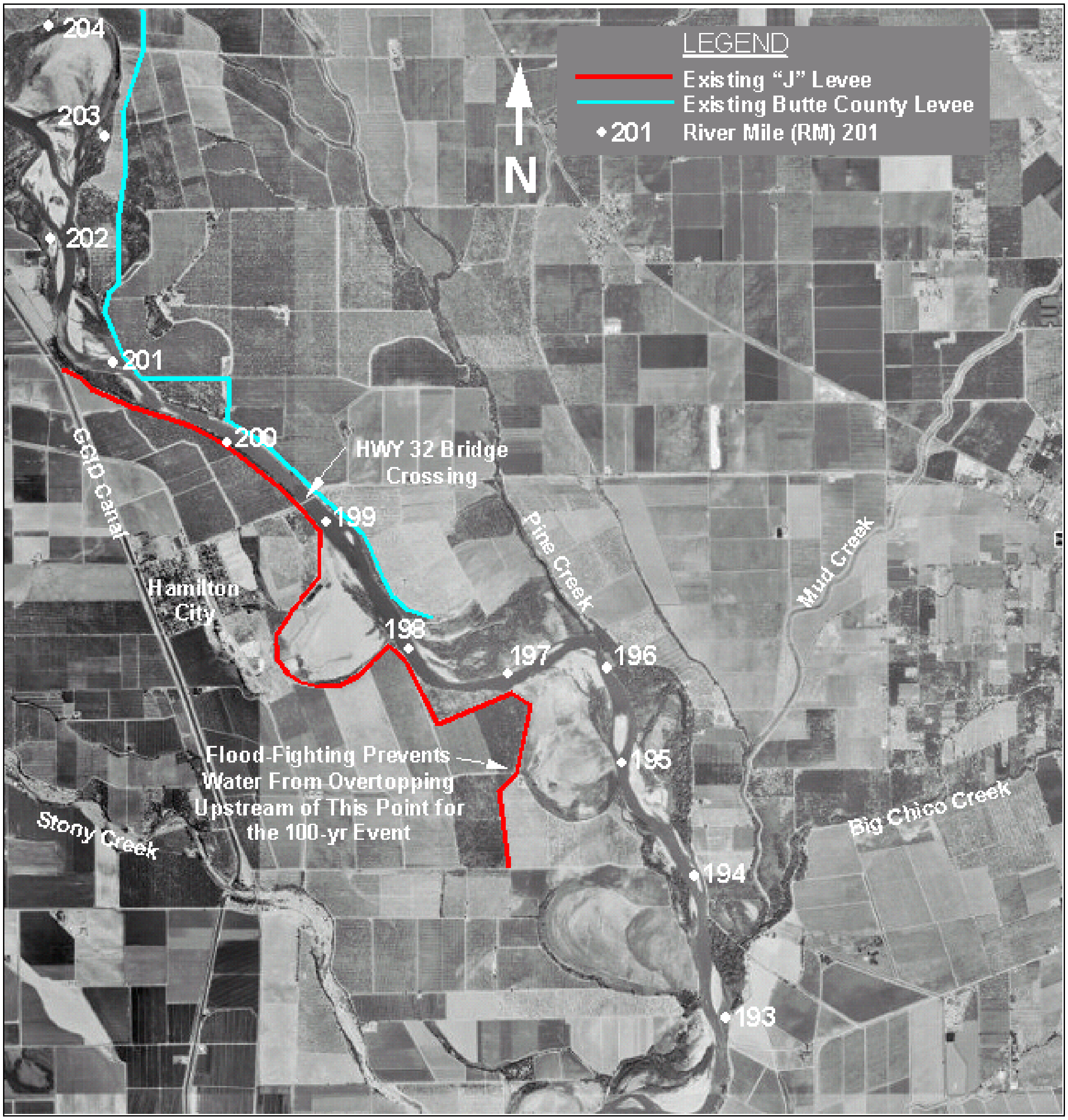

Figure 2. Plan view of the project reach showing the components of the without-project conditions model.

Tentatively Selected Plan. The details of the tentatively selected plan are illustrated in Figure 3. The levee follows what was previously referred to as Alignment 6. The proposed levee provides 40% CNP (Conditional Non-Exceedance Probability) of passing the 320-year flood event to a point that is roughly 5,000 feet upstream of County Road 23. At that location, the levee transitions into a "training levee" that provides 53% CNP of passing the 100-year flood for roughly 3,000 feet. From this point it drops to an elevation that is 2.1 feet below the without-project 100-year water surface elevation, providing roughly a 62% CNP of passing the 20-year flood event (see Figure 3). It was assumed that the J levee would be completely removed for the with-project condition.

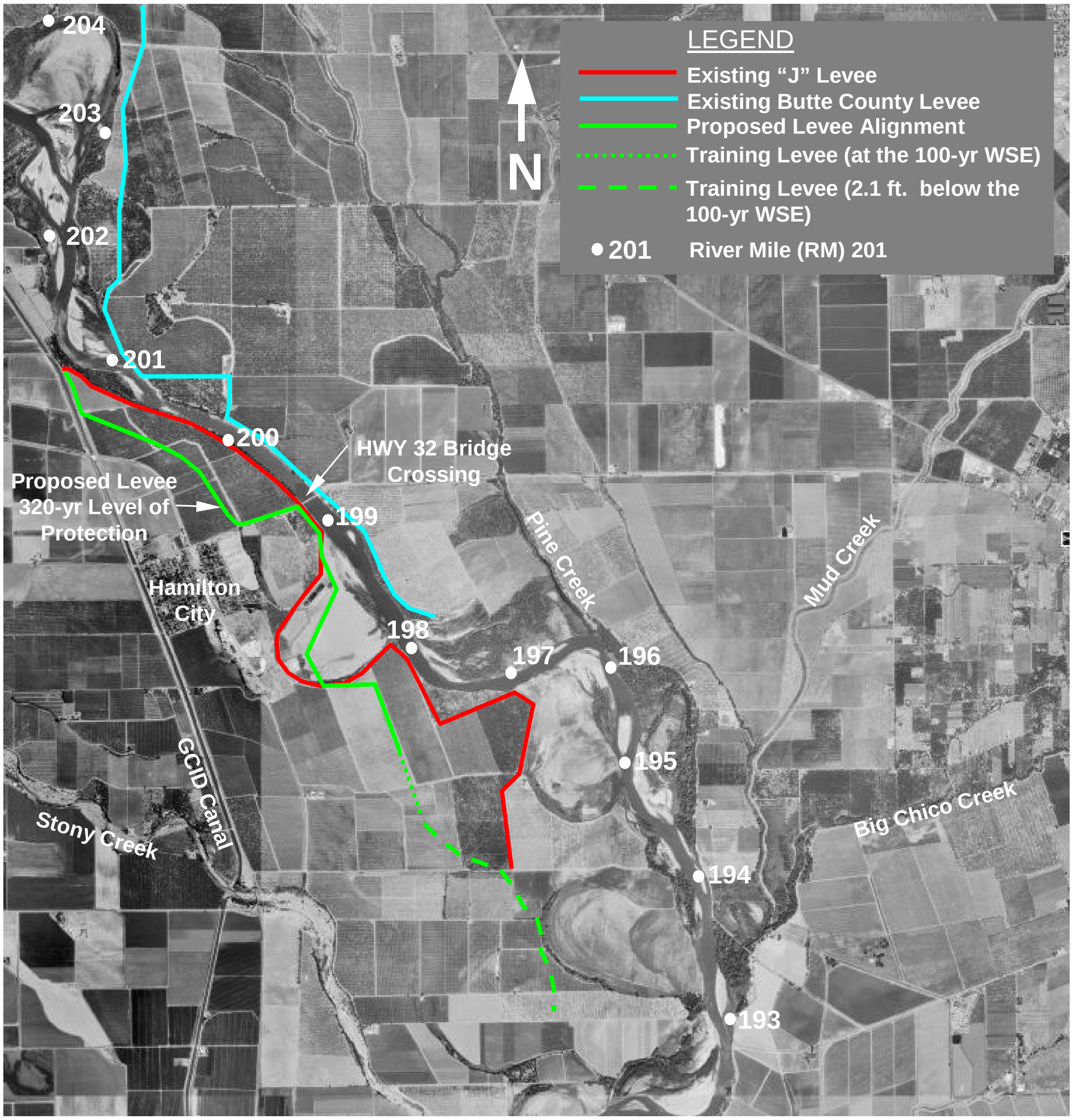

Figure 3. Plan view of the project reach showing the components of the tentatively selected plan.

Modeling Procedures

The Sacramento River and tributary inflows used in the 2-dimensional modeling simulations are shown in **Table 2**. The peak flows were provided by the Sacramento District USACE and were derived from the Sacramento and San Joaquin River Basin Comprehensive Study UNET model. Based on hydrologic analyses and evaluation by the Sacramento District, the inflows from the other tributaries (Rock Creek, Mud Creek, Big Chico Creek, etc.) were considered minor relative to the flows in the Sacramento. Furthermore, the peak inflows from these tributaries are of short duration and occur prior to the peak on the Sacramento River.

Table 2. 2-Dimensional Model Boundary Conditions.			
Flood Event	Sacramento Inflow	Stony Creek Inflow	Tailwater Elevation
1997 Event	167,000 cfs	15,500 cfs	130.5 ft
20-year	190,000 cfs	14,500 cfs	131.0 ft
25-year	206,575 cfs	15,500 cfs	131.3 ft
50-year	237,829 cfs	15,000 cfs	131.9 ft
100-year	275,910 cfs	27,400 cfs	132.5 ft
200-year	315,965 cfs	48,500 cfs	133.4 ft
320-year	342,600 cfs	52,000 cfs	133.6 ft
500-year	424,511 cfs	62,330 cfs	134.1 ft

Downstream water surface elevation boundary conditions were referenced from previous 2-dimensional modeling conducted for the Butte Basin reach of the Sacramento River (Ayres 1997). The Butte Basin model covered the Sacramento River south of the Hamilton City project reach, and provided enough overlap to be used as a reference for the tailwater elevation for this modeling effort. A rating curve was developed as shown in **Figure 4** based on the computed water surface elevation and discharge from the Butte Basin model at the location of the downstream limit of the current model (approx. RM 191). The lowest flow modeled in the Butte Basin model was the 1995 flood event, with a total flow in the Sacramento River of 195,000 cfs at the downstream location of the current model. The tailwater elevations used as boundary conditions for the model are presented in Table 2.

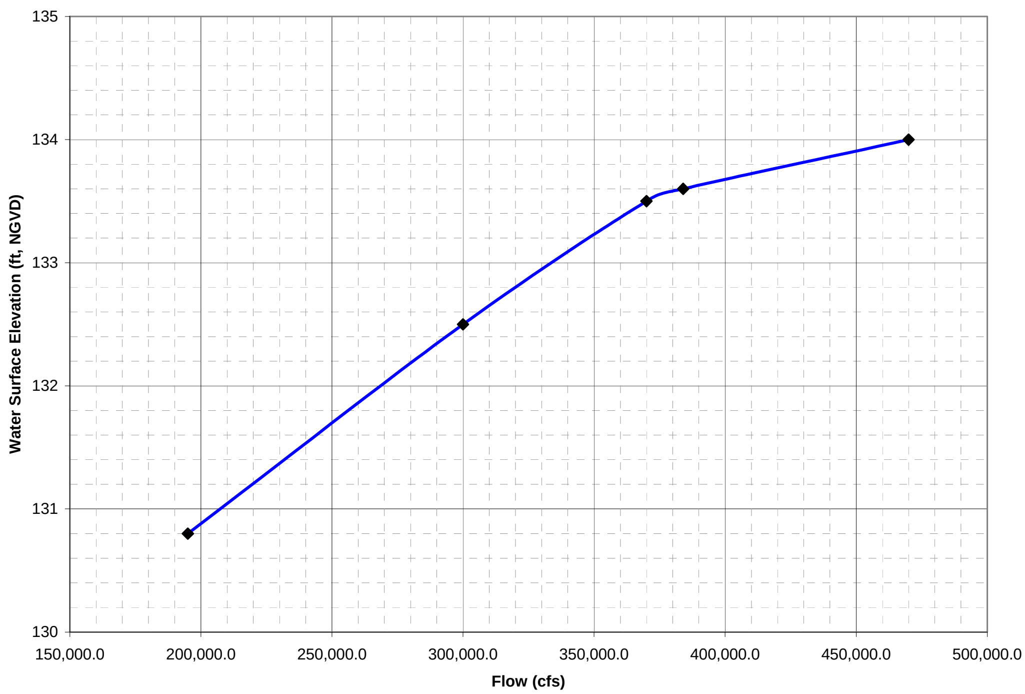

Figure 4. Rating curve for the downstream water surface elevation boundary condition.

Flow conditions in the project reach are fairly complex during flood events. The complexity is due to the presence of levees on both banks of the main channel, HWY 32 that crosses the east floodplain, and the spill of water into the Butte Basin at the downstream limit of the model. Levees within the model limits include the J levee on the west side of the river and the Butte County levees on the east side. As mentioned previously, it was assumed that the J levee would not overtop up to the 100-year event with flood fighting activities (for the without-project model). Otherwise, for most of the modeled flows both the J levee and the Butte County levee overtop and are assumed to function hydraulically as a broad crested weir.

The RMA-2 program does not accurately simulate rapidly varied flow conditions that occur over the crest of a weir. Attempts were made during initial modeling of the project scenarios to manually calculate the flow across the levee using the weir equation. This required an iterative process of extracting water surface data from the model, computing the flow in a spreadsheet, then adjusting the discharge and rerunning the model. As the project assumptions evolved and as more flows were analyzed, this method proved too tedious and inaccurate. One problem is that flow direction over the levees could vary along the levee. For higher flows, water exchanges freely across the levees in both directions. Forcing the model by manually determining flow direction and discharge would have yielded results different from those computed by the model on its own, which more accurately reflect the complex hydraulics within the reach. As a result, it was decided to let RMA-2 compute the flow across the levees on its own. This required increasing the roughness of the levee crest to maintain model stability. Continuity strings were used to check the results. While the results across the crest of the levee (local velocities and depths) cannot be taken as accurate, the overall continuity of the model checked well. This methodology was used for both without-project and project models.

One area of overtopping that required manual calculation for determining the flow is at the lower eastern edge of the model. Water overtops a natural levee feature along the alignment of Big Chico Creek from where it enters the model downstream to the model limit. The water that spills over this feature enters the Butte Basin. A flow boundary condition was set along this alignment to pull flow out of the model. Determining the flow is an iterative process. First, a flow out of this boundary was assumed and the simulation was run. The water surface elevation along the natural levee was entered into a spreadsheet containing the levee elevations. By breaking the natural levee into sections, the overtopping discharge was computed incrementally using the weir equation. The incremental flows were added together to get the total flow across the feature, then the boundary condition was revised and the simulation run again. This was done until the computed discharge matched the modeled discharge.

Modeling Results

The results of the various modeling scenarios are presented as attachments to this memo. For without-project conditions, plots are included showing depth and velocity contours for each flow. For the tentatively selected plan, plots are included showing depth and velocity contours as well as the change in water surface elevation and change in velocity magnitude as compared to the without-project condition for each flow.

General observations

- *Upstream of HWY 32 Bridge Crossing* – In this reach immediately upstream of the bridge crossing the proposed levee alignment is set-back from the river's edge where the J levee is currently located. This opens a small floodplain for the right bank providing relief to flow. Less flow is in the main channel approaching the bridge. This results in a slight decrease in velocity and increase in depth in the main channel in comparison to the without-project condition. This increase in water surface elevation continues upstream to between RM 200 and RM 201, depending on the flow condition. This increase is local to the main channel and does not increase the flood inundation area except where the levee is set back. Therefore, this increase is not an adverse impact.

- *Downstream of Dunning Slough* – This is the area most impacted by the removal of the J levee and the location of the proposed levee alignment. Locally, the proposed levee causes an increase in water surface elevation on the river-side. This is because the levee is set-back and is opening up conveyance area that was not available under the without-project condition. On the landward side of the new levee, between the training dike and the GCID canal a slight increase in water surface is noticed.

- *Between Dunning Slough and the GCID Canal (Hamilton City Area)* – For flows below the 100-year event there is no impact in this area. Above the 100-year event, the proposed levee removes the flooding that occurs when the J levee overtops and allows flow through this area.

- *East Floodplain Downstream of HWY 32* – The increased conveyance provided by the set-back alignment of the proposed levee results in a slight decrease in water surface elevation extending into the east floodplain between County Road 23 and HWY 32.

- *East Floodplain Upstream of HWY 32* – The decrease in water surface elevation in the east floodplain continues upstream of HWY 32.

- *Big Chico Creek / Butte Basin Overflow* – The eastern edge of the model follows Big Chico Creek where it connects to the Sacramento. Along this edge flow overtops a natural levee feature and goes into the Butte Basin overflow area. Due to the widening of the floodplain by the set-back alignment of the proposed levee the water surface elevation along this edge decreases. This results in a slight decrease in the amount of flow spilling into Butte Basin.

Results Summary for the 320-year Flood Event

- See attached plots titled: "40% CNP of Passing the 320-Year Event"
- Flow in Sacramento River is 342,600 cfs; flow in Stony Creek is 52,000 cfs.
- Upstream of the HWY 32 bridge crossing, there is a slight increase in water surface elevation of roughly 0.2 to 0.4 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of roughly 3 feet where the levee is set-back.   There is a similar increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back.
- Flow is removed from the Hamilton City area under the project condition
- Downstream of HWY 32 there is a decrease in water surface elevation of 0.4 to 0.6 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.3 feet carries upstream of HWY 32
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek decreases slightly by less than 0.2 feet
- The overflow to Butte Basin decreases from 23,250 cfs for the without-project condition to 21,000 cfs for the project condition

Results Summary for the 100-year Flood Event

- See attached plots titled: "84% CNP of Passing the 100-Year Event"
- Flow in Sacramento River is 275,910 cfs; flow in Stony Creek is 27,400 cfs
- Upstream of the HWY 32 bridge crossing, there is a slight increase in water surface elevation of roughly 0.2 to 0.3 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back
- Downstream of HWY 32, there is a decrease in water surface elevation of 0.6 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.4 feet carries upstream of HWY 32.
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico creek decreases by as much as 0.4 feet
- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this

Results Summary for the 50-year Flood Event

- See attached plots titled: "96% CNP of Passing the 50-Year Event"
- Flow in Sacramento River is 237,829 cfs; flow in Stony Creek is 15,000 cfs
- Upstream of the HWY 32 bridge crossing there is a slight increase in water surface elevation of roughly 0.1 to 0.2 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back
- Downstream of HWY 32 there is a decrease in water surface elevation of 0.6 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.4 feet carries upstream of HWY 32
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek decreases by less than 0.2 feet upstream of its confluence with Mud Creek. Between the confluence with Mud Creek and RM 193 on the Sacramento River, there is an increase in water surface elevation along the eastern edge of the model of roughly 0.1 foot
- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this

Results Summary for the 25-year Flood Event

- See attached plots titled: "100% CNP of Passing the 25-Year Event"
- Flow in Sacramento River is 206,575 cfs; flow in Stony Creek is 15,500 cfs.
- Upstream of the HWY 32 Bridge crossing, there is a slight increase in water surface elevation of roughly 0.1 feet in the channel.
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar

increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back

- Downstream of HWY 32, there is a decrease in water surface elevation of 0.4 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.2 feet carries upstream of HWY 32
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek increases by less than 0.2 feet in the vicinity of RM 193
- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this
- The inundation limits in the vicinity of County Road 23 (CR 23), west of the levee/dike are slightly reduced for the with project condition

Results Summary for the 20-year Flood Event

- See attached plots titled: "100% CNP of Passing the 20-Year Event"
- Flow in Sacramento River is 190,000 cfs; flow in Stony Creek is 14,500 cfs
- There is no noticeable change in water surface elevation in the channel upstream of the HWY 32 bridge crossing
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back.
- Downstream of HWY 32, there is a decrease in water surface elevation of 0.4 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.2 feet carries upstream of HWY 32.
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek increases by less than 0.2 feet in the vicinity of RM 193.
- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this.
- The inundation limits in the vicinity of County Road 23 (CR 23), west of the levee/dike are slightly reduced for the with project condition

Results Summary for the “1997” Flood Event

- See attached plots titled: "1997 Flood Event"
- Flow in Sacramento River is 167,000 cfs; flow in Stony Creek is 15,500 cfs
- There is no noticeable change in water surface elevation in the channel upstream of the HWY 32 bridge crossing
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the HWY 32 Bridge where the levee is set-back.
- Downstream of HWY 32, there is a decrease in water surface elevation of 0.4 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.2 feet carries upstream of HWY 32.
- The water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek increases by less than 0.2 feet in the vicinity of RM 193.

- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this.
- The inundation limits in the vicinity of County Road 23 (CR 23), west of the levee/dike are slightly reduced for the with project condition

List of Attachments

1) Material types for the without-project conditions model.
2) Material types for the project conditions model.
3) Without-Project Condition, Depth Contours for the 320-Year Event
4) Without-Project Condition, Velocity Contours for the 320-Year Event
5) Without-Project Condition, Depth Contours for the 100-Year Event
6) Without-Project Condition, Velocity Contours for the 100-Year Event
7) Without-Project Condition, Depth Contours for the 50-Year Event
8) Without-Project Condition, Velocity Contours for the 50-Year Event
9) Without-Project Condition, Depth Contours for the 25-Year Event
10) Without-Project Condition, Velocity Contours for the 25-Year Flood Event
11) Without-Project Condition, Depth Contours for the 20-Year Event
12) Without-Project Condition, Velocity Contours for the 20-Year Event
13) Without-Project Condition, Depth Contours for the 1997 Event
14) Without-Project Condition, Velocity Contours for the 1997 Event
15) Tentatively Selected Plan, Depth Contours for the 320-Year Event
16) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 320-Year Event
17) Tentatively Selected Plan, Velocity Contours for the 320-Year Event
18) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition 20-Year Event

19) Tentatively Selected Plan, Depth Contours for the 100-Year Event
20) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 100-Year Event
21) Tentatively Selected Plan, Velocity Contours for the 100-Year Event
22) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition for the 100-Year Event

23) Tentatively Selected Plan, Depth Contours for the 50-Year Event
24) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 50-Year Event
25) Tentatively Selected Plan, Velocity Contours for the 50-Year Event
26) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition for the 50-Year Event

27) Tentatively Selected Plan, Depth Contours for the 25-Year Event
28) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 25-Year Event
29) Tentatively Selected Plan, Velocity Contours for the 25-Year Event
30) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition for the 25-Year Event

31) Tentatively Selected Plan, Depth Contours for the 20-Year Event

32) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 20-Year Event
33) Tentatively Selected Plan, Velocity Contours for the 20-Year Event
34) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition for the 20-Year Event

35) Tentatively Selected Plan, Depth Contours for the 1997 Event
36) Tentatively Selected Plan, Change in Water Surface Elevation in Comparison to the Without-Project Condition for the 1997 Event
37) Tentatively Selected Plan, Velocity Contours for the 1997 Event
38) Tentatively Selected Plan, Change in Velocity in Comparison to the Without-Project Condition for the 1997 Event

Appendix C4.

GEOTECHNICAL
Basis of Design

HAMILTON CITY FLOOD DAMAGE REDUCTION AND ECOSYSTEM RESTORATION, CA

Geotechnical Report

Basis of Design

February 2004

U.S. Army Corps Of Engineers
South Pacific Division – Sacramento District
Geotechnical Branch – Soil Design Section

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1.0 INTRODUCTION

The purpose of this report is to present the findings of a geotechnical study on an existing private levee and a proposed setback levee. The existing private levee is know as the "J-Levee" and is located in the vicinity of Hamilton City, CA (85 miles north of Sacramento) along the west bank of the Sacramento River in Glenn County (Figure 1). Land use in the area is primarily agricultural with fruit and nut orchards being the primary crops. Hamilton City has a population of about 2,000 people.

The J-levee extends approximately two miles north and six miles south of Highway 32 and is bordered on the west by the Glenn Colusa Canal and on the east by the Sacramento River. In recent years the Sacramento River has begun to migrate to the west and is currently eroding into the toe of the levee in the northern part of study area. A 1,000-foot emergency backup levee was built in 2002 by Glenn County to augment the existing J-levee in case of failure.

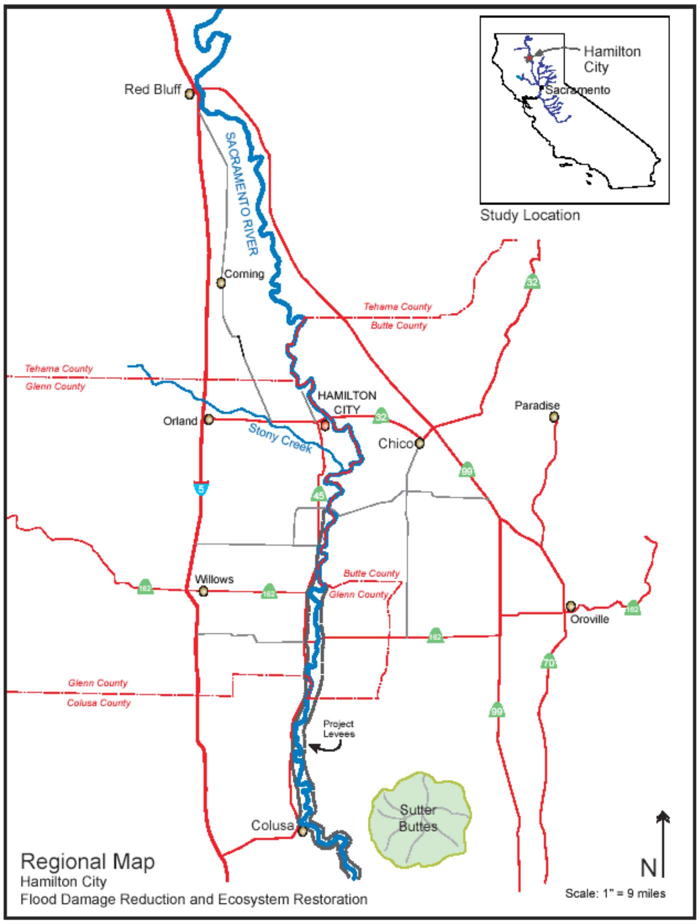
The J-levee was constructed about 1904 by Glenn County landowners and provides some flood protection for Hamilton City. However, it was not constructed to formal engineering standards and is highly erodible when river levels rise. Failure of the J-Levee in 1974 caused flooding in the area and emergency maintenance procedures (flood fighting) are routinely needed during high river levels. Previous experience has shown that when the river stage is sustained at an elevation higher than 142 MSL for several days, seepage will develop under the J-levee into a walnut orchard on the north side of Highway 32. Furthermore, sand boils have developed during past flood events just south of town in the area of the Hamilton City wastewater treatment plant.

This report will discuss the analysis and design of a new setback levee, risk-based evaluations of the existing J-levee, existing explorations and conclusions/recommendations. Upon completion of the feasibility report, additional subsurface explorations and engineering will be performed during the Pre-construction Engineering and Design Phase (PED).

1.1 Regional and Site Geology

Information relative to regional and site geology can be found in Chapter 4 – Affected Environment, page 4-1.

Figure 1: Regional map of the Hamilton City area.



2.0 PROBABILISTIC MODELING

Probabilistic modeling was accomplished using the procedure outlined in Appendix B of ETL 1110-2-556: "Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies" (USACE, 1999). This process calls for evaluation of underseepage and slope stability using standard analytical methods, combined with a judgment evaluation based on site-specific conditions noted in the field and past performance during flood events. Individual probability of failure plots are developed for each of these evaluations and are then combined to form a single curve that gives probable failure and non failure points versus water surface elevations. The probable failure point (PFP) and the probable non-failure point (PNP) are defined as the water surface elevation at which the levee has a 85% and 15% probability of failure, respectively.

2.1 Risk-Based Analysis of the J-Levee

The height of the J-Levee In the area where this analysis is applied varies from 12 to 15 feet and has side slopes of 2H:1V. According to geotechnical explorations conducted by Ayres Associates and DWR, the J-Levee is comprised of silty clay (CL) soils, with 88 – 93% material finer than the #200 sieve (0.003 inch). The foundation soils consist of silty clay (CL) and silty fine sand (SP-SM) to a depth of 50 feet.

North of Dunning Slough, erosion is the major contributor to the probability of failure. During the 1997 flood, the portion of the J-levee between Highway 32 (north) and Dunning Slough (south) sustained erosion damage. A repair attempt with sand covered by plastic sheeting held in place by ropes has not been successful. The plastic sheeting has ripped open and the added sand is mostly gone. The eroded waterside slope is near vertical in some places, exposing the silty sand soil that comprises the levee in this area. Silty sand with no vegetative cover will erode when water velocity exceeds 2 feet per second. At Hamilton City, by the time the water surface reaches the levee toe, the water velocity will be well over 2 feet per second. Therefore, future floodwaters will erode the levee rapidly in this area.

In addition to the erosion damage, rodent holes were noted on both the land and waterside slopes in this area. Rodent holes provide conduits for water to move through the levee rapidly. This water often erodes the sides of the holes, resulting in additional damage to the levee. Just north of Dunning Slough, debris (tires, burlap, and plastic) was observed in the levee section. Erosion of the riverbank has also encroached right up to and into the levee section at three places north of Highway 32. Two of those areas were repaired with rock protection during previous floods. The third area, at the very northern end of the J-Levee, is currently eroding.

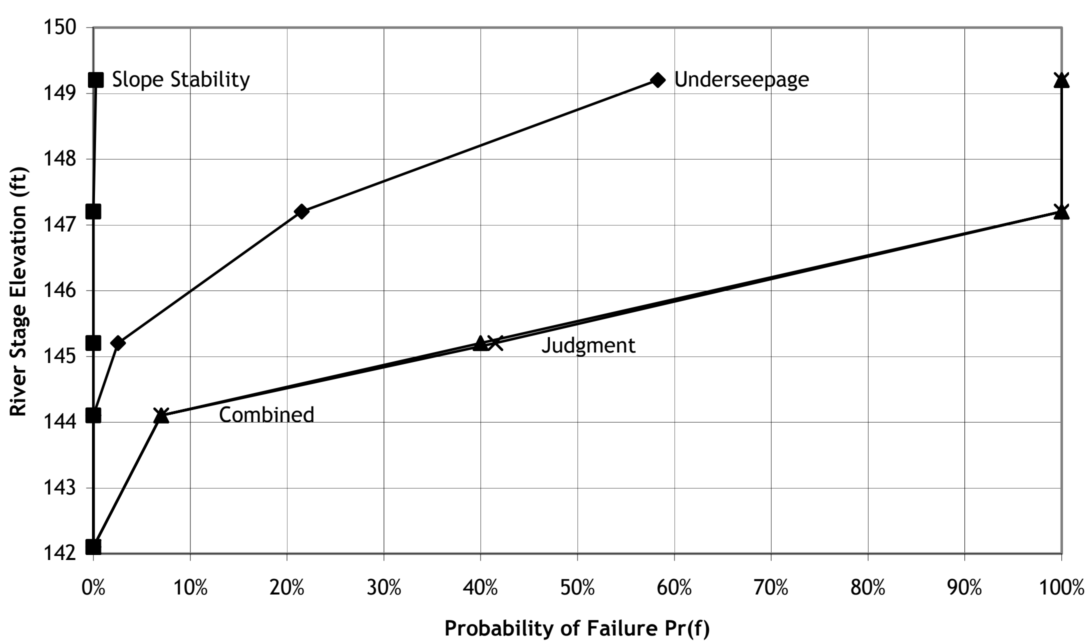
South of Dunning Slough, neither the J-Levee nor its foundation is eroding. Two index points were chosen to prepare Pr(f) curves. The first index point is located at River Mile 198.25, between Highway 32 and Dunning Slough where the levee itself has eroded and the probability of major erosion during future events is high. The Pr(f) curve for that point is shown on Figure 3. At that point, the top of the levee is at elevation 149.2 feet. The PFP is at elevation 146.8 (2.4 feet below the top of levee) and the PNP is at elevation 144.3 (4.9 feet below the top of levee. This curve is applicable north of Dunning Slough (river miles 198 to 201).

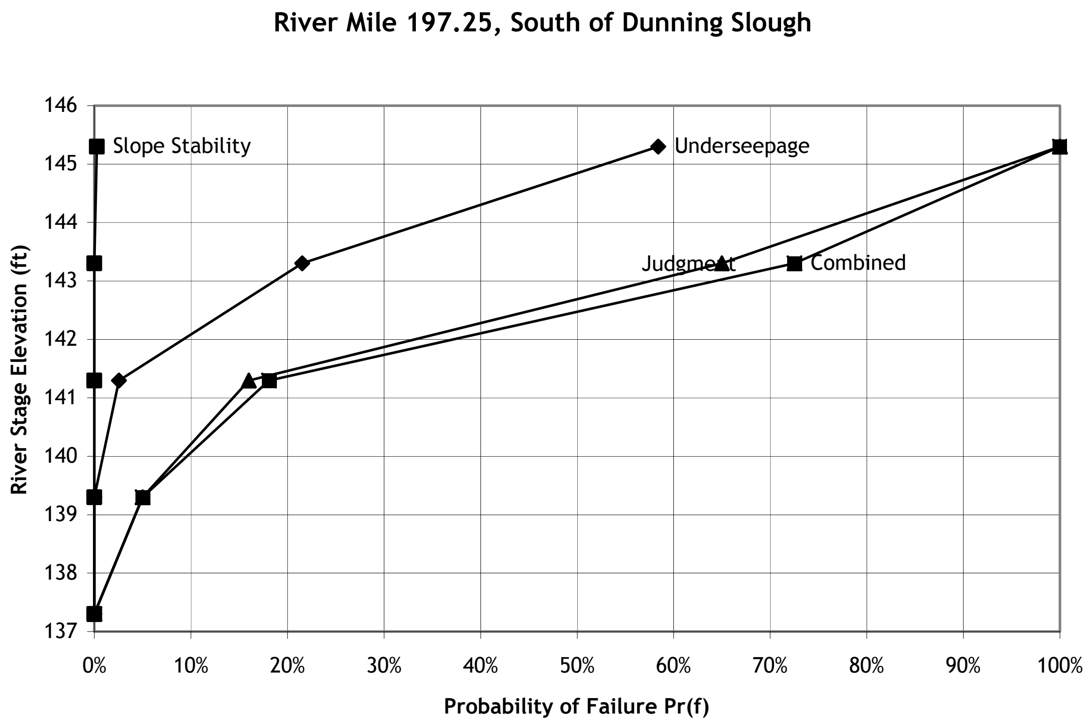
The J-Levee and it's foundation are actively eroding in several areas north of Dunning Slough. Between Highway 32 and Dunning Slough, the levee itself has eroded. North of Highway 32, foundation erosion has cut into the projected toe of the levee in several spots. The index point at River Mile 198.25 is being used for R.M. 198 to 201 primarily due to erosion activity. In addition, the levee geometry (height, side slopes) is similar over this reach, and existing soil borings indicate the levee is made of sandy silt, clay, and silty sand over this reach.

The second index point is at River Mile 197.25 and was chosen primarily because the top of the levee is low in this area. The Pr(f) curve for that point is shown on Figure 4. At that point, the top of the levee is at elevation 145.3 feet. The PFP is at elevation 144.3 feet (1 foot below the top of levee) and the PNP is at elevation 140.8 feet (4.5 feet below the top of levee). This curve is applicable south of Dunning Slough (river miles 198 to 194). As can be seen from the curves, slope stability is not a concern for the J-Levee. Erosion/poor construction/spotty maintenance (in the judgment curve) and underseepage are the likely causes of failure for the J-Levee.

Figure 2: Pr(f) Plots for Existing J-Levee

River Mile 198.25, North of Dunning Slough





2.2 Risk-Based Analysis of the Wastewater Treatment Plant Levee

The Hamilton City wastewater treatment plant (WWTP) is situated along the waterside toe of the J-Levee (RM 198) and is surrounded by an independent levee system. It is comprised of seven settling ponds of which three are usually dry. The ponds are 243 feet wide and range in length from 260 to 500 feet. The average invert of the ponds is located at elevation138 feet (MSL).

The WWTP levee is approximately 6 feet high (measured from the waterside) and has 2:1 landside slopes, 3:1 waterside slopes and a crest width of twelve feet. The crest of the WWTP levee is roughly one foot lower than the J-Levee and has waterside toe and crest elevations of about 142 and 148 feet, respectively. It is comprised of a silty clay and resides on a foundation similar to that of the J-Levee. The upper stratum beneath the WWTP levee is estimated to be 9.5-feet, but is only three feet thick below the settling ponds due to the invert elevation of 138. The lower substratum is a semipervious, silty sand and is thought to extend to a depth of 50 feet or more. A representative cross section is found in Appendix 1.

The WWTP levee was evaluated using the same reliability analysis described earlier. Individual Pr(f) curves were developed for underseepage and judgment, but slope stability was excluded. It was deemed reasonable to exclude this analysis because the same procedure performed on the J-Levee indicated that slope stability was not a concern (see Figure 3). The WWTP levee is not only in better physical condition than the J-Levee, but has a shorter height resulting in a more stable configuration.

