Hydraulic Review Technical Memorandum

San Francisquito Creek Flood Protection Capital Project

Floodwater Conveyance Improvements from East Bayshore Road to San Francisco Bay

SAN FRANCISQUITO CREEK
JOINT POWERS AUTHORITY

DRAFT

August 3, 2010

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1.0 Introduction

1.1 Purpose and Scope

The purpose of this Hydraulic Review Technical Memorandum (TM) is to summarize HDR Engineering, Inc. (HDR) review findings of the Philip Williams & Associates, Ltd. (PWA) hydraulic HEC-RAS model for the downstream portion of San Francisquito Creek. The downstream portion of San Francisquito Creek consists of an approximate 1.5 mile segment extending from the Highway 101 / East Bayshore Road Bridge to the San Francisco Bay. PWA's HEC-RAS model simulated proposed improvements to convey the 100-year flood as a flood management alternative. HDR's review consisted of confirming the PWA Model's compatibility with the selected conceptual level design, and recommending adjustments to the hydraulic model to be consistent with the proposed construction plans.

1.2 Design Constraints

The purpose of this project is to provide the flood protection elements needed to protect homes, businesses, and other facilities in the cities of Palo Alto and East Palo Alto downstream of Highway 101 from the one-percent (1%) design riverine flood event.

HDR worked within the design constraints laid out by the San Francisquito Creek Joint Powers Authority (JPA) to minimize impacts to existing features and structures, minimize increases to the design water surface elevation at Highway 101 / East Bayshore Road, and preserve opportunities for habitat within the creek as much as possible. The levee and floodwall layout proposed in the PWA Model has been reconfigured to fit within existing structures, utilities, and recreational facilities in coordination with the JPA right of way acquisition efforts.

1.3 Previous Studies

Multiple hydraulic studies of San Francisquito Creek have been completed. In May of 2009, Noble Consultants, Inc. released a final report titled, *Development and Calibration/Verification of Hydraulic Model*. Part of Noble's evaluation included the development of an existing conditions hydraulic model, which evaluated the flow capacity of the existing channel and major bridges crossing San Francisquito Creek.

In July of 2009, PWA built upon Noble's hydraulic model to develop flood management alternatives along San Francisquito Creek. PWA's final report titled, *San Francisquito Creek Flood Reduction Alternatives Analysis*, contained three different conceptual alternatives. The downstream portion of the creek was broken into three reaches; the upper reach extends from East Bayshore Road / Highway 101 Bridge to the Palo Alto Municipal Golf Course, the middle reach extends from the golf course to Friendship Bridge and the lower reach extends from Friendship Bridge to the San Francisco Bay. The JPA selected PWA's Alternative 2 model for the design of the downstream portion of San Francisquito Creek. Alternative 2 consisted of setback floodwalls in the upper reach, levee setbacks in the middle reach, an overflow terrace near Friendship Bridge, and the removal of the levee between the Baylands Preserve (also known as the Faber Tract) and the creek on the north side.

2.0 Survey and Mapping

In 2006, Bestor was hired by the United States Army Corps of Engineers (USACE) San Francisco District to provide mapping, for hydraulic modeling purposes, of San Francisquito Creek from the San Francisco Bay to approximately 10 miles upstream. The survey included a detailed topographic survey of the creek channel using ground survey methods. A bathymetric survey was also performed along the creek channel between the San Francisco Bay and the Highway 101 / East Bayshore Road Bridge. The bathymetric survey and conventional survey were merged, and were supplemented by existing LiDAR data provided by the Santa Clara Valley Water District (SCVWD) in order to form a single continuous digital terrain model (DTM) of the entire San Francisquito Creek floodplain.

In 2010, Towill performed aerial mapping of the project area and Baylands Preserve, which covered the entire project area downstream of the Highway 101 / East Bayshore Road Bridge. By compiling the previously mentioned surveys into one, the merged survey provided planimetric detail sufficient for engineering design. Aerial LiDAR was flown to support a scale of 1”=40’, with 1 ft contours. A color digital ortho-rectified aerial photo was taken with a pixel resolution of 0.2 ft.

