200-YEAR POST-FEATHER RIVER WEST LEVEE PROJECT FLOODPLAIN MAPPING

PREPARED FOR:
SUTTER BUTTE FLOOD CONTROL AGENCY (SBFCA)

April 15, 2016

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200-Year Post-Feather River West Levee Project Floodplain Mapping

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1 PURPOSE & INTRODUCTION

This report documents the development of the post-Feather River West Levee Project (FRWLP) 200-year floodplain map by Peterson Brustad Inc. (PBI). The maps show the 200-year residual floodplains within the Sutter Basin after construction of the FRWLP is complete.

Starting in 2007, Sutter Butte Flood Control Agency (SBFCA) embarked on a comprehensive evaluation of the FRWL. This evaluation was necessary to identify the deficiencies of the FRWL, their magnitude and severity, and the remedial measures required to address them. This comprehensive evaluation determined that the existing FRWL contains through- and under-seepage, landside and waterside instabilities, erosion deficiencies, and that a substantial number of geotechnical and other improvements are necessary to bring the FRWL up to current federal and state flood protection standards. SBFCA's goal is to achieve a minimum 200-year level of flood protection for urbanized and urbanizing areas within the Sutter Basin. An overview of the FRWLP is shown in Figure 1-1.

To meet this goal, SBFCA has divided the FRWL into four project areas: Project Areas A, B, C & D (see Figure 1-2). SBFCA has received State funding assistance to evaluate, design and construct 200-year remediation measures along the FRWL in Project Areas B, C, and D. Construction of these improvements began in 2013 and completion is anticipated in 2017. Planning work for Project Area A is ongoing and the goal is to improve this reach to provide a 100-year level of protection.

This report presents the 200-year post-project floodplain extents based upon completion of the FRWLP improvements for Project Areas B, C, D, and the Star Bend setback which run from Thermalito Afterbay to south of Star Bend (River Mile 17.0; Levee STA 478+68). It is important to note that Reaches 26-28 (FRWL stationing 1674+37 thru 1769+31) are not being remediated to provide a 200-year level of protection since these levees are located on high ground and the 200-year water surface would not contribute to the Sutter Basin floodplain if these levees were removed[1]. It is also important to note that this report does not analyze or address flood risk from the Cherokee Canal or Butte Sink.

The 200-year post-FRWLP residual floodplain maps have undergone a number of updates in order to incorporate information from new analyses and to stay current with FRWLP changes. This report incorporates past updates and supersedes all previously dated 200-year analyses and maps developed by PBI.

[1] *Sutter Butte Main Canal: Investigation Regarding Inflow from a Feather River West Levee Breach*, PBI, 2011.