The Pr(f) curve for underseepage is based upon seepage modeling that was performed at three different water elevations of 144, 146 and 147 feet. Statistical analysis based on 51 seepage models showed a probability of failure of 2.9, 21.8 and 33.5% for the three waster surfaces evaluated, respectively.

The Pr(f) curve for judgment is based on erosion, maintenance, vegetative cover, rodent activity and past performance. Erosion on this structure is practically nonexistent and it has been adequately maintained since its construction. Vegetative cover is adequate and rodent activity is minimal. In regards to performance, a reliability of 100% at elevation 143 is assumed to be reasonable since only one foot of differential head would be acting against the levee. Zero percent reliability is expected at an elevation of 147.5, which is 0.5 feet below the crest. This failure point is supported by levee performance during 1997 high water levels. Though a catastrophic failure was not experienced, boiling did occur in the settlement ponds resulting in a condition that could lead to progressive failure.

The "combined" curve in Figure 4 is the multiplicative result of the underseepage and judgment reliabilities for a given water surface elevation. The PNP and PFP are based upon this curve and are found through interpolation at the points of 15% and 85% probability of failure. Through the statistical analysis described herein, the PNP and PFP for the WWTP levee were found to be 144.3 and 147.2, respectively.

Figure 3: Pr(f) Plot for the wastewater treatment facility levee

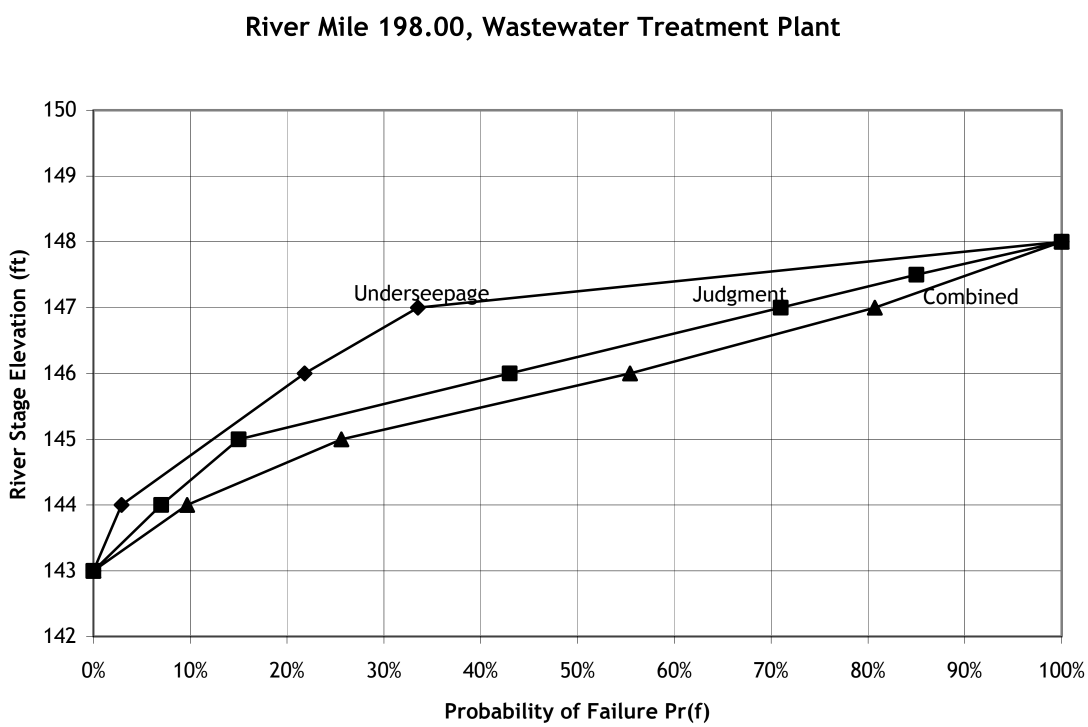


Table 1. PNP/PFP Information

Levee Failure Curve	R.M. 198.25	R.M. 197.25	Wastewater Treatment Plant
Top of Levee	149.2	145.3	148.0
PFP	146.8	144.3	147.2
PNP	144.3	140.8	144.3

3.0 EXISTING EXPLORATIONS

Soil properties for seepage and slope stability analysis were derived from three different exploration projects conducted over the past decade. Copies of the soil logs from these projects are found in Appendices 2 through 4. Location of the borings are shown in Figure 2. Ayres Associates conducted the most recent in October 2001. Their project consisted of 18 soil borings ranging from 16.5 to 46.5 feet in depth. Eight of the borings were located on the existing J-levee and ten were located in areas west of the existing J-levee. These holes are designated SB-1 through SB-18 with approximate locations listed in Table 2 and shown in Figure 4.

In September 2000, the Department of Water Resources conducted a brief geologic investigation in which four boreholes were drilled in the area of the northern most section of the existing J-Levee. These holes ranged from 46.5 to 51.5 feet in depth and are labeled as BH-1 through BH-4. In September 1991, a monitoring well installation project by Brown & Caldwell took place in the area of Dunning Slough and the Hamilton City wastewater treatment plant. This data set, however, is largely incomplete and provided limited information. These holes ranged in depth from 36.5 to 41 feet in depth and are label as MW-4 through MW-7.

Boreholes were driven using hollow stem augers with Shelby tube samples being taken every five to ten feet. The Modesto Formation was encountered in the first 10 to 15 feet and was usually underlain by the Tehama Formation. Geologic control is provided by the more erosion resistant Tehama unit that is comprised of sandstone or siltstone with lenses of cross-bedded pebble and cobble conglomerate. The Modesto Formation contains slightly weathered gravel, sand, silt and clay (DWR, 2000). The lithology encountered in most holes consisted of a relatively impervious top stratum (10 to 15 feet thick) consisting of fine grain materials such as clay or silty clay (CL, CL-ML) and a pervious substratum of poorly graded sands or gravelly sand.

Figure 4: Local map showing location of soil borings.

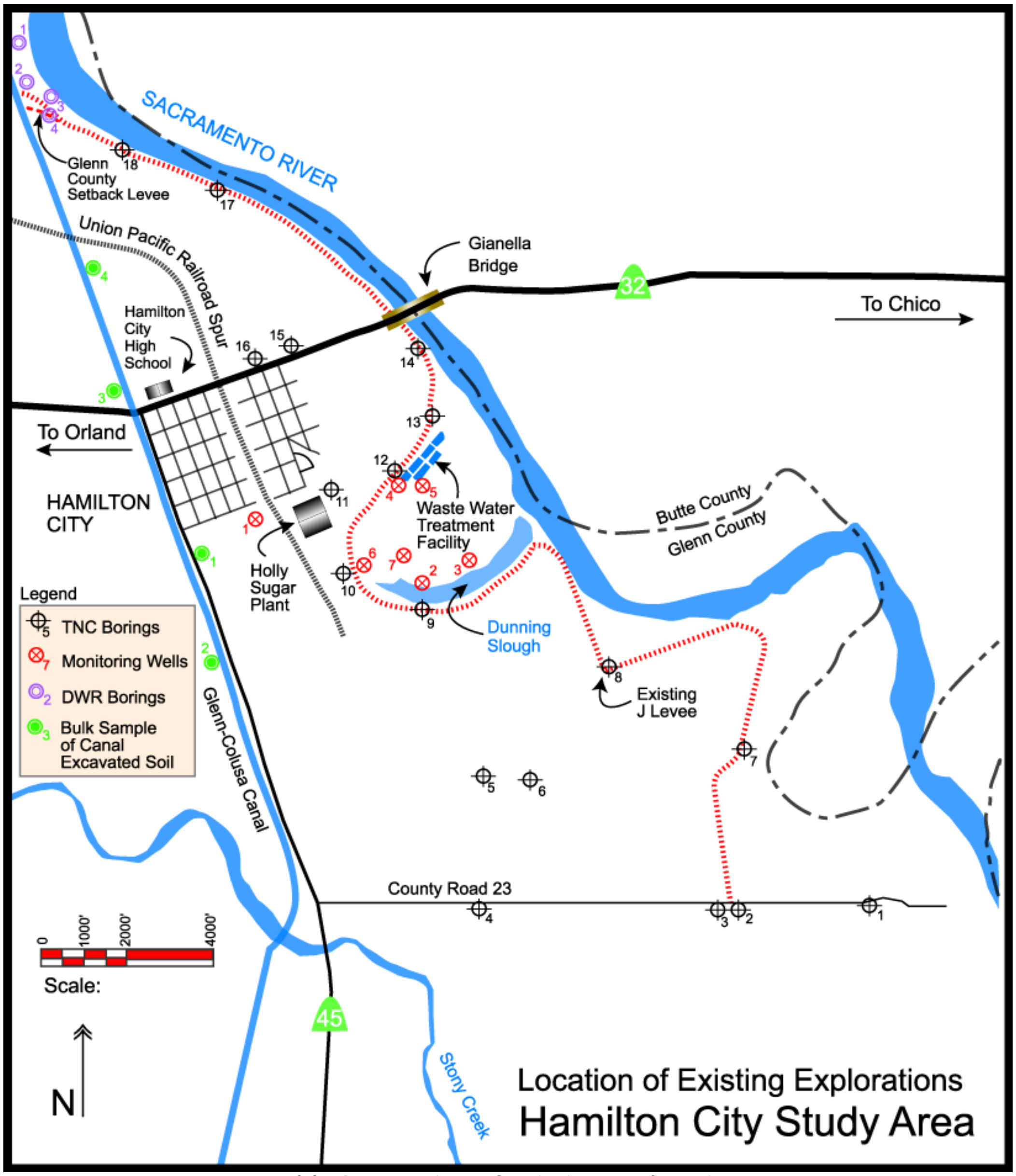


Table 2: Location of existing explorations

Hole #	Location	Latitude	Longitude	Total Depth (ft)	Water Depth (ft)
SB-1	County Road 23	N 39-42-45.5	W 121-57-32.6	26.5	11.9
SB-2	County Road 23	N 39-42-45.3	W 121-58-11.8	31.5	13.9
SB-3	County Road 23	N 39-42-45.6	W 121-58-13.5	26.5	15.8
SB-4	County Road 23	N 39-42-46.0	W 121-59-28.2	36.5	16.3
SB-5	0.5 North of SB-4	N 39-43-15.7	W 121-59-27.3	41.5	19.1
SB-6	0.3 mile east of SB-5	N 39-43-15.2	W 121-59-13.2	36.5	19.7
SB-7	Top of Levee	N 39-43-22.1	W 121-58-09.1	26.5	25.1
SB-8	Top of Levee	N 39-43-41.0	W 121-58-49.6	21.5	-
SB-9	Top of Levee	N 39-43-54.8	W 121-59-47.3	41.5	22.3
SB-10	Sugarwell Road	N 39-44-02.6	W 122-0-04.7	41.5	21.7
SB-11	Sugarwell Road	N 39-44-22.1	W 122-0-11.7	41.5	22.3
SB-12	East of Sewer Ponds	N 39-44-26.0	W 121-59-53	21.5	-

SB-13	Top of Levee	N 39-44-40.3	W 121-59-42.9	16.5	-
SB-14	Top of Levee	N 39-44-55.9	W 121-59-46.6	16.5	-
SB-15	Westermann Farms	N 39-44-54.2	W 122-0-25.0	41.5	17.5
SB-16	Westermann Farms	N 39-44-52.0	W 122-0-31.8	41.5	23.4
SB-17	Top of Levee	N 39-45-33.0	W 122-0-45.6	41.5	29.5
SB-18	Top of Levee	N 39-45-40.6	W 122-01-19.3	46.5	27.0
BH-1	1,000' N. of North End	N 39-46-03.9	W 122-01-47.2	51.0	20
BH-2	150' N. of North End	N 39-45-56.1	W 122-01-40.7	52.0	-
BH-3	N. of Almond Orchard	N 39-45-54.1	W 122-01-34.8	46.5	27
BH-4	Almond Orchard	N 39-45-51.1	W 122-01-34.8	51.5	-
MW-4	Waste Water Plant	N 39-44-26.7	W 121-59-47.1	36.5	16
MW-5	Waste Water Plant	N 39-44-23.9	W 121-59-47.7	36.5	15
MW-6	Waste Water Plant	N 39-44-16.3	W 122-0-02.0	40.5	20
MW-7	Waste Water Plant	N 39-44-05.5	W 121-59-51.6	41.5	15

4.0 NEW LEVEE ANALYSIS

4.1 Selection of Alignment

Six preliminary levee alignments are currently under consideration and are illustrated in the plates of the civil section. Because the alignments are relatively close to each other, foundation conditions are not expected to change significantly among the alignments. For this reason, this initial geotechnical analysis is based upon a single cross section from river mile 199.5, which is several hundred feet upstream of Highway 32. This cross-section of the locally developed setback levee was chosen as the representative profile because of the levee's close proximity to the Sacramento River. For conservatism, the soil parameters chosen to use in the model were chosen such that they represent a worst-case scenario (i.e. high permeabilities and low shear strengths).

4.2 Levee Height

The design water surface elevation for this initial analysis was taken as top of levee. The levee heights under consideration are 14, 10 and 6 feet above the ground surface. The land and waterside slopes were given as 3:1. Settlement is not anticipated to be a problem in the Hamilton City area, therefore no overbuild for settlement will be necessary.

4.3 Seepage Analysis

The GMS 4.0 (Groundwater Modeling System) computer program (developed by WES and Brigham Young University) was used for seepage analysis to compute the exit gradient at the toe of the levee and to determine a piezometric surface to be used in the slope stability analysis. The maximum allowable hydraulic gradient given by ETL 1110-2-555: "Design Guidance on Levees" is 0.3 (USACE, 1997). Soil types used in the model were based on field classifications from the exploration projects previously discussed. Hydraulic conductivities for the material types were selected from various published sources and are listed in Table 3.

The seepage model used in the analysis was comprised of a homogeneous compacted clay embankment ranging from 6 to 14-feet in height underlain by a two-layer foundation. The wastewater containment ponds were not included in the model because the operator of the facility indicated they are lined with betonite. A determination will be made at a later date as to the accurateness of this statement and whether additional analysis and subsequent remediation is necessary. The top stratum of the foundation had a constant thickness of 12 feet and was assigned the same material type as the levee. However, because of the compaction the levee will receive during its construction, the upper zone was given permeability slightly higher than that of the levee. The substratum of the foundation was a poorly graded sand that extended to 50 feet below the top stratum.

The hydraulic gradient at the toe of the 6, 10 and 14-foot embankments were found to be 0.25, 0.39, and 0.54, respectively. The relatively high gradients for the 10 and 14-foot embankments imply that there exists a potential for uplift pressures in the pervious sand layer becoming greater than the effective weight of the clay layer of the foundation. To prevent heaving and/or rupturing it is suggested that a landside seepage berm be used for the 10 and 14-foot embankments.

Initial computations indicate that the 10-foot levee will require a landside seepage blanket that is 12-feet in width and 5-feet in height. The 14-foot levee will require a landside seepage blanket that is 5-feet in height and 30-feet in width. The use of a seepage blanket for the 6-foot levee will not be required. The additional width of the seepage berm will reduce uplift pressures to a tolerable value, as well as provide extra weight to counteract upward seepage forces.

The present alignment of the ring levee and the intermediate setback levee may make the use of a seepage berm difficult in certain areas. The close proximity of residential homes to these alignments may dictate the need of a cutoff wall rather than a berm. If required, the cutoff wall will be designed after soil borings are collected.

Table 3: Hydraulic conductivities used in seepage analysis

Zone	Material	k_h (ft/day)	k_v (ft/day)
Levee	CL	0.3	0.05
Upper Foundation	CL-ML	0.3	0.075
Lower Foundation	SP	7.5	1.875

4.4 Slope Stability

Slope stability analysis was performed using the UTexas4 software package (developed by Dr. Stephen Wright for the Corps of Engineers). The two loading conditions that were analyzed were End-of-Construction (short term analysis) and Steady State Seepage (long term analysis). The case of sudden draw down will be investigated at a later stage in the design process.

Similar to the seepage model, the UTexas4 soil profile was comprised of a levee with a clay foundation underlain by a poorly graded sand layer. Material types were based on field classifications with engineering properties taken from various published sources. The properties used in the model are given in Tables 4 and 5.

The embankment was modeled with 3:1 side slopes and a height of 14 feet. The steady state seepage model had a design water surface at the levee crest. This model included a piezometric surface through the levee whose elevation is given by the seepage analysis. The End-of-Construction model does not include a phreatic surface in its analysis.

Results of the modeling are shown in Figures 7 and 8. The minimum allowable safety factors given by EM 1110-2-1913: "Design and Construction of Levees" are 1.3 and 1.4 for the End-of-Construction (EOC) and Steady State Seepage (SS) analysis, respectively (USACE, 2000). Safety factors for both EOC and SS analysis came to 3.1 and 2.0 indicating that the given levee geometry is stable with the assumed soil properties. Because the tallest levee under consideration had a safety factor that is well above the minimum allowable, the shorter levees were not modeled.

Table 4: Material properties for end of construction

Zone	Material	Unit Weight (pcf)	Friction Angle	Cohesion (psf)
Levee	CL	125	0	1400
Upper Fnd	CL-ML	120	0	800
Lower Fnd	SP	120	35	0

Table 5: Material properties for steady state seepage

Zone	Material	Unit Weight (pcf)	Friction Angle	Cohesion (psf)
Levee	CL	125	31	0
Upper Fnd	CL-ML	120	28	0
Lower Fnd	SP	120	35	0

Figure 5: Results of End of Construction slope stability analysis.

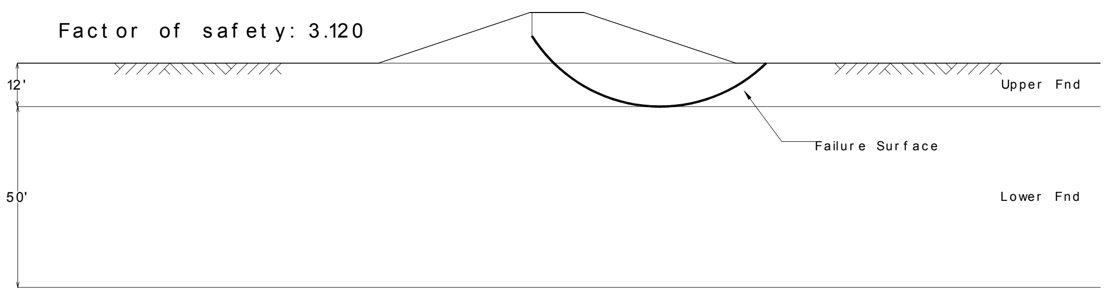
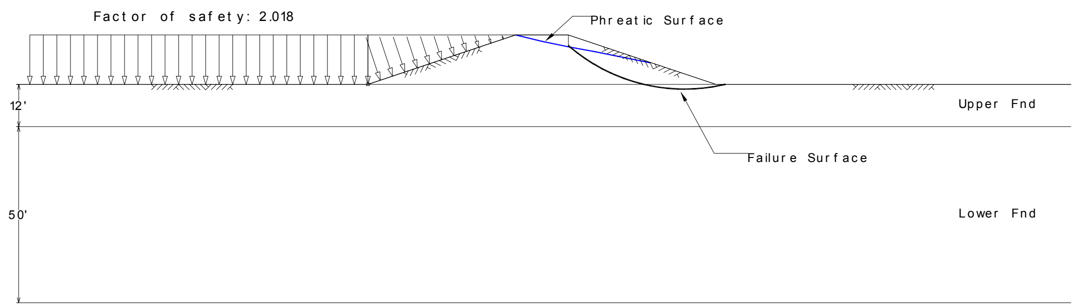


Figure 6: Results of Steady State slope stability analysis.



4.5 Bearing Capacity

Bearing capacity was analyzed for a 14-foot tall embankment with 3:1 sideslopes. The standard bearing capacity equation was used for the analysis was:

$$q_{ult} = (\frac{1}{2})\gamma B N_{\gamma} + C N_c + \gamma D_f(N_q)$$

where

γ = unit weight of soil in pounds per square foot
B = width of footing (embankment) in feet
C = cohesion (undrained shear strength S_u) in pounds per square foot
D_f = depth of footing (embankment) below the ground surface in feet
N_{γ}, N_c, N_q = dimensionless bearing capacity factors

For the undrained and drained conditions, the ultimate bearing capacities came to 4,112 and 99,314 pounds per square foot, respectively. Assuming a unit weight of 125 pounds per cubic foot for the levee material, the minimum factor of safety was found to be 2.3.

4.6 Settlement

Due to lack of appropriate data, settlement calculations are not available at this time. Because there is not a soft clay layer close to the surface in the area of the proposed levee alignments, it is expected that total settlement will be minimal. When this project moves into the Plans & Specs phase and undisturbed samples are collected, a thorough settlement analysis will be completed.

5.0 POTENTIAL BORROW SITES

A preliminary identification of potential borrow sites, based on existing information only, is being conducted for this study. For levee construction the USACE specifies soils with the following characteristics:

- a maximum particle diameter of 3 inches
- a minimum of 15% fines content (silt and clay size particles)
- fines must have a liquid limit less than 45 and a plasticity index between 7 and 15
- no organic material or debris may be present

If such soils are not available locally, soils that do not meet the criteria may be used. In these circumstances, the levee geometry is often modified (wider crest, gentler side slopes) to accommodate the less suitable soils. High plasticity clays may be mixed with 3-5% lime to prevent the formation of desiccation cracks in the completed levee. Explorations conducted by others (Ayres Associates, 2000 & DWR, 2000) indicate the overall soil conditions in the area to consist of a blanket layer of fine-grained material (silts, clays, sandy silts, sandy clays) overlying a layer of sand or gravelly sand.

It is possible that a sufficient quantity of suitable material will be available locally. Preliminary tests by others indicate the material content of the upper stratum does contain the required minimum fines content for levee construction. Furthermore, the GCID has offered the canal-excavated soil that currently resides along the Glen Colusa canal as borrow material for the new levee. This is the same material that was used to build the 1000-foot cutoff levee in the north end. Stipulation to its use, however, is that the berm is not to degrade to less than four feet above the canal design water surface. The four-foot berm is intended to keep people from driving into the canal from Highway 45.

A preliminary field investigation of the canal-excavated soil indicates that this material is suitable as a borrow source. Laboratory analyses (Appendix 5) of four bulk samples collected from various locations along the canal (Figure 4) indicate that the given material meets the USACE criteria as stated above. If it is found that additional material is needed, the local project sponsor will assist in identifying potential borrow sites and the Corps will evaluate the sites to determine suitability based on existing information. However, until specific borrow sites are identified and site explorations are performed, no assumptions should be made relating to borrow source suitability.

6.0 CONSTRUCTABILITY

Construction issues in the study area are primarily of a timing concern. Consideration should be given to avoiding construction during the rainy season because the development of soft or saturated soils can significantly slow or halt construction progress.

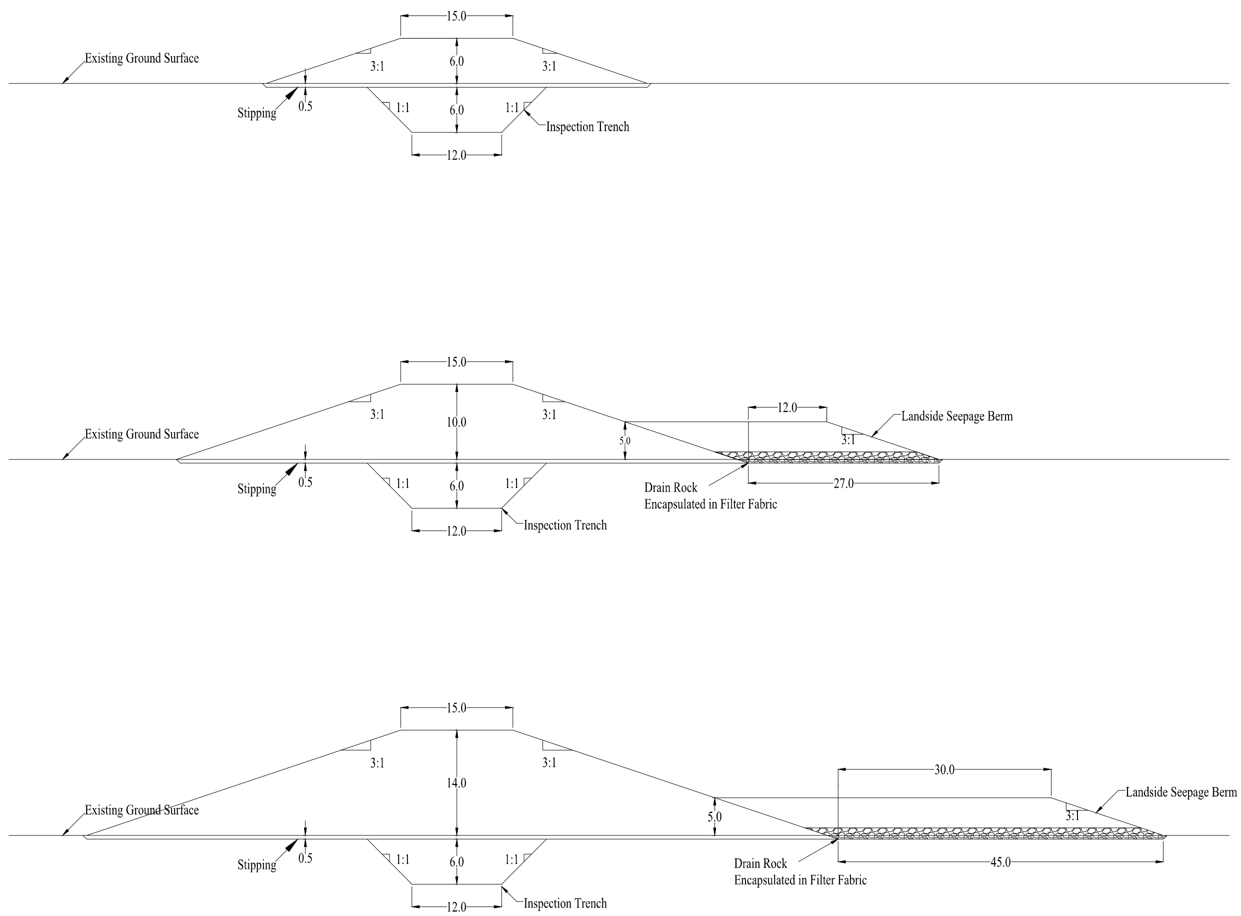
7.0 CONCLUSION

This analysis focused on three levee geometries with crest elevations set to 6, 10 and 14 feet (Figure 7). The components common to all trial cross sections include a crest width of 15-feet, embankment side slopes at 3H:1V (18 degrees) and a six-foot deep inspection trench with sides at 1:1. The crest width and relatively flat embankment angles allow maintenance and emergency repair equipment to safely traverse the levees. The inspection trench allows for the discovery of undocumented utilities and unexpected soil conditions.

From a structural standpoint, it was found that all three levees have a factor of safety against slope failure that is well above the USACE criteria. However, due to high exit gradients at the toe of the proposed levees, a landside seepage berm is suggested for the 10 and 14-foot embankments. The 10-foot levee will require a landside seepage blanket that is 27-feet in width (as measured from the landside toe of the levee to the toe of the berm) and 5-feet in height. The 14-foot levee will require a landside seepage blanket that is 45-feet in width (as measured from the landside toe of the levee to the toe of the berm) and 5-feet in height. The additional width of the seepage berm will reduce uplift pressures to a tolerable value, as well as provide extra weight to counteract upward seepage forces.

The present alignment of the ring levee and the intermediate setback levee may make the use of a seepage berm difficult in certain areas. The close proximity of residential homes to these alignments may dictate the need of a cutoff wall rather than a seepage berm. If required, the cutoff wall will be designed after soil borings are collected.

Figure 7: Final design of three proposed levee sizes.



8.0 RECOMMENDATIONS

The following recommendations are made for the next phase of the project:

1. Conduct subsurface investigations including standard penetration tests and collect both disturbed and undisturbed samples along the chosen alignment to further define the subsurface conditions. This includes the collection of undisturbed samples to perform triaxial and consolidation testing of foundation clay layers.

2. Perform additional seepage, slope stability and settlement analyses based on the results of the triaxial and consolidation testing listed in #1.

3. Investigate the borrow areas which were identified in this study. This consists of backhoe test pits and the collection of bulk samples for laboratory testing.

9.0 REFERENCES

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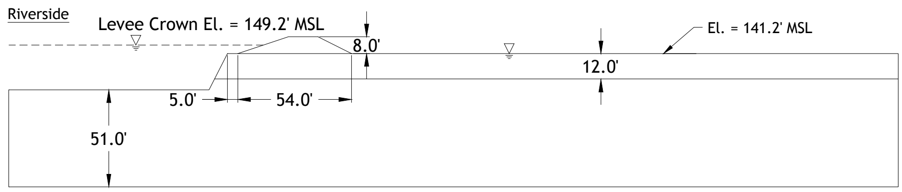
U.S. Army Corps of Engineers (USACE) 2000. Headquarters, EM 1110-2-1913, Design and Construction of Levees.

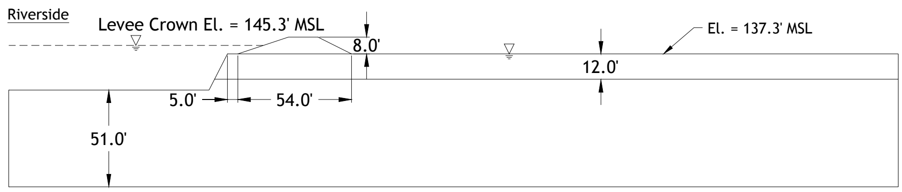
Appendix 1

Representative Cross Sections and Soil Parameters used in the PNP/PFP Analysis

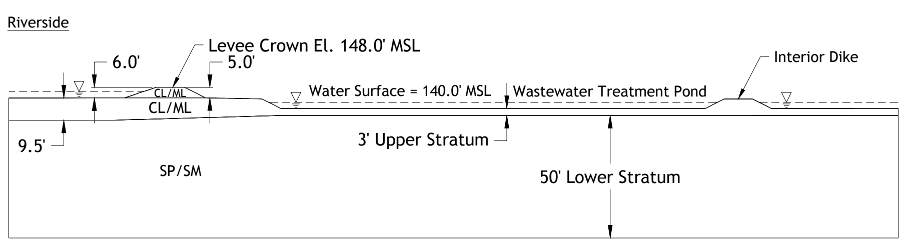
Figure 8: Typical Cross Sections used in PNP/PFP Analysis



North of Dunning Slough, RM 198.25, Seepage Model



South of Dunning Slough, RM 197.25, Seepage Model



Wastewater Treatment Plant Seepage Model

Notes:
1. Approximately 1,000' to river from levee.
2. See Table 6 for parameters used in the seepage model.

Table 6: Soil Parameters used in Reliability Analysis.

North and South of Dunning Slough

Variable	Expected Value	Expected Value $+\sigma$	Expected Value $-\sigma$
K_v of Upper Layer (ft/day)	0.075	0.142	0.0075
K_h of Lower Layer (ft/day)	7.5	12	3
Thickness of Upper Layer (ft)	12	16	8
Thickness of Lower Layer (ft)	51	61	41

NOTE: Blanket analysis was used for North and South Slough seepage analysis.

WWTP Levee

Variable	Expected Value	Expected Value $+\sigma$	Expected Value $-\sigma$
K_v of Upper Layer (ft/day)	0.028	0.14	0.014
K_h of Upper Layer (ft/day)	0.252	1.26	0.126
K_v of Lower Layer (ft/day)	1.87	6.22	0.622
K_h of Lower Layer (ft/day)	16.80	56.0	5.6
Thickness of Upper Layer underneath Pond (ft)	3.0	5.5	2.0
Thickness of Upper Layer at Riverside (ft)	9.5	10.5	5.0
Thickness of Lower (ft)	50.0	60	35.0

NOTE: Finite element analysis was used for the WWTP seepage analysis using Seep2D from the GMS computer application.