The horizontal datum for the surveys were based on the North American Datum of 1983 (NAD83), California Zone 3. The vertical datum was based on the North American Vertical Datum of 1988 (NAVD88). All elevations provided within this report reflect the vertical datum of NAVD88.

3.0 Hydraulic Model Development

HDR completed the review of the JPA selected Alternative 2 hydraulic model. All model results were produced using HEC- RAS Version 4.1.0, developed by USACE. The hydraulic model was run under steady-state conditions with the downstream boundary representing a fixed water level in the San Francisco Bay and the upstream boundary representing flow equivalent to runoff from the upper watershed. All analyses assumed that all upstream flow would be contained within the channel and conveyed through the Highway 101 / East Bayshore Road Bridge into the downstream portion of San Francisquito Creek.

The hydraulic model does contain cross-sectional information for approximately 8.9 miles upstream of Highway 101 that was not reviewed by HDR. The upstream portion of the model is being completed by SCVWD in partnership with HDR’s hydraulic model.

4.0 Downstream Boundary Conditions

4.1 Starting Water Surface Elevation

The downstream boundary condition used in the PWA Model was set to the starting water surface elevation of 7.1 feet (NAVD 88), equivalent to the Mean Higher High Water (MHHW) elevation, which represents the average of the higher high water height of each tidal day. Additional tidal information has become available since the release of the PWA Model, which has required a change in the modeled starting water surface elevation.

The USACE is in the final stages of preparing for release of their *Shoreline Study* report. It is anticipated that this report will include information for the 100-year tidal stage elevation and estimated sea level rise values. Due to the delay of the release of this report and the JPA's short design schedule, the JPA directed HDR to use the currently published 100-year tide value of 10.35 feet from the 2005 *USACE 905b Reconnaissance Study*, plus the expected sea level rise value of 26 inches, for a total of 12.52 feet (NAVD 88).

In May 2010 it was decided that a lower combination 100-year tidal elevation including sea level rise totaling 11.3 feet should be modeled as the starting water surface elevations. This was the anticipated value to be published in the *Shoreline Study*.

After careful consideration and review of the 2010 *HDR Design Criteria Technical Memorandum* by the JPA and SCVWD, the decision was reversed in July 2010 to move forward with the 30% Design Plans, Specifications and Estimate (PS&E) using the more conservative starting water surface elevation of 12.52 feet. This variation in the starting water surface elevation led to changes in the hydraulic model, and resulting changes to the top of levee (TOL) and floodwall elevations, as well as overall footprint and alignment modifications. Table 1 summarizes the starting water surface elevations that have previously been modeled. Note the bold elevation of 12.52 feet is the selected starting water surface elevation.

Table 1 – Starting Water Surface Elevations Comparison

Starting Water Surface Elevations (NAVD 88, feet)	
Downstream Boundary Description	Elevation (feet)
Mean Higher High Water (MHHW)	7.1
100-Year Tidal Elevation (USACE 2005)	10.35
100-Year Tidal Elevation + 26" Sea Level Rise	12.52
USACE Shoreline Study, 100-Year Tidal Elevation + Sea Level Rise (Unpublished)	11.3

4.2 Proposed Peak Discharges

The design flows developed for San Francisquito Creek are based on a rainfall runoff hydrologic model developed by Wang et al for USACE. The methodologies and results of the model were documented in the report entitled *Santa Clara Valley Water District San Francisquito Creek Hydrology Report* (Wang et al 2007). The recommended peak discharges summarized in Table 2 are equivalent to the 100-year flood event.

Table 2 – Peak Discharges

San Francisquito Creek 100-Year Event		
Location Description	Model Station	Peak Discharge (cfs)
At Highway 101	80+28	9,300
At O'Connor Pumping Plant	30+00	9,400

4.3 Design Water Surface Elevation Profile

The design water surface elevation profile created within HEC-RAS was used to determine the TOL elevations for design purposes. The profile has been updated significantly from the PWA Model due to the change of the starting WSE. The profile has also been updated to reflect the coincidental 100-Year fluvial and tidal event plus the estimated sea level rise in anticipation of revised Federal Emergency Management Agency (FEMA) criteria. Significant impacts to the water surface elevation profile are also attributed to proposed changes to the channel configuration, which are summarized in Section 8.0.