Figure 1-1. Overview of SBFCA's FRWLP

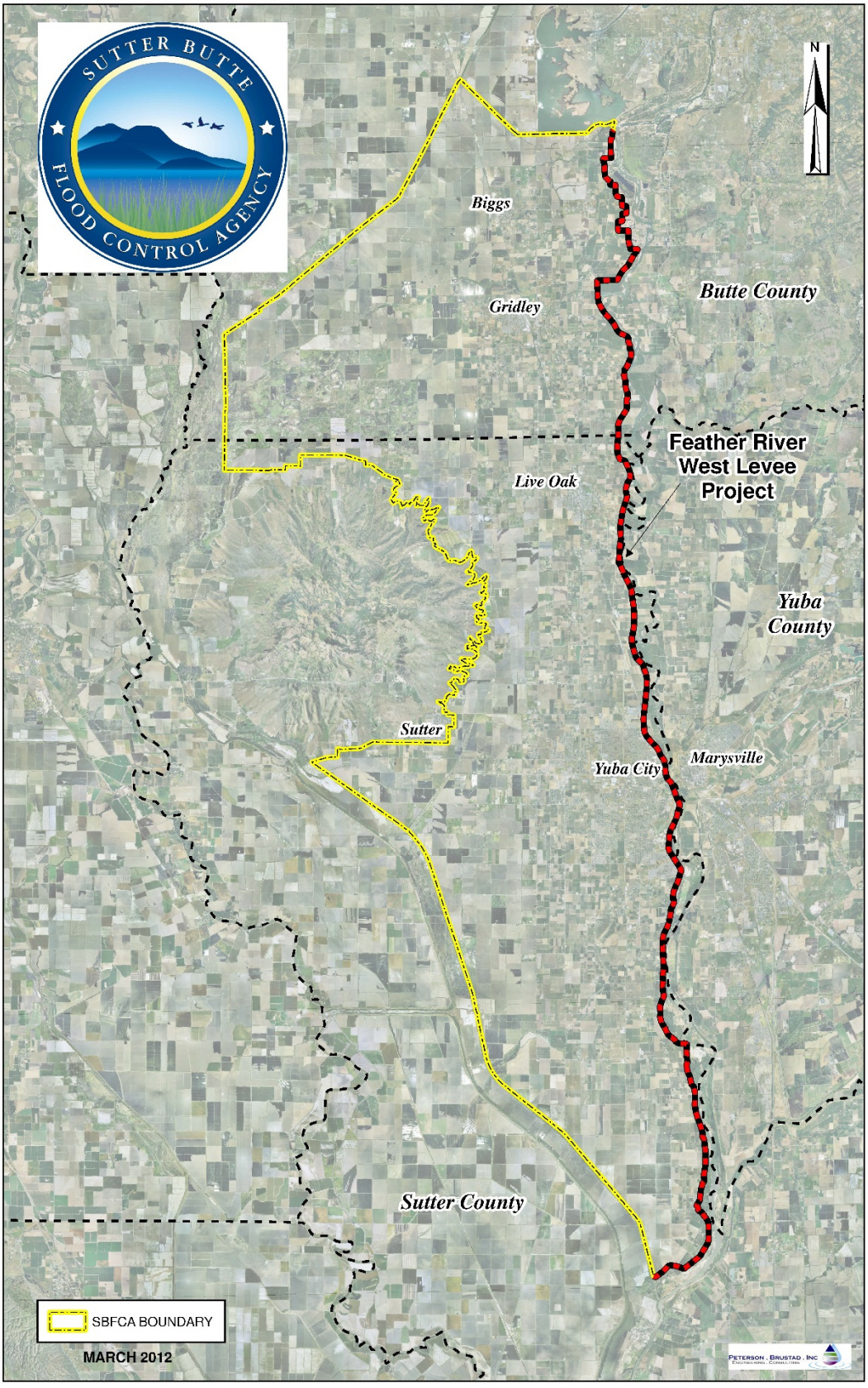
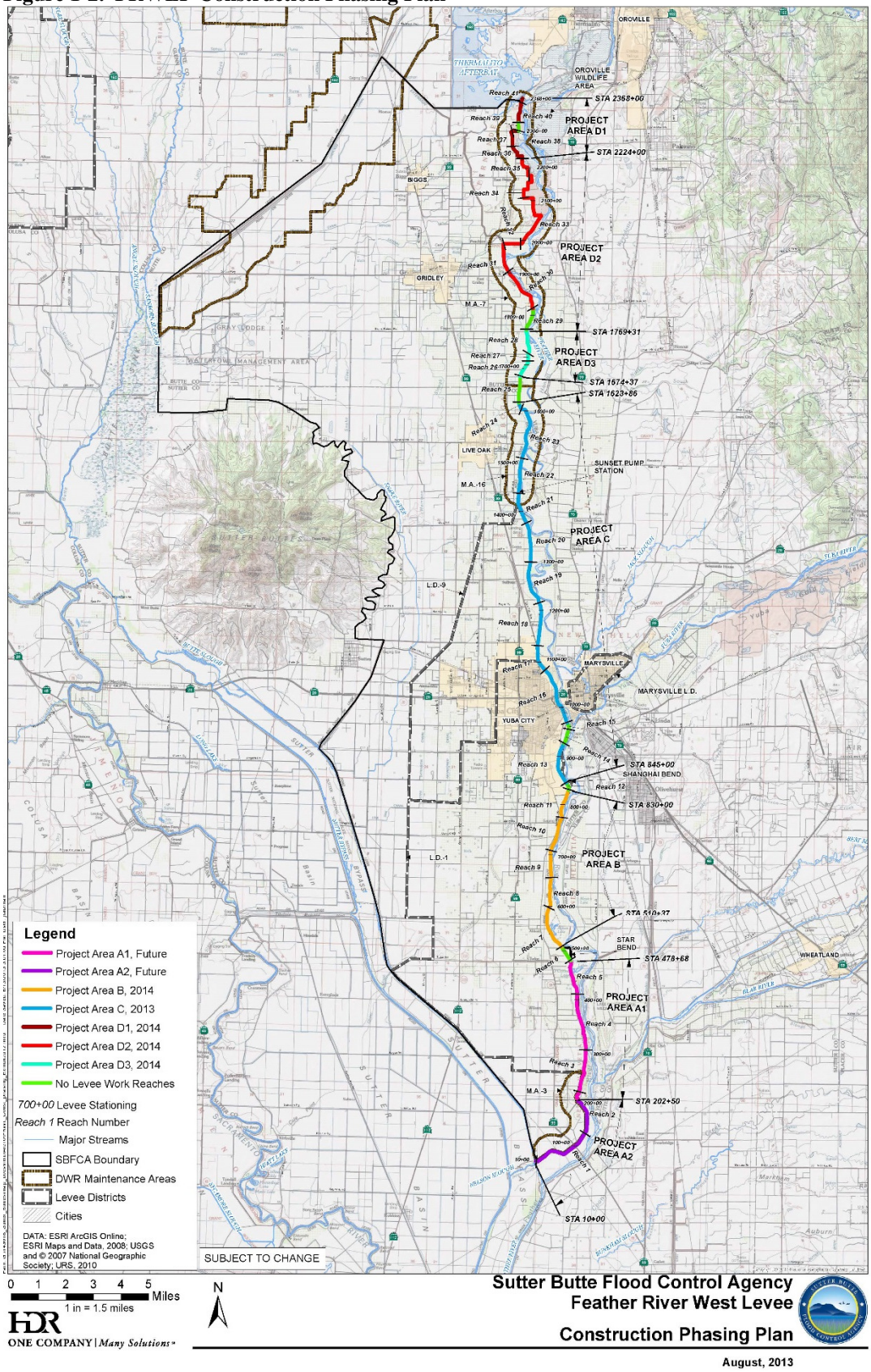