Appendix 2

Soil Logs From Ayres Associates

LOG OF SOIL BORING

Date Completed: 10/23/00
Logged By: Thomas W. Smith
Total Depth: 26.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: In field on south side of County Road 23
GPS Coordinates: Latitude: N 39° 42' 45.5" Longitude: W 121° 57' 32.6"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 131.0 ft
5		SPT 5.0-6.5	2-4-3	7			**Silty fine SAND (SM)**, light brown, moist
							Sandy SILT layer (ML)
10		SPT 10.0-11.5	7-10-8	18			**Silty fine SAND (SM)**, light brown, moist
					Groundwater at 11.9 ft on 10/23/00		**Gravelly SAND (SP)**, medium brown, moist
15		SPT 15.0-16.5	26*-6-3	9	Sample SB1-1 15.0-20.0 ft Small Bag	No tests	**15.0 ft** Increasing sand size with depth
20		SPT 20.0-21.5	10-12-6	18			
						? ? ?	**Sandy GRAVEL (GP)**, saturated, multicolored (black, gray, white, tan, red) rounded to sub-rounded ? ? ?
25		SPT 25.0-26.5	7-5-3	8			
							Bottom of Boring at 26.5 ft
30							
35							
40							

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SB-1
1 of 1

* Rock in sampler, disregard value
? Estimated break in material type

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/23/00
Logged By: Thomas W. Smith
Total Depth: 31.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: In field on South Side of County Road 23.
Approx. 1/2 mile West of SB-1 along County Road 23
GPS Coordinates: Latitude: N 39° 42' 45.3" Longitude: W 121° 58' 11.8"

Depth (ft)	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
						Approximate Ground Surface Elevation: 132.0 ft
5	SPT 5.0-6.5	3-3-3	6	Sample SB2-1 0-4.0 ft Small Bag	No tests	**Silty CLAY (CL)**, medium brown, moist
10	SPT 10.0-11.5	5-5-5	10			
						Fine SAND with 10% silt (SP-SM), medium brown, moist
				Groundwater at 13.9 ft on 10/23/00		**Fine Sandy SILT (ML)**, medium brown, moist
15	SPT 15.0-16.5	3-2-7	9	Sample SB2-2 15.5-16.5 ft Small Bag	No tests	**Silty Fine SAND (SM)**, medium brown, saturated
	SPT 17.5-19.0	2-5-5	10			
20	SPT 20.0-21.5	8-8-6	14			
				Sample SB2-3 21.0-27.5 ft Small Bag	No tests	**Clean Gravelly SAND (SP)**, saturated, multicolored (black, gray, white, tan, red) rounded to sub-rounded **Increasing gravel content with depth**
25	SPT 25.0-26.5	6-8-7	15			
30	SPT 30.0-31.5	15-24-21	45			
35						Bottom of Boring at 31.5 ft
40						

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SB-2
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/23/00
Logged By: Thomas W. Smith
Total Depth: 26.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: County Road 23. Boring is 43' South from edge of pavement
GPS Coordinates: Latitude: N 39° 42' 45.6" Longitude: W 121° 58' 13.5"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 134.0 ft
					Sample SB3-1 1.0-3.0 ft Small Bag	G,H,A **CL**	
5		SPT 5.0-6.5	5-7-5	12			**Silty CLAY (CL)**, light brown, low moisture
10		SPT 10.0-11.5	7-10-9	19			**Fine SAND (SP)**, light brown, moist
							Clayey SILT (ML), medium brown, moist
15		SPT 15.0-16.5	3-4-7	11	Sample SB3-2 15.0-15.5 ft Small Bag	G, H, A **ML**	**Fine Sandy SILT (ML)**, medium brown, moist
						Groundwater at 15.8 ft on 10/23/00	
		SPT 17.5-19.0	4-4-7	11			
20		SPT 20.0-21.5	3-2-5	7			
					Sample SB3-3 21.0 - 26.5 ft Small Bag	G **SP**	**Gravelly, Medium to Coarse SAND (SP)**, saturated, multicolored (black, gray, white, tan, red) rounded to sub-rounded **24.0 ft Increasing gravel content**
25		SPT 25.0-26.5	11-12-12	24			
							Bottom of Boring at 26.5 ft
30							
35							
40							

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SB-3
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/23/00
Logged By: Thomas W. Smith
Total Depth: 36.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: County Road 23. Approx. 1 Mile East of Road 23 and Hwy 45 Intersection
GPS Coordinates: Latitude: N 39° 42' 46.0" Longitude: W 121° 59' 28.2"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 139.0 ft
5		SPT 5.0-6.5	5-7-7	14			**Silty CLAY (CL)**, light brown, slight moisture
10		SPT 10.0-11.5	4-4-5	9	Sample SB4-1 10.5-11.5 ft Small Bag	No tests	**Fine SAND (SP)**, light brown, moist
15		SPT 15.0-16.5	3-7-8	15	Groundwater at 16.3 ft on 10/23/00		**Silty SAND (SM)**, medium brown, saturated **Medium grained SAND (SP) with up to 2 inch Gravel** saturated, multicolored (black, gray, white, tan, red) rounded to sub-rounded
20		SPT 20.0-21.5	6-5-5	10			**Increasing sand size with depth**
25		SPT 25.0-26.5	9-9-9	18	Sample SB4-2 25.0-26.5 ft Small Bag	No tests	
30		SPT 30.0-31.5	No Test	Sampler wedged with inflowing sand against the inside of the flight auger			
35		SPT 35.0-36.5	23-25-20	45	Sample SB4-3 35.0-36.5 ft Small Bag	No tests	Bottom of Boring at 36.5 ft
40							

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SB-4
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Intersection of field roads approx. 0.5 mi due North of SB-4
GPS Coordinates: Latitude: N 39° 43' 15.7" Longitude: W 121° 59' 27.3"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 139.5 ft
5		SPT 5.0-6.5	6-4-3	7			**Silty CLAY (CL)**, medium brown, moist
10		SPT 10.0-11.5	2-3-4	7			**Silty Fine SAND (SM)**, medium brown, moist
15		SPT 15.0-16.5	2-2-4	6			**Clayey SILT (ML)**, medium brown, moist
		Groundwater at 19.1 ft on 10/24/00					
20		SPT 20.0-21.5	6-10-10	20	Sample SB5-1 20.0-21.0 ft Small Bag	G, H, A **ML**	**Silty Fine SAND (SM)**, medium brown, saturated
25		SPT 25.0-26.5	18-23-28	51	Sample SB5-2 25.0-25.5 ft Small Bag	No tests	
					Sample SB5-3 25.5-26.5 ft Small Bag	No tests	**Sandy GRAVEL (GW)**, saturated, multicolored (black, gray, white, tan, red) angular to rounded Gravel 2 inch size
30		SPT 30.0-31.5	25-13-12	25	Sample SB5-4 30.0-31.5 ft Small Bag	G **GW**	
35		SPT 35.0-36.5	26-29-19	48	Sample SB5-5 35.5-41.5 ft Small Bag	G **GW**	
40		SPT 40.0-41.5	34-29-31	60			Bottom of Boring at 41.5 ft

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SB-5
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometera 95833

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 36.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Off Dirt Road Edge, 0.3 miles East of SB-5 on south side of road
GPS Coordinates: Latitude: N 39° 43' 15.2" Longitude: W 121° 59' 13.2"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 139.0 ft
5					Sample SB6-1 1.0-10.0 ft Small Bag	G, H, A **CL**	
		SPT 5.0-6.5	12-11-7	18			**Silty CLAY (CL),** light brown, dry
10							
		SPT 10.0-11.5	3-3-5	8			
		SPT 12.0-13.5	2-3-3	6			**Clayey SILT (ML),** medium brown, moist
15							
		SPT 15.0-16.5	1-2-3	5			**Silty CLAY (CL),** medium brown, moist
20					Groundwater at 19.7 ft on 10/24/00		
		SPT 20.0-21.5	3-2-3	5			**Silty Fine SAND (SM),** medium brown, saturated
25							
		SPT 25.0-26.5	5-8-11	19			**25.25 - 26.0 ft Color change from brown to gray**
							Gravelly SAND (SP/GP), saturated
30							
		SPT 30.0-31.5	35-24-24	N.A.	Low recovery most likely hit large gravel		
35							
		SPT 35.0-36.5	15-14-8	22			
							Bottom of Boring at 36.5 ft
40							

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SB-6
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G - Grain Size Distribution A - Atterberg Limits H - Hydrometera 95833

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 26.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J Levee
GPS Coordinates: Latitude: N 39° 43' 22.1" Longitude: W 121° 58' 9.1"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 144.0 ft
					Sample SB7-1 1.0-3.0 ft Small Bag	No tests	0-4 inch Road gravel surfacing
5					Sample SB7-2 3.0-5.0 ft Small Bag	No tests	Alternating 1 inch layers of **ML** and **CL** **Silty Fine Sandy CLAY (CL),** medium brown, moist **Clayey Fine Sandy SILT (ML),** gray-brown, moist Sampler showed layers of brown and gray-brown
		SPT 5.0-6.5	22-13-17	30			
10		SPT 10.0-11.5	3-2-2	4			
							Silty Fine Sandy CLAY (CL), medium brown, moist
15		SPT 15.0-16.5	6-8-10	18			
							Fine SAND (SP), light brown, moist
		SPT 17.5-19.0	6-9-10	19			**Sandy GRAVEL (GP),** moist, gravel to 1 1/2 inch
20		SPT 20.0-21.5	3-4-10	14			
							Fine SAND (SP), medium brown, moist
25					Groundwater at 25.1 ft on 10/24/00		
		SPT 25.0-26.5	3-5-5	10			Bottom of Boring at 26.5 ft
30							
35							
40							

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SB-7
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G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 21.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J Levee
GPS Coordinates: Latitude: N 39° 43' 41.0" Longitude: W 121° 58' 49.6"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 145.0 ft
5		SPT 5.0-6.5	5-5-6	11	Sample SB8-1 5.0-6.5 ft Small Bag	G, H, A CL	**Silty CLAY (CL),** medium brown, moist
10		SPT 10.0-11.5	3-2-4	6			**Increasing silt content at 11.0 ft**
15		SPT 15.0-16.5	5-4-4	8			**Fine SAND (SP),** medium brown, moist
						? ? ?	**Silty Fine SAND (SM)** ? ?
20		SPT 20.0-21.5	6-10-14	24			
25							Bottom of Boring at 21.5 ft No Groundwater Encountered
30							
35							
40							

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SB-8
1 of 1

? Estimated material type change

G - Grain Size Distribution A - Atterberg Limits H - Hydrometera 95833

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J Levee
GPS Coordinates: Latitude: N 39° 43' 54.8" Longitude: W 121° 59' 47.3"

Depth (ft)	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
						Approximate Ground Surface Elevation: 148.0 ft
0						0-4 inch Road Gravel
5	SPT 5.0-6.5	4-4-3	7			**Silty CLAY (CL)**, medium brown, moist
10	SPT 10.0-11.5	7-8-12	20			Color increases in darkness 10.0-11.5 ft
15	SPT 15.0-16.5	3-3-4	7	SB9-1 15.5-16.5 ft Small Bag	No tests	**Increasing silt content, Silty CLAY (CL)**
20	SPT 20.0-21.5	2-4-4	8			
22.3				Groundwater at 22.3 ft on 10/24/00		
25	SPT 25.0-26.5	2-2-3	5			
30	SPT 30.0-31.5	13-15-16	31			**Gravelly, Fine to Medium SAND (SP)**, saturated
35	SPT 35.0-36.5	10-25-37	62			**Sandy GRAVEL (SP/GP)**, saturated
40	SPT 40.0-41.5					Bottom of Boring at 41.5 ft

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G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Holly Sugar property just east of the J levee on Sugarwell Road
GPS Coordinates: Latitude: N 39° 44' 2.6" Longitude: W 122° 00' 4.7"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 140.0 ft
							0-2 feet **Road Base Gravel (GW)**
5		SPT 5.0-6.5	3-3-3	6			**Silty CLAY (CL)**, dark brown, moist Color change to medium brown at 5.0 ft
10		SPT 10.0-11.5	3-5-8	13			
15		SPT 15.0-16.5	1-2-2	4			
20		SPT 20.0-21.5	2-4-4	8	Groundwater at 21.7 ft on 10/24/00		**Fine Sandy Clayey SILT (ML),** light brown, saturated
25		SPT 25.0-26.5	2-2-3	5	Sample SB10-1 26.0-26.5 ft Small Bag	G, H, A **ML**	**Sandy SILT (ML)**, medium brown, saturated
30		SPT 30.0-31.5	2-3-18	21			**Gravelly, Fine to Medium SAND (SP)**, saturated light brown
35		SPT 35.0-36.5	17-18-23	41			
40		SPT 40.0-41.5	26-22-21	43	Sample SB 10-2 41.0-41.5 ft Small bag	No tests	Bottom of Boring at 41.0 ft

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G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/24/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: 0.4 mi North of SB-10 on Sugarwell Road (Holly Sugar Property)
GPS Coordinates: Latitude: N 39° 44' 22.1" Longitude: W 122° 00' 11.7"

Depth (ft)	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
						Approximate Ground Surface Elevation: 139.5 ft
0–5						**Clayey SILT (ML)**, dark brown with occasional small gravel pieces to about 5 ft.
5	SPT 5.0-6.5	4-4-4	8		? ? ?	**Silty CLAY (CL), medium brown, moist** ? ? ?
10	SPT 10.0-11.5	3-4-5	9			
15	SPT 15.0-16.5	4-4-6	10			
20	SPT 20.0-21.5	3-4-7	11			**Very Fine Sandy Clayey SILT (ML)**, medium brown, moist
				Groundwater at 22.3 ft on 10/24/00		
25	SPT 25.0-26.5	1-1-2	3			**Very Fine Sandy SILT (ML)**, medium brown, saturated decreasing clay and increasing sand
30	SPT 30.0-31.5	2-5-7	12			**Increasing Sand (SM)**
35	SPT 35.0-36.5	18-16-12	28	Sample SB11-1 35.0-36.5 ft Small Bag	G GW	**Sandy GRAVEL (GW)**, saturated, multicolored (black, gray, white, tan, red) angular to rounded
40	SPT 40.0-41.5			Sample SB11-2 40.0-41.5 ft Small Bag	No tests	**Silty SAND (SP-SM)**, medium brown, saturated Bottom of Boring at 41.5 ft

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SB-11
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? Estimated break in material type

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 21.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J Levee, Due East of Sewer Ponds
GPS Coordinates: Latitude: N 39° 44' 26.0" Longitude: W 121° 59' 53.0"

Depth (ft)	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
						Approximate Ground Surface Elevation: 149.0 ft
5	SPT 5.0-6.5	3-3-3	6			**Silty CLAY (CL),** medium brown, moist
						Increasing darkness with depth
10	SPT 10.0-11.5	4-4-4	8			
						Clayey SILT (ML), medium brown, moist
15	SPT 15.0-16.5	3-4-7	11		? ? ?	**Silty CLAY (CL),** medium brown, moist ? ?
						Fine SAND (SP), light to medium brown, moist
20	SPT 20.0-21.5	4-5-5	10	Sample SB12-1 20.0-21.5 ft Small Bag	No tests	
25						Bottom of Boring at 21.5 ft No Groundwater Encountered
30						
35						
40						

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? Estimated break in material type

G - Grain Size Distribution A - Atterberg Limits H - Hydrometera 95833

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 16.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J levee Between Hwy 32 and Sewer Ponds
GPS Coordinates: Latitude: N 39° 44' 40.3" Longitude: W 121° 59' 42.9"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 148.0 ft
							Clayey, Fine Sandy SILT (ML), medium brown, moist
5		SPT 5.0-6.5	2-3-3	6			**Silty SAND (SM),** medium brown, moist
							Increasing darkness with depth
10		SPT 10.0-11.5	4-3-5	8			
							Fine SAND (SP), moist
15		SPT 15.0-16.5	5-8-10	18			
							16.0 ft, Some medium to coarse sand with small gravel pieces.
20							
25							Bottom of Boring at 16.5 ft No Groundwater Encountered
30							
35							
40							

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G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 16.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Top of Existing J levee near Hwy 32
GPS Coordinates: Latitude: N 39° 44' 55.9" Longitude: W 121° 59' 46.6"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 150.0 ft
							Clayey, Fine, Sandy SILT (ML), medium brown, moist
5		SPT 5.0-6.5	1-1-2	3	Sample SB14-1 5.0-6.5 ft Small Bag	G, H, A **ML**	
10		SPT 10.0-11.5	2-3-5	8			
							Silty Fine SAND (SM), medium brown, moist
15		SPT 15.0-16.5	4-6-7	13			
							Moist Fine SAND (SP), medium brown, moist
20							
25							Bottom of Boring at 16.5 ft No Groundwater Encountered
30							
35							
40							

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J LEVEE FOUNDATION INVESTIGATION
SACRAMENTO RIVER AT HAMILTON CITY, CA
Project No. 33.0127.00

SB-14
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Westermann Farms North of Hwy 32
GPS Coordinates: Latitude: N 39° 44' 54.2" Longitude: W 122° 00' 25.0"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 141.0 ft
5		SPT 5.0-6.5	4-5-6	11			**Silty CLAY (CL)**, dark brown, moist **Color change to light brown at 5.0 ft**
10		SPT 10.0-11.5	3-3-6	9			
15		SPT 15.0-16.5	5-6-8	14	SB15-1 15.0-16.5 ft Small Bag	G, H, A CL	
					Groundwater at 17.5 ft on 10/25/00		
20		SPT 20.0-21.5	3-4-4	8			
25		SPT 25.0-26.5	1-1-2	3			
							Sandy Clayey SILT (ML), dark brown, saturated
30		SPT 30.0-31.5	4-5-4	9			
							Fine SAND (SP) with 2-3 inch layers of Silty SAND (ML), Light brown
35		SPT 35.0-36.5	17-18-23	41			**At 36.0 ft includes small gravel**
40		SPT 40.0-41.5	18-14-13	27			Bottom of Boring at 41.5 ft

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Project No. 33.0127.00

SB-15
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Westermann Farms North of Hwy 32
GPS Coordinates: Latitude: N 39° 44' 52.0" Longitude: W 122° 00' 31.8"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 142.0 ft
							Silty CLAY (CL), dark brown, moist
5		SPT 5.0-6.5	6-5-4	9			Color change to Medium brown at 4.0 ft
10		SPT 10.0-11.5	3-4-6	10			
15		SPT 15.0-16.5	\23,50+	50+			
							Gravelly, fine to medium SAND (SP), moist, multicolored (black, gray, white, tan, red) rounded to sub-rounded Gravel up to 2 inches
20		SPT 20.0-21.5			Sample SB16-1 20.0-21.5 ft Small Bag	G **SP**	
					Groundwater at 23.4 ft on 10/25/00		
25		SPT 25.0-26.5	20-26-19	45			
					Sample SB16-2 25.5-26.5 ft Small Bag	G **GW**	**Sandy GRAVEL (GW)**, saturated, multicolored (black, gray, white, tan, red) rounded to sub-rounded
30		SPT 30.0-31.5	22-17-16	33			
35		SPT 35.0-36.5	14-11-8	19	Sample SB16-3 35.0-36.5 ft Small Bag	No tests	
40		SPT 40.0-41.5	24-26-29	55			Bottom of Boring at 41.5 ft

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SACRAMENTO RIVER AT HAMILTON CITY, CA
Project No. 33.0127.00

SB-16
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 41.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Westermann Farms on Top of Existing J Levee
GPS Coordinates: Latitude: N 39° 45' 33.0" Longitude: W 122° 00' 45.6"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 152.0 ft
							0-1.0 ft Road Base 3 inch angular **Gravel (GP)**
5							**Silty CLAY (CL)**, medium brown, moist
		SPT 5.0-6.5	6-5-4	9			
10		SPT 10.0-11.5	3-4-6	10	Sample SB17-1 10.0-11.5 ft Small Bag	G, H, A **CL**	
15		SPT 15.0-16.5	23, 50+	50+			
							Clayey, Silty, Very Fine SAND (SM), light brown, moist
20		SPT 20.0-21.5					
25		SPT 25.0-26.5	20-26-19	45			**Interbedded layers of fine SAND and and Silty Fine SAND (SP-SM)**
					Groundwater at 29.5 ft on 10/25/00		
30		SPT 30.0-31.5	22-17-16	33			
							Silty Fine SAND (SM), gray / green with 1/4 inch root piece saturated
35		SPT 35.0-36.5	14-11-8	19			
40		SPT 40.0-41.5	24-26-29	55			Bottom of Boring at 41.5 ft

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J LEVEE FOUNDATION INVESTIGATION
SACRAMENTO RIVER AT HAMILTON CITY, CA
Project No. 33.0127.00

SB-17
1 of 1

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

LOG OF SOIL BORING

Date Completed: 10/25/00
Logged By: Thomas W. Smith
Total Depth: 46.5 ft

Sampler: Standard Penetration Test (SPT)
Driller: Taber Consultants
Rig: CME-45
Location: Westermann Farms on Top of Existing J Levee
GPS Coordinates: Latitude: N 39° 45' 40.6" Longitude: W 122° 01' 14.3"

Depth (ft)	Sample	Sample Type	SPT - blows per 0.5 ft	SPT N Value	Sample Number, Description and Depth (ft)	Laboratory Test and U.S.C.S. Classification	Field Description
							Approximate Ground Surface Elevation: 152.0 ft
							0-1.0 ft Road Base 3 inch angular **Gravel (GP)**
5							**Silty CLAY (CL),** dark brown, moist
		SPT 5.0-6.5	4-5-4	9	no recovery		
10		SPT 10.0-11.5	3-3-5	8	Sample SB18-1 10.0-11.5 ft Small Bag	G, H, A **CL**	
15		SPT 15.0-16.5	4-6-8	14			
20		SPT 20.0-21.5	3-3-4	7			**Color change to medium brown, increase in silt content**
25		SPT 25.0-26.5	3-5-6	11			
							Sandy Silty CLAY (CL), medium brown, moist to saturated
					Groundwater at 27.0 ft on 10/25/00		
30		SPT 30.0-31.5	4-6-8	14			
							Layers of Silty CLAY (CL), medium brown and light olive 30.5-31.0 ft Medium Brown 31.0-31.5 ft Light Olive
35		SPT 35.0-36.5	7-9-9	18	Sample SB18-2 35.0-36.5 ft Small Bag	No tests	
40		SPT 40.0-41.5	27-29-42	71	Sample SB18-3 41.0-41.5 ft	No tests	

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TNC Foundation Investigation
J Levee Relocation
Project No. 33.0127.00

SB-18
1 of 2

G - Grain Size Distribution A - Atterberg Limits H - Hydrometer

Appendix 3

Soil Logs From Department of Water Resources

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 3
HOLE NO. BH-1
ELEV. ____ FEET
DEPTH 51 FEET

PROJECT "J" LEVEE INVESTIGATION
FEATURE N/A
LOCATION
CONTR. LAYNE-CHRISTENSEN DRILL RIG CME-750

DATE DRILLED 7/26/2000
ATTITUDE VERTICAL
LOGGED BY B. ROSS.C. GOLSH
DEPTH TO WATER 20.0'

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (ELEV) – 2.5	CL	QUATERNARY TERRACE DEPOSITS 0-10.0' 0-2.5' Silty Clay, dry to slightly moist, firm; dark grayish-brown (2.5Y4/2).	1	DS	Shelby Tube-150lbs.
				AD	
5.0 – 10.0	ML	5.0'-7.5 Clayey Silt, dry, crumbly; light olive brown (2.5Y5/3).	2	DS	Shelby Tube-200lbs.
8.0 (ELEV)				AD	
10.0	ML	TEHAMA FORMATION 10.0'-51.0' 10.0'-10.5' Silt, minor clay, slightly moist, stiff, very slightly plastic; yellowish-brown (10YR5/6).	3	DS	Shelby Tube-350lbs. for 6.0"
				AD	
12.0	GC	12.0'-13.5' Clayey Silt with fine gravel, slightly moist, stiff; yellowish-brown (10YR5/6).	4	DS	California Modified Blow Count-8,9,16
14.0				AD	
15.0	CL	15.0'-16.5' Silty Clay, slightly moist, firm, slightly plastic, CaCO2 present, mottled; yellowish-brown and grayish-brown (10YR5/4 & 10YR5/2).	5	DS	California Modified Blow Count-14,16,20

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 2 of 3
HOLE NO. BH-1

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0 (ELEV.)			5	DS	
				AD	
18.0	CL	17.0'-18.5' Silty Clay, firm, slightly plastic, CaCO2 present, mottled; light brownish-gray (10YR6/2).	6	DS	California Modified Blow Count-14,15,23
				AD	▽ 20'
20.0	CL/ML	20.0'-21.5' Silty Clay and Clayey Silt, both slightly moist, firm to stiff; light brownish-gray to light yellowish-brown (2.5Y6/2 &10YR6/4).	7	DS	California Modified Blow Count-11,17,23
22.0				AD	
	CL	22.5'-24.0' Silty Clay, soft to firm, slightly plastic, lightly mottled; light olive brown (2.5Y5/4).	8	DS	California Modified Blow Count-11,13,16
24.0 (ELEV.)				AD	
26.0	CL	25.0'-26.5' Silty Clay, moist, firm, very slightly plastic; light olive brown (2.5Y5/3). Color change in shoe to yellowish-brown (10YR5/6).	9	DS	California Modified Blow Count-5,7,11
				AD	
28.0	ML	27.5'-29.0' Clayey Silt, stiff, slightly moist; yellowish-brown (10YR5/4).	10	DS	Shelby Tube-400lbs. for 18.0"
				AD	
30.0	CL	30.0'-31.0' Silty Clay, moist, stiff, slightly plastic, mottled; dark brown (7.5YR4/4).	11	DS	California Modified Blow Count-20,38,50
	GC	31.0'-31.5' Clayey Sandy Gravel, sub-angular to sub-rounded clasts of chert and quartz; matrix light brownish-gray (2.5Y6/2).			
32.0				AD	
34.0	GP	32.5'-34.0' Sandy Gravel, minor silt and clay, wet to saturated, clasts sub-angular to sub-rounded quartz and black lithics, maybe greenstone or schists; matrix light brownish-gray (2.5Y6/2).	12	DS	California Modified Blow Count-25,41,38
				AD	
	SM	35.0'-36.0' Silty Sand, fine sand, saturated; yellowish-brown (10YR5/4).	13	DS	California Modified Blow Count-22,25,35

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 3 of 3
HOLE NO. BH-1

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
36.0 (ELEV.)	GP	36.0'-36.5' Sandy Gravel, minor silt and clay, clasts of quartz, chert; matrix yellowish-brown (10YR5/4).	13	DS	
				AD	
38.0	GP	37.5'-39.0' Sandy Gravel, minor silt and clay, clasts of quartz, chert; matrix light olive brown (2.5Y5/4).	14	DS	California Modified Blow Count-26,27,30
				AD	
40.0	SP	40.0'-41.0' Silty Sand, fine sand, saturated; light olive brown (2.5Y5/3). Coarsens down sample, very little fines, quartz and black lithic fragments. Down 6" sample fines again to sand/silt combination.	15	DS	California Modified Blow Count-10,16,40
	SW	41.0'-41.5' Gravelly Sand, fine sand with minor silt; olive brown (2.5Y4/4).			
42.0				AD	
	SW	42.5'-43.5' Gravelly Sand, wet, all clasts, no fines.	16	DS	California Modified Blow Count-14,21,32
44.0 (ELEV.)	CL	43.5'-44.0' Silty Clay, interbedded fine sand, wet; brown (10YR4/3).		AD	
	SM	45.0'-46.0' Silty Sand, interbedded fine sand to gravel, moist, no cohesion, coarsens up sample, less fines, not consolidated; olive brown (2.5Y4/4).	17	DS	California Modified Blow Count-14,21,32
46.0		46.0'-46.5' Silty Sand, fine sand, minor gravel and clay blebs; olive brown (2.5Y4/4).			
				AD	
48.0	GP	48.0'-49.0' Sandy Gravel, minor silt, wet, clasts sub-angular to sub-rounded quartz and chert; matrix dark grayish-brown (2.5Y4/2).	18	DS	California Modified Blow Count-12,75,33
	SM	49.0'-49.5' Silty Sand, fine sand, some gravel, moist to wet; dark grayish-brown (2.5Y4/2).		AD	
50.0	GP	50.0'-51.0' Sandy Gravel, fine to medium sand, gravel sub-angular to sub-rounded clasts of quartz and chert to 2" diameter, saturated, no matrix. Down sample increased silt; matrix olive brown (2.5Y4/4).	19	DS	California Modified Blow Count-33,50 for 6"
					BOH-51.0'
52.0					
54.0					

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DRILL HOLE LOG

SHEET 1 of 3
HOLE NO. BH-2
ELEV. ______ FEET
DEPTH 52.0 FEET

PROJECT "J" LEVEE INVESTIGATION
FEATURE N/A
LOCATION
CONTR. LAYNE-CHRISTENSEN DRILL RIG CME-750

DATE DRILLED 7/26/2000
ATTITUDE VERTICAL
LOGGED BY B. ROSS.C. GOLSH
DEPTH TO WATER Not Taken

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (ELEV)		QUATERNARY TERRACE DEPOSITS 0-12.0'			
	CL	0-2.5' Silty Clay, dry to slightly moist, stiff; light olive brown (2.5Y5/3).	1	DS	Shelby Tube-150lbs.
2.0 – 4.0				AD	
6.0	CL	5.0' Silty Clay, dry, stiff; very dark grayish-brown (2.5Y3/2).	2	DS	Shelby Tube-200lbs.
	ML	7.5' Clayey Silt, stiff, slightly moist; dark yellowish-brown (10YR4/4).			
8.0 (ELEV)				AD	
10.0	ML	10.0'-12.0' Clayey Silt, minor fine sand, slightly moist, crumbly; dark grayish-brown (10YR4/2).	3	DS	Shelby Tube-350lbs.
12.0		TEHAMA FORMATION 12.0'-52.0'			
	SM	12.0'-12.5' Silty Sand, very fine sand, minor clay, stiff, organics; yellowish-brown (10YR5/6).		AD	
14.0	CL	15.0'-17.0' Silty Clay, stiff, slightly moist, slightly plastic, mottled, lots of CaCO2; light yellowish-brown (2.5Y6/3).	4	DS	Shelby Tube-350lbs. for 24.0"

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 2 of 3
HOLE NO. BH-2

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0 (ELEV.)			4	DS	
18.0				AD	
20.0	CL	20.0'-22.0' Silty Clay, stiff, slightly plastic, mottled, lots of CaCO2; light yellowish-brown (2.5Y6/3).	5	DS	Shelby Tube-400lbs. for 24.0"
22.0				AD	
24.0 (ELEV.)					
26.0	GM	25.0'-27.5' Sandy Gravel, minor silt and clay, wet to saturated; matrix yellowish-brown (10YR5/4).	6	DS	Shelby Tube-350lbs.
28.0				AD	
30.0	CL/ML	30'-31.5' Silty Clay and Clayey Silt, moist, stiff, plastic, some organics; light reddish-brown to yellowish-brown (2.5YR6/3 &10YR5/6).	7	DS	California Modified Blow Count-15,28,37
32.0				AD	
34.0					
	CL/ML	35.0'-36.5' Silty Clay and Clayey Silt, moist, stiff, slightly plastic, some organics; (continued next page)	8	DS	California Modified Blow Count-15,19,24

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The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 3 of 3
HOLE NO. BH-2

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
36.0 (ELEV.)	CL/ML	Light reddish-brown to yellowish-brown (2.5YR6/3 to 10YR5/6).	8	DS	
38.0				AD	
40.0	ML	40.0'-42.5' Clayey Silt, moist, stiff, slightly mottled; brown (10YR5/3).	9	DS	Shelby Tube-300lbs.
42.0				AD	
44.0 (ELEV.)	GM	45.0'-46.0' Silty Sandy Gravel, wet, clasts sub-angular to sub-rounded, quartz and chert to 2.5" diameter; matrix brown (7.5YR5/4).	10	DS	Shelby Tube-450lbs. for 12.0"
46.0					
48.0				AD	
50.0	GC	50.0'-50.75' Clayey Silty Gravel, wet, dense; matrix yellowish-brown (10YR5/4).	11	DS	California Modified Blow Count-32,50 for 3.0"
	GM	51.0'-52.0' Silty Sandy Clayey Gravel, wet, lots of quartz & lithics; yellowish-brown (10YR5/4).	12	DS	California Modified Blow Count-39,50 for 5.0"
52.0					BOH-52.0'
54.0					

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DEPARTMENT OF WATER RESOURCES

SHEET 3 of 3
HOLE NO. BH-3

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
36.0 (ELEV.)			12	DS	Shelby Tube-200 lbs.
38.0	ML	37.5'-40.0' Silt, minor clay and very fine sand, soft; dark yellowish-brown (10YR4/4).	13	DS	Shelby Tube-250 lbs.
40.0	ML	40.0'-42.0' Clayey Silt, minor fine sand, moist; light olive brown (2.5Y5/4).	14	DS	Shelby Tube-200-300 lbs. for 24.0"
42.0				AD	
44.0 (ELEV.)	CL	45.0'-46.0' Silty Clay, moist, slightly plastic; light olive brown (2.5Y5/4).	15	DS	California Modified Blow Count-6,16,33
46.0	SW	46.0'-46.5' Gravelly Sand, fine sand to fine gravel, angular; light yellowish-brown (2.5Y6/3).			BOH-46.5'
48.0					
50.0					
52.0					
54.0					

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DRILL HOLE LOG

SHEET 1 of 3
HOLE NO. BH-4
ELEV. ______ FEET
DEPTH 51.5 FEET

PROJECT "J" LEVEE INVESTIGATION
FEATURE N/A
LOCATION
CONTR. LAYNE-CHRISTENSEN DRILL RIG CME-750

DATE DRILLED 7/25/2000
ATTITUDE VERTICAL
LOGGED BY B. ROSS,C. GOLSH
DEPTH TO WATER Not Taken

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (ELEV.)	CL	QUATERNARY TERRACE DEPOSITS 0-17.75'	1	DS	Shelby Tube-50lbs. for 18.0"
2.0		0-1.5' Silty Clay, firm, slightly plastic, fresh rootlets; very dark grayish-brown (10YR3/2).		AD	
4.0					
6.0	ML	5.0'-6.25' Clayey Silt, some fine sand, moist, soft, plastic; yellowish-brown (10YR5/4). 6.25'-7.5' Clayey Silt, soft to firm, slightly plastic; brown (10YR4/3).	2	DS	Shelby Tube-150lbs.
8.0 (ELEV.)				AD	
10.0	CL	10.0'-11.5' Sandy Clay, fine to medium sand, slightly moist, stiff; dark brown (7.5YR4/4).	3	DS	Shelby Tube-350lbs. for 18.0"
12.0				AD	
	CL	12.5'-14.0' Silty Clay, minor fine sand, slightly moist, slightly plastic, stiff; brown (10YR4/3).	4	DS	California Modified Blow Count-14,17,17
14.0				AD	
	CL	15.0'-15.75 Silty Clay, slightly moist, slightly plastic, stiff; brown (10YR4/3).	5	DS	California Modified Blow Count-7,13,15

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DEPARTMENT OF WATER RESOURCES

SHEET 2 of 3
HOLE NO. BH-4

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0 (ELEV.)	SC	15.75'-16.5' Clayey Sand, fine sand, slightly moist; light yellowish-brown (2.5Y6/3).	5	DS	
		TEHAMA FORMATION 17.75'-51.5'		AD	
18.0	ML	17.5'-19.0' Clayey Silt, moist, soft; light olive to grayish-brown (2.5Y5/2-3).	6	DS	California Modified Blow Count-7,8,13
				AD	
20.0	ML	20.0'-20.75' Clayey Silt, moist, soft, slightly plastic; grayish-brown (2.5Y5/2).	7	DS	California Modified Blow Count-7,15,23
	CL	20.75'-21.5' Silty Clay, moist, firm, mottled; brown (10YR5/3).			
22.0				AD	
	ML	22.5'-25.0' Clayey Silt, slightly moist, non-plastic, mottled; brown to light brownish gray (10YR4/3&10YR6/2).	8	DS	Shelby Tube-200 lbs.
24.0 (ELEV.)					
26.0	ML	25.0'-27.5' Clayey Silt, moist, slightly plastic, mottled; greyish-brown (10YR5/2).	9	DS	Shelby Tube-150lbs.
28.0				AD	
30.0	CL	30.0'-31.5' Silty Clay, slightly moist, firm, mottled; yellowish-brown (10YR5/4).	10	DS	Shelby Tube-400lbs. for 18.0"
32.0				AD	
	CL	32.5'-34.0' Silty Clay, slightly moist, firm, mottled; light olive brown (2.5Y5/3) to yellowish-brown (10YR5/4).	11	DS	California Modified Blow Count-14,18,29
34.0				AD	
	ML	35.0'-36.5' Clayey Silt, slightly moist, soft, not mottled; yellowish- brown (10YR5/4).	12	DS	Shelby Tube-350lbs. for 18.0"

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SHEET 3 of 3
HOLE NO. BH-4

DRILL HOLE LOG

PROJECT & FEATURE

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
36.0 (ELEV.)			12	DS	
				AD	
38.0	CL	37.5'-39.0' Clay, some silt, moist, soft, slightly plastic; light olive brown (2.5Y5/3) to light yellowish-brown (2.5Y6/3).	13	DS	California Modified Blow Count-10,14,19
				AD	
40.0	ML	40.0'-41.5' Clayey Silt, moist, crumbly, not plastic, possibly old soil; brown (10YR5/3).	14	DS	Shelby Tube-400lbs. for 18.0"
42.0				AD	
	ML	42.5'-44.0' Clayey Silt, moist, soft, slightly plastic; brown (10YR4/3).	15	DS	California Modified Blow Count-10,11,14
44.0 (ELEV.)				AD	
46.0	ML	45.0'-47.5' Clayey Silt, moist, firm, crumbly; brown (10YR5/3).	16	DS	Shelby Tube-250lbs.
48.0				AD	
50.0	ML	50.0'-51.5' Clayey Silt, minor fine sand, moist, crumbly, slight mottling, some organics; brown (10YR5/3).	17	DS	California Modified Blow Count-28,12,18
52.0					BOH-51.5'
54.0					

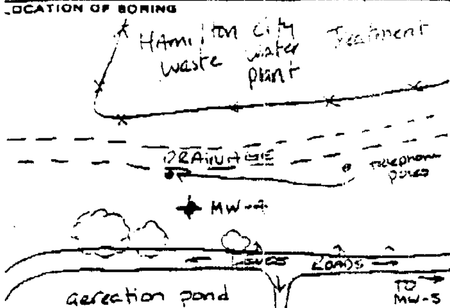
Appendix 4

Soil Logs From Brown & Caldwell

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-0[illegible] [illegible]; Page 2

BROWN AND CALDWELL — BOREHOLE LOG

LOCATION OF BORING



CLIENT	Holly [illegible]
LOCATION	Hamilton City
JOB NO.	[illegible]
BORING NO.	MW-4
WATER LEVEL	
TIME	
DATE	
CASING DEPTH	
SHEET	1 OF 2
DRILLING START TIME	0950
DRILLING FINISH TIME	1135
DRILLING START DATE	9/23/91
DRILLING FINISH DATE	9/23/91
DRILLING CONTRACTOR	[illegible] Drilling
DRILLING METHOD	hollow stem auger [illegible]
SAMPLING METHOD	[illegible] 3 [illegible] mod split spoon [illegible]
N/S	
E/W	
ELEV.	
SURFACE CONDITIONS	[illegible]

WELL CONST. CASING	WELL CONST. ANNULUS	SAMPLER TYPE	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
	cement grout	auger	0–4	GM	0-5' Logged by [illegible]: Silty Gravel w/ some clay, [illegible]% silt, 20% gravel up to [illegible] mm, [illegible] plastic clay, light tan [illegible]
blank	bent.	SS	5–7		5-7' same as above
2"			7–9	ML	7-9.5' Clayey silt - [illegible] streaks (Fe staining) [illegible] med. stiff 30% Clay [illegible]% silt
			9–10		9.5-13' Sand w/ some silt, [illegible] brn, 95% v. fine to fine sand, sub-round to S.A., [illegible] mica, [illegible] v. well sorted, soft [illegible]
	sand		11–13	SP	13-17 Silty Sand: [illegible] brn, 90% well sorted fine sand, 10% silt, organics at bottom, [illegible] saturated at [illegible]
slot			13–14		
0.020"	3		14–16	SM	17-19 Clay w/ some silt, [illegible]% clay, high plasticity, [illegible] [illegible] blocks, [illegible], med. dense, saturated.
slot	NC	continuous	17–18	CL	18-20 Silty sand [illegible]% v. fine to fine sands, 15% silt, [illegible] v. well sorted, black, micaceous, saturated.
2"			19–20	SM	

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-0[illegible] [illegible]; Page 3

BROWN AND CALDWELL — BOREHOLE LOG

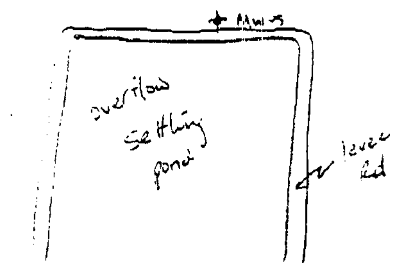
LOCATION OF BORING	
CLIENT	Holly Sugar [illegible]
LOCATION	Hamilton City
JOB NO.	[illegible]
BORING NO.	MW-#4
SHEET	2 of 2
WATER LEVEL	
TIME	
DATE	
CASING DEPTH	
DRILLING	START TIME / FINISH TIME; DATE / DATE
DRILLING CONTRACTOR	
DRILLING METHOD	
SAMPLING METHOD	
N/S	E/W	ELEV.
SURFACE CONDITIONS	

WELL CONST. CASING	WELL CONST. ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALL OUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
2" Sch 40, PVC - 0.020" Screen	No. 3 Sand					20		20-25 NR - [illegible]
		NL				22		
		NL				23	NR	
		SS				25		25-26 1/2 Sand: [illegible], about 5% silt, [illegible], many [illegible], some volcanics, [illegible], some coarse grains, [illegible]
						26	SW	
		NL				28	NL	
						30	SW	30-31 Same [illegible] as above
		SS				31	SP	31-31.5 Sand: [illegible] Sand: fine to v. coarse ([illegible]), [illegible], metamorphics, [illegible], red, [illegible], white, yellow, gradational [illegible] contact
		NL				33		
		SS				35		35-36 1/2 Sands as above, fines upward sequence - [illegible] from [illegible] samples.
						36	SP	
						37-40		

Sent By: RWQCB SACRAMENTC; 916 255 3015; May-7-01 9:12; Page 4

BROWN AND CALDWELL – SURFACE LOG

LOCATION OF BORING



CLIENT: [illegible]

LOCATION:

JOB NO.: [illegible]

BORING NO.: MW-5

SHEET 1 OF 2

WATER LEVEL:

TIME:

DATE:

CASING DEPTH:

DRILLING CONTRACTOR: Woodward Drilling

DRILLING METHOD: Hollow stem auger 8"

SAMPLING METHOD:

DRILLING	START	FINISH
TIME	14:20	16:00
DATE	9/23/91	9/23/91

N/S: E/W: ELEV.:

SURFACE CONDITIONS: [illegible]

WELL CONST. (CASING, ANNULUS) | SAMPLER TYPE | INCHES DRIVEN / INCHES RECOVERED | SAMPLE NO. / SAMPLE DEPTH | BLOWS/6" SAMPLER | DEPTH IN FEET | SOIL CALLOUT

Well construction (handwritten): blank PVC Sch 40, 2" — cement/bentonite grout; bent.; screen — sand; 2" 0.020 slot; Continuous sampler

DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
0–5	SC	0-4.5 Clayey sand & silt 60% silt, 30% v. fine sand, 10% low plastic clay, Fe streaks micaceous, med. stiff, dry. Some organics (wood [illegible] ...)
		4.5-6.2 Silty sand 80% v. fine micaceous sand, 20% silt, soft, finely interbedded clay seams locally, orange-brown.
		6.2-7.4 Silty clay w/ trace of sand; 80% med. plastic clay w/ silty sand stringers 15% silt 5% v. fine sand micaceous med-orange brown w/ black stringers (upper 6" silty sand) sl. moist.
5–7	SM	
7	CL	7.4-8 Sand 85% v. fine to fine sands well sorted, 15% silt, soft, loose, sl. moist, orange-brown.
8	SP	
9	CL	8-9.2 Silty clay 60% clay, med. plastic, 35% silt 5% v. fine sands in silty areas, color streaks from orange-brn to black (clays). Clay zones up to 6" thick.
9–10	SM	
11–13	NR	9.2-10 Silty sand w/ clay zones, 80% fine to m. c sands, well sorted, bottom 4" coarser, moist, orange-brown to gray → black clays, [illegible] zones finely inter-bedded w/ some [illegible]
14	SM	10-13.5 NR
15–17	NR	13.5-15 Silty sand same as above but color grading from dk brown to blk, blk zones [illegible] 30% clay, 40% silt, 30% v. fine sands – saturated. Shoe had pieces of decomposed wood & bog sediments.
17–18	Pt.	
19	SM	
20		

BROWN AND CALDWELL — BOREHOLE LOG

LOCATION OF BORING	CLIENT Hall [illegible]	BORING NO. Mw-5
See Pg 1	LOCATION	JOB NO.
	WATER LEVEL	SHEET 2 OF 2
	TIME	DRILLING
	DATE	START TIME / FINISH TIME
	CASING DEPTH	
	DRILLING CONTRACTOR	DATE / DATE
	DRILLING METHOD	
	SAMPLING METHOD	

N/S | E/W | ELEV.