5.0 Freeboard

After completing the review of the PWA Model it was determined that inadequate freeboard had been provided to satisfy FEMA's design criteria for leveed riverine channels as found in Chapter 44 of the Code of Federal Regulations, Section 65.10 (44 CFR 65.10). PWA's Alternative Analysis stated that the alternatives investigated were developed with the primary goal of reducing peak water levels only below the existing left and right levee crest elevations during a 100-year fluvial flood event in conjunction with the MHHW tidal elevation.

The levee design water surface elevation plus an additional height is required to establish the TOL to reduce the risk of overtopping. Three feet of height has been added to the 100-year design water surface elevation, in accordance with 44 CFR 65.10, throughout the downstream portion. Also in accordance with 44 CFR 65.10, four feet of height (in lieu of three feet) has been added to the design water surface elevation for 100 feet upstream and downstream of constrictions, including the Highway 101 / Bayshore Road Bridge and Friendship Bridge.

Wind run up and wave set up must also be contained within the freeboard height, or additional levee or floodwall height will need to be added until such containment is met. It is assumed that the wind and wave analysis will be completed by the *Shoreline Study*.

6.0 Energy Losses

6.1 Manning's "n" Values

Manning's "n" values, or roughness coefficients, selected by PWA were reviewed and deemed appropriate for the proposed design conditions. The proposed channel configuration is fairly uniform throughout the entire project limits; therefore, it was anticipated to see fairly consistent roughness coefficients throughout the creek. Cross-section 2+00 was revised to reflect a lower channel roughness coefficient of 0.030 instead of 0.050 which was contained in the PWA model. The coefficient was revised to better match channel roughness coefficients for the rest of the downstream portion. See Figures 1 and 2 for typical Manning's "n" value distribution through cross-sections for both levee and floodwall sections.

6.2 Expansion / Contraction Coefficients

Expansion and contraction coefficients selected by PWA were reviewed and revised if necessary to reflect the proposed design channel configuration. Major contraction areas were modeled, which included Highway 101/ Bayshore Road Bridge and Friendship Bridge. Increased expansion and contraction coefficients were also used to model the Baylands Preserve breached levee. Additional information regarding the updated modeling approach through the Baylands Preserve and into the San Francisco Bay can be found in Section 8.4.

6.3 Ineffective Flow Areas

Active and ineffective flow areas were reviewed and adjusted to more appropriately model hydraulic flow patterns within San Francisquito Creek and Baylands Preserve. Multiple ineffective flow areas were added to the hydraulic model to better reflect flow conditions through contraction and expansion areas.

7.0 Hydraulic Structures

There are two bridges impacting the downstream reach, which include Hwy 101/ Bayshore Road and Friendship Bridge. Although the Hwy 101/ Bayshore Road are located at the upstream limit of the project study, the future construction of the bridge structure has major impacts upon the design water surface elevation downstream.

The California Department of Transportation (Caltrans) is currently working towards the release of a 30% design for the reconfiguration of West Bayshore Road, Highway 101, and East Bayshore Road (Station 80.28), combining all three structures into one bridge. Caltrans is currently reviewing the HEC-RAS model and updating the bridge geometry per the planned design. The revised model will be provided back to HDR and SCVWD to refine the design water surface profile and TOL elevation.

Downstream of Highway 101 (Station 29+88), Friendship Bridge, a pedestrian bridge, spans the existing creek. The geometry of the bridge constricts the channel significantly. A bypass channel into the golf course will be constructed to widen the channel floodplain. Additional information regarding the channel configuration at Friendship Bridge can be found in Section 8.3.

8.0 Channel Configuration

8.1 Cross-Section Layout and Orientation

HDR has reviewed the cross-section orientations selected by the previous modelers (PWA and Noble) and they appear adequate for this preliminary modeling purpose. The hydraulic model was trimmed to Station 2+00. Multiple interpolated cross-sections extending into the San Francisco Bay were removed downstream of Station 2+00 from the PWA Model after reviewing the model results. Interpolated cross-sections were used when the change in velocity head was too large to accurately determine the energy gradient. That is not the case of the revised model.