Figure 1-2. FRWLP Construction Phasing Plan



2 HORIZONTAL AND VERTICAL DATUM

The referenced horizontal projection is the North American Datum 1983, California State Plane Coordinate System, Zone II. The referenced vertical datum is the North American Vertical Datum of 1988 (NAVD88). All units are in U.S. Survey feet.

3 H&H ANALYSIS

3.1 HYDRAULIC ANALYSIS SUMMARY

In total, the 200-year post-FRWLP floodplain map incorporates potential 200-year flooding from interior drainage sources, Sutter Bypass levee breaches, and Feather River levee breaches south of Star Bend. As noted in Section 1, the map reflects levee failures in FRWLP reaches 26-28, however, the levee in those reaches is located on high ground, so failure in the 200-year event would not release any into the Sutter Basin. Also, it does not address flood risk from the Cherokee Canal or Butte Sink. The 200-year map is a compilation of previous mapping analyses conducted by PBI and can be divided up into three distinct areas of technical work:

1) the areas of potential flooding from interior drainage sources
2) the Town of Sutter area, which is defined as the area bounded by Wadsworth canal in the east, the Sutter Bypass in the west, and the Sutter Buttes in the north; and
3) the southern area of the Sutter Basin, which is defined as the area bounded by Wadsworth Canal and Sutter Bypass in the west, and Feather River in East

The 200-year potential flooding from interior drainage was analyzed via a study conducted by PBI in 2012[2]. Residual 200-year floodplains from PBI's 2012 interior drainage analysis were brought in and overlaid onto the final composite floodplain map. The drainage sheds for the interior drainage analysis are shown in Figure 3-1.

The 200-year residual floodplain for the Town of Sutter area was analyzed via a study conducted by PBI in 2015[3]. The floodplain is the result of a single levee breach on the Sutter Bypass at RM 87.48, which is the location that was determined to produce the worst case scenario of flooding for this area.