SURFACE CONDITIONS

NR = No recovery

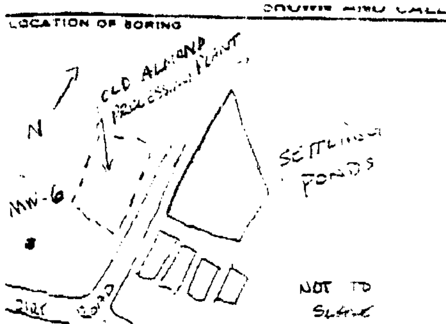
NL = Not logged

WELL CONST. CASING	ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
		NR				20	NR	15-17 NR
						1		17-17.3 decomposed wood debris - all organic [illegible]
						2		13.3-20 Silty Sand, 90% fine to med. sand but well sorted, micaceous 10% silt loose, saturated [illegible]
						3		
						4		20-25 - NR - lost sample
						5		
		SS				6	SW	25-26.5 100 [illegible] coarse sands & pebbles. Rest are v. coarse sands to gravel, w/ 10% silt, well graded gravels up to 100 mm. Channel deposit. It gray overall color. Pebbles are metamorphics, basalts, granites & overy color
	Sand	NL				7		
						8		
						9	NL	
		SS				30		31-31.5 coarse sands w/ small gravels (same as above sands)
						1	SW	
	#3					2		
		NL				3		
						4		35-36.5 Coarse Sands, [illegible], same as above [illegible] gravels
						5		
		SS				6	SW	TD @ 35'
						7		
						8		
						9		
						0		

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 8:13; Page 6/11

BROWN AND CALDWELL — BOREHOLE LOG

LOCATION OF BORING



CLIENT	Holly Sugar Corp
LOCATION	Hamilton City
JOB NO.	12278
BORING NO.	MW-6
WATER LEVEL	
TIME	
DATE	
CASING DEPTH	
SHEET	1 of 3
DRILLING CONTRACTOR	Woodward Drilling
DRILLING METHOD	Hollow Stem Auger Wireline System
SAMPLING METHOD	[illegible] 3 Ca. mod. split spn.

DRILLING	START	FINISH
TIME	1505	1630
DATE	9/24/91	9/24/91

N/S E/W ELEV.

SURFACE CONDITIONS: few weeds, dry, hot (100°F+)

ABOVE GRND COMPLETION w/ STEEL MONUMENT

WELL CONST. CASING	ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
						0		0-5': Silt w/ some Clay: 90% silt 10% plastic clay, lt brown, dry, loose.
						1		
						2	ML	
						3		
						4		5-10: silty Clay: 80% med plastic clay 20% silt, lt brown, dry, hard, dense, some root traces, slightly moist at 10'
	slurry					5		
BLANK						6		
	bentonite-cement					7		
PVC		CA				8		10-20: Same as above except for mottling of orange and black, becoming more plastic. at 18' trace of v. fine sands.
SCH 40	3/8					9		
2"	BENT	continuous				10		
						11		
						12	CL	
						13		
						14		
	SAND					15		
						16		
Slot	3					17		
	NO					18		
						19		19'- 1st Saturated Sands
						20		

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 9:14; Page 7/11

BROWN AND CALDWELL — BORING LOG

LOCATION OF BORING	CLIENT [illegible]	BORING NO. MW-6
See pg. 1	LOCATION	JOB NO.
	WATER LEVEL	SHEET 2 OF 3
	TIME	DRILLING
	DATE	START / FINISH
	CASING DEPTH	TIME / TIME
	DRILLING CONTRACTOR	DATE / DATE
	DRILLING METHOD	
	SAMPLING METHOD	

N/S | E/W | ELEV.

SURFACE CONDITIONS

NL = not logged

DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
20	NR	20 - 25 - No recovery; [illegible] in sands that [illegible] core barrel. Switch to sampling every 5 ft.
25	SW	25-26 1/2 Sand poorly sorted, 5% silt is matrix, [illegible] fining sequence w/ silt layer on top, lt gray, saturated; [illegible] pebbles
27	NR	
30	SW	30 - 31.5 Sand: same as above but more pebbles (up to 5 mm in zones), poorly sorted, lt gray, saturated.
32	NL	
35	SW	35 - 36 1/2 same as above.
37	NL	
40		

Well construction (vertical annotations): Sch 40 PVC 0.020" Slotted; 2"; Annulus: Sand, #3; Sampler type: core, cont; SS (25, 30, 35).

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 9:14; Page 7/11

LOCATION OF BORING

See pg. 1

CLIENT	Holly Sugar Co.				BORING NO. MW-6
LOCATION		JOB NO.			SHEET 2 OF 3
WATER LEVEL					DRILLING
TIME					START / FINISH
DATE					TIME / TIME
CASING DEPTH					DATE / DATE
DRILLING CONTRACTOR					
DRILLING METHOD					
SAMPLING METHOD					

WELL CONST. (CASING, ANNULUS) | SAMPLER TYPE | INCHES DRIVEN / INCHES RECOVERED | SAMPLE NO. / SAMPLE DEPTH | BLOWS/6" SAMPLER | DEPTH IN FEET | SOIL CALLOUT

N/S | E/W | ELEV.

SURFACE CONDITIONS

NL = not logged

MATERIALS ENCOUNTERED AND DRILLING CONDITIONS

Depth (ft)	Sampler type	Soil callout	Materials encountered and drilling conditions
20–25	core	NR	20-25 – No recovery; probably in sands that slid out of core barrel. Switch to sampling every 5 ft.
25–26½	SS	SW	25-26½ Sand, poorly sorted, 5% silt in matrix, upward fining sequence w/ silt layer on top, lt gray, saturated; has pebbles
26½–30		NR	
30–31.5	SS	SW	30-31.5 Sand, same as above but more pebbles (up to 5 mm in zones), poorly sorted, lt gray, saturated.
31.5–35		NL	
35–36½	SS	SW	35-36½ same as above.
36½–40		NL	

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 9:14; Page 8/11

BROWN AND CALDWELL — [illegible]

LOCATION OF BORING

See pg [illegible]

CLIENT	[illegible]			BORING NO.	MW-6
LOCATION		B&C NO.		SHEET	3 OF 3
WATER LEVEL				DRILLING	
TIME				START	FINISH
DATE				TIME	TIME
CASING DEPTH					
DRILLING CONTRACTOR				DATE	DATE
DRILLING METHOD					
SAMPLING METHOD					

N/S | E/W | ELEV.

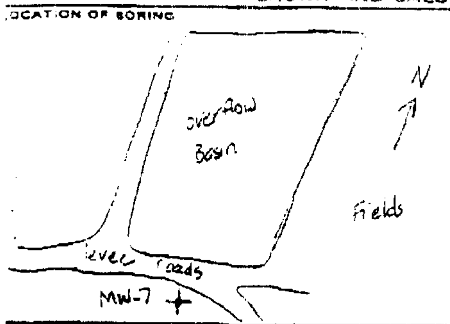
SURFACE CONDITIONS

WELL CONST. CASING	ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
						40		Gravelly
		[illegible]					GW	40 - 41½ - V Sand, poorly sorted coarse to pebble, increase in pebbles downward.
						1		
						2		
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		
						1		
						2		
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 8:14; Page 9/1[illegible]

BROWN AND CALDWELL — BOREHOLE LOG

LOCATION OF BORING



CLIENT	[illegible]
LOCATION	Hamilton City
JOB NO.	[illegible]328
BORING NO.	MW-7
SHEET	1 OF 3
WATER LEVEL	
TIME	
DATE	
CASING DEPTH	
DRILLING START TIME	0809
DRILLING FINISH TIME	11:10
DRILLING START DATE	9/24/01
DRILLING FINISH DATE	9/24/01
DRILLING CONTRACTOR	Woodward Drilling
DRILLING METHOD	[illegible] Auger
SAMPLING METHOD	[illegible] core [illegible] split spoon
N/S	
E/W	
ELEV.	
SURFACE CONDITIONS	[illegible] levee road

WELL CONST. CASING	ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
	grout					0–5	ML	0-5 clayey silt 70% silt 30% clay, local [illegible] soft [illegible] sl. plastic when moist med. brown, gravels @ 4'
	cement	cored				5–10	NR	5-20 NR [illegible] in core barrel, cuttings [illegible] gravels w/ silty matrix, pebbles up to [illegible] mm
	bentonite					10–12		1st H2O @ [illegible]
	bent seal	continuous				12–15		
	sand					15–17		
screen	#3					17–20		

Sent By: RWQCB SACRAMENTO; 916 255 3015; May-7-01 3:[illegible]5; Page 10/11

BROWN AND CALDWELL — BOREHOLE LOG

LOCATION OF BORING

See Pg 1

CLIENT [illegible]

LOCATION [illegible]

JOB NO.

BORING NO. MW-7

SHEET 2 OF 3

WATER LEVEL

TIME

DATE

CASING DEPTH

DRILLING: START TIME / FINISH TIME; DATE / DATE

DRILLING CONTRACTOR

DRILLING METHOD

SAMPLING METHOD

N/S | E/W | ELEV.

SURFACE CONDITIONS

WELL CONST.: CASING	WELL CONST.: ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
						20		20-25: NR but recovered some coarse sands and [illegible] fell in the core barrel recovered a lot of H_2O. 80% coarse sand, 20% med. [illegible]. black in overall color
						1		
						2		
						3	NR	
						4		25-30: only [illegible] of recovery. Sand: 90% fine to med. coarse black sands in a [illegible] matrix; sand is well sorted
						5		
						6		
0.020" slotted	Sand #3	core				7		
						8	GW	
						9		
						30		30-40 - NR - probably gravels
						1		
						2		
						3		
2" Sch 40 PVC		continuous				4		
						5	GW?	
						6		
						7		
						8		
						9		
						40		

LOCATION OF BORING

CLIENT		BORING NO.
LOCATION	JOB NO.	MW-7
WATER LEVEL		SHEET 3 OF 3
TIME		DRILLING
DATE		START TIME / FINISH TIME
CASING DEPTH		
DRILLING CONTRACTOR		DATE / DATE
DRILLING METHOD		
SAMPLING METHOD		

N/S | E/W | ELEV.

SURFACE CONDITIONS

WELL CONST. CASING	ANNULUS	SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	SAMPLE NO. / SAMPLE DEPTH	BLOWS/6" SAMPLER	DEPTH IN FEET	SOIL CALLOUT	MATERIALS ENCOUNTERED AND DRILLING CONDITIONS
						40	SP	40 - 41.5 Sands [illegible] upward sequence well sorted [illegible] sequence.
						1		
						2		Sands are [illegible] same as previous wells MW-[illegible] -5
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		
						1		
						2		
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		

Appendix 5

Laboratory Analysis of the Glenn Colusa Canal-Excavated Material

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION TEST SUMMARY

DIVISION OF ENGINEERING
CIVIL ENGINEERING
DAMS AND CANALS SECTION

PROJECT: Hamilton City **FEATURE:** ______ Sheet 1 of X

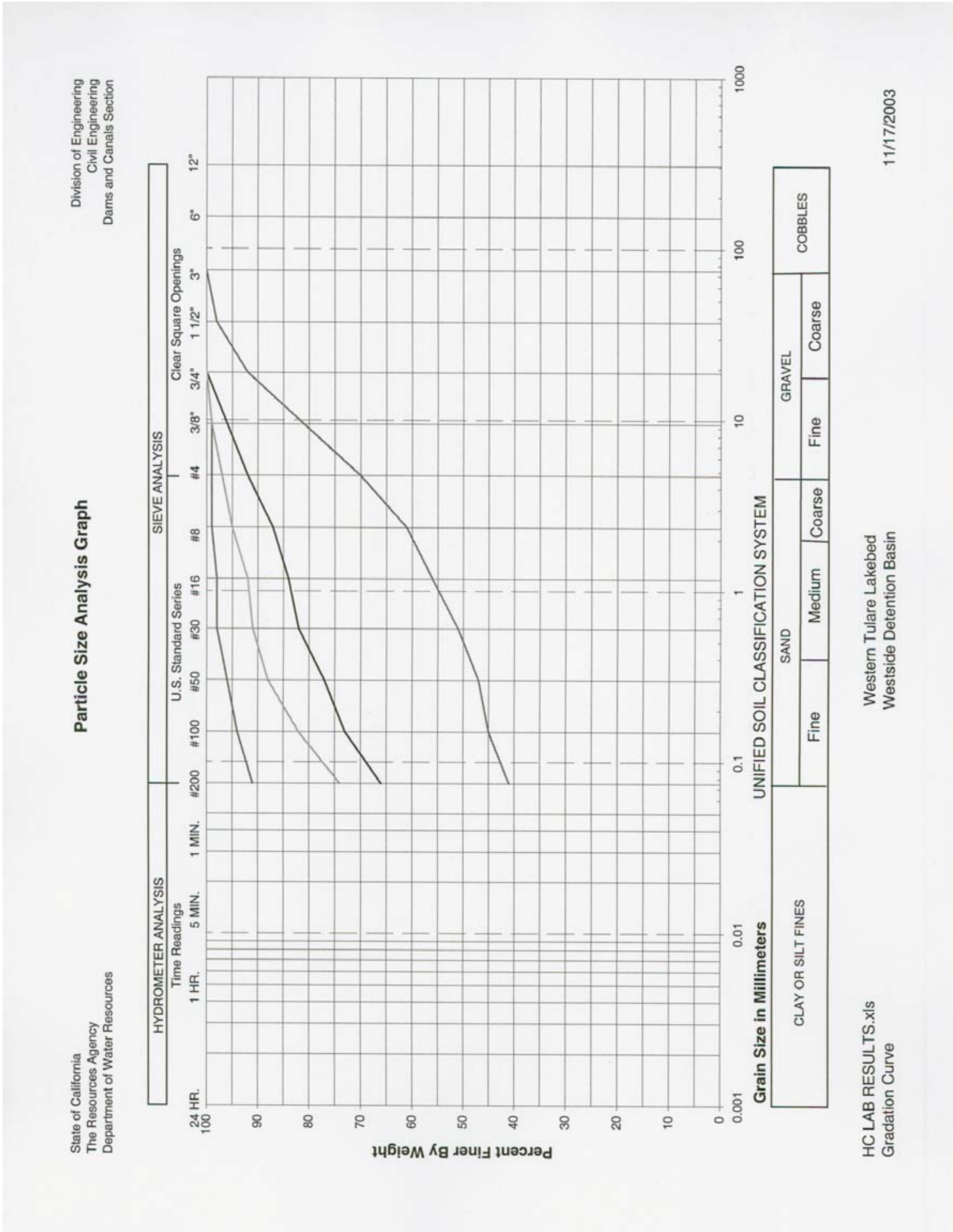
LAB. NO.	HOLE NO.	F.S. NO.	DEPTH (feet)	Gravel 6.0" 152 mm	Gravel 3.0" 75 mm	Gravel 1.5" 37.5 mm	Gravel 3/4" 19 mm	Gravel 3/8" 9.5 mm	Sand 4 4.75 mm	Sand 8 2.36 mm	Sand 16 1.18 mm	Sand 30 0.6 mm	Sand 50 0.3 mm	Sand 100 0.15 mm	Sand 200 0.075 mm	Hydrometer Silt & Clay 5M 0.005 mm	Hydrometer Silt & Clay 2M 0.002 mm	Hydrometer Silt & Clay 1M 0.001 mm	Atterberg Limits L.L.	Atterberg Limits P.I.	Moisture Content %	Percent Organics	Group Symbol	Group Name
03-1150		#1	0.5 - 1.0				100	99	99	99	98	98	96	94	91				35	16			CL	Lean clay
03-1151		#2					100	96	92	87	84	82	77	73	66				33	16			s(CL)	Sandy lean clay
03-1152		#3			100	98	92	81	70	61	56	51	47	45	41				30	14			(GC)s	Clayey gravel with sand
03-1153		#4					100	99	97	95	92	91	88	82	74				32	15			(CL)s	Lean clay with sand

(Column groups: PERCENT FINER — MECHANICAL ANALYSIS (GRAVEL, SAND); HYDROMETER (SILT & CLAY); CLASSIFICATION)

DATE: 11/14/2003
INITIAL: djn
REQUEST NO.: 2003-36

REMARKS: ______

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD


Particle Size Analysis Graph
State of California
The Resources Agency
Department of Water Resources
Division of Engineering
Civil Engineering
Dams and Canals Section
HYDROMETER ANALYSIS
Time Readings
24 HR.
1 HR.
5 MIN.
1 MIN.
SIEVE ANALYSIS
U.S. Standard Series
Clear Square Openings
#200
#100
#50
#30
#16
#8
#4
3/8"
3/4"
1 1/2"
3"
6"
12"
Percent Finer By Weight
Grain Size in Millimeters
UNIFIED SOIL CLASSIFICATION SYSTEM
CLAY OR SILT FINES
SAND
Fine
Medium
Coarse
GRAVEL
Fine
Coarse
COBBLES
HC LAB RESULTS.xls
Gradation Curve
Western Tulare Lakebed
Westside Detention Basin
11/17/2003

Appendix C5.

CIVIL DESIGN

Hamilton City Flood Damage Reduction And Ecosystem Restoration Feasibility Study

Civil Design
Table of Contents

I. INTRODUCTION 1
A. Site Location. 1
B. Study Area Description 1
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A. Design Alternatives 2
B. Description of Alternative Plans 2
C. Recommended Plan 3
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IV. RELOCATIONS. 4
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B. With Project (Recommended Plan) Drainage Features 9
VI. HAUL ROUTES 9

Hamilton City Flood Damage Reduction
And Ecosystem Restoration Feasibility Study
Appendix C5 - Civil Design

I. Introduction

A. Site Location.

The Hamilton City study area is located in Glenn County about 5 miles west of Chico on State Highway 32 along the right bank of the Sacramento River and about 85 miles north of Sacramento. See Figure C5-1.

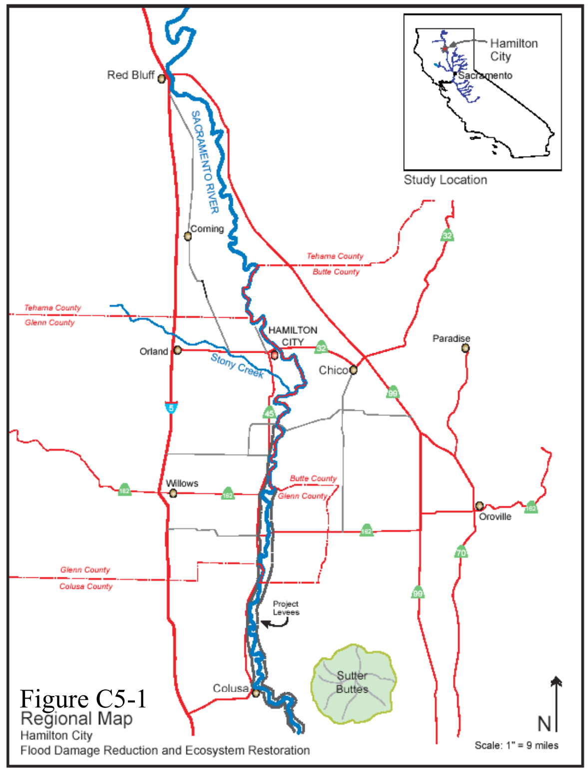

Figure C5-1
Regional Map
Hamilton City
Flood Damage Reduction and Ecosystem Restoration

B. Study Area Description

The study area includes Hamilton City and the surrounding rural area. The study area is bounded by the Sacramento River to the east and the Glenn Colusa Canal to the west and extends about two miles north and six miles south of Hamilton City. Hamilton City has a population of about 2,000 people. Surrounding land use is typically agricultural with fruit and nut orchards being the primary crops.

An existing private levee, constructed by landowners in about 1904 and known as the "J" levee, provides some flood protection to the town and surrounding area. The "J" levee, however, is not constructed to any formal engineering standards and is largely made of silty sand soil. It is extremely susceptible to erosion and flood fighting is necessary to prevent levee failure and flooding when river levels rise. Since the construction of Shasta Dam in 1945, flooding in Hamilton City due to failure of the "J" levee has occurred once (1974). In addition, extensive flood fighting has been necessary to avoid flooding in 1983, 1986, 1995, 1997, and 1998. Currently, the Sacramento River is actively eroding into the toe of the levee at the northern end of the study area. Glenn County has built a backup levee, about 1,000 feet in length, to protect the community in the event the toe erosion causes failure at the northern end of the "J" levee.

II. Site Selection.

A. Design Alternatives

Design alternatives for different levels of flood protection were also investigated. Each design provides a reliability of passing an event at 90-percent confidence relative to the *n*-year design. These include the following criteria:

Table C5-1: Design Reliability

Damage Impact Area	*n*-Year Design	Frequency of Exceedance (90% Confidence)	Conditional Non-Exceedance					
			10-year flood	25-year flood	50-year flood	100-year flood	250-year flood	500-year flood
Northern Area	320	1 in 75	100	100	96	84	49	17
Southern Area #1	100	1 in 35	100	96	81	53	20	6
Southern Area #2	20	1 in 11	93	46	20	6	1	0

Discuss the selection of the project site and evaluation of alternative layouts, alignments, components, aesthetics, relocation of facilities, etc., and describe components and features, including the improvements required on lands to enable the proper disposal of dredged or excavated material. In the event only a minimum design documentation report (DDR) is to be prepared, the site selection information in the engineering appendix to the feasibility report shall be sufficiently detailed to support the development of project real estate requirements and preparation of P&S.

B. Description of Alternative Plans

The individual alternatives with Ecosystem Restoration (ER) and Flood Damage Reduction (FDR) benefits are briefly summarized below in Table C5-2 and are described in more detail in the main report.

Table C5-2 Alternatives and Major Features with Relative Benefits

Preliminary Combined Alternatives[2]	Increase in Habitat Units (AAHU)	Flood Damage Reduction Benefits[3] ($1,000)
1-Locally Developed Setback Levee with 500-yr FDR	783	676
2-Intermediate Setback Levee with 500-yr FDR	795	483
3-Ring Levee with 500-yr FDR	895	470
4-Locally Developed Setback Upstream of Dunning Slough, Intermediate Setback Levee Downstream of Dunning Slough with 500-yr FDR	642	493
5-Intermediate Setback Upstream of Dunning Slough, Locally Developed Setback Downstream of Dunning Slough with 500-yr FDR	937	666
6-Intermediate Setback Upstream of Highway 32, Locally Developed Setback Downstream of Highway 32 with 500-yr FDR	888	676

C. Recommended Plan

The levee is approximately 6.77 miles long. It starts at County Road 203, runs offset of the "J" Levee to Dunning Slough where it goes in a southerly direction to St. John Road (County Road 23) and turns southerly to end about 1.1 miles south of County Road 23. The levee generally has a 15-foot top width, 3/1-side slope on the waterside and 3/1-side slope on the landside. It also has a 0 to 27-foot-wide seepage berm on the landside depending on the levee height. It is to be capped with a 4-inch gravel road for maintenance and all-weather protection. The foundation is to be cleared/grubbed and then excavated underneath with a 6-foot-deep inspection trench to the Tehama Formation. An erosion protection trench (*in-situ*) filled with entrenched riprap will be placed about 200 feet from the levee on the waterside at various locations. See Figures C5-6through 11 for levee alignment, entrenchment detail, and reference location. A typical cross-section for entrenched rock is shown in the Hydraulic Report, Appendix C3. This riprap feature is to protect the levee from the river's tendencies to meander throughout the floodplain belt as it has in the past. Additional erosion protection will be done in reaches where velocities are higher than the scour velocities, such as under the Highway 32 Bridge. These erosion protection sites, whether larger stone or some other alternative, will be designed to be self-mitigating and add to Shaded Riverine Aquatic habitat (SRA) as best as possible.

III. Real Estate.

Typical real estate footprint requirements for the setback levee and the new levee with and without landside seepage berms are shown in typical cross section detail in Figure C5-2. Refinement of these footprints will be provided in final design in order to incorporate necessary foundation treatment prior to construction of the levee. Cross section #1 shows a typical section of new embankment paralleling the west approach to the Highway 32 Bridge. Cross section #2 is typical for controlling seepage within the Irvine Fitch boat ramp facility. Cross section #3 illustrates the typical levee section for most of the reach above and downstream of Highway 32. Cross section # 4 is typical for the training levee. Approximately forty feet landward of all the new levees and/or berm toes will be temporarily needed for staging of equipment and materials necessary for construction. Cross section #5 shows the design for ramping up and over the training levee at the County Road 23 crossing.

To support the construction, operation and maintenance of the selected plan, real estate requirements vary slightly from alternative to alternative but are consistent with standard practices described in the Real Estate Appendix. In general, the proposed alignment of the selected plan consists of a setback levee constructed on the right bank of the Sacramento River. This work will begin at approximately river mile (RM) 200.3 (near the intersection of Road 203 and the "J" levee continuing downstream to about a mile south of Road 23 (RM 193). The environmental features of the project will have requirements that impact all or portions of lands within the project area. The setback and new replacement levees will require a flood protection levee easement, affecting 19 of the 21 parcels and covering an area of about 144.64 acres. For the areas where restoration is to occur, fee title will be required, affecting 15 parcels and covering an area of 1,469.92 acres. There is also a requirement for a one-year temporary work area easement, affecting 17 parcels and covering an area of 27.96 acres. The existing "J" levee, constructed by landowners in about 1904, will provides minimal flood protection to the northern part of Hamilton City and surrounding area. This levee will be breached to allow for flows after the setback levee is completed. It is anticipated that this entire levee, both north and south of Highway 32 can be constructed in one work season. See Figures C5-6 through C5-11 for a more detail look at the selected plan alignment and specific features of the proposed levee and rock protection.

IV. Relocations.

In general, actual relocations of existing utilities and other facility features with the selected plan are minimal. Most of the lands are currently designated agriculture. The largest utility within the area is the existing sewage treatment ponds located nestled into the upstream arc of Dunning Slough. These ponds and ancillary structures within its limits are currently protected by a ring levee and it is not anticipated there will be any impact to its operation. Road 23 will need to ramp over the new training levee. A PG&E gas main located upstream of the Highway 32 bridge will require more detail to ensure that the inspection trench of the proposed setback levee will not interfere with the operation and maintenance of the gas line. Figure C5-3 illustrates a few of the primary features that will be impacted by the selected plan and the recommended method of repair.

Table C5-3 summarizes the various facilities, public and private utilities, and roads that are potentially impacted with the selected plan. As shown, the project will affect the following utility/facility items:

Table C5-3 Relocation and Cost Schedule		
Utility/Facility Feature	**Impact**	**Cost (1,000) [1]**
Water	None	-
Power	None	-
Sewage Treatment Ponds	None [2]	-
Telephone	None	-
Irvine Fitch Park, Hwy 32, and Interior Drainage	Resurface, Culvert and Surface Drainage Ditches	$ 250
Fiber Optics line Hwy 32	None	-
High Pressure Gas line north of Hwy 32	None [3]	-
County Road 203	Elevate road 1 to 1 ½ feet for 1,000-foot reach at	$ 158
911 Telephone line on County Rd 23	Protect in place	-
USRR spur line	Protect in place	-
Private Residence RM 203 utilities	Protect in place [4]	-
Road 23	Raise and Relocate	$ 80
City Roads	Raise and Relocate	$ 75
Local Interior Drainage		
Total Costs		$ 563

[1] Include 25% contingency.
[2] Sewage Treatment Ponds - Adjustments to the internal storm drains to accommodate any waterside improvements.
[3] The High Pressure Gas line will not be moved. The setback alignment intersects gas line and measures will need to ensure levee inspection trench and compaction effort does not affect gas line.
[4] This assumes residence has not been lost to waterside erosion of the structure's foundations.

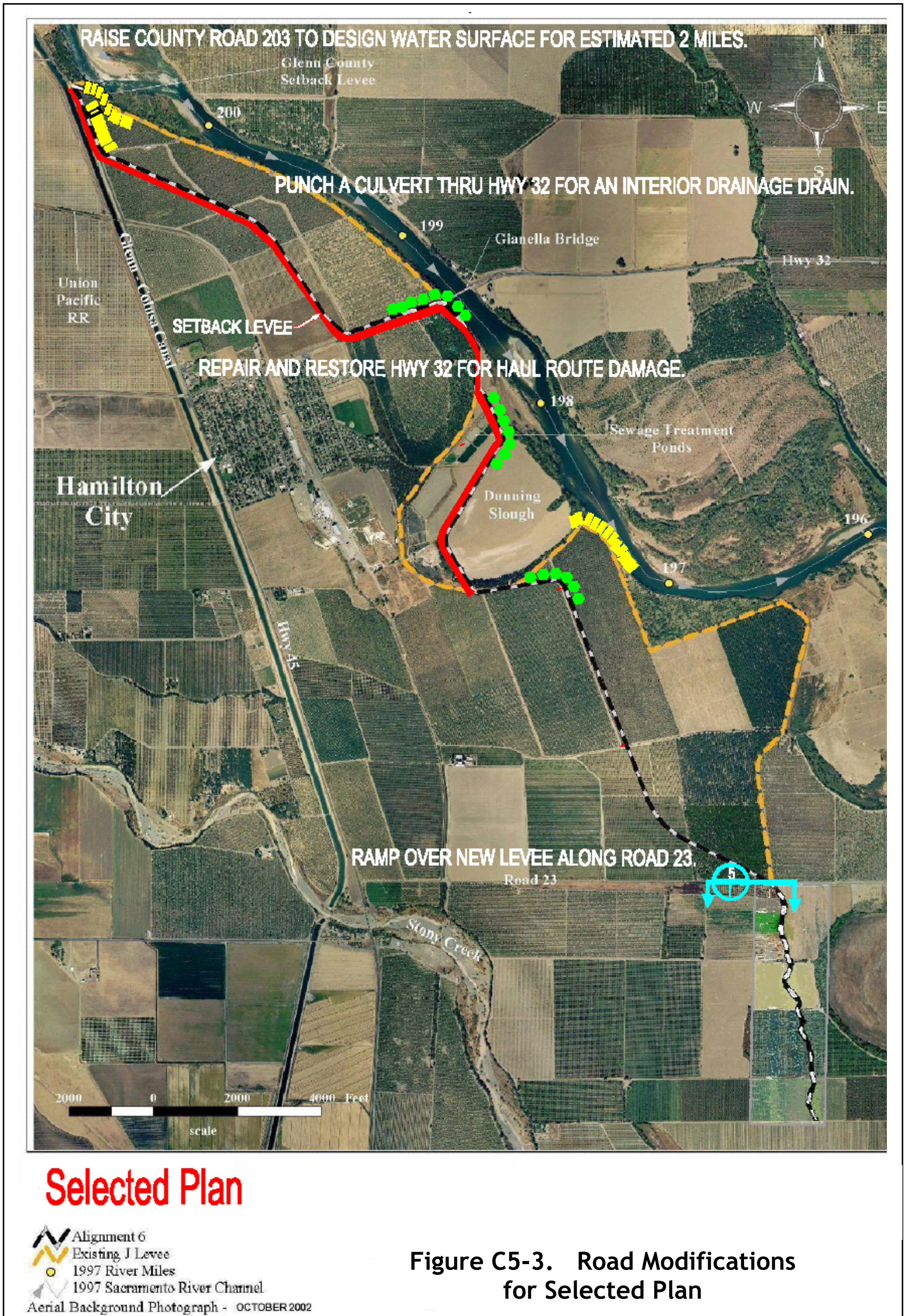

Figure C5-3. Road Modifications for Selected Plan

V. Interior Drainage

A. Without Project (Existing) Drainage Features

The Hamilton City storm water system now drains toward the river to its outfall near the access road of the sewage treatment ponds and the "J" levee. From there it is pumped over the road and "J" Levee into a ditch that follows the "J" Levee around Dunning Slough then tapers out to seep into the ground in front of the "J" Levee. This ditch is on the riverside of the "J" levee with a small outfall into the river. The majority of the storm water is very low and seeps into this ditch before getting to the river. Several times (3 or 4) during the rainy season the pump is turned on to pump the impounded storm water into the ditch. At this time the two sides of the "J" Levee are dry from river flows.

When the river is in flood stages but not overtopping the "J" Levee, the interior drainage is filling the storm drains to capacity. Two Interior Drainage pumps are added to the existing storm pump to take the combined flows over the road and "J" levee into the same existing ditch around Dunning Slough. At this stage the ditch is nearly filled by the river overflows.

When the river is at a flood stage over the "J" Levee, the flows inundate the storm drain outfall and interior drainage systems flooding the lower parts of the city then sweeping around Holly Sugar plant into the river overflows.