8.2 Smoothed Channel Width

After careful evaluation of the PWA Model proposed channel widths, it was discovered that the channel geometry unintentionally encroached onto multiple existing structures, utilities, and recreational features. The preliminary levee footprint was completed independent of real estate and other channel constraints. HDR narrowed the channel width significantly to satisfy design constraints mentioned in Section 1.2, and in coordination with the JPA's desire to limit encroachments and impact to adjacent residences, businesses and facilities.

Overall, the channel widths transitions were made more gradual to develop a smoother water surface profile. One major channel constraint that was previously unidentified was the International School of the Peninsula (Station 69+50). After determining what access road widths were required behind this school, the channel width was reduced an additional 36 feet from the Alternative 2 model to a maximum width of 140 feet.

The radius of the large bend spanning from Station 60+00 through 50+00 was also increased to better satisfy USACE guidance for channel bends found in *EM 1110-2-1601, Hydraulic Design of Flood Control Channels* (USACE 1994). For designing the large bend, a ratio of radius to width of 2.5 to 3.5 was used.

8.3 Bypass Levee Configuration at Friendship Bridge

The PWA Model contained a fairly significant impact to the Palo Alto Municipal Golf Course. The model contained a bypass channel allowing a portion of the main channel flow to be diverted around the Friendship Bridge abutment through the edge of Palo Alto Municipal Golf Course and then merging back together into the existing leveed channel. The maximum channel width modeled was equal to 450 feet. After review of the Friendship Bridge and bypass area it was determined that a maximum channel width of only 300 feet would produce an acceptable design water surface elevation. The narrowing of the channel width also decreased the amount of golf course property needed to construct the bypass levee.

8.4 Baylands Preserve (Faber Tract)

A portion of the Baylands Preserve is located on the landside of the north levee between Friendship Bridge and the San Francisco Bay. This area of land is owned by the City of Palo Alto and managed by the United States Fish and Wildlife Service.

A secondary model reach was added to the hydraulic model to more appropriately model the Baylands Preserve tidal condition. Two levees, one running north-south and the other east-west, provide protection to the Baylands Preserve from the San Francisco Bay. At the intersection of the two levees, a small breach approximately 200 feet wide has been cut allowing tidal interaction between the Bay and Preserve, restoring the Baylands Preserve into a tidal marsh. These two levees, referred to as the Baylands Levees for the purpose of this report, are approximately at elevation 10 feet and are significantly overtopped during the 100-Year tidal event plus sea level rise, elevation 12.52 feet.

The PWA Model assumed that once the design flow of 9,400 cubic feet per second (cfs) enters into the Baylands Preserve, the Baylands Levees had negligible impacts on the water surface elevation within the Preserve. After additional evaluation of the tidal interaction, HDR determined that the Baylands Levees do influence the water surface elevation within the Preserve area and that the levee impacts cannot be ignored.

To model the Baylands Preserve impacts to channel water surface elevation, a weir at an elevation of 8.0 feet, was added to the hydraulic model along the degraded levee (reduced to Stations 28+00 to 11+00) to estimate the flow leaving the creek channel and flowing into the Baylands Preserve. The flow entering the Baylands Preserve was then modeled through the secondary model reach out through the small breach. This revised model will become the hydraulic model used to finalize the TOL design.

9.0 Findings and Recommendations

Many changes to the PWA Model were completed to better model the JPA's conceptual level design as well as reflect a more feasible and constructible project. HDR recommends revisions to the downstream boundary conditions as well as revisions to the channel configuration. The revisions recommended by HDR to the hydraulic model reflect modifications to the alternative to reduce impacts to existing features, such as homes, businesses, existing utilities, and recreational facilities.