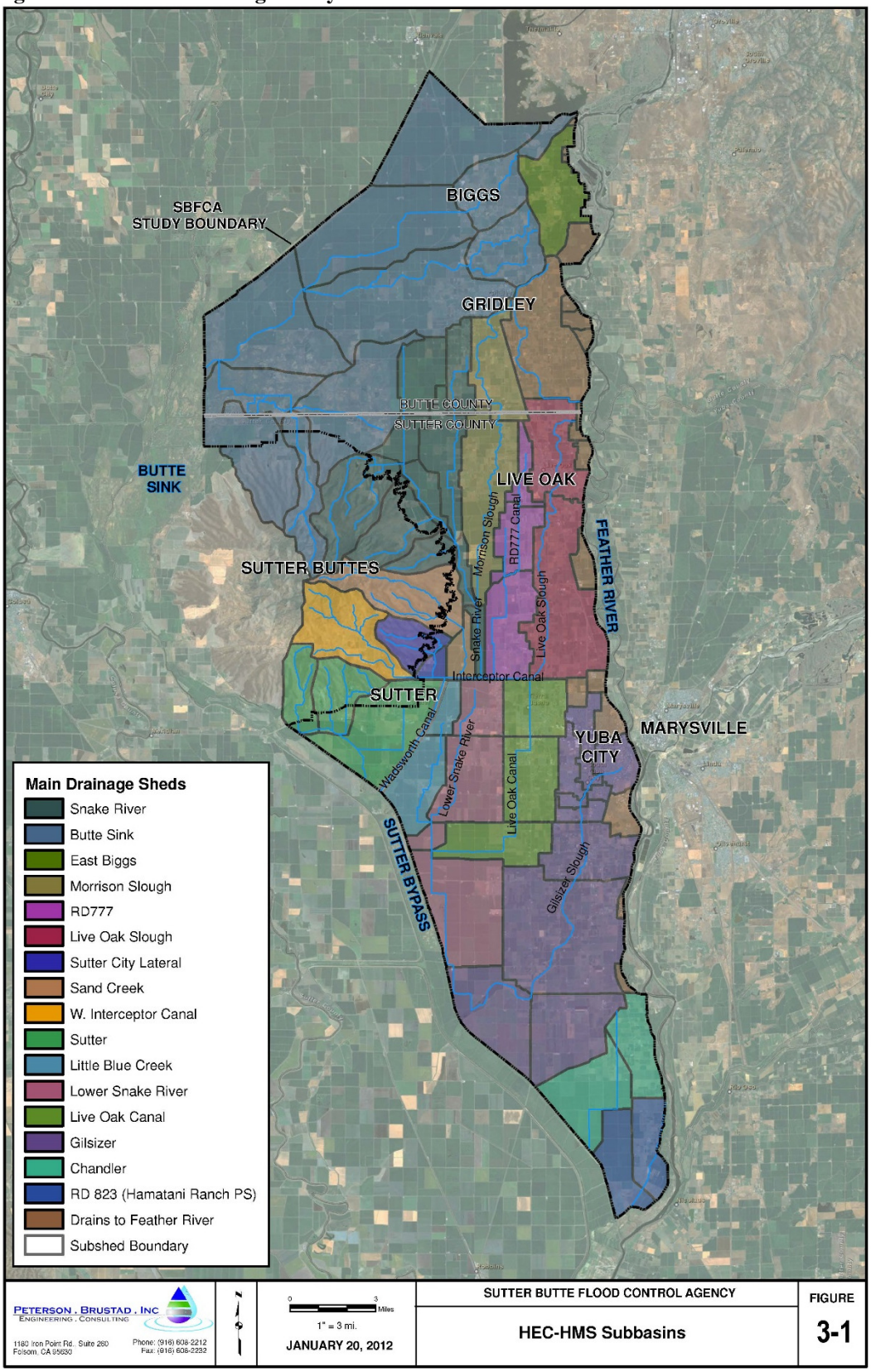
To delineate the residual floodplain for the southern area of the Sutter Basin, two levee breach scenarios were simulated at locations which were determined to produce the worst case scenario of flooding for this area:

1) RM 84.0 along the Sutter Bypass, located just downstream of the confluence of Wadsworth Canal and the Sutter Bypass
2) RM 17.0 along the Feather River, located just downstream of Star Bend and the limits of FRWLP 200-year improvements

[2] *Sutter Butte Flood Control Agency Interior Drainage Analysis,* Peterson Brustad, Inc., 2012
[3] *Sutter Triangle 200-year Residual Floodplain Mapping and Refinement,* Peterson Brustad Inc., 2015

The residual floodplains from these two breach scenarios were then overlaid upon each other to create a composite map that reflects the maximum risk of flooding to the Sutter Basin from either of these two scenarios. The hydraulic analysis and sources of information are further described in the following sections.