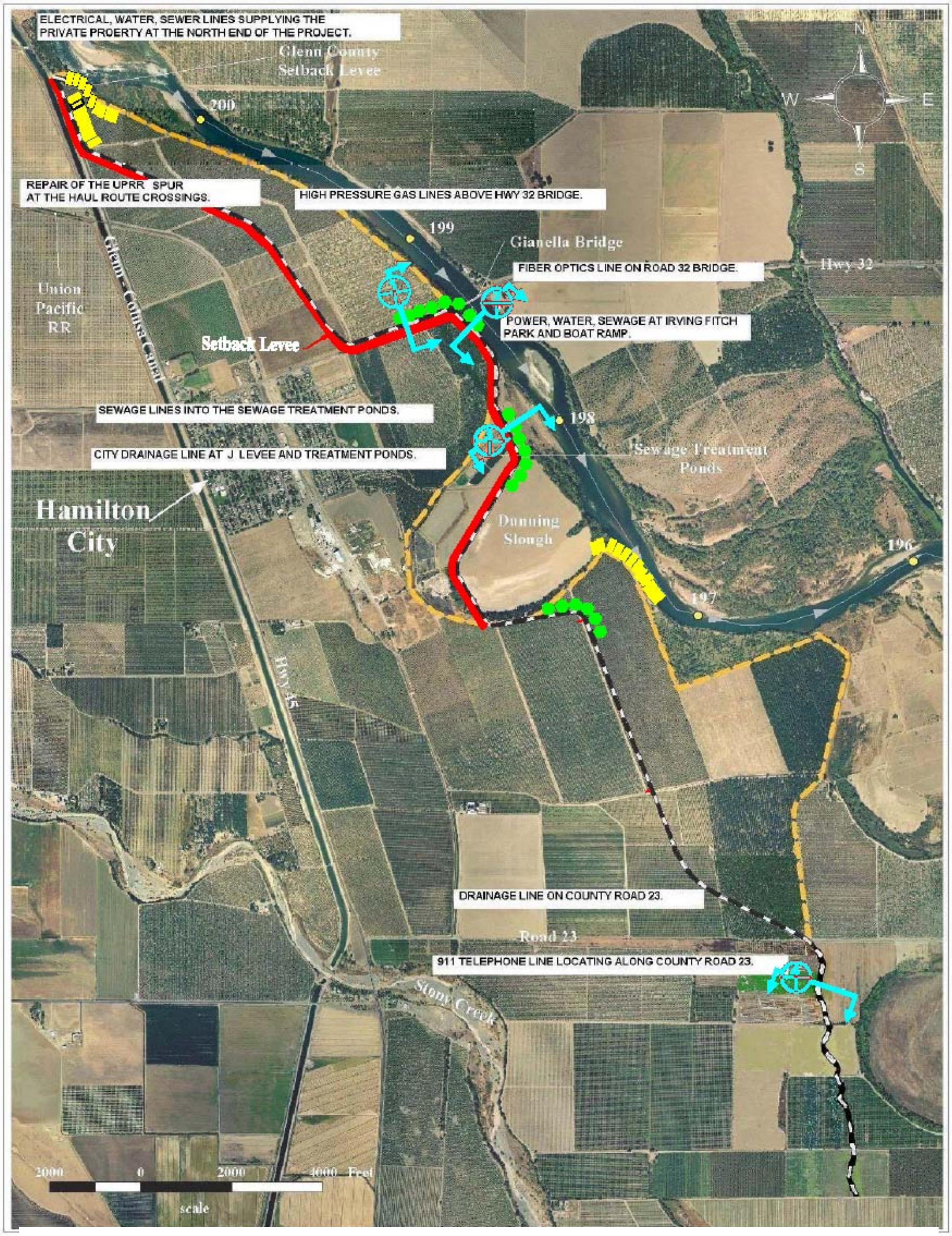

Fig C5-4 Utility Locations & Features

Legend

Existing Levee

Riprap (armoring)

Entrenched Launched Rock

Seepage Berm

B. *With Project (Recommended Plan) Drainage Features*

The Hamilton City Storm system drains as it does now. A small cut-off dike across the Holly Sugar pond to the "J" levee will be built to keep the small drainage area behind the sewer ponds from flanking into the existing ditch. In addition, the landside drain ditch on the proposed levee will be enlarged to carry the drainage from behind the sewer ponds into the new interior drain about midway around Dunning Slough.

At flood stages where the interior drainage and the storm drain is about to overwhelm the City storm channel thus flooding the city, several large culverts are to be placed through the road and "J" levee to take the drain flows into the existing ditch, then along ditch. The pump can be turned off if it already hasn't been cut-off. This is to be design as a fail-safe system, unlike the existing system, and no pumps or "flap" valves are to be used. This ditch is to be realigned to about a point midway along Dunning Slough to carry the drainages along the backside of the Project Levee down to a point at the mergence with the wrap-around waters coming from the end of the levee. It can also be terminated at the location of the next enlarged penetration of the storm drainpipe of the Project levee.

VI. Haul Routes

Haul routes to and from the various sources for embankment fill, stone armoring, or spoiling excavated materials and debris will be refined later. It is tentatively decided that most of the embankment fill will be processed material from the GCID spoil site. This material will be tested prior to construction to ensure the material properties conform to recommended soils specified for this use. Rock sources are within relatively short distances from the project. Rock selected for placement will be laboratory tested as recommended in the Geotechnical Appendix C4 to ensure compatibility to specifications. The following map, Figure C5-5, shows the tentatively designated construction haul routes necessary for project work. The SPRR spur, Highway 32 Bridge, as well as the other county/city roads and structures will need to be protected in place and repaired if damaged.

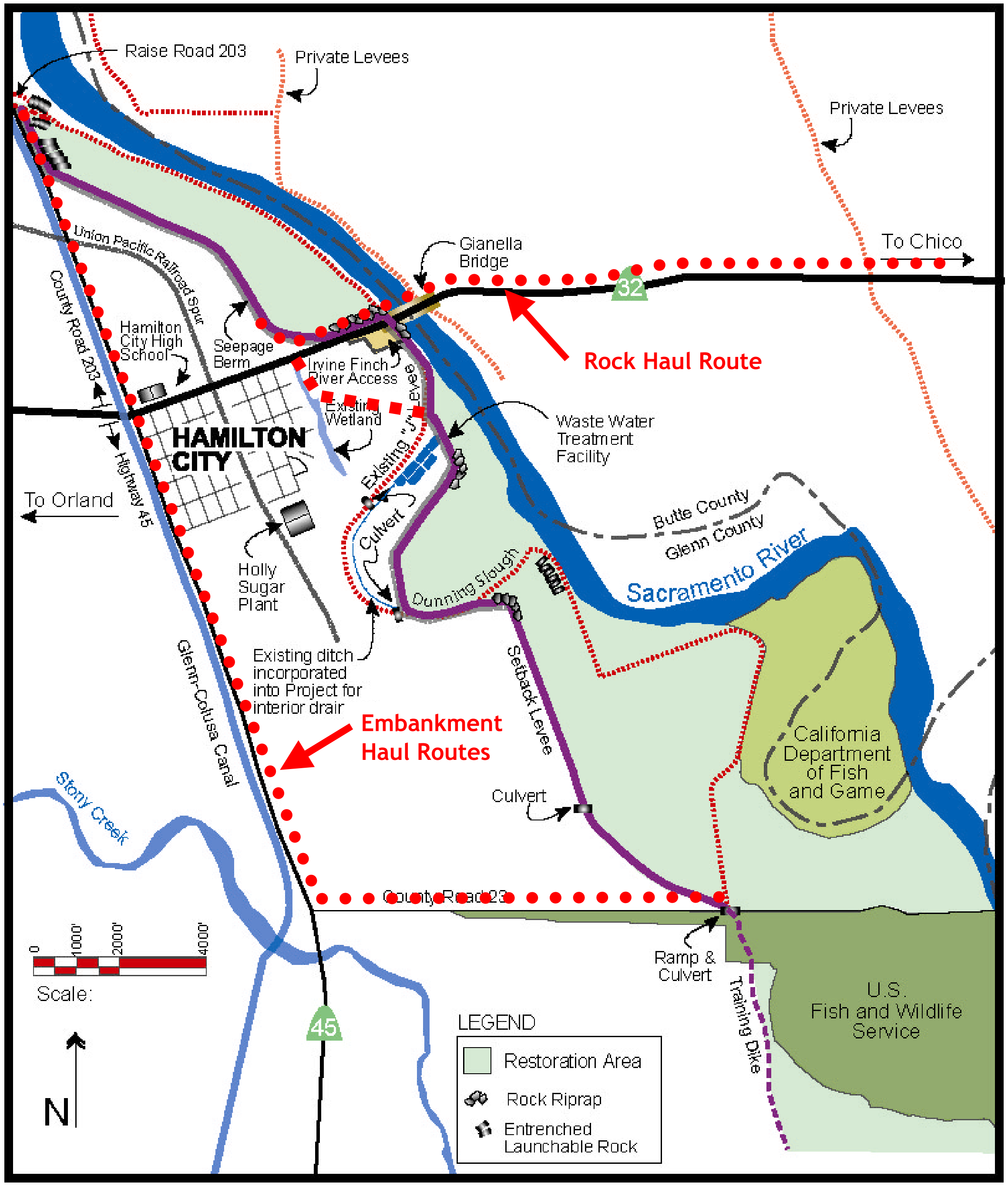

Figure C5-5 Embankment and Rock Haul Routes Within the Project Area/Site

Appendix C6.

HAZARDOUS, TOXIC AND/OR RADIOLOGICAL WASTE (HTRW)

HTRW SECTION

Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study

FINAL

US Army Corps of Engineers ®

Sacramento District
Environmental Design Section

January 2004

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FIGURE

Figure 1: Study Area - Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study

ATTACHMENTS

Attachment A: Study Area for Hamilton City Flood Reduction Study Area
Attachment B: Well Search for Hamilton City Flood Reduction Study Area
Attachment C: EDR NEPA Check Report
Attachment D: EDR Area Study Report
Attachment E: EDR Well Search Report

ACRONYMS and ABBREVIATIONS

AST	Aboveground Storage Tank
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
DDT	dichlorodiphenyltrichloroethane
DDTr	DDT derivatives including DDD (dichlorodiphyltrichloroethylene)
DHS	Department of Health Services
DO	Dissolved Oxygen
DOGGR	Division of Oil, Gas and Geothermal Resources
DPR	Department of Pesticide Regulation
DTSC	Department of Toxic Substances Control
EDR	Environmental Data Resources, Inc.
FS	Feasibility Study (Sacramento & San Joaquin Comprehensive Study - the Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study)
GCC	Glenn-Colusa Canal
Gpd	Gallons per day
HTRW	Hazardous, Toxic and/or Radioactive Waste
LUFT	Leaking Underground Fuel Tank
mg/kg	milligrams per kilogram
NEPA	National Environmental Policy Act
NPL	National Priorities List
pCi/L	Pico-curies per liter
ppb	parts per billion
PWS	Public water supply system
SWF/LF	Solid Waste Facilities/Landfill Sites
SWIS	Solid Waste Information System

1.0 HAZARDOUS, TOXIC AND/OR RADIOLOGICAL WASTE

1.1 Overview

This Appendix identifies potential hazardous, toxic and/or radiological waste (HTRW) issues that may need to be taken into consideration when evaluating the various alternatives associated with the Sacramento & San Joaquin Comprehensive Study - the Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study (FS). Hamilton City is located in Glenn County, California. The FS Study Area for HTRW (Study Area) surrounds Hamilton City and is bounded by the Glenn-Colusa Canal (GCC) on the west and by the Sacramento River on the east. The north and south borders are located about two miles and 6 miles from Hamilton City respectively (Figure 1: Study Area for Hamilton City Flood Damage and Ecosystem Restoration Feasibility Study).

In order to complete this HTRW assessment, available aerial photos and regulatory agency database records were reviewed, the Study Area was visited, and interviews were conducted with appropriate personnel from State and local agencies. Federal, State, and County database searches were conducted by Environmental Data Resources, Inc. (EDR), which provided three reports: NEPA Check Report, Area Study Report and Well Search Report with two maps: Study Area for Hamilton City Flood Reduction Study Area and Well Search for Hamilton City Flood Reduction Study Area (See Attachments A-E). As a result of these assessment activities, four areas are identified as areas of potential concern: the Sewage Treatment Facility, the Former Holly Sugar Lime Disposal Area, farms with agricultural chemicals and storage tanks and J.R. Simplot Fertilizer Company. If those four areas are not protected, some or all of the Study Area may be adversely affected in the event of a flood.

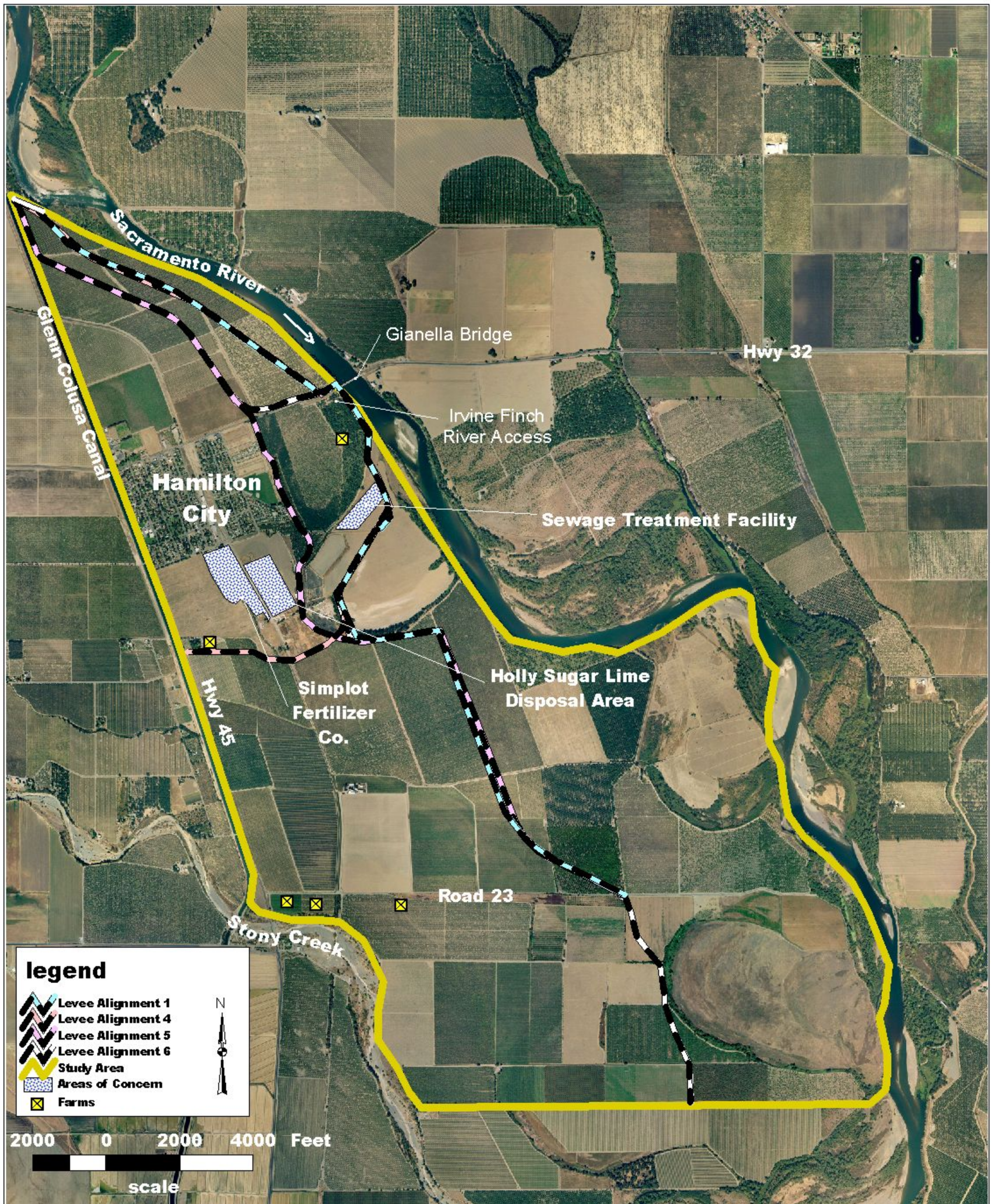

Figure 1	STUDY AREA	Hamilton City Flood Damage Reduction and Ecosystem Restoration, CA *map created January 23, 2004*

1.2 Review of Regulatory Agency Records

Regulatory agency records searches were conducted by Environmental Data Resources, Inc. The EDR reports: Area Study Report, NEPA Check Report and the EDR Well Search Report (EDR, 2003) are attached as attachments A through E. The following list presents the agencies from which data were obtained:

United States Environmental Protection Agency
California Environmental Protection Agency
California Department of Health Services
California Integrated Waste Management Board
California Regional Water Quality Control Board

1.3 Soils

Soils in the Study Area on the west side of Dunning Slough primarily consist of Modesto Formation. These soils are marked by high silt content and a distinct red color. Stream channel deposits are located within the historic meander belt (the Sacramento River Conservation Area), east of Dunning Slough, towards the Sacramento River.

1.4 Flood Map Review

A US Army Corps of Engineers flood map and the EDR map (Attachment B: EDR Map of Study Area) show the flood prone area around Hamilton City. Most of the Study Area would likely be affected by a 100-year flood from the Sacramento River.

1.5 Aerial Photographs

Two aerial photos taken in 1995 and 2002 are very similar geographically and there were no significant changes in Hamilton City and the surrounding areas between 1995 and 2002.

1.6 Groundwater Wells

There are 12 wells (Attachment C: EDR Well Search Map) in the Study Area that are used for domestic, irrigation and industrial purposes. Based on the well database, the well depths are 40 feet to 246 feet and depths to the water table are 13 feet to 23 feet. Water levels in one well fluctuated between 37 feet and 42 feet during the summer of 1977.

A review of EDR groundwater quality records indicated that water quality data exists for several wells within the subject Study Area. At least five wells were tested for groundwater quality between 1984 and 1996 and most samples were analyzed for inorganic compounds, organic compounds, pH, sodium, total dissolved solids, color specific conductance, total alkalinity, bicarbonate alkalinity, total hardness, metals, corrosivity, and nitrate. The analytical data indicate good quality water.

1.7 Public Water Supply System

A public water supply system (PWS) is any water system that provides water to at least 25 people for a minimum of 60 days annually. PWSs provide water from wells, rivers, and other sources. Hamilton City has one PWS: Irvine Finch River Access. This PWS has not had a violation or enforcement action.

1.8 National Priorities List Site

According to the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) list and National Priorities List (NPL) there are no suspected abandoned, inactive, or uncontrolled hazardous waste sites or Superfund sites within the Study Area. The Emergency Response Notification System (ERNS) database identifies South 1st Street & Walsh Ave as a site having had a reported release of oil or hazardous substances. No details on the reported release are available.

1.9 Disposal Sites

The Solid Waste Facilities/Landfill Sites (SWF/LF) records typically contain an inventory of solid waste disposal facilities or landfills in a particular state. The data comes from the Integrated Waste Management Board's Solid Waste Information System (SWIS) database. No landfills were listed within the Study Area. However, a review of the SWF/LF list has revealed one waste disposal site within the Study Area: the Holly Sugar Lime Disposal Site, located ½ mile southeast of First Street. The site was formerly owned and operated by the Holly Sugar Company. During the site visits, mounds of lime (calcium carbonate) were observed; some were overgrown with vegetation. The exact size of the lime disposal area is not known, but from the 1995 aerial photo, the disposal area is estimated to be about 30 acres. Currently the site is off-limits to the public. According to Holly Sugar/Spreckel Sugar Co. in Tracy, CA, the Hamilton City plant was closed about seven years ago. The disposal site was used for lime disposal and has not been used for the past 12 years. There are no records that lime was the only product disposed of here. The lime has been hauled and used for soil conditioning at a different location. The October 2002 aerial photo still shows whitish areas. There is no estimated time frame for when all the lime will be finally removed.

The main buildings of the former Holly Sugar Plant are currently leased to J.R. Simplot Fertilizer Company, Mineral & Chemical Group, a distributor of fertilizers. Various fertilizers (i.e., Di-Ammonium Phosphate, Urea, Ammonium Sulfate, Mono-Ammonium Phosphate, Ammoniacal Nitrogen and Phosphoric Acid) are shipped to, and distributed from, the site via rail or trucks. According to the warehouse manager, only seasonal fertilizer is stored at the Hamilton City warehouse. About 80 tons to 400 tons of fertilizer has been stored daily in the company's warehouse, according to the company records for recent years. The fertilizer is stored loosely on the warehouse floor, which is several inches above the ground surface. The fertilizers are loaded into trucks by either shovel or motorized loaders.

In case of flood, some or all of the lime or the fertilizer may be washed away which could impact the water quality in the Sacramento River.

1.10 Leaking Underground Fuel Tanks

The California Regional Water Quality Control Board Leaking Underground Fuel Tank (LUFT) list shows that there are five LUFT sites within the Study Area: Double E Market, Jackpot Food Mart, Kaplan Almond Farmland, Benjamin's Service, Inc., and Cal-Farm Supply. According to Geotracker (http://www.geotracker.swrcb.ca.gov), all five sites were closed and no further actions are needed at those sites. GeoTracker is a geographic information system that provides online access to environmental data provided by the State Water Resource Control

Board. GeoTracker is the interface to the Geographic Environmental Information Management System, a data warehouse which tracks regulatory data concerning underground fuel tanks, fuel pipelines, and public drinking water supplies. The website provides regulatory history, location information, analytical data, detailed release information, remediation at each LUFT site, and wells estimated to be nearby each LUFT site.

1.11 Underground Storage Tanks and Aboveground Storage Tanks

According to the State Water Resources Control Board's Substances Storage container Database, there are four registered underground storage tank (USTs) and aboveground storage tank (AST) sites in the Study Area:

Double E Market, 575 Sacramento St.,

Jackpot Food Mart, 585 Sierra St.,

Hamilton Gas Mini Mart, 601 6th, St., and

Hamilton Union Elementary School, 277 Capay St.

Contents of the USTs and ASTs are gasoline, diesel, waste oil or other unspecified products. It is common that a typical farm has underground or aboveground storage tanks. There are a few farms located in the Study Area. According the EDR reports, there are no records of USTs or ASTS on the farm properties.

According to the EDR reports, the following are listed as historical UST sites:

Hamilton Union High School, Highways 32/45

James Mills/Growers Service Co, 3rd/Walsh

James Mills Orchards, Third/Walsh, and

Hamilton City Ranch, 1st/Sacramento.

1.12 Oil and Gas Wells

Based on information obtained at the Division of Oil, Gas and Geothermal Resources (DOGGR), Department of Conservation, State of California (DOGGR, 2001) there are seven oil and gas wells in the Study Area. All oil and gas wells are located on the outskirts of Hamilton City between the Glenn-Colusa Canal and the Sacramento River. These wells were drilled in the early to mid-1900's and all were found dry. According to files stored at the Regional Office, 801 K Street, 20th Floor, Sacramento, CA, all the oil and gas wells were properly abandoned and certified by the Division of Oil, Gas and Geothermal Resources, Department of Conservation, State of California.

1.13 Cal-Sites

The California Environmental Protection Agency Cal-Sites List, which combines the Abandoned Sites Program Information System and the State "Superfund" list, provides locations of known hazardous waste sites. No sites were identified within the Study Area.

1.14 Hazardous Waste Generators

The California Department of Health Services (DHS) Toxic Substances Control Division, Hazardous Waste Information System lists hazardous waste generators. The data is extracted from the copies of hazardous waste manifests received each year by the Department of Toxic Substances Control (DTSC). DHS identified three hazardous waste generators in the Study Area as follows;

- Bob's Auto & Truck Repair, 595 Los Robles Ave., Hamilton City
- Martin Byron Vangundy III, 440 Main St., Hamilton City
- Hamilton Union Elementary School District, 277 Capay St., Hamilton City

1.15 DDT and Agricultural Chemicals

Organochlorine pesticides such as 4, 4' dichlorodiphenyltrichloroethane (DDT) and its breakdown products may be present in the soil at the Study Area, which has a history of prolonged agricultural use. A program of sampling and analysis was conducted on agricultural properties in Glenn County by the California Department of Food and Agriculture in 1985. The results of this sampling and analysis are reported in "Agricultural Sources of DDT Residues in California's Environment." (DPR, 1985)

Soil samples were collected from the top 6 inches of soil on properties in areas of "historic widespread and repeated applications of DDT" and analyzed for DDT and its breakdown products (DDTr). Two soil samples were collected in the eastern section of Glenn County (exact locations of sampling are not available at this time) and found to have concentrations ranging from 0.278 milligram per kilogram (mg/kg) to 0.581 mg/kg of DDT and its breakdown products.

Soils with total DDT and DDTr at concentrations above 1 mg/kg or soluble concentrations above 0.1 mg/l are classified as hazardous waste under California regulations. The samples collected in Glenn County are all below the 1 mg/kg waste classification limit. Ecological risk numbers for DDT and DDTr may be lower than the California Hazardous Waste Criteria. This does not rule out the possibility that greater concentrations may be encountered in the Study Area. Most of the Study Area outside of Hamilton City has been orchards and farmlands for many years. If the Sacramento River overflows, pesticides and herbicides residue from past applications, or agricultural chemicals that may be stored in the flood prone area, may be dispersed. The toxic nature of some pesticides (including DDT residues) and other agricultural chemicals have the potential to adversely affect riparian and aquatic ecologies.

1.16 Radon

The National Radon Database has been developed by the U.S. Environmental Protection Agency (USEPA) and is a compilation of the EPA/State Residential Radon Survey and the National Residential Radon Survey. The study covers the years 1986-1992. According to the study, data have been supplemented by information collected at private sources such as universities and research institutions, where it is necessary.

According to the database, ten (10) sites in Glenn County, in which the Study Area is located, were tested for radon at the lst floor level and/or basement. Average radiological activity was 0.430 pico-curies per liter (pCi/L) at 1st floor and 2.4 pCi/L in basement, which are below the action level of 4 pCi/L in the EPA guidelines. It is unlikely that radon presents a significant concern within the Study Area.

1.17 Radioactive Material/Waste Sites

Radioactive material/wastes sites in the Study Area were researched in the following web sites:

* ATSDR - Public Health Concern At Department of Energy Sites at (http://www.atsdr.cdc.gov/HAC/DOE/doe4.html),
* Radioactive Waste website at (http://www.cs.virginia.edu/~jones/tmp352/projects98/group14/disposal.html#_1_1), and
* Low-Level Radiation Waste Disposal Sites at (http://www.millennium-ark.net/News_Files/NBC/NRC.low.level.waste.dispos.html).

No radioactive material/waste site was found in the Study Area.

1.18 Lead

Due to the lack of structures and civil improvements on the flood prone area of the Study Area, it is unlikely that lead in the form of lead-based paint presents a significant concern to the flood water.

1.19 Asbestos

Because the flood prone area of the Study Area is characterized by orchards and farmland, the potential for encountering asbestos-containing construction materials in the flood prone area is remote. However, if the entire Study Area is flooded, there is a possibility that asbestos-containing material from older buildings may be released to the water.

2.0 SITE VISITS

Site visits to Hamilton City were conducted on 12 July 2001 and 28 March 2003. The purpose of the site visits was to become familiar with the Study Area, follow up on issues identified in the database searches, look for any visible issues that may not have been previously identified, and to collect additional information.

The Sewage Treatment Facility (Order # 98-081, permitted by the Regional Water Quality Control Board, State of California) is located southeast of Hamilton City. It has been operational since 1968. According to the Maintenance Superintendent, Hamilton City Community Services District (Puente, 2001 and 2003), raw sewage from Hamilton City is transported by gravity flow and pumped into one of seven ponds at the Sewage Treatment Facility. The plant has a sewage treatment capacity of 500,000 gallons per day (gpd), but currently is operating at an average of 225,000 gpd. The sewage is treated biologically. There is no effluent from the treatment plant and all treated water is dissipated by evaporation and percolation. The sludge in the open ponds could potentially contain accumulated heavy metals from storm water runoff. The influent to the treatment plant is tested for dissolved oxygen (DO) and temperature weekly. No other tests are conducted. Water in ponds is a blue-green color and populated with ducks, turtles, and frogs. A number of dragonflies were seen over the ponds. A herbicide, *Round-Up*, is occasionally used to eliminate unwanted weeds at the site.

The Sewage Treatment Facility is surrounded by a levee which prevents floodwater from entering. According to the Superintendent, this treatment plant has never been flooded since its opening in 1968.

The J.R. Simplot Fertilizer Company was visited and the company provided types and amounts of fertilizers stored at the warehouse. The warehouse sits on a concrete pad and mounds of various fertilizers are placed on the warehouse floor.

The lime disposal area near the eastside section of the former Holly Sugar Company property was visually inspected, and some lime mounds, overgrown with vegetation, could be seen from a road near Dunning Slough.

3.0 AREAS OF CONERN AND RECOMMENDATIONS

The environmental assessment indicates evidence of areas of potential environmental concern within the Study Area. Research and assessment have identified the following four areas of concern.

3.1 Sewage Treatment Facility

Raw sewage is pumped into open ponds at the treatment plant at an average of 225,000 gpd. If the treatment plant is flooded, raw sewage and accumulated sludge could be dispersed to the environment, which could pose chemical and biological hazards to the public and the environment. The treatment plant needs to be protected from floods at all times.

3.2 Former Holly Sugar Lime Disposal Site

Most of the contents at the lime disposal site are believed to be calcium carbonate, which can be found in dietary or food products as an additive. Some of the lime has been hauled away to a different location for soil conditioning, however, it is not known how much lime remains at the disposal site. A large amount of lime may pose an adverse threat to aquatic life. If Alignment #3 (new levee construction) is selected, mitigation of the lime (i.e., removal) may be necessary.

3.3 Agricultural Chemicals and Fuel Storage Tanks

Fertilizers, pesticides and fuels for machinery are hazardous materials commonly stored on farm property. There are several farms located in the Study Area. Since the flood prone area of the Study Area has been used as orchards and farmland, pesticides, agricultural chemicals, and fuels for machinery may exist. Neither exact concentrations of pesticides nor the quantity of agricultural chemicals at the flood prone area is known at this time. About two million pounds of pesticides were applied in Glenn County in 1998 and 1999 according to a Pesticide Regulation report compiled by the State.

There are no records of hazardous materials stored on any farms in the Study Area. If pesticides, herbicides, fuel or any other hazardous materials are stored in non-seal-tight containers in the flood prone area, some or all of those hazardous materials may be released to the environment via overflow water from the Sacramento River. If large quantities of agricultural chemicals and/or fuel for machinery are released to the environment, the riparian and aquatic habitats, and associated biota may be adversely impacted. Agricultural chemicals in particular should be stored in watertight containers.

3.4 J.R. Simplot Fertilizer Company

The J.R. Simplot Fertilizer Company stores various types of highly water-soluble fertilizers on the warehouse floor. The amount of fertilizers stored in the warehouse fluctuates seasonally. The company records show that between 80 tons and 400 tons of fertilizers were stored in the warehouse at all times in recent years. If the warehouse is flooded, the water-soluble fertilizers will be dispersed and may adversely affect the environment and the surrounding areas including Hamilton City, the Sacramento River and the Glenn-Colusa Canal.

4.0 ENVIRONMENTAL IMPACT OF ALTERNATIVES

From the 2002 aerial photo and the EDR database search reports (Attachments A-E), HTRW sites, agricultural chemical and fuel storage areas do not appear to exist on the section of farmland close to the Sacramento River. All the HTRW sites listed in Section 1.0 except the Holly Sugar Lime Disposal Site are located within the Hamilton City.

If Alternative #1 or #6 is selected, there will be very little impact on the Hamilton City community and the surrounding farmlands.

If Alternative #4 is selected and implemented, in the event of a flood, agricultural chemicals and fuels that may be stored on farm properties located south of the proposed levee could contaminate the Sacramento River and pose chemical hazards to the public and the environment.

If Alternative #5 is selected, the Sewage Treatment Facility may flood. This would result in raw sewage, accumulated sludge contaminating the Sacramento River, which could pose significant biological and/or chemical hazards to the public and the environment. Relocation or protection of the Sewage Treatment Facility is recommended. Irvine Finch River Access near the Sacramento River and the State Highway 32 may flood, but, impacts to the environment would be minimal based on the site inspections conducted on 12 July 2001 and 28 March 2003.

5.0 REFERENCES

EDR Search Data: The EDR Area Study Report, EDR NEPA Check and EDR Well Search Report, EDR Area Study, Inquiry Number: 647007.ls, July 2001

EDR Search Data: The EDR Well Search Report, EDR Area Study, EDR NEPA Check reports, Inquiry Number: 94699.1w, EDR, March 2003

Office Visit and document review at Division of Oil, Gas and Geothermal Resources (DOGGR), Department of Conservation, State of California, 2001

Department of Pesticide Regulation (DPR), CA, 1985, *Agricultural Sources of DDT Residues in California's Environment*, 1985

Interview with Mr. Jose Puente, Maintenance Superintendent, Hamilton City Community Services District, Hamilton City, California, (530) 826-3208

Appendix C7.

MECHANICAL
(Not Applicable)

Appendix C8.

COST ENGINEERING
(M-CACES)

****TOTAL PROJECT COST SUMMARY**** 08/05/2004

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE DRAFT FEASIBILITY REPORT
PROJECT: HAMITON CITY - LEVEE RERSTORATION ALT's
LOCATION: CALIFORNIA H_Alt 6_300

U. S. ARMY CORPS OF ENGINEER
SACRAMENTO DISTRICT
P.O.C. FRANK Y.F. FONG, CHIEF, COST ENGINEERING

Current MCACES Estimate Prepared: 1-Oct-2003
Effective Price Level (EPL): 1-Oct-2003

ACCOUNT NO.	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	FULLY FUNDED ESTIMATE (4: FEATURE OMB MID PT (%)	COST ($K)	CNTG ($K)	FULL ($K)
	FEDERAL COSTS								
6	FISH & WILDLIFE, Mit.	20,530	4,010	19.532	24,540	5.6%	21,676	4,234	25,910
11	LEVEES & FLOODWALLS	740	181	24.000	921	5.3%	782	188	970
18	CULT. RESRC PRESERV. (1	136	34	25.000	170		144	36	180
	SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS	21,406	4,225		25,631		22,602	4,458	27,060
30	PLAN/ENGINEERING/DESIGN	2,450	619	25.000	3,069	11.8%	2,744	686	3,430
31	CONSTRUCTION MANAGE'MT	1,730	431	25.000	2,161	18.9%	2,056	514	2,570
	SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION	25,586	5,275		30,861		27,402	5,658	33,060
	NON-FEDERAL CONTRIBUTION (3	1,295	337		1,632		1,400	350	1,750
	TOTAL FEDERAL COSTS	**$24,291**	**$4,938**		**$29,229**		**$26,002**	**$5,308**	**$31,310**
	NON-FEDERAL COSTS								
1	LANDS AND DAMAGES	11,000	2,347	21.000	13,347	5.8%	11,669	2,451	14,120
2	RELOCATIONS	450	113	25.000	563	6.6%	480	120	600
30	PLAN/ENGINEERING/DESIGN	43	11	26.000	54	11.1%	48	12	60
31	CONSTRUCTION MANAGE'MT	41	10	24.000	51	17.6%	48	12	60
	SUBTOTAL NON-FEDERAL	11,534	2,481		14,015		12,245	2,595	14,840
	NON-FEDERAL CONTRIBUTION (3	1,295	337		1,632		1,400	350	1,750
	TOTAL NON-FEDERAL COSTS	**$12,829**	**$2,818**		**$15,647**		**$13,645**	**$2,945**	**$16,590**
	TOTAL FEDERAL AND NON-FEDERAL COSTS	**$37,120**	**$7,756**		**$44,876**		**$39,647**	**$8,253**	**$47,900**

GENERAL NOTES

(1 Cultural Resources Preservation costs associated with mitigation and/or data recovery up to one percent of the total Federal cost are not subject to cost sharing.
(2 Federal administrative costs for non-Federal land acquisition.
(3 Preliminary Cost Allocation for a multipurpose project are presented on table 3-17 of the Main Report. Federal and Non-federal Cost Sharing requirements of allocated costs are shown in Tables 9-4, 9-5, and 9-6 of the Main Report
(4 The Fully Funded cost estimate was prepared in compliance with EC 11-2-183 published in March 2002.