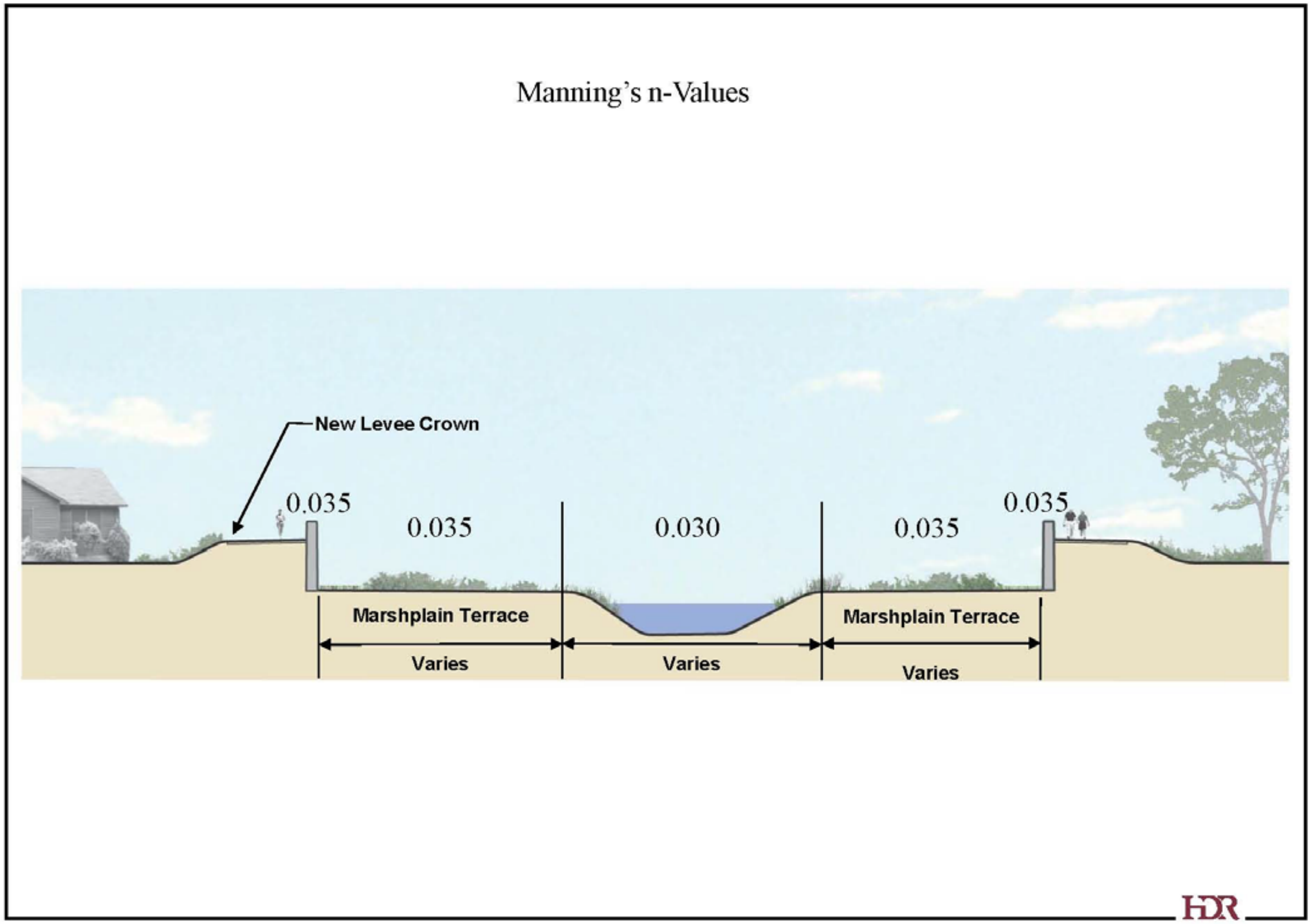
With the completion of the updated Alternative 2 hydraulic model, additional channel design features can been analyzed. All future design considerations will be summarized in the accompanying Design Technical Memorandums to be released with each design deliverable.

10.0 References

- Philip Williams & Associates, Ltd. (2009), San Francisquito Creek Flood Reduction Alternatives Analysis. July 17.
- Noble Consultants, Inc. (2009), Final Report, San Francisquito Creek, Development and Calibration/Verification of Hydraulic Model. May 26.
- Caltrans (Not Yet Released) analysis was developed for the design of a new bridge at West Bayshore Road, Highway 101, and East Bayshore Road.
- Santa Clara Valley Water District San Francisquito Creek Hydrology Report (Wang et al 2007).
- USACE (Not Yet Released), Shoreline Report.
- USACE (1994), EM 1110-2-1601, Hydraulic Design of Flood Control Channels. June 30.
- USACE (2005) 905b Analysis Reconnaissance Study. March 14.
- HDR (2010) Draft Design Criteria Technical Memorandum. May 21.