Figure 3-1. Interior Drainage Analysis HEC-HMS Subbasins



Reference: PBI 2012 Interior Drainage Analysis

3.2 HYDRAULIC MODEL SOURCES

For the 200-year residual floodplain mapping, PBI utilized existing FLO-2D and HEC-RAS hydraulic models that were developed by PBI as part of the 2011 U.S. Army Corps of Engineers (USACE) Sutter Basin Feasibility Study (SBFS)[4] and the 2012 Feather River West Levee Project Design Water Surface Profiles[5].

Both the existing HEC-RAS model and the existing Sutter Basin FLO-2D model have undergone extensive quality control and quality assurance reviews as part of the SBFS. For example, both models have gone through an internal QA/QC process, an Independent Technical Review (ITR) process performed by MBK Engineers, as well as the USACE Sacramento District-level Quality Control process, USACE Agency Technical Review process, and USACE Independent Expert Peer Review process. Full details in regards to the development of these models can be found in the associated referenced documentation.

The main riverine components in the HEC-RAS model are the Feather River, Yuba River, Bear River, Sutter Bypass, Tisdale Bypass, and portions of the Yolo Bypass and Sacramento River and other smaller tributaries. The model extends from the Yolo Bypass (approximately 6 miles downstream of Fremont Weir) at the southern end to Oroville Dam at the northern end. The HEC-RAS model extents are shown in Figure 3-2.

The FRWLP HEC-RAS model was calibrated to the January 1997 flood event and verified to the January 2006 flood event. The model was configured and executed using HEC-RAS version 4.1.

The one-dimensional HEC-RAS model uses storage areas to represent the floodplains behind the existing levees. The storage areas account for the volume of overland flow but are not adequate for mapping residual floodplains. Therefore, to route the two-dimensional overland flow and map the residual floodplains, PBI utilized the existing FLO-2D model developed as part of the USACE SBFS.

FLO-2D is a two-dimensional finite difference modeling software program that simulates complex topography and roughness while reporting volume conservation. It numerically routes flood hydrographs over a system of grids that represent the floodplain topography, and predicts the area of inundation and floodwave attenuation. The Sutter Basin model was configured and executed using FLO-2D version 2009.06.

The FLO-2D model simulates inundation within the Sutter Basin associated with levee breaches and overtopping along the Sutter Bypass, and Feather River. River channel hydraulics are not included in the FLO-2D model. The river channel hydraulics are

[4] *Sutter Basin Feasibility Study Hydraulics Report,* Peterson Brustad, Inc., December 2012
[5] *Design Water Surface Profiles for the Feather River West Levee Project Addendum #1,* Peterson Brustad Inc., July 2012