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DISTRICT APPROVED:

______________________________ CHIEF, COST ENGINEERING

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DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	% *	REASON
	Effective Price Level (EPL) 1-Oct-2003							
	Levee Alt 6							
06	**FISH AND WILDLIFE FACILITIES**							
0603	WILDLIFE FACILITIES AND SANCTUARIES,							
060301	Site Work: - Wildlife Facilities ER Levee Component							
	Mob., Demob. and Preparatory Work:	1	JOB	LS	344,185	86,000	25.0	-
	Site Work (Setback Levee)							
	Levee Foundations & Clearing Grubbing	5.705	miles	@130000/Mi		0	0.0	-
	Levee Found & Clear&Grub (5.705 Mi.)	159,740	CY	4.65	742,791	186,000	25.0	-
	Remove "J" Levee to onsite Stockpile	247,700	CY	6.00	1,486,200	372,000	25.0	-
	Erosion protection=Entreached	0.586	miles	@4680000/Mi		0	0.0	-
	Erosion prot=Entreach (0.586 Mi)							
	1 Clear Levee Fill Borrow Site	7.15	AC	2,970	21,236	5,000	23.5	-
	2 Load Levee Fill at Borrow Site	65,632	CY	4.40	288,781	72,000	24.9	-
	3 Haul Levee Fill from Borrow Site	24,612	C/M	1.07	26,335	7,000	26.6	-
	4 DERRICK STONE MATERIAL	96,690	TON	21.32	2,061,431	512,000	24.8	-
	5 HAUL DERRICK STONE 80K LB GVW	403.00	HRS	254.84	102,701	26,000	25.3	-
	6 PLACE DERRICK STONE FROM LEVEE	96,690	TON	1.70	164,373	41,000	24.9	-
	7 Place Levee Fill	16,408	CY	3.74	61,366	15,000	24.4	-
	8 Compact Levee Fill	16,408	CY	1.89	31,011	8,000	25.8	-
	Levee Material from onsite Stockpile	247,700	CY	4.00	990,800	248,000	25.0	-
	Erosion protection=Riprap	0.473	miles	@900000/Mi		0	0.0	-
	Erosion prot=Riprap (0.473 Mi)							
	Erosion prot. Riprap 3'-2h on 1v							
	Erosion protection Riprap	26,015.000	TON	14.50	377,218	94,000	24.9	-
	PLACE Erosion protection Riprap	26,015.000	TON	2.00	52,030	13,000	25.0	-
	15 ft Crown Road	5.705	miles	@135000/Mi		0	0.0	-
	15 ft Crown Road (5.705 mi)							
	1 Patrol Road Agg. Frm Qry to site	16,744	TON	43.75	732,550	183,000	25.0	-
	2 PLACE AGG.BASE FROM COMM.SOURCE	16,744	TON	2.00	33,488	8,000	23.9	-
	Erosion Prodection HYDROSEEDING	5.705	miles	@50000/Mi		0	0.0	-
	1 HYDROSEEDING (5.705 mi)	2,139,375	SF	0.13	278,119	70,000	25.2	-
	Fencing	6.770	miles	@30000/Mi		0	0.0	-
	1 Fencing (6.770 MI)	35,745	LF	5.55	198,385	50,000	25.2	-
	Seepage Berm	44,700	CY	30.00	1,341,000	335,000	25.0	-
	Subtotal, Construction Costs:				$9,334,000			
	Contingencies @ average of 25.0 % +/- *					$2,331,000		A
060301	Site Work: - Wildlife Facilities ER Levee Component			TOTAL:		$11,665,000		
060373	Habitat and Feeding Facilities:							
	Site Work: - REVEGITATION							
	Mob & Demob	1	JOB	LS	48,550	7,000	14.4	-
	Cottonwood	200.0	AC	9,700	1,940,000	291,000	15.0	-
	Riparian	796.6	AC	7,500	5,974,500	896,000	15.0	-
	Grassland	70.4	AC	3,600	253,440	38,000	15.0	-
	Savannah	147.9	AC	6,900	1,020,510	153,000	15.0	-
	Sccrub	261.2	AC	7,500	1,959,000	294,000	15.0	-
	Subtotal, Construction Costs:				$11,196,000			
	Contingencies @ average of 15.0 % +/- *					$1,679,000		A
060373	Habitat and Feeding Facilities:			TOTAL:		$12,875,000		
			Grand Subtotal		$20,530,000			
			Contingencies			$4,010,000		
06	FISH AND WILDLIFE FACILITIES		Grand Total			$24,540,000		

DETAILED ESTIMATE OF FIRST COST(Cont'd)

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	% *	REASON
	Effective Price Level (EPL) 1-Oct-2003							
11	**LEVEES AND FLOODWALLS**							
1101	LEVEES							
1101	FDR Levee Component							
110101	Mob., Demob. and Preparatory Work:	1	JOB	LS	28,464	7,000	24.6	-
110102	Site Work							
	Levee Foundations & Clearing Grubbing	1.065	miles	@130000?Mi		0	0.0	-
	Levee Found & Clear& Grub (1.065 Mi)	29,820	CY	4.40	131,208	30,000	22.9	-
	Erosion protection=Riprap	0.019	miles	@900000/Mi		0	0.0	-
	Erosion protection=Riprap (0.019 Mi)							
	EXCAVATION	186.000	CY	48.00	8,928	2,000	22.4	-
	Riprap - slope	224.000	CY	49.00	10,976	3,000	27.3	-
	Riprap - toe	67.000	CY	60.00	4,020	1,000	24.9	-
	Increase in ER Levee Compoment	66,000	CY	4.00	264,000	64,000	24.2	-
	TRAINING DIKE							
	Training Dike	28,500	CY	4.00	114,000	29,000	25.4	-
	15 ft Crown Road	1.065	miles	@135000/MI		0	0.0	-
	15 ft Crown Road (5.705 mi)							
	1 Patrol Road Agg. Frm Qry to site	3,956	TON	31.00	122,636	31,000	25.3	-
	2 PLACE AGG.BASE FROM COMM.SOURCE	3,956	TON	5.00	19,780	5,000	25.3	-
	Erosion Prodection HYDROSEEDING	1.065	miles	@35000/Mi		0	0.0	-
	HYDROSEEDING (1.065 Mi)	449,856	SF	0.08	35,988	9,000	25.0	-
	Subtotal, Construction Costs:				$740,000			
	Contingencies @ average of 24.5 % +/- *					$181,000		A
1101	**LEVEES**			**TOTAL:**		**$921,000**		
18	**CULTURAL RESOURCE PRESERVATION**							
	Estimated Study @ 0.6% of Federal Obligations				136,000	34,000	25.0	
	Subtotal, Construction Costs:				$136,000			
	Contingencies @ average of 25.0 % +/- *					$34,000		A
18	**CULTURAL RESOURCE PRESERVATION**			**TOTAL:**		$170,000		
30	**PLANNING, ENGINEERING & DESIGN**							
302301	PLANS AND SPECIFICATION				444,590	111,000		
302302	Surveys and Mapping, except RE				123,850	31,000		
302302	Survey Markers				80,130	20,000		
302304	Hydraulics Studies				145,710	36,000		
302305	Geotechnical Studies(Geol and Soils)				183,450	46,000		
302306	Revegetation Plan				207,910	52,000		
302304	ENVIRONMENTAL STUDIES DOCUMENTS				163,910	42,000		
302305	HTRW STUDIES/REPORT				72,840	18,000		
302306	CULTURAL RESOURCE				91,070	23,000		
302307	COST ESTIMATE				145,680	36,000		-
302308	OTHER STUDIES/INVESTIGATIONS				50,990	13,000		
302309	CONTRACT AWARD DOCUMENTS				291,400	73,000		
3025	CLOSE OUT				189,390	47,000		
3026	PROGRAMS AND PROJECT MGMT				259,080	71,000		-
	Subtotal				$2,450,000			
	Contingencies @ average of 25.3 % +/- *					$619,000		A
30	**PLANNING, ENGINEERING & DESIGN**			**TOTAL:**		$3,069,000		
31	**CONSTRUCTION MANAGEMENT (S & I)**							
312311	SUPERVISION AND ADMINISTRATION				741,050			
	Subtotal				$1,730,000			
	Contingencies @ average of 24.9 % +/- *					$431,000		A
31	**CONSTRUCTION MANAGEMENT (S & I)**			**TOTAL:**		**$2,161,000**		

DETAILED ESTIMATE OF FIRST COST(Cont'd)

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	% *	REASON
	Effective Price Level (EPL) 1-Oct-2003							
	NON-FEDERAL							
01	**LANDS AND DAMAGES**							
01	SUNK COSTS							
012303	CONSTRUCTION CONTRACT(S) DOCUMENTS							
	Real Estate Planning Documents				370,000	37,000	10.0	-
	Real Estate Acquisition Documnts				380,000	38,000	10.0	-
	Real Estate Appraisal Documents				160,000	16,000	10.0	-
	Real Estate Payment Documents				10,090,000	2,256,000	22.4	-
	Subtotal, Construction Costs:				$11,000,000			
	Contingencies @ average of	21.3 % +/- *				$2,347,000		A
01	**LANDS AND DAMAGES**		**TOTAL:**			**$13,347,000**		
02	**RELOCATIONS**							
0203	Local / Interior Drainage							
	Interior Drainage	300	CFS	400	120,000	29,000	24.2	-
	Local Drainage including Trailer Park ditch & Surface Drainage Canal		LS		80,000	19,000	23.8	-
	Subtotal, Construction Costs:				$200,000			
	Contingencies @ average of	24.0 % +/- *				$48,000		A
0203	Local / Interior Drainage		TOTAL:			$248,000		
0205	Road 23							
	Raise Road 23	1	LS		65,000	15,000	23.1	-
	Subtotal, Construction Costs:				$65,000			
	Contingencies @ average of	23.1 % +/- *				$15,000		A
0205	Road 23		TOTAL:			$80,000		
0206	Road 203							
	Raise Road 203	1	LS		125,000	35,000	28.0	-
	Subtotal, Construction Costs:				$125,000			
	Contingencies @ average of	28.0 % +/- *				$35,000		A
0206	Road 203		TOTAL:			$160,000		
0207	City Roads							
	Raise and relocate		LS		60,000	15,000	25.0	-
	Subtotal, Construction Costs:				$60,000			
	Contingencies @ average of	25.0 % +/- *				$15,000		A
0207	City Roads		TOTAL:			$75,000		
			Grand Subtotal		$450,000			
			Contingencies			$113,000		
02	**RELOCATIONS**		Grand Total			$563,000		
30	**PLANNING, ENGINEERING & DESIGN**				43,000	11,000	25.6	-
	Subtotal				$43,000			
	Contingencies @ average of	25.6 % +/- *				$11,000		A
30	**PLANNING, ENGINEERING & DESIGN**		**TOTAL:**			**$54,000**		
31	**CONSTRUCTION MANAGEMENT (S & I)**				41,000	10,000	24.4	-
	Subtotal				$41,000			
	Contingencies @ average of	24.4 % +/- *				$10,000		A
31	**CONSTRUCTION MANAGEMENT (S & I)**		**TOTAL:**			**$51,000**		

Thu 05 Aug 2004 Tri-Service Automated
Cost Engineering System (TRACES) TIME
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Eff. Date 05/11/03 PROJECT HAMBK6:
Hamilton base estimate
HAM -
CIT 001 TITLE PAGE
1

Hamilton
base estimate

Designed By:
U.S. ARMY CORPS OF ENGINEERS
Estimated By:

Prepared By:
CESPK-ED-C (LEAHY)

Preparation Date:
05/11/03
Effective Date of Pricing:
05/11/03
Est Construction Time:
365 Days

Sales Tax:
7.70%

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For Official Use Only.

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

Thu 05 Aug 2004 Tri-Service Automated Cost Engineering System (TRACES) TIME 13:33:07
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** PROJECT INDIRECT SUMMARY - Level 6 **

QUANTITY	UOM	TOTAL DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
		F FEDERAL						
		F- 6 Fish & Wildlife Fac.(Mitigation)						
		F- 603 Fish & Wildlife Sancturaries						
		F- 60301 Mob., Demob. and Preparatory Wo:						
		F- 60301 1 Mob., Demob. and Preparatory Wo:						
1.00	JOB	266,587	26,659	23,460	31,671	6,968	355,344	355343.68
		TOTAL Mob., Demob. and Preparatory Wo:						
1.00	JOB	266,587	26,659	23,460	31,671	6,968	355,344	355343.68
		F- 60302 Levee Foundations & Clearing						
		F- 6030201 Levee Foundations & Clear&Grub						
159740.00	CY	557,172	55,717	49,031	66,192	14,562	742,675	4.65
		TOTAL Levee Foundations & Clearing						
5.71	MI	557,172	55,717	49,031	66,192	14,562	742,675	130179.59

F- 60303 Remove "J" Levee to onsite Ste
247700.00 CY 1,133,344 113,334 99,734 134,641 29,621 1,510,675
6.10

F- 60304 Erosion protection=Entreached

F- 6030401 Clear Levee Fill Borrow Site
7.15 AC 16,022 1,602 1,410 1,903 419 21,356
2987.20

F- 6030402 Load Levee Fill at Borrow Site
65632.00 CY 216,934 21,693 19,090 25,772 5,670 289,159
4.41

F- 6030403 Haul Levee Fill from Borrow Site
24612.00 C/M 19,693 1,969 1,733 2,339 515 26,249
1.07

F- 6030404 DERRICK STONE MATERIAL
96690.00 TON 1,546,579 154,658 136,099 183,734 40,421 2,061,491
21.32

F- 6030405 HAUL DERRICK STONE 80K LB GVW
403.00 HRS 77,050 7,705 6,780 9,153 2,014 102,702
254.84

F- 6030406 PLACE DERRICK STONE FROM LEVEE
96690.00 TON 123,318 12,332 10,852 14,650 3,223 164,374
1.70

F- 6030407 Place Levee Fill
16408.00 CY 46,313 4,631 4,076 5,502 1,210 61,732
3.76

F- 6030408 Compact Levee Fill
16408.00 CY 23,649 2,365 2,081 2,809 618 31,523
1.92

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TOTAL Erosion protection=Entreached
0.59 MI 2,069,557 206,956 182,121 245,863 54,090 2,758,587
4707486

F- 60305 Levee Material from onsite Ste
247700.00 CY 748,410 74,841 65,860 88,911 19,560 997,582
4.03

F- 60306 Erosion prot. Riprap 3'-2h on 1v

F- 6030601 Erosion protection Riprap
26015.00 TON 284,346 28,435 25,022 33,780 7,432 379,015
14.57

F- 6030602 PLACE Erosion protection Riprap
26015.00 TON 39,041 3,904 3,436 4,638 1,020 52,039
2.00

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TOTAL Erosion prot. Riprap 3'-2h on 1v
0.47 MI 323,387 32,339 28,458 38,418 8,452 431,054
911318.75

F- 60307 15 ft Crown Road

F- 6030701 Patrol Road Agg. Frm Qry to site
16744.00 TON 550,149 55,015 48,413 65,358 14,379 733,313
43.80

F- 6030702 PLACE AGG.BASE FROM COMM.SOURCE
16744.00 TON 52,055 5,205 4,581 6,184 1,360 69,385

4.14

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TOTAL 15 ft Crown Road

5.71 MI 602,203 60,220 52,994 71,542 15,739 802,698
140700.85

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency
in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

Thu 05 Aug 2004 Tri-Service Automated
Cost Engineering System (TRACES) TIME
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Eff. Date 05/11/03 PROJECT HAMBK6:
Hamilton base estimate
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** PROJECT
INDIRECT SUMMARY - Level 6 **

QUANTITY UOM	TOTAL DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
			F- 60308 Erosion Prodection HYDROSEEDIG				
			F- 6030801 HYDROSEEDING				
			F- 603080101 Native Grass Seed				
49.00 AC	213,417	21,342	18,781	25,354	5,578	284,471	5805.52
			TOTAL HYDROSEEDING				
2139375 SF	213,417	21,342	18,781	25,354	5,578	284,471	0.13
			TOTAL Erosion Prodection HYDROSEEDIG				
5.71 MI	213,417	21,342	18,781	25,354	5,578	284,471	49863.40
			F- 60309 Fencing				
			F- 6030901 Fencing				
35745.60 LF	148,388	14,839	13,058	17,628	3,878	197,791	5.53
			TOTAL Fencing				
6.77 MI	148,388	14,839	13,058	17,628	3,878	197,791	29215.86

F- 60310 Seepage Berm								
F- 6031001 Haul Seepage Berm Material	144.00 HR	30,610	3,061	2,694	3,636	800	40,801	283.34
F- 6031003 Seepage Berm Mat.(Drain Rock)	89400.00 TON	930,466	93,047	81,881	110,539	24,319	1,240,252	13.87
F- 6031004 Place Seepage Berm Material	144.00 HR	49,783	4,978	4,381	5,914	1,301	66,357	460.81
TOTAL Seepage Berm	44700.00 CY	1,010,858	101,086	88,956	120,090	26,420	1,347,409	30.14
TOTAL Fish & Wildlife Sancturaries	1.00 JOB	7,073,322	707,332	622,452	840,311	184,868	9,428,286	9428286
F- 673 Habitat & Feeding Facilities								
F- 673 1 Mob & Demob	1.00 JOB	36,000	3,600	3,168	4,277	941	47,986	47985.70
F- 67301 Cottonwood	200.00 AC	1,455,000	145,500	128,040	172,854	38,028	1,939,422	9697.11
F- 67302 Riparian	796.60 AC	4,500,790	450,079	396,070	534,694	117,633	5,999,265	7531.09
F- 67303 Grassland	70.40 AC	190,080	19,008	16,727	22,582	4,968	253,364	3598.93
F- 67304 Savannah	147.90 AC	761,685	76,169	67,028	90,488	19,907	1,015,277	6864.62
F- 67305 Scrub	261.20 AC	1,475,780	147,578	129,869	175,323	38,571	1,967,120	7531.09
TOTAL Habitat & Feeding Facilities	1.00 JOB	8,419,335	841,934	740,901	1,000,217	220,048	11,222,435	11222435
TOTAL Fish & Wildlife Fac.(Mitigation)	1.00 JOB	15,492,657	1,549,266	1,363,354	1,840,528	404,916	20,650,720	20650720
F-11 LEVEES								
F-1101 Mob., Demob. and Preparatory Wo:								
F-1101 1 Mob., Demob. and Preparatory Wo:	1.00 JOB	13,329	1,333	1,173	1,584	348	17,767	17767.18

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                                          TOTAL Mob., Demob. and Preparatory Wo:
 1.00 JOB        13,329     1,333     1,173     1,584       348        17,767
17767.18


LABOR ID: MV_YC1    EQUIP ID: REG07A                                    Currency
in DOLLARS                                     CREW ID: CREW01   UPB ID: UP97EA
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QUANTITY UOM  TOTAL DIRECT  FIELD OH  HOME OFC    PROFIT      BOND    TOTAL COST
UNIT COST
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                                  F-1102  Levee Foundations & Clear&Grub

                                  F-110201  Levee Foundations & Clear&Grub
29820.00 CY         98,325     9,832     8,653    11,681     2,570       131,060
 4.40

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                                          TOTAL Levee Foundations & Clear&Grub
 1.07 MI        98,325     9,832     8,653    11,681     2,570       131,060
123061.30


                                  F-1103  Erosion protecton = Riprap

                                  F-110301  EXCAVATION
186.00 CY           6,709       671       590       797       175         8,943
48.08
                                  F-110302  Riprap - slope
224.00 CY           8,263       826       727       982       216        11,014
49.17
                                  F-110303  Riprap - toe
67.00 CY           3,015       302       265       358        79         4,019
59.98

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                                          TOTAL Erosion protecton = Riprap
 0.02 MI        17,987     1,799     1,583     2,137       470        23,975
1261861

                                  F-1104  Increase in ER Levee Component
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66000.00 CY 202,472 20,247 17,818 24,054 5,292 269,883
4.09

F-1105 Training Dike
28500.00 CY 84,363 8,436 7,424 10,022 2,205 112,451
3.95

F-1106 15 ft Crown Road

F-110601 Patrol Road Agg. Frm Qry to site
3956.00 TON 91,948 9,195 8,091 10,923 2,403 122,560
30.98

F-110602 PLACE AGG.BASE FROM COMM.SOURCE
3956.00 TON 15,616 1,562 1,374 1,855 408 20,816
5.26

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TOTAL 15 ft Crown Road
1.07 MI 107,564 10,756 9,466 12,779 2,811 143,376
134625.47

F-1107 Erosion Prodection Hydroseeding

F-110702 HYDROSEEDING

F-11070201 Native Grass Seed
10.00 AC 28,430 2,843 2,502 3,378 743 37,896
3789.60

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TOTAL HYDROSEEDING
449856.00 SF 28,430 2,843 2,502 3,378 743 37,896
0.08

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TOTAL Erosion Prodection Hydroseeding
1.07 MI 28,430 2,843 2,502 3,378 743 37,896
35583.06

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TOTAL LEVEES
1.00 JOB 552,471 55,247 48,617 65,634 14,439 736,409
736408.75

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TOTAL FEDERAL
1.00 JOB 16,045,128 1,604,513 1,411,971 1,906,161 419,355 21,387,129
21387129

N NON-FEDERAL

N-02 RELOCATIONS

N-0203 Local / Interior Drainage

N-020301 Interior Drainage

N-02030101 PUMPING FACILITY(3-1200GPM PUMS) in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

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QUANTITY UOM		TOTAL DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
	N-0203010101 PUMPING FACILITY(3-1200GPM PUMS)							
0.51 JOB		13,949	1,395	1,228	1,657	365	18,593	36521.53
	TOTAL PUMPING FACILITY(3-1200GPM PUMS)							
0.51 JOB		13,949	1,395	1,228	1,657	365	18,593	36521.53
	N-02030102 CONCRETE							
	N-0203010201 Concrete Forming							
344.53 SF		3,668	367	323	436	96	4,889	14.19
	N-0203010202 Concrete							
53.45 CY		18,480	1,848	1,626	2,195	483	24,633	460.89
	N-0203010203 Curing							
360.76 SF		845	84	74	100	22	1,126	3.12
	N-0203010204 Darby							
880.65 SF		1,160	116	102	138	30	1,546	1.76
	N-0203010205 Float							
880.65 SF		1,241	124	109	147	32	1,654	1.88
	TOTAL CONCRETE							
53.45 CY		25,393	2,539	2,235	3,017	664	33,847	633.30
	N-02030103 Reinforce Steel							
	N-0203010301 Reinforce Steel							
5599.70 LB		11,364	1,136	1,000	1,350	297	15,147	2.70

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TOTAL Reinforce Steel
5599.14 LB 11,364 1,136 1,000 1,350 297 15,147
2.71

N-02030105 GRATING

N-0203010501 STEEL ACCESS PLATFORMS
3499.51 LBS 22,788 2,279 2,005 2,707 596 30,374
8.68

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TOTAL GRATING
139.98 SF 22,788 2,279 2,005 2,707 596 30,374
216.99

N-02030106 MISCELLANEOUS METALS

N-02030106 1 MISCELLANEOUS FABRICATION
763.54 LBS 4,051 405 357 481 106 5,400
7.07

N-02030106 4 Prep & paint
25.33 SF 357 36 31 42 9 476
18.79

N-0203010650 TRANSPORT MISCELLANEOUS METALS
763.09 LBS 566 57 50 67 15 754
0.99

N-0203010660 INSTALL MISCELLANEOUS METALS
763.09 LBS 1,388 139 122 165 36 1,849
2.42

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TOTAL MISCELLANEOUS METALS
763.54 LBS 6,361 636 560 756 166 8,479
11.11

N-02030107 GEOCOMPOSIT DRAIN SYSTEM

N-0203010701 Geosynthetic Wall Drain
3.93 SY 2,895 289 255 344 76 3,859
982.76

N-0203010702 18" DIA. PREFORATED PIPING
13.09 LF 9,029 903 795 1,073 236 12,035
919.52

N-0203010703 DRAIN ROCK
10.47 TON 917 92 81 109 24 1,222
116.69

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TOTAL GEOCOMPOSIT DRAIN SYSTEM
338.47 SF 12,840 1,284 1,130 1,525 336 17,115
50.57

N-02030108 ELECTRIC SERVICE TO PUMPS

in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

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QUANTITY UOM	TOTAL DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
N-02030108 1 INSTALL TRANS.w/CONC PULL BOXES							
0.51 JOB	5,524	552	486	656	144	7,363	14463.18
N-02030108 3 INST EL.CABLE & PULL BOXES							
0.51 JOB	5,518	552	486	656	144	7,355	14446.68
TOTAL ELECTRIC SERVICE TO PUMPS							
0.51 JOB	11,042	1,104	972	1,312	289	14,718	28909.85
TOTAL Interior Drainage							
300.00 CFS	103,736	10,374	9,129	12,324	2,711	138,274	460.91
N-020302 Trailer Park Ditch & Surface D/C							
N-02030202 CONCRETE							
N-0203020201 Concrete Forming							
588.00 SF	4,654	465	410	553	122	6,203	10.55
N-0203020202 Concrete							
200.00 CY	32,860	3,286	2,892	3,904	859	43,800	219.00
N-0203020203 Curing							
1350.00 SF	701	70	62	83	18	935	0.69
N-0203020204 Darby							
695.25 SF	916	92	81	109	24	1,220	1.76
N-0203020205 Float							
695.25 SF	979	98	86	116	26	1,305	1.88

TOTAL CONCRETE
200.00 CY 40,110 4,011 3,530 4,765 1,048 53,464
267.32

N-02030203 Reinforce Steel

N-0203020301 Reinforce Steel
20000.00 LB 13,365 1,337 1,176 1,588 349 17,815
0.89

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TOTAL Reinforce Steel
20000.00 LB 13,365 1,337 1,176 1,588 349 17,815
0.89

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TOTAL Trailer Park Ditch & Surface D/C
1.00 JOB 53,475 5,348 4,706 6,353 1,398 71,279
71279.22

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TOTAL Local / Interior Drainage
1.00 JOB 157,212 15,721 13,835 18,677 4,109 209,553
209553.10

N-0205 Road 23

N-020507 Raise Road 23

N-02050701 Patrol Road Agg. Frm Qry to site
1262.00 TON 49,095 4,909 4,320 5,832 1,283 65,440
51.85

N-02050702 PLACE AGG.BASE FROM COMM.SOURCE
1262.00 TON 5,205 521 458 618 136 6,939
5.50

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TOTAL Raise Road 23
0.43 MI 54,300 5,430 4,778 6,451 1,419 72,378
168322.07

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TOTAL Road 23
1.00 JOB 54,300 5,430 4,778 6,451 1,419 72,378
72378.49

N-0206 Road 203

N-020607 Raise Road 203

N-02060701 Patrol Road Agg. Frm Qry to site
2495.00 TON 82,284 8,228 7,241 9,775 2,151 109,679
43.96

N-02060702 PLACE AGG.BASE FROM COMM.SOURCE
2495.00 TON 7,808 781 687 928 204 10,408
4.17

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LABOR ID: MV_YC1 EQUIP ID: REG07A Currency in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

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QUANTITY UOM	TOTAL DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Raise Road 203							
0.85 MI	90,092	9,009	7,928	10,703	2,355	120,087	141278.99
TOTAL Road 203							
1.00 JOB	90,092	9,009	7,928	10,703	2,355	120,087	120087.14
N-0207 City Roads							
N-020707 Raise and Relocate							
N-02070701 Patrol Road Agg. Frm Qry to site							
1233.00 TON	40,934	4,093	3,602	4,863	1,070	54,562	44.25
N-02070702 PLACE AGG.BASE FROM COMM.SOURCE							
1233.00 TON	3,904	390	344	464	102	5,204	4.22
TOTAL Raise and Relocate							
0.42 MI	44,838	4,484	3,946	5,327	1,172	59,766	142300.30
TOTAL City Roads							
1.00 JOB	44,838	4,484	3,946	5,327	1,172	59,766	59766.13
TOTAL RELOCATIONS							
1.00 JOB	346,442	34,644	30,487	41,157	9,055	461,785	461784.86
TOTAL NON-FEDERAL							

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 1.00 JOB       346,442    34,644    30,487    41,157     9,055       461,785
461784.86

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                                          TOTAL Hamilton base estimate
 1.00 EA     16,391,570 1,639,157 1,442,458 1,947,319   428,410    21,848,914
21848914

                                 Contingency
                                                                       35,963

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                                   TOTAL INCL OWNER COSTS
                                                                   21,884,877
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LABOR ID: MV_YC1    EQUIP ID: REG07A                                  Currency
in DOLLARS                                          CREW ID: CREW01   UPB ID: UP97EA


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   QUANTITY UOM  MANHRS     LABOR  EQUIPMNT  MATERIAL     OTHER    TOTAL COST UNIT
COST
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F FEDERAL

F- 6 Fish & Wildlife Fac.(Mitigation)

F- 603 Fish & Wildlife Sancturaries

F- 60301 Mob., Demob. and Preparatory Wo:

F- 60301 1 Mob., Demob. and Preparatory Wo:
1.00 JOB 0 133,294 133,294 0 0 266,587
266587.20

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TOTAL Mob., Demob. and Preparatory
Wo: 1.00 JOB 0 133,294 133,294 0 0 266,587
266587.20

F- 60302 Levee Foundations & Clearing

F- 6030201 Levee Foundations & Clear&Grub
159740.00 CY 4,760 291,103 266,069 0 0 557,172
3.49

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TOTAL Levee Foundations & Clearing
5.71 MI 4,760 291,103 266,069 0 0 557,172
97663.80

F- 60303 Remove "J" Levee to onsite Ste
247700.00 CY 10,080 610,428 522,916 0 0 1,133,344
4.58

F- 60304 Erosion protection=Entreached

F- 6030401 Clear Levee Fill Borrow Site
7.15 AC 0 8,336 7,686 0 0 16,022
2241.07

F- 6030402 Load Levee Fill at Borrow Site
65632.00 CY 0 104,878 112,056 0 0 216,934
3.31

F- 6030403 Haul Levee Fill from Borrow Site
24612.00 C/M 0 11,812 7,880 0 0 19,693
0.80

F- 6030404 DERRICK STONE MATERIAL
96690.00 TON 0 0 0 0 1,546,579 1,546,579
16.00

F- 6030405 HAUL DERRICK STONE 80K LB GVW
403.00 HRS 0 46,216 30,833 0 0 77,050
191.19

F- 6030406 PLACE DERRICK STONE FROM LEVEE
96690.00 TON 0 73,969 49,349 0 0 123,318
1.28

F- 6030407 Place Levee Fill
16408.00 CY 0 21,131 25,182 0 0 46,313
2.82

F- 6030408 Compact Levee Fill
16408.00 CY 0 16,236 7,413 0 0 23,649

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1.44

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                                                 TOTAL Erosion protection=Entreached
       0.59 MI        0   282,578   240,400         0 1,546,579     2,069,557
3531667

                                         F- 60305  Levee Material from onsite Ste
  247700.00 CY    8,060   469,950   278,460         0         0       748,410
3.02

                                         F- 60306  Erosion prot. Riprap 3'-2h on 1v

                                         F- 6030601  Erosion protection Riprap
   26015.00 TON   1,110    65,564    50,723   168,059         0       284,346
10.93
                                         F- 6030602  PLACE Erosion protection Riprap
   26015.00 TON     420    26,616    12,425         0         0        39,041
1.50

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                                                 TOTAL Erosion prot. Riprap 3'-2h on
1v      0.47 MI    1,530    92,180    63,148   168,059         0       323,387
683692.80


                                         F- 60307  15 ft Crown Road

                                         F- 6030701  Patrol Road Agg. Frm Qry to site
   16744.00 TON   2,880   173,769   136,008   240,372         0       550,149
32.86
                                         F- 6030702  PLACE AGG.BASE FROM COMM.SOURCE
   16744.00 TON     560    35,488    16,566         0         0        52,055
3.11

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                                                 TOTAL 15 ft Crown Road
       5.71 MI    3,440   209,257   152,574   240,372         0       602,203
105557.10


LABOR ID: MV_YC1    EQUIP ID: REG07A                                        Currency
in DOLLARS                                            CREW ID: CREW01   UPB ID: UP97EA


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   QUANTITY UOM  MANHRS     LABOR  EQUIPMNT  MATERIAL     OTHER    TOTAL COST UNIT
COST
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									F- 60308 Erosion Prodection HYDROSEEDIG
									F- 6030801 HYDROSEEDING
49.00	AC	98	7,435	378	205,604	0	213,417	4355.44	F- 603080101 Native Grass Seed
2139375	SF	98	7,435	378	205,604	0	213,417	0.10	TOTAL HYDROSEEDING
5.71	MI	98	7,435	378	205,604	0	213,417	37408.70	TOTAL Erosion Prodection HYDROSEEDIG
									F- 60309 Fencing
35745.60	LF	80	4,436	263	143,689	0	148,388	4.15	F- 6030901 Fencing
6.77	MI	80	4,436	263	143,689	0	148,388	21918.42	TOTAL Fencing
									F- 60310 Seepage Berm
144.00	HR	288	19,611	10,999	0	0	30,610	212.57	F- 6031001 Haul Seepage Berm Material
89400.00	TON	0	0	0	930,466	0	930,466	10.41	F- 6031003 Seepage Berm Mat.(Drain Rock)
144.00	HR	288	16,514	33,269	0	0	49,783	345.71	F- 6031004 Place Seepage Berm Material
44700.00	CY	576	36,125	44,268	930,466	0	1,010,858	22.61	TOTAL Seepage Berm
1.00	JOB	28,624	2,136,785	1,701,768	1,688,190	1,546,579	7,073,322	7073322	TOTAL Fish & Wildlife Sancturaries
									F- 673 Habitat & Feeding Facilities
1.00	JOB	0	0	0	0	36,000	36,000	36000.00	F- 673 1 Mob & Demob
									F- 67301 Cottonwood

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    200.00 AC        0         0         0         0 1,455,000     1,455,000
7275.00
                                        F- 67302  Riparian
    796.60 AC        0         0         0         0 4,500,790     4,500,790
5650.00
                                        F- 67303  Grassland
     70.40 AC        0         0         0         0   190,080       190,080
2700.00
                                        F- 67304  Savannah
    147.90 AC        0         0         0         0   761,685       761,685
5150.00
                                        F- 67305  Scrub
    261.20 AC        0         0         0         0 1,475,780     1,475,780
5650.00

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                                                TOTAL Habitat & Feeding Facilities
      1.00 JOB       0         0         0         0 8,419,335     8,419,335
8419335

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                                                TOTAL Fish & Wildlife
Fac.(Mitigation)      1.00 JOB  28,624 2,136,785 1,701,768 1,688,190 9,965,914
15,492,657  15492657


                                        F-11  LEVEES

                                        F-1101  Mob., Demob. and Preparatory Wo:

                                        F-1101 1  Mob., Demob. and Preparatory Wo:
      1.00 JOB       0     6,665     6,665         0         0        13,329
13329.36

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                                                TOTAL Mob., Demob. and Preparatory
Wo:      1.00 JOB       0     6,665     6,665         0         0        13,329
13329.36


LABOR ID: MV_YC1    EQUIP ID: REG07A                                    Currency
in DOLLARS                                        CREW ID: CREW01   UPB ID: UP97EA


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   QUANTITY UOM  MANHRS     LABOR  EQUIPMNT  MATERIAL     OTHER    TOTAL COST UNIT
COST
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F-1102 Levee Foundations & Clear&Grub

F-110201 Levee Foundations & Clear&Grub
29820.00 CY 840 51,371 46,953 0 0 98,325
3.30

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TOTAL Levee Foundations & Clear&Grub
1.07 MI 840 51,371 46,953 0 0 98,325
92323.49

F-1103 Erosion protecton = Riprap

F-110301 EXCAVATION
186.00 CY 54 3,266 3,444 0 0 6,709
36.07

F-110302 Riprap - slope
224.00 CY 34 1,912 1,206 5,145 0 8,263
36.89

F-110303 Riprap - toe
67.00 CY 16 893 583 1,539 0 3,015
45.00

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TOTAL Erosion protecton = Riprap
0.02 MI 104 6,070 5,233 6,684 0 17,987
946678.04

F-1104 Increase in ER Levee Component
66000.00 CY 2,880 125,161 77,308 0 2 202,472
3.07

F-1105 Training Dike
28500.00 CY 1,200 52,151 32,212 0 1 84,363
2.96

F-1106 15 ft Crown Road

F-110601 Patrol Road Agg. Frm Qry to site
3956.00 TON 444 26,226 20,289 45,433 0 91,948
23.24

F-110602 PLACE AGG.BASE FROM COMM.SOURCE
3956.00 TON 168 10,646 4,970 0 0 15,616
3.95

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TOTAL 15 ft Crown Road
1.07 MI 612 36,872 25,259 45,433 0 107,564
100999.20

F-1107 Erosion Prodection Hydroseeding

F-110702 HYDROSEEDING

F-11070201 Native Grass Seed
10.00 AC 8 607 31 27,793 0 28,430
2843.04

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TOTAL HYDROSEEDING
449856.00 SF 8 607 31 27,793 0 28,430
0.06

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TOTAL Erosion Prodection
Hydroseeding 1.07 MI 8 607 31 27,793 0
28,430 26695.25

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TOTAL LEVEES
1.00 JOB 5,644 278,897 193,661 79,910 4 552,471
552471.20

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TOTAL FEDERAL
1.00 JOB 34,268 2,415,681 1,895,429 1,768,100 9,965,918 16,045,128
16045128

N NON-FEDERAL

N-02 RELOCATIONS

N-0203 Local / Interior Drainage

N-020301 Interior Drainage

N-02030101 PUMPING FACILITY(3-1200GPM PUMS)

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency
in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

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QUANTITY UOM MANHRS LABOR EQUIPMNT MATERIAL OTHER TOTAL COST UNIT
COST

N-0203010101 PUMPING FACILITY(3-1200GPM
PUMS) 0.51 JOB 70 3,182 312 10,455 0 13,949
27399.31

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TOTAL PUMPING FACILITY(3-1200GPM

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PUMS)      0.51 JOB       70     3,182       312    10,455         0        13,949
27399.31

                                           N-02030102  CONCRETE

                                           N-0203010201  Concrete Forming
     344.53 SF        51      2,509        565       594         0         3,668
10.65
                                           N-0203010202  Concrete
      53.45 CY       203      9,645      2,647     6,188         0        18,480
345.77
                                           N-0203010203  Curing
     360.76 SF        15        764         69        12         0           845
2.34
                                           N-0203010204  Darby
     880.65 SF        20      1,054        106         0         0         1,160
1.32
                                           N-0203010205  Float
     880.65 SF        20      1,054        187         0         0         1,241
1.41

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                                                TOTAL CONCRETE
      53.45 CY       309     15,026      3,574     6,793         0        25,393
475.11


                                           N-02030103  Reinforce Steel

                                           N-0203010301  Reinforce Steel
    5599.70 LB       101      7,210      2,704     1,450         0        11,364
2.03

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                                                TOTAL Reinforce Steel
    5599.14 LB       101      7,210      2,704     1,450         0        11,364
2.03


                                           N-02030105  GRATING

                                           N-0203010501  STEEL ACCESS PLATFORMS
    3499.51 LBS       91      6,073      3,047     3,896     9,772        22,788
6.51

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                                                TOTAL GRATING
     139.98 SF        91      6,073      3,047     3,896     9,772        22,788
162.79


                                           N-02030106  MISCELLANEOUS METALS

                                           N-02030106 1  MISCELLANEOUS FABRICATION
     763.54 LBS       25      1,485        392     2,174         0         4,051
5.31
                                           N-02030106 4  Prep & paint
      25.33 SF         7        354          3         0         0           357
14.10
                                           N-0203010650  TRANSPORT MISCELLANEOUS METALS
     763.09 LBS        5        279        287         0         0           566
0.74
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N-0203010660 INSTALL MISCELLANEOUS METALS
763.09 LBS 18 1,134 253 0 0 1,388
1.82