Figure 1

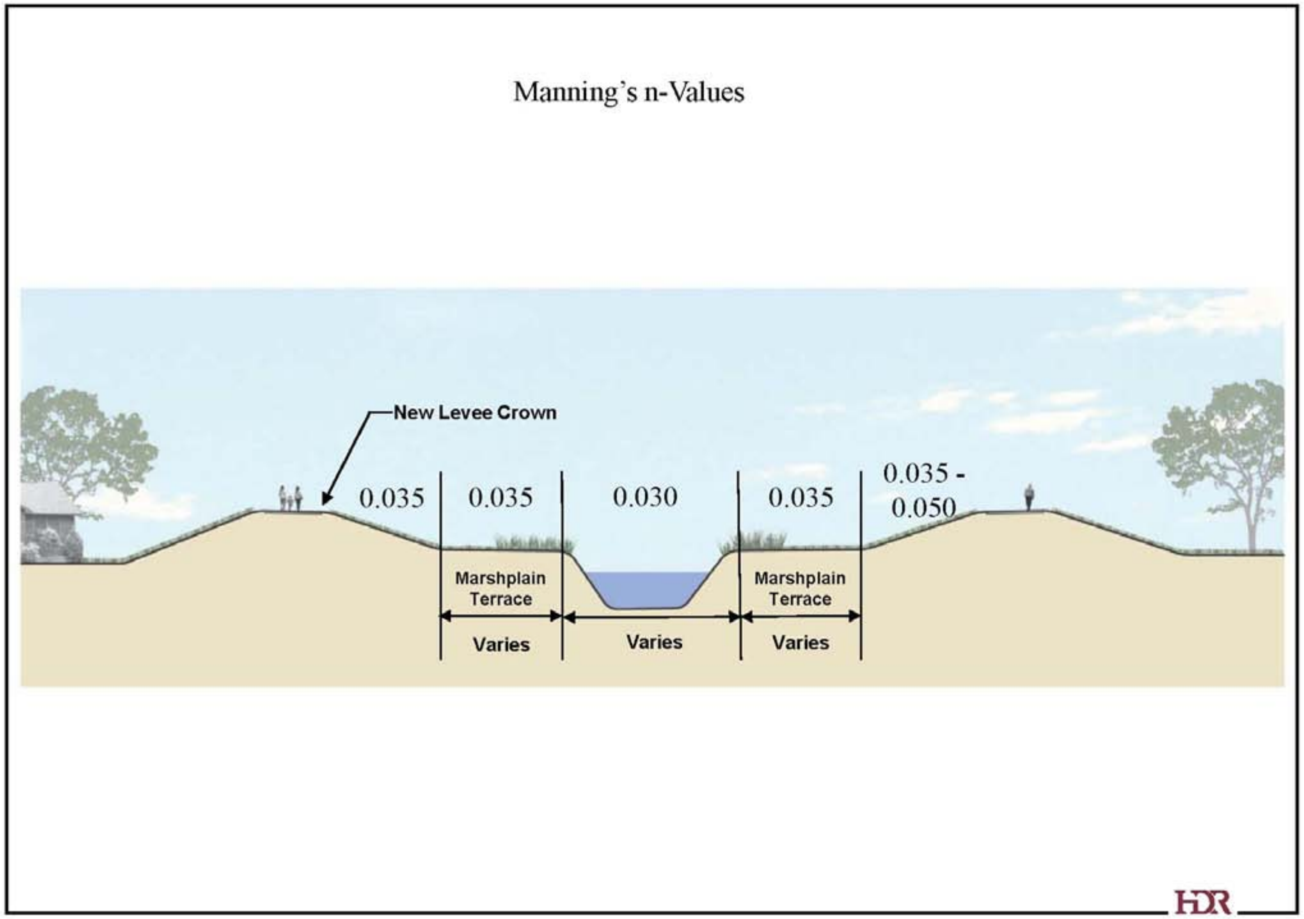
Manning's n-Values – Typical Section with Floodwalls



San Francisquito Creek with Floodwalls
Figure 1

Figure 2

Manning's n-Values – Typical Section with Levees



San Francisquito Creek with New Levees
Figure 2

Figure 3

Project Design Features