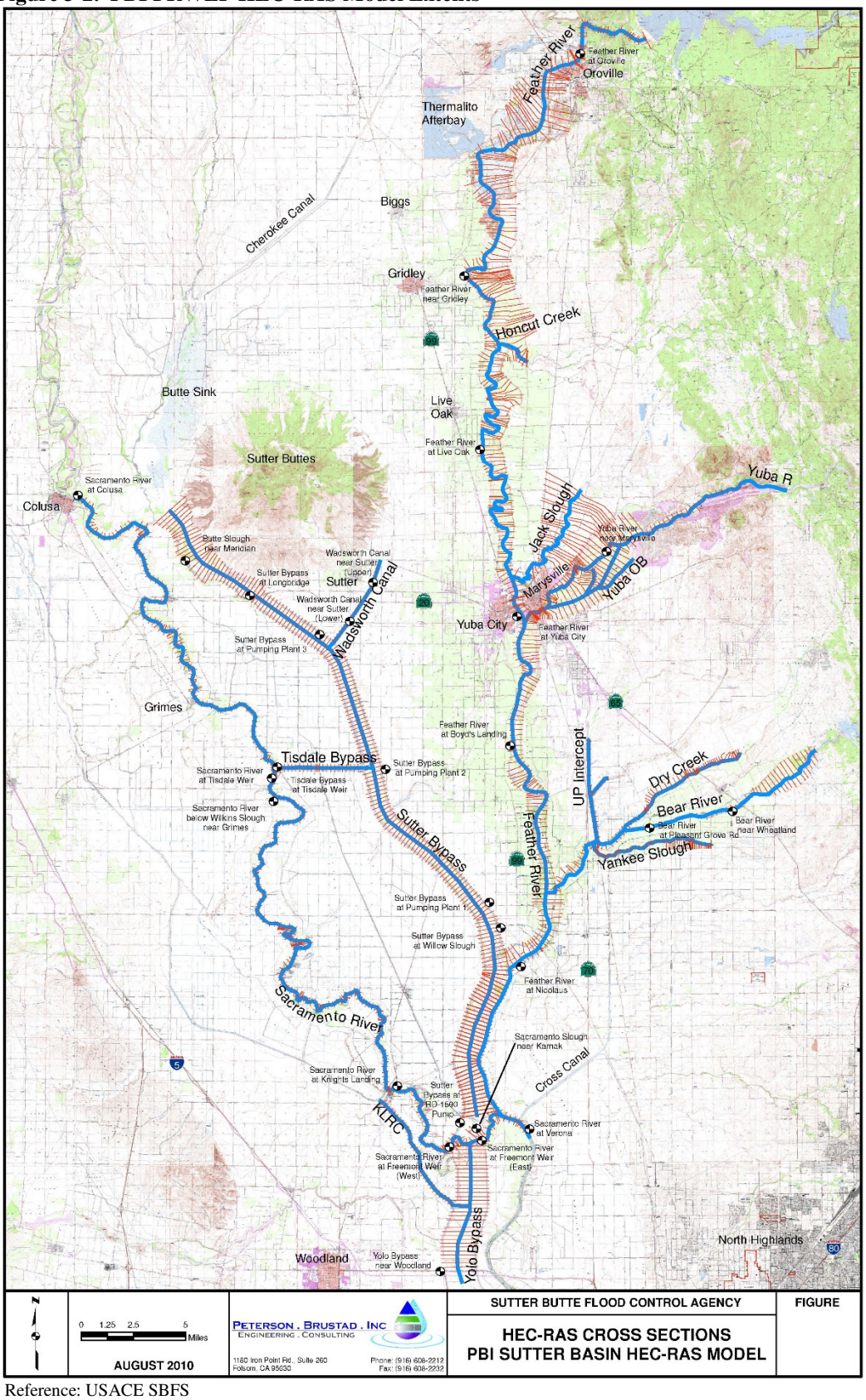
computed within HEC-RAS and then any overland flows are imported into the FLO-2D model.

The FLO-2D study area covers approximately 300 square miles of Sutter and Butte County. The study area is generally flat and ranges in elevation from 25 ft-NAVD88 (southern end) to 130 ft-NAVD88 (northern end). The study limits are approximately bounded by the following:

- Northern Boundary – Cherokee Canal and Thermalito Afterbay
- Eastern Boundary – Feather River
- Western Boundary – Eastern edge of the Sutter-Buttes & the Sutter Bypass
- Southern Boundary – Feather River