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TOTAL MISCELLANEOUS METALS
763.54 LBS 54 3,252 935 2,174 0 6,361
8.33

N-02030107 GEOCOMPOSIT DRAIN SYSTEM

N-0203010701 Geosynthetic Wall Drain
3.93 SY 41 2,595 272 27 0 2,895
737.29
N-0203010702 18" DIA. PREFORATED PIPING
13.09 LF 90 4,842 275 3,912 0 9,029
689.84
N-0203010703 DRAIN ROCK
10.47 TON 7 448 258 210 0 917
87.54

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TOTAL GEOCOMPOSIT DRAIN SYSTEM
338.47 SF 138 7,885 806 4,149 0 12,840
37.94

N-02030108 ELECTRIC SERVICE TO PUMPS

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency
in DOLLARS CREW ID: CREW01 UPB ID: UP97EA
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QUANTITY UOM MANHRS LABOR EQUIPMNT MATERIAL OTHER TOTAL COST UNIT
COST

N-02030108 1 INSTALL TRANS.w/CONC PULL
BOXES 0.51 JOB 43 2,250 0 3,274 0 5,524
10850.62
N-02030108 3 INST EL.CABLE & PULL BOXES
0.51 JOB 48 2,514 403 2,600 0 5,518
10838.24

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               ------- --------- --------- --------- ---------   -----------
                                                TOTAL ELECTRIC SERVICE TO PUMPS
      0.51 JOB      91     4,764       403     5,875         0       11,042
21688.85

               ------- --------- --------- --------- ---------   -----------
                                                TOTAL Interior Drainage
    300.00 CFS     855    47,391    11,781    34,793     9,772      103,736
345.79


                                        N-020302  Trailer Park Ditch & Surface D/C

                                        N-02030202  CONCRETE

                                        N-0203020201  Concrete Forming
    588.00 SF       60     2,971       669     1,013         0        4,654
7.91
                                        N-0203020202  Concrete
    200.00 CY      160     7,615     2,090    23,156         0       32,860
164.30
                                        N-0203020203  Curing
   1350.00 SF       12       603        54        44         0          701
0.52
                                        N-0203020204  Darby
    695.25 SF       16       832        84         0         0          916
1.32
                                        N-0203020205  Float
    695.25 SF       16       832       148         0         0          979
1.41

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                                                TOTAL CONCRETE
    200.00 CY      264    12,853     3,045    24,212         0       40,110
200.55


                                        N-02030203  Reinforce Steel

                                        N-0203020301  Reinforce Steel
  20000.00 LB       80     5,692     2,135     5,539         0       13,365
0.67

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                                                TOTAL Reinforce Steel
  20000.00 LB       80     5,692     2,135     5,539         0       13,365
0.67

               ------- --------- --------- --------- ---------   -----------
                                                TOTAL Trailer Park Ditch & Surface
D/C      1.00 JOB     344    18,545     5,179    29,751         0       53,475
53475.35

               ------- --------- --------- --------- ---------   -----------
                                                TOTAL Local / Interior Drainage
      1.00 JOB   1,199    65,936    16,960    64,544     9,772      157,212
157211.67


                                        N-0205  Road 23

                                        N-020507  Raise  Road 23
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                                        N-02050701  Patrol Road Agg. Frm Qry to site
    1262.00 TON     288    17,377    13,601    18,117         0        49,095
38.90
                                        N-02050702  PLACE AGG.BASE FROM COMM.SOURCE
    1262.00 TON      56     3,549     1,657         0         0         5,205
4.12

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                                          TOTAL Raise  Road 23
       0.43 MI      344    20,926    15,257    18,117         0        54,300
126279.18

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                                          TOTAL Road 23
       1.00 JOB     344    20,926    15,257    18,117         0        54,300
54300.05


                                        N-0206  Road 203

                                        N-020607  Raise  Road 203

                                        N-02060701  Patrol Road Agg. Frm Qry to site
    2495.00 TON     432    26,065    20,401    35,818         0        82,284
32.98
                                        N-02060702  PLACE AGG.BASE FROM COMM.SOURCE
    2495.00 TON      84     5,323     2,485         0         0         7,808
3.13

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LABOR ID: MV_YC1    EQUIP ID: REG07A                                      Currency
in DOLLARS                                            CREW ID: CREW01   UPB ID: UP97EA
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   QUANTITY UOM  MANHRS     LABOR  EQUIPMNT  MATERIAL     OTHER    TOTAL COST UNIT
COST
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                                          TOTAL Raise  Road 203
       0.85 MI      516    31,389    22,886    35,818         0        90,092
105990.83

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                                                   TOTAL Road 203
       1.00 JOB     516    31,389    22,886    35,818         0        90,092
90092.20

                                               N-0207  City Roads

                                               N-020707  Raise and Relocate

                                               N-02070701  Patrol Road Agg. Frm Qry to site
    1233.00 TON     216    13,033    10,201    17,701         0        40,934
33.20
                                               N-02070702  PLACE AGG.BASE FROM COMM.SOURCE
    1233.00 TON      42     2,662     1,242         0         0         3,904
3.17

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                                                   TOTAL Raise and Relocate
       0.42 MI      258    15,694    11,443    17,701         0        44,838
106757.04

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                                                   TOTAL City Roads
       1.00 JOB     258    15,694    11,443    17,701         0        44,838
44837.96

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                                                   TOTAL RELOCATIONS
       1.00 JOB   2,317   133,944    66,546   136,180     9,772       346,442
346441.88

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                                                   TOTAL NON-FEDERAL
       1.00 JOB   2,317   133,944    66,546   136,180     9,772       346,442
346441.88

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                                                   TOTAL Hamilton base estimate
       1.00 EA   36,585 2,549,625 1,961,976 1,904,280 9,975,690    16,391,570
16391570

                                              Prime Contractor's Field Overhead
                                                                    1,639,157

                                                                  -----------
                                                SUBTOTAL
                                                                   18,030,727
                                              Prime's Home Office Expense
                                                                    1,442,458

                                                                  -----------
                                                SUBTOTAL
                                                                   19,473,185
                                              Prime Contractor's Profit
                                                                    1,947,319

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                                                SUBTOTAL
                                                                   21,420,504
                                              Prime Contractor's Bond
                                                                      428,410

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TOTAL INCL INDIRECTS
21,848,914
Contingency
35,963

TOTAL INCL OWNER COSTS
21,884,877

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency in DOLLARS CREW ID: CREW01 UPB ID: UP97EA

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** CONTRACT **

					QUANTITY	UOM
UNIT	TOTAL		ADJ UNIT	TOTAL		
		F FEDERAL				
		F. 6 Fish & Wildlife Fac.(Mitigation)				
		F. 6.03 Fish & Wildlife Sancturaries				
		F. 6.03.01 Mob., Demob. and Preparatory Wo:				
355343.68	355,344	F. 6.03.01. 1 Mob., Demob. and Preparatory Wo:	344185.00	344,185	1.00	JOB
355343.68	355,344	F. 6.03.01 Mob., Demob. and Preparatory Wo:	0.00	344,185	1.00	JOB
		F. 6.03.02 Levee Foundations & Clearing				
4.65	742,675	F. 6.03.02.01 Levee Foundations & Clear&Grub	4.65	742,791	159740.00	CY

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                     F. 6.03.02 Levee Foundations & Clearing              5.71 MI
    130179.59        742,675                      0.00       742,791

                     F. 6.03.03 Remove "J" Levee to onsite Ste
                     F. 6.03.03.00 <<< Not Identified >>>            247700.00 CY
         6.10      1,510,675                      6.00     1,486,200

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                     F. 6.03.03 Remove "J" Levee to onsite Ste       247700.00 CY
         6.10      1,510,675                      6.00     1,486,200

                     F. 6.03.04 Erosion protection=Entreached
                     F. 6.03.04.01 Clear Levee Fill Borrow Site           7.15 AC
      2987.20         21,356                   2970.00        21,233
                     F. 6.03.04.02 Load Levee Fill at Borrow Site     65632.00 CY
         4.41        289,159                      4.40       288,781
                     F. 6.03.04.03 Haul Levee Fill from Borrow Site   24612.00 C/M
         1.07         26,249                      1.07        26,335
                     F. 6.03.04.04 DERRICK STONE MATERIAL             96690.00 TON
        21.32      2,061,491                     21.32     2,061,431
                     F. 6.03.04.05 HAUL DERRICK STONE 80K LB GVW        403.00 HRS
       254.84        102,702                    254.84       102,701
                     F. 6.03.04.06 PLACE DERRICK STONE FROM LEVEE     96690.00 TON
         1.70        164,374                      1.70       164,373
                     F. 6.03.04.07 Place Levee Fill                   16408.00 CY
         3.76         61,732                      3.74        61,366
                     F. 6.03.04.08 Compact Levee Fill                 16408.00 CY
         1.92         31,523                      1.89        31,011

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                     F. 6.03.04 Erosion protection=Entreached             0.59 MI
   4707485.72      2,758,587                      0.00     2,757,230

                     F. 6.03.05 Levee Material from onsite Ste
                     F. 6.03.05.00 <<< Not Identified >>>            247700.00 LS
         4.03        997,582                      4.00       990,800

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                     F. 6.03.05 Levee Material from onsite Ste       247700.00 CY
         4.03        997,582                      4.00       990,800

                     F. 6.03.06 Erosion prot. Riprap 3'-2h on 1v
                     F. 6.03.06.01 Erosion protection Riprap          26015.00 TON
        14.57        379,015                     14.50       377,218
                     F. 6.03.06.02 PLACE Erosion protection Riprap    26015.00 TON
         2.00         52,039                      2.00        52,030

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                     F. 6.03.06 Erosion prot. Riprap 3'-2h on 1v          0.47 MI
    911318.75        431,054                      0.00       429,248

                     F. 6.03.07 15 ft Crown Road
                     F. 6.03.07.01 Patrol Road Agg. Frm Qry to site   16744.00 TON
        43.80        733,313                     43.75       732,550
                     F. 6.03.07.02 PLACE AGG.BASE FROM COMM.SOURCE    16744.00 TON
         4.14         69,385                      2.00        33,488

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                     F. 6.03.07 15 ft Crown Road                          5.71 MI
    140700.85        802,698                      0.00       766,038

                     F. 6.03.08 Erosion Prodection HYDROSEEDIG
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                    F. 6.03.08.01 HYDROSEEDING                            2139375.00 SF
        0.13        284,471                     0.13        278,119

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                    F. 6.03.08 Erosion Prodection HYDROSEEDIG                   5.71 MI
    49863.40        284,471                     0.00        278,119


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                                                                      QUANTITY UOM
         UNIT           TOTAL                   ADJ UNIT           TOTAL
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                    F. 6.03.09 Fencing
                    F. 6.03.09.01 Fencing                                 35745.60 LF
        5.53        197,791                     5.55        198,388

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                    F. 6.03.09 Fencing                                        6.77 MI
    29215.86        197,791                     0.00        198,388

                    F. 6.03.10 Seepage Berm
                    F. 6.03.10.01 Haul Seepage Berm Material                144.00 HR
      283.34         40,801                   280.00         40,320
                    F. 6.03.10.03 Seepage Berm Mat.(Drain Rock)           89400.00 TON
       13.87      1,240,252                    13.90      1,242,660
                    F. 6.03.10.04 Place Seepage Berm Material               144.00 HR
      460.81         66,357                   460.81         66,357

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                    F. 6.03.10 Seepage Berm                               44700.00 CY
       30.14      1,347,409                    30.00      1,349,337


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                    F. 6.03 Fish & Wildlife Sancturaries                      1.00 JOB
  9428285.76      9,428,286                     0.00      9,342,335

                    F. 6.73 Habitat & Feeding Facilities
                    F. 6.73. 1 Mob & Demob
                    F. 6.73. 1.00 <<< Not Identified >>>                      1.00 LS
    47985.70         47,986                 48550.00         48,550

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F. 6.73. 1 Mob & Demob 1.00 JOB
47985.70 47,986 48550.00 48,550

F. 6.73.01 Cottonwood
F. 6.73.01.00 <<< Not Identified >>> 200.00 LS
9697.11 1,939,422 9700.00 1,940,000

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F. 6.73.01 Cottonwood 200.00 AC
9697.11 1,939,422 9700.00 1,940,000

F. 6.73.02 Riparian
F. 6.73.02.00 <<< Not Identified >>> 796.00 LS
7536.77 5,999,265 7500.00 5,970,000

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F. 6.73.02 Riparian 796.60 AC
7531.09 5,999,265 7500.00 5,970,000

F. 6.73.03 Grassland
F. 6.73.03.00 <<< Not Identified >>> 70.40 LS
3598.93 253,364 3600.00 253,440

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F. 6.73.03 Grassland 70.40 AC
3598.93 253,364 3600.00 253,440

F. 6.73.04 Savannah
F. 6.73.04.00 <<< Not Identified >>> 147.90 LS
6864.62 1,015,277 6900.00 1,020,510

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F. 6.73.04 Savannah 147.90 AC
6864.62 1,015,277 6900.00 1,020,510

F. 6.73.05 Scrub
F. 6.73.05.00 <<< Not Identified >>> 261.20 LS
7531.09 1,967,120 7500.00 1,959,000

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F. 6.73.05 Scrub 261.20 AC
7531.09 1,967,120 7500.00 1,959,000

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F. 6.73 Habitat & Feeding Facilities 1.00 JOB
11222434.72 11,222,435 0.00 11,191,500

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F. 6 Fish & Wildlife Fac.(Mitigation) 1.00 JOB
20650720.48 20,650,720 0.00 20,533,835

LABOR ID: MV_YC1 EQUIP ID: REG07A Currency
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UNIT	TOTAL	DESCRIPTION	ADJ UNIT	TOTAL	QUANTITY	UOM
		F.11 LEVEES				
		F.11.01 Mob., Demob. and Preparatory Wo:				
		F.11.01. 1 Mob., Demob. and Preparatory Wo:				
17767.18	17,767	F.11.01. 1.00 <<< Not Identified >>>	28464.00	28,464	1.00	EA
17767.18	17,767	F.11.01. 1 Mob., Demob. and Preparatory Wo:	28464.00	28,464	1.00	JOB
17767.18	17,767	F.11.01 Mob., Demob. and Preparatory Wo:	0.00	28,464	1.00	JOB
		F.11.02 Levee Foundations & Clear&Grub				
		F.11.02.01 Levee Foundations & Clear&Grub				
4.40	131,060	F.11.02.01.00 <<< Not Identified >>>	4.40	131,208	29820.00	CY
4.40	131,060	F.11.02.01 Levee Foundations & Clear&Grub	0.00	131,208	29820.00	CY
123061.30	131,060	F.11.02 Levee Foundations & Clear&Grub	0.00	131,208	1.07	MI
		F.11.03 Erosion protecton = Riprap				
		F.11.03.01 EXCAVATION				
48.08	8,943	F.11.03.01.00 <<< Not Identified >>>	48.00	8,928	186.00	CY
48.08	8,943	F.11.03.01 EXCAVATION	49.00	8,928	186.00	CY
		F.11.03.02 Riprap - slope				
49.17	11,014	F.11.03.02.00 <<< Not Identified >>>	49.00	10,976	224.00	CY
49.17	11,014	F.11.03.02 Riprap - slope	49.00	10,976	224.00	CY
		F.11.03.03 Riprap - toe				
		F.11.03.03.00 <<< Not Identified >>>			67.00	CY

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        59.98           4,019                    60.00          4,020

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                        F.11.03.03 Riprap - toe                              67.00 CY
        59.98           4,019                    60.00          4,020


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                        F.11.03 Erosion protecton = Riprap                    0.02 MI
   1261861.25          23,975                     0.00         23,924

                        F.11.04 Increase in ER Levee Component
                        F.11.04.00 <<< Not Identified >>>
                        F.11.04.00.00 <<< Not Identified >>>              66000.00 CY
         4.09         269,883                     4.00        264,000

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                        F.11.04.00 <<< Not Identified >>>                 66000.00 CY
         4.09         269,883                     4.00        264,000


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                        F.11.04 Increase in ER Levee Component            66000.00 CY
         4.09         269,883                     0.00        264,000

                        F.11.05 Training Dike
                        F.11.05.00 <<< Not Identified >>>
                        F.11.05.00.00 <<< Not Identified >>>              28500.00 LS
         3.95         112,451                     4.00        114,000


LABOR ID: MV_YC1    EQUIP ID: REG07A                                        Currency
in DOLLARS                                          CREW ID: CREW01   UPB ID: UP97EA


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         UNIT           TOTAL                  ADJ UNIT         TOTAL
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                        F.11.05.00 <<< Not Identified >>>                 28500.00 CY
         3.95         112,451                     4.00        114,000


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F.11.05 Training Dike 28500.00 CY
3.95 112,451 0.00 114,000

F.11.06 15 ft Crown Road
F.11.06.01 Patrol Road Agg. Frm Qry to site
F.11.06.01.00 <<< Not Identified >>> 3956.00 TON
30.98 122,560 31.00 122,636

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F.11.06.01 Patrol Road Agg. Frm Qry to site 3956.00 TON
30.98 122,560 31.00 122,636

F.11.06.02 PLACE AGG.BASE FROM COMM.SOURCE
F.11.06.02.00 <<< Not Identified >>> 3956.00 TON
5.26 20,816 5.00 19,780

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F.11.06.02 PLACE AGG.BASE FROM COMM.SOURCE 3956.00 TON
5.26 20,816 5.00 19,780

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F.11.06 15 ft Crown Road 1.07 MI
134625.47 143,376 0.00 142,416

F.11.07 Erosion Prodection Hydroseeding
F.11.07.02 HYDROSEEDING
F.11.07.02.01 Native Grass Seed 449856.00 SF
0.08 37,896 0.08 35,988

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F.11.07.02 HYDROSEEDING 449856.00 SF
0.08 37,896 0.00 35,988

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F.11.07 Erosion Prodection Hydroseeding 1.07 MI
35583.06 37,896 0.00 35,988

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F.11 LEVEES 1.00 JOB
736408.75 736,409 0.00 740,000

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F FEDERAL 1.00 JOB
21387129.23 21,387,129 0.00 21,273,836

N NON-FEDERAL
N.02 RELOCATIONS
N.02.03 Local / Interior Drainage
N.02.03.01 Interior Drainage
N.02.03.01.01 PUMPING FACILITY(3-1200GPM PUMS) 1.00 JOB
18593.11 18,593 19300.00 19,300
N.02.03.01.02 CONCRETE 53.00 CY
638.62 33,847 600.00 31,800
N.02.03.01.03 Reinforce Steel 5600.00 LB
2.70 15,147 2.75 15,400
N.02.03.01.05 GRATING 140.00 SF
216.96 30,374 220.00 30,800
N.02.03.01.06 MISCELLANEOUS METALS 760.00 LBS
11.16 8,479 11.00 8,360

```
                      N.02.03.01.07 GEOCOMPOSIT DRAIN SYSTEM              340.00 SF
     50.34             17,115                     50.50        17,170
                      N.02.03.01.08 ELECTRIC SERVICE TO PUMPS               1.00 JOB
  14718.01             14,718                  14700.00        14,700

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                      N.02.03.01 Interior Drainage                        300.00 CFS
    460.91            138,274                    400.00       137,530

                      N.02.03.02 Trailer Park Ditch & Surface D/C


LABOR ID: MV_YC1    EQUIP ID: REG07A                                     Currency
in DOLLARS                                 CREW ID: CREW01   UPB ID: UP97EA
□

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Cost Engineering System (TRACES)                                          TIME
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         UNIT          TOTAL                    ADJ UNIT          TOTAL
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                      N.02.05.07 Raise  Road 23
                      N.02.05.07.01 Patrol Road Agg. Frm Qry to site     1262.00 TON
     51.85             65,440                     52.00        65,624
                      N.02.05.07.02 PLACE AGG.BASE FROM COMM.SOURCE      1262.00 TON
      5.50              6,939                      5.25         6,626

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                      N.02.05.07 Raise  Road 23                             0.43 MI
 168322.07             72,378                 151200.00        72,250
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	N.02.06 Road 203				
	N.02.06.07 Raise Road 203				
	N.02.06.07.01 Patrol Road Agg. Frm Qry to site			2495.00	TON
43.96	109,679	44.00	109,780		
	N.02.06.07.02 PLACE AGG.BASE FROM COMM.SOURCE			2495.00	TON
4.17	10,408	4.00	9,980		
	N.02.06.07 Raise Road 203			0.85	MI
141278.99	120,087	147060.00	119,760		
	N.02.06 Road 203			1.00	JOB
120087.14	120,087	0.00	119,760		
	N.02.07 City Roads				
	N.02.07.07 Raise and Relocate				
	N.02.07.07.01 Patrol Road Agg. Frm Qry to site			1233.00	TON
44.25	54,562	44.00	54,252		
	N.02.07.07.02 PLACE AGG.BASE FROM COMM.SOURCE			1233.00	TON
4.22	5,204	4.00	4,932		
	N.02.07.07 Raise and Relocate			0.42	MI
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	N.02.07 City Roads			1.00	JOB
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	N NON-FEDERAL			1.00	JOB
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	Hamilton base estimate			1.00	EA
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LABOR ID: MV_YC1   EQUIP ID: REG07A   Currency in DOLLARS   CREW ID: CREW01   UPB ID: UP97EA

Thu 05 Aug 2004   Tri-Service Automated Cost Engineering System (TRACES)   TIME 13:33:07
Eff. Date 05/11/03   PROJECT HAMBK6: Hamilton base estimate
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Appendix C9.

STRUCTURAL
(Not Applicable)

Appendix C10.

HABITAT REVEGETATION REPORT

Hamilton City
Flood Damage Reduction and Ecosystem Restoration, California

Habitat Revegetation Report

Landscape Architectural Unit
Civil Design B Section

US ARMY CORPS OF ENGINEERS
Sacramento District

May 2004

Hamilton City, Flood Damage Reduction and Ecosystem Restoration Project, CA
Habitat Revegetation Report

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Hamilton City, Flood Damage Reduction and Ecosystem Restoration, CA
Habitat Revegetation Report

Revegetation Basis of Design

February 2004

1. Introduction

This report studies revegetation methods for the various restoration alternatives for the Hamilton City Flood Damage Reduction and Ecosystem Restoration Project (the "Project"). As such it addresses only one of the ecosystem restoration measures that is explained along with other measures in section 3.3 of the Feasibility report. The measure addressed is the restoration of native vegetation

This report provides a methodology for revegetation of all of the project alternatives. In general, for each of the alternatives all land on the waterside of the levee would be revegetated. This report is concerned with efforts to revegetate various types of native riparian habitats within the floodplain areas formed between the Project levee and the Sacramento River within the Project limits. The design concept consists of planting and establishing the various riparian habitats using established agricultural techniques tailored to the Sacramento River beginning in 1989. The specific types of riparian habitat to be established will be located based on hydrologic modeling, flooding frequency, soil properties, and depth to water table. The revegetation efforts and methods presented in this report describe the process to establish riparian habitats within the Hamilton City Project.

Therefore, this report looks at the technical requirements for determining and establishing appropriate vegetative habitat types. The requirements for each habitat type are considered and documented in this report. The level of detail used to assess the technical requirements is generalized to the two proposed major classes of habitat types, grassland and habitat types with woody vegetation. Since the level of detail for this feasibility study did not include site specific design and mapping, all proposed techniques and methods are general and will be adapted to site specific conditions in the next phase of the project, the Project Engineering Design (PED) Phase. Specific Site conditions that may require adjustment or change of implementation technique include but are not limited to: topology, previous land use, specific weed infestations in the various fields, Soil types and groundwater conditions. Quantities are established in this report which can be extended across the habitat acreages of the various alternatives. Refer to chapter 3 of the main report.

The selected alternative is a combined flood damage reduction and ecosystem restoration solution. An overall takeoff of quantities for the selected alternative is provided as well

2. References

Riparian Restoration Plan for the Pine Creek Unit, Upper Sacramento River Wildlife Area Sacramento River mile 194.5-197R Butte County, California; Prepared by Sacramento River Partners for the California Department of Fish and Game Wildlife Conservation Board. April 24, 2003

Preliminary plant design model: soil stratigraphy and elevation**.** The Nature Conservancy, Sacramento River Project. 2003.

2003 Site Assessments: Haleakala, RX Ranch, Sunset Ranch, and Deadman's Reach. The Nature Conservancy, Sacramento River Project. August 2002.

Woodson Bridge/Kopta Sough Restoration Project, Appendix A: Kopta Slough Restoration Design, September 23, 2003; CESPK-ED-E, Civil Design B

Field Notes and Observations, James Lee, CESPK-ED-D, September 2003 Field Visit.

EC 1165-2-201 Ecosystem Restoration in the Civil Works Program.

Donald Twiss, PE: Personal communication, RE: wave wash barriers.

3. Revegetation Goals & Objectives

3.1 The objectives for the revegetation design are:

a. Revegetate floodplain areas on the waterside of the Project levee and training dikes with various native riparian habitat types.
b. Maximize habitat diversity in the Project area by recreating a diverse mosaic of riparian habitat types as dictated by physical site conditions.
c. Create self sustaining riparian habitats based on site conditions.
d. Provide wave wash protection to levees and training dikes as necessary.
e. Provide vegetative erosion protection for the levees and training dikes as necessary.

3.2 To accomplish these revegetation goals, the following measures have been developed:

a. Maximize habitat diversity by planting differing subtypes of riparian forest, savannah, scrub or grassland to create mosaics of habitat types.
b. Establish container, or pole cutting plantings to self-sufficient state by irrigating for the three-year establishment phase.
c. Protect container or pole cutting plantings during establishment from rodent browse.
d. Protect container or pole cutting plantings from maintenance activities during the establishment phase.
e. Maximize habitat diversity by leaving small (2-10 acres) open areas with no woody vegetation. These will provide edge effects, areas that will provide areas of different

vegetative maturity and an opportunity to assess the effectiveness of revegetation of woody plant material by actively establishing native grasses and letting woody plants volunteer in smaller areas within the context of larger active revegetation projects. This may be limited to 10 acres total area.

f. Maximize habitat by protecting and preserving existing naturally occurring native vegetation where possible.
g. Maximize habitat by planting native grass and forbs in all habitat areas and actively managing during the establishment phase.
h. Maximize habitat by controlling invasive exotic weed species within Project limits during the establishment phase.

4. Design Criteria

4. 1 Site Description: Hamilton City is located along the right bank of the Sacramento River in Glenn County, California, about 85 miles north of Sacramento. The Project area lies roughly to the east of the Hamilton City between river miles 193 and 201. The areas to be revegetated in all alternatives consist of lands on the waterside (East) of all proposed levee alternatives. The Project area to be revegetated encompasses roughly 1500 acres.

4. 2 Existing Site Conditions and Analyses: Hydrologic modeling**, s**oil types, flood frequency, and depth to groundwater are the primary factors affecting which habitat types are best suited for any given area. Both The Nature Conservancy (TNC) and the Sacramento River Partners have done extensive floodplain restoration along the Sacramento River in the Project area. Both organizations have noted specific relationships between soil types, flood frequency, and depth to groundwater and the habitat types these factors will support. Refer to Table 1 for a summary of these relationships. These factors will be measured and mapped during the Preconstruction, Engineering and Design (PED) phase of the Project to produce a revegetation design based on the above factors.

4.2.1 Soils/Sediment: The soils in the area are alluvial deposits. Some areas have deep continuous soil profiles consisting of various types of loamy soils; others have gravel or clay lenses deposited by the river in point bars and oxbow channels, respectively. These features can be abandoned by the river when the channel migrates or avulses and subsequently have sediment deposited during flooding. The discontinuity in soil textures vertically can have the effect of interrupting capillary ground moisture creating droughty areas, which typically support scrub or grassland areas as opposed to the riparian forest or savannah communities supported by deeper soils. This creates a complex mosaic of various soil types with differing strata that affect the depth to groundwater.

4.2.2 Groundwater: The groundwater table varies throughout the year and also varies based on distance to river and the permeability of soil substrates. The late summer and fall months are the months of lowest river levels, groundwater levels, and general soil moisture. Theses are the critical months during which plant stress is highest and has a great impact on what types of vegetation will survive. Typically, grasslands require less moisture, followed by Scrub, savannah, and riparian forest.

Table 1 – Site Condition – Physical Factor Design Key

Physical Factors					Habitat Recommendation			
Groundwater		Flood Frequency		Dominant Soil type	TNC recommendation (Plant Communities Based on Holland Veg Classification)	Broad Category (from EA, based on HEP)	River Partners' Habitat Type(s)	
							Series	Tiles (dominant tile in bold)
Impenetrable soil Layer above groundwater	Yes →	**More than 6' of Soil?**	Yes →	Clay, Clay Loam	Valley grassland	Grassland	Purple/Nodding needle grass	
				Silty, Silt Loam	Upland Savanna	Savanna	Valley Oak	VO1; VO4; **EB2**
No (go down one level)		No (Riparian Scrub **EB2**, V01		Loam, Sandy Loam				
				Sand/Gravel	Riparian Scrub	Scrub	Mexican Elderberry	V01; VO4; **EB2**
Groundwater >20'	Yes →	Infrequently flooded?	Yes →	Clay, Clay Loam	Valley Oak	Savanna	Valley Oak,	**VO2-3**; EB1; SY1
				Silty, Silt Loam	Upland Savanna			
No (go down one level)		No (go down one level)		Loam, Sandy Loam				
				Sand/Gravel	Riparian Scrub	Scrub	Mexican Elderberry	**EB1**; VO3
Groundwater 9'-15'	Yes →	Occasionally flooded	Yes →	Clay, Clay Loam	Valley Oak	Savanna	Box Elder	**BE1**
				Silty, Silt Loam			Fremont Cottonwood	FC2-4; **VO3-4**; EV1; EB3; SY1
No (go down one level)				Loam, Sandy Loam				
				Sand/Gravel	Riparian Scrub	Scrub	Mexican Elderberry	**EB1**
Groundwater 6'-9'	Yes →	Occasionally flooded	Yes →	Clay, Clay Loam	Lower mixed forest	Riparian	Mixed Willow	**MW3**
				Silty, Silt Loam			Fremont Cottonwood	MW3; **FC**1,**2**,4; EV1; BE1; EB3
No (go down one level)				Loam, Sandy Loam			Fremont Cottonwood	**FC**1,**2** 4; EB3; MW1
				Sand/Gravel	River Scrub	Scrub	Mixed Willow	**FC1**; MW1
Groundwater <6'	Yes →	Frequently flooded	Yes →	Clay, Clay Loam	Cottonwood/Willow	Riparian	Mixed Willow	**MW3**
				Silty, Silt Loam			Fremont cottonwood	**FC1**,2 4, BE1
				Loam, Sandy Loam				
				Sand/Gravel	River Scrub	Scrub	Mixed Willow	**MW2**

Note: This Key was adapted from a key provided by The Nature Conservancy (TNC) for the UCSACE Woodson Bridge/Kopta Slough Feasibility Study

4.2.3 Flooding: Frequency and depth of flooding influences plant survival based on the ability of different plant species to survive certain durations of flood events. With the Project (Setback Levees) in place, the flood frequency ranges from about 1 to 15 years. Periodic flooding is important to establishing a number of the native species, which are adapted to seasonal flooding. Periodic flooding is also beneficial as it replenishes ground water providing higher ground water levels later into the growing season. Finally, periodic flooding is beneficial as it is a natural river function that can disturb areas, initiate cycles of vegetative succession contributing to habitat diversity, and restore natural topographic variation to previously laser-leveled fields.

4.2.4 Landform: The landform in the project area is generally flat. Nearly all areas have been under cultivation as orchards or row crops and have been leveled. Some remnants of river activity are present in abandoned channels and other subtle patterns of relief created by old river activity. These create areas with different depth to groundwater as well as areas that are more prone to flooding. Some limited grading may be done to recreate topography for drainage and flood damage control purposes. This work will require definition in the Project Engineering Design (PED) Phase.

4.2.5 Existing Vegetation: The project area to be revegetated currently is mostly occupied by orchards or row crops. Some areas have been long abandoned (more than 10 years) and are in a fallow state infested heavily with noxious invasive weeds. Small linear patches of native vegetation remain on edges of fields and along the banks of the river. Existing native vegetation in the areas to be restored will be retained and protected in place during restoration activities. This includes patches of grasses and forbs that can provide a seed source for nearby restored area. Existing orchards in the restoration areas will need to be cleared and grubbed.

Some of the existing orchard trees may be retained to provide temporary cover for various animal species before the newly planted native vegetation matures sufficiently to provide adequate cover. It is likely that retaining a small percentage of trees in scattered individual locations will suffice for this purpose These trees will likely slowly die in period of a few years after orchard irrigation and pest control practices are ended. To prolong the life of existing orchard trees remaining, they may receive limited irrigation during the three year irrigation period for the new native vegetation . After the orchard trees die they will provide valuable habitat as snags.

4.2.6 Threatened or Endangered Species: Revegetation activities shall be designed to avoid unacceptable impacts to State or Federally listed threatened or endangered species (e.g., Swainson's Hawk, Valley Elderberry Longhorn Beetle). Unavoidable impacts shall be fully mitigated in accordance with applicable laws. Elderberry plants (Sambucus mexicana) are currently included in the revegetation plan. No elderberry plants will be planted if a memorandum of understanding (MOU) regarding allowing take of VELB cannot be negotiated between the Department of Water Resources and the USFWS. If an agreement cannot be made, the species mixes will be adjusted.

4.2.7 Levee Construction: Careful consideration and protection of existing native vegetation will need to be specified and incorporated into construction documents and field guidance. Revegetation activities will need to be coordinated with levee, training dike and erosion protection construction.

4.3. Habitats: Four broad categories of riparian habitat types are planned for restoration, Riparian, Savannah, Scrub, and Grassland. These categories were developed for the purposes of evaluating the habitat outputs of the projects for this feasibility study. For the actual planting design, these broad habitat categories will be further broken down into subcategories to develop habitat types suited for their specific locations, soil, flooding, and depth to groundwater conditions. These habitat types may correspond roughly to Holland's habitat classification scheme or may correspond to the more specific CNPS 's (California Native Plant Society) vegetation classification system (Sawyer and Keeler-Wolf 1995). The basic approaches are outlined here and will be refined during the PED phase.

TNC and the USFWS have been using Holland's classification system since 1989 to restore 3,500 acres of the Sacramento River National Wildlife Refuge, with documented success for avian, mammal, and invertebrate targets as well as natural processes such as soil development.

The River Partners restoration plan classified the habitat types based on the CNPS 's (California Native Plant Society) vegetation classification system (Sawyer and Keeler-Wolf 1995). This methodology was developed by TNC beginning in 1989 and refined by cooperative work between the USFWS, Point Reyes Bird Observatory, and TNC since 1993, then adopted by the Partner's staff after they stopped working at TNC's Sacramento River Project. The River Partners have used this approach in their Riparian Restoration Plan for the Pine Creek Unit for the California Department of Fish and Game. This classification system classifies vegetation types based on the dominant plant found in each type. Their definition of dominance is not fixed but relates to percent cover or number of plants as applicable. The CNPS system further breaks down the vegetation types into sub-categories that they call "series". These contain associations of plant species. These associations are used by the SRP to add further complexity and diversity to support specific habitat objectives and have been named "tiles".

Refer to Table 2 for a breakdown of how the different methodologies relate to the four broad habitat categories used in the plan formulation process for measuring and assessing habitat outputs. Table 2 also outlines site physical characteristics, design characteristics and habitat benefits from the various vegetation series.

Approximate planting densities for the various habitat types are given in the chart. Where ranges are stated it is our goal to provide the maximum densities. However, as the habitat types to be provided have not yet been mapped based on soil and groundwater surveys, absolute costs of revegetation are currently based on projections of the habitat types to be created based on extrapolation from other areas. For this reason, if a greater percentage of more costly habitat types than are currently estimated are dictated by the soil and ground water conditions to be mapped in the PED phase, some leeway for reducing costs to fit within an authorized project must remain. Therefore, ranges, of planting densities are given.

Table 2. Rationale for vegetation series planting design

Broad Category	*Holland Classification*	*CNPS Series*	*Planting Location/ Physical Characteristics*	*Design Characteristics*	*Habitat Benefits*
Riparian Forest	Riparian Forest	California Sycamore	Soil: loams Water table: typically >15 feet Location near water bodies, or in areas that are likely to be less favorable to cottonwood trees	Creates a grove of sycamores in relatively slow growing tiles, or near the river Density: approx. 225-265 woody plants per acre + 140- 265 herbaceous plants per acre.	Sycamore trees provide nesting cavities and vegetative structure typically in a relatively short period.
	Great Valley Cottonwood Forest	Fremont Cottonwood	Soil: Sandy loams Water table: 8-15 feet	Large variety of woody species, Density: approx. 320-360 woody plants per acre + 180-360 herbaceous plants per acre	Favored by many neotropical migrants (common yellowthroat, yellow billed cuckoo). Because of rapid growth, potentially provides LWD (Large Woody Debris) and SRA (Shaded Riverine Aquatic habitat) in erosive areas or near the river.
	Great Valley Mixed Riparian Forest	Fremont Cottonwood (Box elder)	Soil: loams Water table: 8-15 feet	Creates a grove of low stature trees that fits into a patchy mosaic. Density: approx. 320-360 woody plants per acre + 180-360 herbaceous plants per acre	Shade tolerant box elder will provide additional structure, under the dominant cottonwoods.
	Great Valley Mixed Riparian Forest and Great Valley Willow Scrub	Mixed Willow	Soil: loams Water table: <12 feet	Composed of willow species only; inserted within Fremont cottonwood and Valley oak series, composing approximately 5% of these areas. Density: approx. 225-265 woody plants/acre + 140- 265 herbaceous plants per acre.	Favored by many neotropical migrants (i.e. Wilson's warbler, yellow breasted chat). Provides a dense screen, if a favorable site.
Scrub	Riparian Scrub	Mexican Elderberry (Coyote brush)	Soil: loams Water table: >12 feet	Composed of shrub species only; inserted within Fremont cottonwood and Valley oak series, composing approximately 10% of these areas. Density: approx. 225-265 woody plants/ acre + 140- 265 herbaceous plants per acre.	Dense thicket of shrubs; cover for quail and doves; nesting habitat favored by neotropical migrants (for example blackheaded grosbeaks), elderberry are critical habitat for valley elderberry longhorn beetles and along with coyote brush provide food for beneficial insects.
Savanna	Great Valley Oak Riparian Forest and Riparian Forest	Valley Oak	Soil: Silt and clay loams; stratified textural layers, extremely sandy areas will support savanna rather than woodland or forest. Water gable: >15 ft or with soil layers that will not permit root growth (pure sand or gravel)	Focus on drought-tolerant species. Density: approx. 175-200 woody plants/ acre +100-200 herbaceous plants per acre	Favored by many resident and migratory birds. Acorns will eventually provide a food source for a variety of species. Once established, cover species will compete against perennial pepperweed and star thistle and provide nesting substrate for ground nesters and neotropical migrants if vines can trellis on trees.

Notes: Table adapted from "Riparian Restoration Plan for the Pine Creek Unit" by Sacramento River Partners

Refer to Table 3 for a breakdown of the vegetative associations into "tiles". The Number of tiles or their usage may be simplified for practical application if necessary. Each tile type will be developed into a pre-planned layout showing the plant material layout for an area 10 plant locations wide by 10 plant locations long. Vegetation series will be mapped onto the project areas based on soil, flood frequency, depth to groundwater and flood impacts. All mapped vegetation series will be further divided into tiles, which will be determined by target percentages of various tiles for each series that will be developed during PED phase. Other deciding factors, such as proximity to river, levees, existing elderberry shrubs and professional judgment may also be used in determining specific tile location.

Table 3. Rationale for Vegetation Tiles

Broad Category	*Vegetation Series*	*Association or Tile Description*	*Rationale for inclusion*
Riparian	California Sycamore	SY1	Creates a grove of sycamores for cavity nesters (such as ringtails, owls, or wood ducks) close to the water, or to provide more rapid structure in areas that may be too dry to support cottonwood. Rapid growth may make these good candidates for large woody debris. Typically will be placed next to water bodies or embedded in valley oak series.
	Fremont Cottonwood	FC1	A mixture of newly recruited species (predominantly cottonwood and willow) similar to that found in the are south of Field 4, and additional species (found along the east border) that will provide more varied structure (box elder, Oregon ash, valley oak) or cover (rose, coyote brush, and blackberry).
		FC2	Composition in this association is more even than the above with fewer willows but more cottonwood. Most shaded area, should provide potential LWD in a short period. May attract yellow-billed cuckoos.
		FC3	This association could have been placed into other categories (more willows, 48%, and valley oak, 26%, are planned than cottonwood, 14%), but these areas will be initially domesticated by cottonwood. We believe that the areas planted to this series will eventually transition to valley oak, but the fast growing species will provide good habitat, before the transition is complete.
		FC4	Mixed riparian species with taller stature plants (for LWD or shaded riverine aquatic) and a more open understory, with far fewer willows, than FC4. Box elder will provide mid-canopy structure.
	Fremont Cottonwood (Box elder)	BE1	Intended to create a more patchy effect across the site. May create less shade for native herbaceous plants. Box elder can tolerate a variety of conditions.
	Mixed Willow	MW1	Mixed willow series dominated by arroyo willow, which is prevalent and growing well in several newly recruited areas in the area. Willows typically provide visual screens and increase wildlife cover, reduce flood velocities and capture debris or sediment. These associations will provide continuous habitat in newly recruited areas.
		MW2	As above, but with sandbar willow for areas with sandy soil and high seasonal water table or prone to high velocity flows.
		MW3	As above, but for areas with finer texture soil. Black willow typically grows in relatively dense patches, and this association mimics that effect. This association will typically reach greater heights than the other ones.
	Wild grape	EV1	Composition: Contains a relatively even mix of all species on the site.

Broad Category	*Vegetation Series*	*Association or Tile Description*	*Rationale for inclusion*
Scrub	Mexican Elderberry (Coyote brush)	EB1	Intended for dry areas of site, and will typically be embedded in other series (especially valley oak). High proportion of elderberry will provide habitat for Valley Elderberry Longhorn Beetle. In areas of good soil, will provide a shrubby thicket for bird cover. Elderberry and coyote brush create a light gap for native herbaceous plants. These shrubs typically have a high survivorship in areas of poor soil.
		EB2	As above, but with a high proportion of coyote brush and no willows. Intended for extremely dry areas.
Scrub, continued	Mexican Elderberry (Coyote brush), continued	EB3	As above, includes a wider variety of species. Includes some trees (for trellis support and shade) and climbing vines clematis, Dutchman's pipe vine, and poison oak, which can provide important sources of food and cover for neotropical birds. Pipe vine is important in the lifecycle of the pipe vine swallowtail butterfly. Intended for areas with better soil moisture than the other areas. Typically embedded in Fremont cottonwood series.
Savanna	Valley Oak	VO1	Excludes elderberry for areas near the levee. High percentages of low-statured plants (coyote brush, blackberry, mulefat, rose, willows).
		VO2	Excludes elderberry for areas near the levee.
		VO3	As above, but with a diverse species (including elderberry) to occupy a variety of conditions.
		VO4	As above, but for the most extreme dry areas of the site, contains elderberry.
Grassland		GR1	Creeping Wildrye Grasslands in lower more frequently flooded areas, emphasis on Leymus triticoides includes Leymus triticoides, Elymus trachycaulus, Elymus glaucus, Hordeum brachyantherum , Hordeum b. ssp californicum, Mulenbergia rigens, Grindelia spp. (Creeping wildrye Slender wheatgrass, California barley, meadow barley, Deer grass, Gum plant, forbes)
		GR2	Grasslands in upland, drier areas with sandy soils emphasis on pine bluegrass, needlegrasses, includes Poa secunda, Stipa spp, Leymus triticoides, Elymus glaucus, Hordeum californica, Bromus carinatus, Grindelia spp (Sandhill Bluegrass, Needlegrasses, Creeping wildrye, Blue wildrye, California barley, California Brome, Gum plant, forbes)
		GR3	Grasslands in upland drier areas with silty/clayey soils emphasis on needlegrasses, includes Stipa spp, Leymus triticoides, Elymus glaucus, Hordeum californicum, Grindelia camphorum (Needlegrasses, Creeping wildrye, Blue wildrye, California barley, Gum plant, forbes)
		GR4	Native Erosion control mix for reseeding habitat areas disturbed in construction. Includes California brome, Six weeks fescue, California barley, Blue wildrye, Creeping Wildrye, Needle grass, Pine blue grass, lupine spp, California poppy, Achillea millefolium, Gum plant
		GR5	Annual Non native Erosion control mix for non-habitat areas, such as levee slopes. Includes Blando brome, Zorro fescue, Rose clover, lupine spp, California poppy, Achillea millefolium, Sweet Alyssum, Gum plant)
			Forbes in native grass mixes may be seeded at end of 3-season establishment period, as selective herbicides will kill most non-grass species. Application will likely be no till overseeding.

Adapted from "Riparian Restoration Plan for the Pine Creek Unit" by Sacramento River Partners

4.4. Habitat Acreage: The projected with–project conditions shown below were determined using a model developed by The Nature Conservancy for projected riparian restoration communities for the RX Ranch reference site. For more information refer to the Ecosystem Plan Formulation Methodology section of the report Appendix A.3

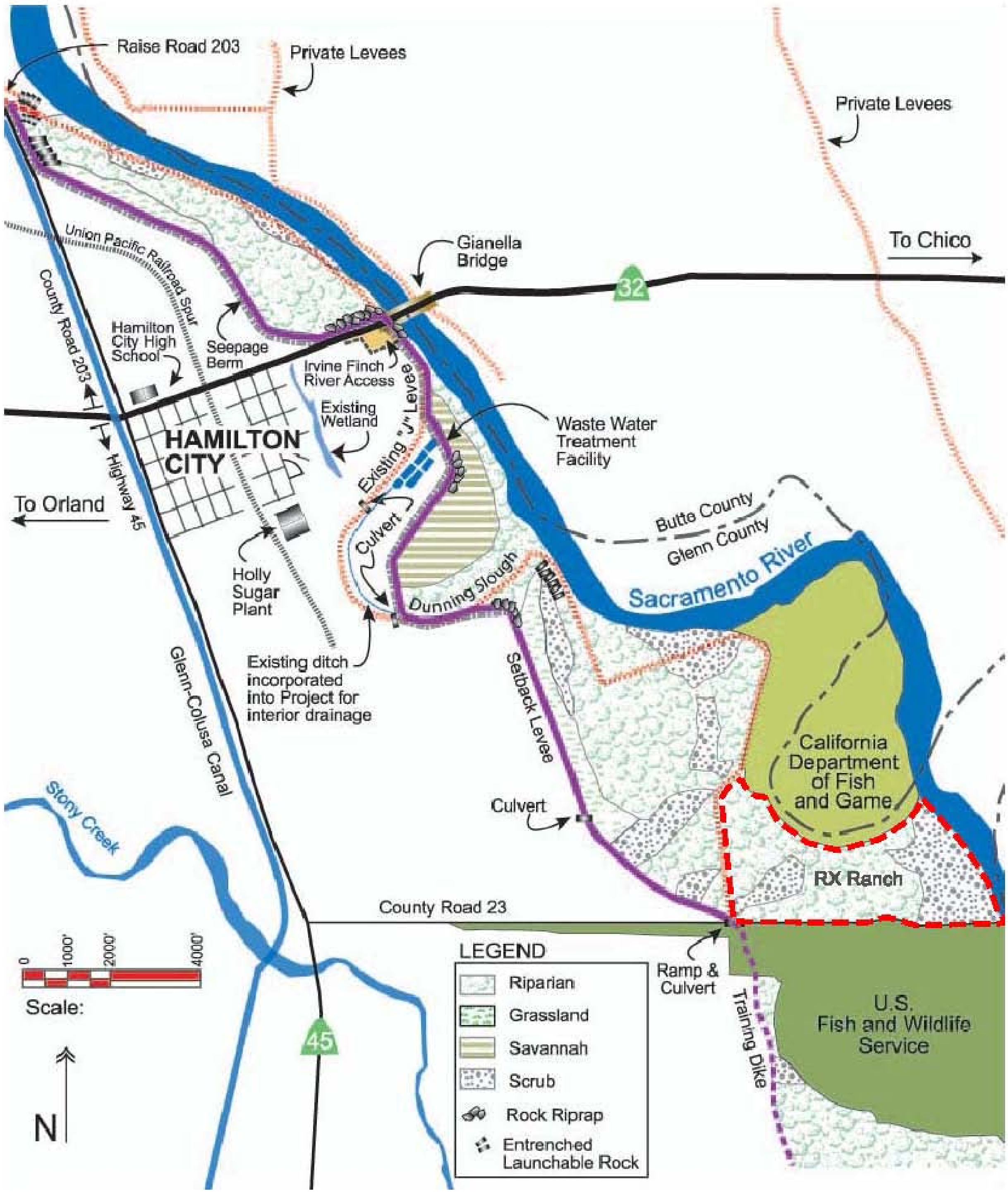

Figure 1 Preliminary Mapping of projected habitat areas

The following percentages of habitat types are projected over the Project area, these are subject to change based on actual soil conditions to be mapped during the PED phase.

Scrub	261.2 acres	18%
Riparian Forest	996.6 acres	73%
Grassland	70.4 acres	5%
Oak Savanna	147.9 acres	4%
TOTAL	1476.1 acres	100%

5. Implementation

5.1. Construction phasing and coordination: Revegetation activities will need to be coordinated with levee and training dike construction as well as erosion protection. There is a potential for the levee construction contractor(s) to be working in the same area at the same time as the revegetation contractor(s). To reduce conflicts between various contractors under different contracts with the government, implementation of revegetation should be phased to limit, as much as possible, ongoing revegetation adjacent to construction activities. It is preferable that removal of the existing J levee occurs after the revegetated areas behind them have been through at least one growing season.

Phasing of revegetation into several years will also provide some insurance that unfavorable weather or flooding does not impact as large an acreage in the vulnerable first year of establishment. In the second and third years, the more established plants can survive extended flooding much better. Phasing of revegetation into several sequential contracts may also be desirable so that lessons learned from early efforts may be applied to subsequent contracts. In any phasing scenario, the size of the revegetation areas must be sufficiently large to prevent undue damage from herbivores, and take advantage of economies of scale. To provide economies of scale, it is suggested that the minimum size for revegetation fields should be no less than 20 acres; the minimum size for contracts should be no less than 200 acres, unless specific conditions requiring smaller contracts or sites arise. In order to give contractors the flexibility to most efficiently utilize the resources available to them, it is anticipated that the scheduling in the contract will allow for flexibility for phasing the project. The contract will likely provide a fixed period of time (e.g., six years) within which the contractor shall install and establish for three years all areas within the contract. This should allow the contractor to phase the installation based on availability of materials, labor and equipment.

5.2. Preservation of Existing Vegetation: Existing native vegetation to be preserved shall be surrounded by protective fencing near flood control feature construction areas requiring vehicular access or access by mechanized construction equipment. Existing sensitive State or Federally listed threatened or endangered species and adjacent existing native plant communities located within the project limits or adjacent to access routes shall be surrounded during construction by protective fencing.

5.3 Erosion control The following erosion control measures are generalized, as site level planning is not being done for the feasibility phase of this project for restoration activities. During PED the corps will be adjusting the erosion control measures to minimize cost based on site specific drainage patterns and topology. Permanent erosion control vegetation in habitat areas will consist of native vegetation. Erosion control on levees and for disturbance from construction activities outside habitat areas will consist of exotic and/or native grasses best suited for the particular areas needing protection. Erosion control mix for engineered, compacted soils such as levee slopes may include Blando brome, Zorro fescue, Rose clover, lupine spp, California poppy, Achillea millefolium, Sweet Alyssum, and Gum plant. Various erosion control and weed suppression crops of winter wheat, beans, peas and oats may be grown in habitat areas for temporary erosion control and weed suppression.

5.3.1. Storm Water Runoff Erosion A storm water prevention plan (SWPPP) will be provided with the plans and specs that specifies minimum acceptable erosion and sedimentation best management practices (BMP's). The SWPPP also outlines the procedures for complying with NPDES (National Pollution Discharge Elimination System) pollution prevention requirements and permitting. The SWPPP shall comply with Corps of Engineers, Sacramento District Work instructions for Storm Water Pollution Prevention Plan (04-01-01) NPDES laws require all construction projects over one acre in size to comply with local NPDES permitting requirements. In California, this means that between Oct 1 and March 31 erosion and sediment control BMP's must be in place.

5.3.1.1 Best Management Practices For the majority of the largely flat site, Erosion controls BMP's will consist of seeding fast growing temporary vegetative cover in all areas. Permanent native vegetative cover will be no-till drill seeded into the temporary cover. Areas disturbed by construction with steeper topography that generate sheet flow will receive appropriate erosion control BMP's, such straw mulch, bonded fiber matrix hydromulch, and erosion control fabric etc. in addition to the vegetative cover. Areas disturbed by construction with topography that concentrates flow or conveys concentrated off site run-on will receive erosion BMP's, such straw mulch, bonded fiber matrix hydromulch, cobble dissipaters and erosion control fabric etc., in addition to the vegetative cover

Sedimentation control BMP's will consist of straw rolls, silt fences and/or sedimentation ponds, which will be implemented where necessary to prevent discharge of sediment-laden runoff into receiving waters. Additionally, vegetative buffer strips 50 feet in width will be used on the downslope edges of sites bordering receiving waters. These strips may be native grass established before soil disturbing activities or may be existing vegetation left in place permanently or temporarily until cover vegetation is established on the rest of the sites.

5**.3.1.1 Rainwater Erosion on Proposed Levees** Where rock is not present, erosion from rainfall runoff will need to be controlled by establishing erosion control grasses on the levees in areas. While grasses establish in the first season after seeding, erosion control will be provided by straw mulch with tackifier. Sufficient overburden of soil will need to be designed into the levees to allow ripping and cultivation of soil of the compacted levee surfaces to allow grasses to thrive. Native and non-native species may be used, as levees and training dikes are an artificially dry habitat with highly compacted soils. These harsh conditions require use of grasses adapted to drier conditions and poorer soil than the immediately surrounding area.

5.3.2. Wave Wash Erosion: Wave wash erosion on the river side of the proposed levee and training dikes will be a concern in areas where rock is not present. The projected habitat type for the majority of the project restoration areas will be riparian forest, which should provide sufficient attenuation from wave wash after about 5- 10 years of establishment. In the interim, the levees would be protected by erosion control vegetation. Establishing native grass on the levees would require a minimum of 24" of uncompacted soil on the levee to allow the grass to grow, as highly compacted levee surfaces are not conducive to native grass growth. Exotic annual and perennial grasses can be grown on compacted levee material though an overburden of 12" of cultivated soil will be beneficial in promoting a denser more effective stand of vegetation. Temporary straw mulch will be required to protect newly constructed levees from rain runoff until the erosion control vegetation is established.

5.4. Removal of Orchards: Removal of orchards constitutes an activity that disturbs soil requiring it to be coordinated with site prep and grass seeding activities. Existing orchards will be removed using bulldozers or other appropriate heavy equipment. The value of orchard wood for wood chips sent to cogeneration plants may help offset the cost of orchard removal Disposal of wood from cleared orchards into landfills should be discouraged. Depressions from removal of root wads will need to be graded to a level condition. After removal of orchards, site preparation and weed control will proceed.

5.5 Site Preparation/Weed Control: Site preparation and weed control are the two most important components of a successful restoration program. It is crucial that the specific steps and timing of the treatments respond to the actual field conditions and weather patterns. Unpredictable conditions necessitate the ability of the resident engineer to be able to respond to continually changing circumstances throughout each growing season and at each step of the implementation process. This will require the contract for implementation to be carefully structured so that rapid contract modifications are not required for the contractor to be able to respond to field and weather conditions.

The following two sub-sections detail site preparation and weed control steps for the two general categories of restoration communities: grasslands and tree/shrub dominated communities. These recommendations are preliminary and will be adapted in the PED phase to the latest and most effective native grassland restoration methods. Grassland restoration is still in it's infancy along the Sacramento River with recent projects indicating that a lengthy weed control program prior to seeding is a fundamental necessity for establishing native grasses. Recent regulations limiting spraying seasons certain types of herbicide have also impacted typical herbicide treatment programs used in the past.

5.5.1 Grassland Communities

For establishing grassland communities, site preparation methods include a number of steps and would require approximately two years to complete. Final site preparation will be field dependent and adjusted for the weeds and the previous land use on the particular field. The steps below are intended as a no-till drill seeding site preparation methodology. These prescriptions assume heavy weed infestations, fields with lighter weed infestations would require fewer applications of herbicide. Fields planted from clean crop cultivation may require less weed abatement and a different set of site preparation steps.

Weed control activities of sufficient duration and intensity are key to success. Eliminating the initial season of weed control is inadvisable. All herbicide applications must be permitted by the Glenn County Department of Agriculture.

step	item	Season	month
1	Remove orchard or row crops	1	April-August
2	level	1	April-August
3	disk	1	April-August
4	Seed cover crop	1	September/October
5	mow	2	March/April
6	Spray herbicide	2	April/May
7	Spray herbicide	2	December/January
8	No till Drill Native grass Seed	2	January
9	Spray w/ herbicide(s)	2	Feb-March
10	Spray w/ herbicide(s)	2	March- April
11	Mow	3	May
12	Spray w/ herbicide(s)	3	June/July
13	Spray w/ herbicide(s)	3	Feb-March
14	burn	3	May
15	Spray w/ herbicide(s)	4	December
18	No till drill seed forbs	4	December/January

5.5.2 Forest, Savanna, or Scrub Communities

For establishing communities dominated by trees and shrubs (forest, savanna, scrub), methods of site preparation include several steps. Final site preparation will be field dependent, adjusted for the weeds and the previous land use on the particular field. Establishing trees and shrubs in the first year followed by grass establishment in the second year allows for weed control efforts in year one to work towards the necessary weed control efforts needed for native grass establishment.

The following steps may be taken for establishing tree and shrub dominated communities:

step	item	Season	month
a	Grow container plants	0	prior year
1	Remove orchard or row crops	1	April-August
2	level	1	April-August
3	disk	1	April-August
4	install irrigation	1	April-August
5	plant deepot container plants	1	September
6	plant herbacious container plants	1	September
7	Seed cover crop	1	September/October

8	mow	2	February
9	Spray herbicide(s)	2	March
10	Spray herbicide(s)	2	April May
11	Spray herbicide(s)	2	December/January
12	No till Drill Native grass Seed	2	January
13	Spray w/ herbicide(s)	2	Feb-March
14	Mow	2	May
15	Spray w/ herbicide(s)	2	October
16	Spray w/ herbicide(s)	3	March
17	Mow	3	May
18	No till Drill forbs	3	October

5.6 Native Grass Seeding: Native grass mixes will be applied by no till drill seeding. Native grass mixes will be applied with mycorhizal inoculum applied at the same time the seed is drilled. Due to anticipated usage of selective herbicides, forbs, if used, may be overseeded by no till drill seeding at the end of the second or third year of maintenance Success of establishment of Forbs by overseeding is currently under investigation. If trials of forb overseeding are sufficiently successful, forbs may be overseeded in this project. If trials are not indicating success, limited amounts of forb seeding may be done to test potential methods for establishing forbs

5.6 Plant Material: All woody and herbaceous plant material to be propagated in containers or by cuttings shall be collected within 20 miles of the Project area to ensure local ecotypes are used. The seed will be collected the year preceding planting to allow sufficient propagation time for the specified container sizes. Woody and some herbaceous plant materials will be installed from containerized plants grown in containers specialized for revegetation planting ranging in sizes from 7 cu. inches (Super Stubby) in volume to 180 cu inches (Treepot 4) in volume. Willow and cottonwood species may be planted from pole cuttings collected in the project vicinity, or from containerized plantings. Plant containers shall be specialized revegetation containers with narrow proportions for deep rooting. Containerized plants will be grown from locally collected seeds, cuttings or root divisions. Collection of seed or cuttings shall be carried out in accordance with all applicable laws and with required permits. Containerized plantings will be fertilized with 20 grams of slow release fertilizer pellets or tablets. Refer to the following table for species and container types. Seed for Native grass seeding may be commercially grown from Sacramento Valley ecotypes, preferably collected from within 20 miles of the Project area.

Table 04: Preliminary Restoration Plant List

Botanical Name	*Common Name*	*Plant Type*	*Primary Habitat Category*	*Propagule type or container size*
Aristolochia californica	Dutchman's pipevine	Vine	Riparian	Treeband
Clematis ligusticifolia	Clematis	Vine	Riparian	Deepot 40
Vitus californica	California Grape	Vine	Riparian	Deepot 40
Acer Negundo	Box Elder	Tree	Riparian	Deepot 40
Alnus Rhombifolia	White Alder	Tree	Riparian	Deepot 40
Fraxinus latifolia	Oregon Ash	Tree	Riparian	Deepot 40
Platanus racemosa	California Sycamore	Tree	Riparian	Deepot 40
Populus fremontii	Fremont poplar	Tree	Riparian	Deepot 40/ cutting
Quercus lobata	Valley Oak	Tree	Savanna	Deepot 40
Salix goodingii	Black willow	Tree	Riparian	Deepot 40/ cutting
Salix lasiolepis	Arroyo willow	Tree	Riparian	Deepot 40/ cutting
Baccharis pilularis	Coyote Brush	Shrub	Savanna	Deepot 40
Baccharis salicifolia	Mule Fat	Shrub	Riparian	Deepot 40
Calycanthus occidentalis	Spicebush	Shrub	Riparian	Deepot 40
Rosa californica	California Rose	Shrub	Riparian	Deepot 40
Rubus ursinus	California Blackberry	Shrub	Savanna	Deepot 40
Salix exigua	Sandbar Willow	Shrub	Savanna	Deepot 40/ cutting
Sambucus mexicanas	Mexican elderberry	Shrub	Savanna	Deepot 40
Toxicodendron diversiloba diversilobium (optional)	Poison Oak	Shrub/Vine	Savanna	Treeband
Artemesia douglasii	Mugwort	Herbaceous perennial	Riparian	Treeband
Leymus triticoides	Creeping wildrye	Perennial Grass	Riparian	Super Stubby
Solidago canadensis	Goldenrod	Herbaceous perennial	Savanna	Super Stubby
Urtica holoserica	Hoary nettle	Herbaceous perennial	Riparian	Treeband
Muhlenbergia rigens	Deergrass	Herbaceous perennial	Riparian	Super Stubby
Carex barbarae	Santa Barbara Sedge	Perennial sedge	Riparian	Treeband
Plant species percentages per vegetation type classification or "tile" will be developed during PED phase.				

5.7. Plant Installation methods:

5.7.1. Planting Layout: Plants will be planted in regularly spaced rows to facilitate establishment irrigation and weed control. Adjustments to plant spacing, holding density constant, may be done to optimally accommodate weed control equipment such as mowers, herbicide spray booms, and various cultivation implements in the aisles between the rows of plants. Planting rows will undulate or curve slightly to minimize appearance of rows. Refer to the following chart for planting spacing at various densities. Actual spacing may vary dependant on equipment to be used.

density		sq. ft. per plant	Sq. spacing (in ft)	row X aisle spacing (in ft)	
360	ppa	121	11.0	10.1	12
265	ppa	164	12.8	11.0	15
220	ppa	198	14.1	13.2	15
200	ppa	218	14.8	14.5	15
175	ppa	249	15.8	16.6	15
150	ppa	290	17.0	14.5	20

5.7.2. Irrigation: Temporary irrigation for the planting installation and following three-year maintenance period will be provided. The goal of the irrigation is to increase plant survival rates, growth rates and encourage deep plant rooting. This requires frequent watering in the first season, followed by increasingly infrequent and deep watering in the second and third years. Irrigation in most locations will be by drip. Irrigation tubing and pipe will be removed from the site at the end of the establishment period. Flood or overhead irrigation systems are less effective for plant establishment, require larger amounts of water, and result in higher rates of weed growth. Many native species do not do well with flood irrigation, as they are not adapted to this watering regime in the summer months, resulting in repeated leaf senescence throughout the growing season. There fore re-use of existing overhead spray and flood irrigation systems in not feasible.

5.7.3. Irrigation water source: Irrigation water source will likely be provided from 18 existing wells. These wells currently provide irrigation water for nearly the entire area to be restored. The existing wells are currently sized for irrigating orchards and row crops by a combination of methods such as overhead spray, microspray, drip and flood. These methods generally require greater system capacity than drip irrigation. Therefore the existing wells will likely provide sufficient capacity.

5.7.4. Irrigation at each plant location: Each planting location will be provided with a minimum of at least one drip emitter. At each location, the main or large woody plant will be installed adjacent to the drip emitter(s). At selected plant locations secondary, herbaceous plant material may be installed at the outside of the emitters for a total of two plants at those planting locations.

5.7.5. Planting: Planting will be scheduled for fall. Planting may be delayed for one or two seasons after grass seeding if overall reduction of weed controls costs are anticipated. Costs of the different methods will be evaluated in PED phase.

Planting pits will be dug to the size of the planting stock and native soil will be used as backfill. Watering basins will not be required, however the contactor will be responsible for ensuring that required irrigation water is available to the plants' root zone. Weed control mulch mats will not be required. At a minimum, all plants will be provided with a browse guard to reduce above ground rodent damage and to provide protection from weed control herbicide spraying. Browse guards will be at a minimum milk cartons or equivalent protection. Milk carton (and tube type) browse guards also provide some protection from herbicide spray drift when the plant is very young. All plants shall be irrigated within several hours of installation to prevent undue planting stress and to ensure complete settling of back fill in planting hole. Contract specifications should provide a short-term guarantee (30 day) on plant survival to motivate contractor to install plants with adequate care. Pre-emergent herbicide may be applied immediately around plant to minimize need for weeding in the browse guards.

5.6. As-Builts:
As-built plans based on the contract documents shall be drawn to scale and show any deviations from the contract plans by the installation contractor. As built plans shall be created electronically using AutoCAD or Intergraph CADD software. Arcview GIS software may also be used. As builts shall include lists of plants as planted by zones and sub-zones, or tiles, and shall be prepared in a computerized spreadsheet. As-builts shall be used for maintenance records and monitoring work.

6. Establishment/Maintenance

An establishment and maintenance program will be a critical component of a successful revegetation program.

6.1. Regular Maintenance: The maintenance period for establishing the plants will be for 3 growing seasons after installation. Maintenance items will include: weed control, irrigating plants, planting upkeep, and some minor re-planting efforts. Monitoring and reporting of the project will be required for each year along with three yearly reports. Items to be included are:

6.1.1. Irrigation Program: The following schedule will form the basis of watering, to be adjusted to weather conditions during the establishment phase. It is important to note that irrigation schedules need to be adaptive to prevailing weather conditions and that the following are meant as guidelines.

1. First Season: Start irrigation in April (or when soil moisture levels require irrigation), with twice weekly watering of 2 gallons per watering. Beginning in June (the hot season) increase volume to 3 gallons per watering. At beginning of September (the end of the hot season), reduce watering frequency to reflect lower water needs (e.g., 1 day per week with volume of 6 gallons per irrigation). End irrigation after October 31

2. Second Season: Start irrigation in mid April (when soil moisture levels require irrigation), with weekly watering of 10 gallons per watering. Beginning in June increase volume to 15 gallons per watering. At beginning of September, reduce watering frequency to every other week with volume of 30 gallons per irrigation. End irrigation

after October 31.

3. Third Season: Start irrigation in mid April, with watering every other week of 30 gallons per watering. Beginning in June decrease frequency of watering to once every three weeks with a volume of 50 gallons per watering. At beginning of September, reduce watering frequency to once a month with volume of 100 gallons per irrigation. End irrigation after October 31.

Unusually hot, dry and windy weather may require additional irrigation. Maximum plant growth is achieved by limiting water stress on plants; however, deep infrequent watering should be the rule to supply adequate soil moisture in the desired deep root zone. Plant roots do not “seek” water; rather they grow and persist in areas that have adequate moisture, soil and oxygen. Therefore frequent shallow irrigation must be avoided. Also, plants respond to water stress with physiological changes that reduce water consumption, thus the plants should be slowly weaned from ample watering in the first season so that by the end of the maintenance period, the plants have hardened to conditions without irrigation. Extremely droughty conditions at the end of the maintenance period may require an additional season or two of irrigation.

6.1.2. Weed Control: During the establishment phase, a regular weed control program shall be implemented including the appropriate use of herbicides, mechanical, and hand weed control methods. The area immediately around each planting location will be kept free from weeds by herbicide application and by hand weeding.

Weeds in the aisles between the rows (the middles)and in the rows with the plant locations (the strips) will be controlled by mowing and by timed nonselective, pre-emergent and/or selective broadleaf herbicide applications in the first and second growing seasons. Timing is dependant on the growing conditions based on weather. Refer to section 5.5 for timing and and type of weed control measures needed for the various habitat types to be restored. The approximately 3-5 foot wide strips will be sprayed several times per year with non selective and/or pre-emergent herbicides. The approximately 8-12 foot wide middles will be sprayed several times per year with selective and/or pre-emergent herbicides

Alternate methods of weed control in conjunction with delayed planting will be evaluated during the PED phase for potential cost savings and improvement in habitat establishment.

Certain types of herbicides may be restricted in use due to proximity of sensitive crops such as cotton, grapes and pistachios. Also, endangered species restrictions for Valley Elderberry longhorn beetle could limit herbicide use in certain areas. The following measures as appropriate will be used in areas where herbicide application limitations apply:

1. Use herbicides registered for use near sensitive crops. Application procedures and equipment are also subject to regulations, which must be followed.
2. Use mowing to control weeds. Additional mowing may be needed, up to once a month April through July.
3. Use Disking to control weeds. May be needed on regular basis April through July.
4. Delay seeding native grass seeds until the 3rd year of establishment, thereby allowing

use of glyphosphate (Roundup) herbicide for weed control.
5. Utilize pre-emergent herbicides.

Pre- and post-seeding weed control is crucial. The timing of mowing and spraying are critical and usually occur in a very short time frame.

6.1.3. Replanting / Replacement: Mortality rates should be measured by planting area and by species. Replacement of plants will be required if mortality rates for any of the above are higher than 15 percent the first season, 25 percent the second season and 35 percent the third season. Replacement planting to original planting quantities will be required if the above mortality rates are exceeded. Species for replanting may be adjusted if mortality rates for individual species indicate they are not suited for certain areas. Past results indicate that an overall survival rate of 80% should be easily met for the entire Project area.

6.1.4. Monthly Maintenance Reports: Monthly records of maintenance activities and project conditions shall be kept. The monthly reports should include general weather and climate conditions, major events such as storms, fire, vandalism, herbivore browse, irrigation scheduling and quantity, weed growth and weed control activities and general description of plant performance. Monthly reports shall be submitted to the Corps on an ongoing monthly basis

6.1.4. Yearly Maintenance Reports: Compilation of monthly records of maintenance activities and project conditions will be required to be submitted to the Corps each December 1 in an annual, year-end report.

6.2. Monitoring: A simplified monitoring program shall be developed and implemented during the 3-year establishment period. All hand planted species in the irrigation rows should be monitored, as well as the grasslands to determine restoration establishment success. The monitoring program shall be developed and carried out by experienced biologists, and at a minimum consist of the following:

- Mortality rates
- Photographs (Permanent color photograph stations)
- Plant counts (by species and area)
- Yearly reports

7. Success Criteria

The following success criteria will be targeted for the end of the maintenance period:

- Minimum 65% survival of container plants per “tile” and per species.
- Minimum 85% survival of container plants overall.
- Control of exotic weed species. (Long-term establishment and regeneration of native plants not threatened by exotic weeds)
- Successful introduction of native grasses and herbaceous vegetation. This should be defined as patches of native grass and herbaceous perennials established over a minimum 15% of the site.

Success will be measured by annual plant survival counts during the 3 year plant establishment period.

8. Post Establishment Operations and Maintenance.

At the end of the three year establishment period, the Project will be turned over to the State for operations and maintenance for the life of the project. Infrastructure related to the restoration such as gates, locks, fences and maintenance access roads will be maintained in operational condition. Removal of trash and other unnatural debris will be encouraged.

In terms of vegetation management, post establishment operations and maintenance for the restoration aspects of the Project generally consist of benign neglect. Successful restoration is defined as sustained self-sufficiency of the native vegetation, therefore mowing, clearing, weeding and herbicide application will not be allowed unless called for as an adaptive management action to improve project performance or for Public Health and safety. Areas adjacent to farm fields may be maintained free of elderberries by removing elderberry plants periodically from restorarion areas within 100 ft of the flood control levee

Yearly reports will be submitted to the USACE Sacramento District Engineer, Environmental Resources Branch and Landscape Architecture Unit. These reports will contain the checklist from the annual spring inspection. The reports will also contain photographs from set photographic monitoring points. Additional monitoring, though useful and is encouraged, will be at the discretion of the State, local sponsor and stakeholders.

Grazing within strict limitations may be permitted to mimic natural herbivore browse. Generally 5-10 years after establishment, the site can be grazed intensely for short periods of time up to 3 times per decade. Grazing can be managed to help control exotic weeds by carefully timing grazing.

The following uses may be permitted

- hiking
- bird watching
- hunting
- fishing
- camping within limited designated camp grounds should also be allowed.
- Access to the river for a boating (designated boat ramp)

The following uses shall not be permitted:

- mountain biking
- off road vehicle use

9. Revegetation Quantities

The following tables outline quantities expected for the projected habitat types.

Table 5
Plant quantities

habitat type	woody ppa	herbaceous ppa	acres	total woody plants	total herbaceous plants
riparian	264	264	796.6	210,302	210,302
cottonwood	360	360	200	72,000	72,000
scrub	264	264	261.2	68,957	68,957
savannah	200	200	147.9	29,580	29,580
grassland	0	0	70.4	-	-
			1476.1	380,839	380,839
			30% cuttings	114,252	
			80% containers	266,587	
				50% treeband	190,420
				50% super cell	190,420

Table 6
Drip tubing quantities

item	Average Row Spacing	Length in feet of one side of square acre	no of rows at 15' oc square acre	total length of rows in square acre	total number of acres	total length of drip tubing required, in feet
drip tubing	15	209	14	2,904	1,400	4,065,198

End of Revegetation Report
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