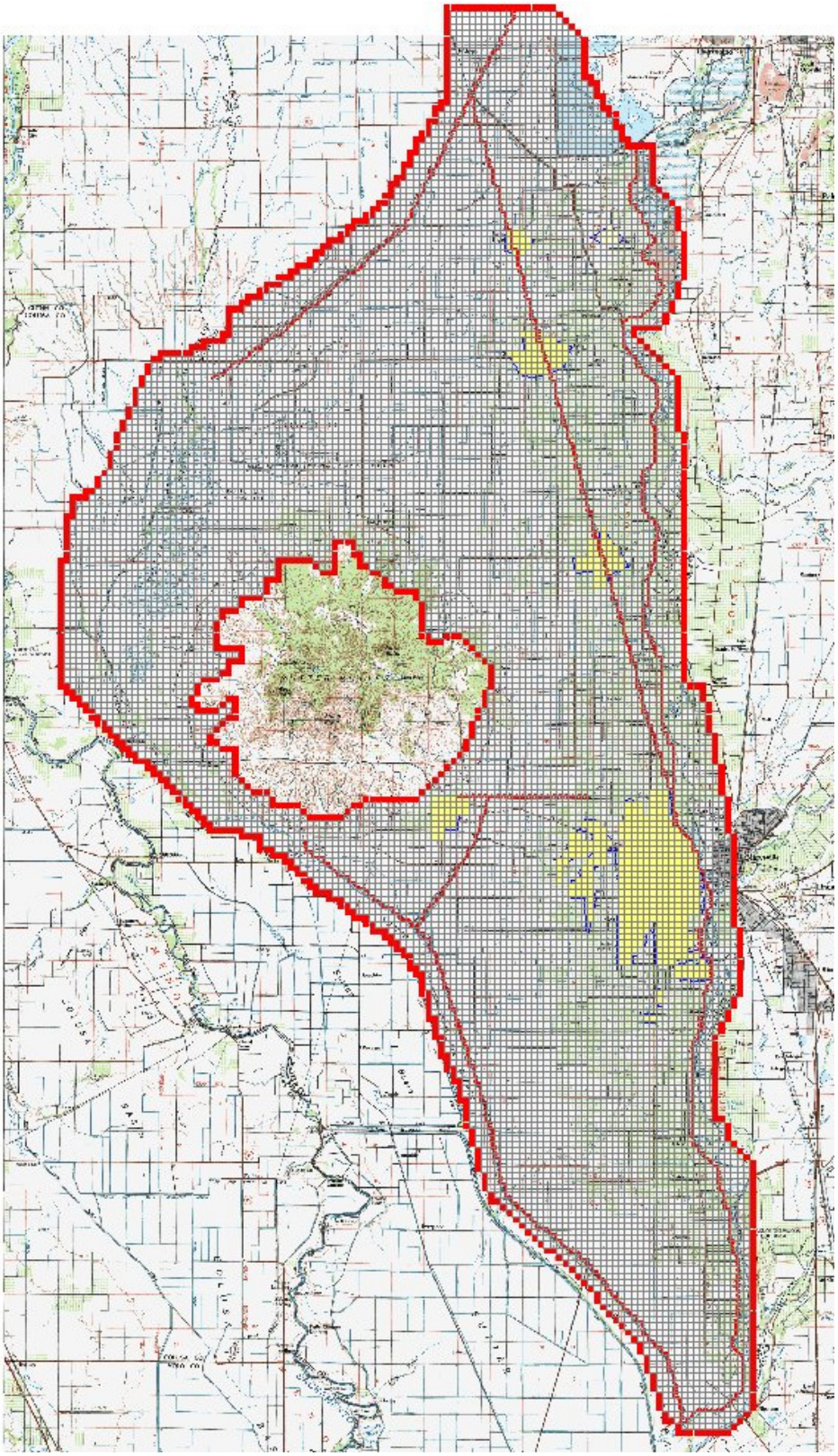
The FLO-2D model extents are shown in Figure 3-3.

Figure 3-2. PBI FRWLP HEC-RAS Model Extents



Reference: USACE SBFS

Figure 3-3. PBI Sutter Basin FLO-2D Model Extents



Reference: USACE SBFS

3.3 HYDROLOGY

For the HEC-RAS model inflow parameters, PBI utilized 1/100, 1/200 and 1/500 annual exceedance probability (AEP) 30-day storm event hydrographs provided by the USACE. The inflow hydrology is a compilation from various technical studies previously completed by the USACE including the Comp Study[6] and the Lower Feather River Floodplain Mapping Study[7]. Minor updates to the inflow hydrology were also incorporated by the USACE as part of the SBFS. The inflows were applied to the most upstream cross sections of the HEC-RAS model. In developing the n-year hydrographs the USACE used two different storm centerings: 1) the Sacramento River storm centering and 2) the Shanghai Bend storm centering. For the 200-year event, the Shanghai Bend storm centering produces higher stages in the Feather River and the Sacramento storm centering produces higher stages in the Sutter Bypass. A summary of the Shanghai and Sacramento storm centering inflows are shown in Table 3-1 and Table 3-2.

Table 3-1. Final Shanghai Storm Centering Peak Inflow Values

Description	1/100 AEP Storm Event (cfs)	1/200 AEP Storm Event (cfs)	1/500 AEP Storm Event (cfs)
Bear River	40,600	46,800	54,200
Best Slough	3,900	4,600	5,500
Dry Creek	7,000	8,100	9,400
Feather River	150,000	174,000	320,000
Jack Slough	4,500	5,400	6,600
Sacramento River	52,900	58,200	62,600
Sutter Bypass	156,000	218,000	273,000
Yuba (Englebright)	141,000	208,000	294,000
Yuba (Deer Creek)	9,500	10,700	12,400
Yuba (Dry Creek)	8,900	10,100	11,600
Honcut Creek	27,900	33,400	41,500
Wadsworth Canal	1,500	1,550	1,600
UP Interceptor Canal	5,700	7,300	9,500
Yankee Slough	2,100	2,800	3,800

Reference: USACE SBFS

[6] *Sacramento and San Joaquin River Basins: Comprehensive Study, Technical Studies Documentation,* United States Army Corps of Engineers, 2002

[7] *Lower Feather River Floodplain Mapping Study,* United States Army Corps of Engineers, December 2004

Table 3-2. Final Sacramento Storm Centering Peak Inflow Values

Description	1/100 AEP Storm Event (cfs)	1/200 AEP Storm Event (cfs)	1/500 AEP Storm Event (cfs)
Bear River	48,200	53,600	60,700
Best Slough	4,700	5,300	6,200
Dry Creek	8,300	9,300	10,500
Feather River	150,000	150,000	292,000
Jack Slough	4,300	5,100	6,400
Sacramento River	55,500	59,300	67,900
Sutter Bypass	184,000	229,000	327,000
Yuba (Englebright)	124,000	170,000	244,000
Yuba (Deer Creek)	11,100	12,200	13,700
Yuba (Dry Creek)	10,400	11,400	12,900
Honcut Creek	26,900	32,100	40,100
Wadsworth Canal	1,500	1,550	1,600
UP Interceptor Canal	6,800	8,400	10,600
Yankee Slough	2,500	3,200	4,300

Reference: USACE SBFS

3.4 METHODOLOGY

The hydraulic modeling and inundation analysis for developing the 200-year map was a multi-step process. Breach scenarios were simulated using the 1-D HEC-RAS model and the 200-year breach flow hydrographs were exported from HEC-RAS and input into the Sutter Basin FLO-2D model to delineate the extents and depths of flooding. A summary of the analysis is as follows:

1. HEC-RAS Model Simulation Runs – SB 87.48, SB 84.0, and FR 17.0 were simulated individually using the SBFS HEC-RAS model and SBFS breach assumptions.

2. FLO-2D Model Simulation Runs – The HEC-RAS breach hydrographs from locations SB 87.48, SB 84.0, and FR 17.0 were used as input data for the existing FLO-2D model. FLO-2D simulations were then conducted for each levee breach individually in order to delineate the residual floodplains.

3. Develop the Composite FLO-2D Floodplain for SB 84.0 and FR 17.0 Breaches – The results obtained from the FLO-2D simulation runs were uploaded into ArcGIS and overlaid upon each other in order to develop the 'worst case scenario' residual floodplain resulting from a combination of the simulated levee breaches. This was accomplished by using the following procedure:

    i. The maximum flow depth at each FLO-2D 1,000 ft grid was selected from either of the two levee breach simulations at SB 84.0 and FR 17.0

4. Incorporate Interior Drainage and Sutter Area Floodplains – The interior drainage floodplain and the floodplain for the Sutter area were added to the map.

5. Refined the Floodplains for the Sutter Area and the Southern Sutter Basin – The FLO-2D model provided water surface elevations throughout the study area in 1000'x1000' grid cells. These results were refined to produce more detailed floodplain delineations through the following GIS processes. Note that this process was only applied to the Sutter Basin and Sutter area residual floodplains. The refinement process was not applied to the residual floodplains from the Interior Drainage Analysis.

   i. Create a detailed water surface - The FLO-2D water surface elevation results were formatted as GIS shapefiles with 1000'x1000' grid cells. These shapefiles were converted to a smoothed, raster water surface with 5'x5' grid cells.

   ii. Create a detailed ground surface – Detailed ground topography available from CVFED LiDAR[8] data was converted to a raster digital elevation model (DEM) with 5'x5' grid cells.

   iii. Compute detailed flood depths – Floodplain depths were produced by subtracting the ground elevation layer from the water surface elevation layer, each with 5'x5' grid cells. Through this process, areas of high ground that produced negative depths were discarded from the depth layer.

   iv. Post-processing of detailed flood depths – The raw GIS results produced several shallow areas of flooding that were surrounded by high ground and were isolated from the source of flooding. These shallow areas were removed from the detailed depth layer and shown as dry land in the final, post-processed GIS files.

3.5 BREACH ASSUMPTIONS

The breaching parameters utilized in the SBFS HEC-RAS model are based upon historical breach information and technical guidance and were developed in coordination with the USACE as part of the SBFS.

The most relevant historical breach information for the Feather River was found within a Grand Jury Report[9] for the 1955 levee breach along the Feather River at Shanghai bend. The reports states, "*Water from the Feather River escaped through a small break in the levee which increased in size to approximately 2,200 feet and inundated thousands of acres to the west and backed up via Gilsizer Slough thereby flooding almost the entire City of Yuba City*". The USACE analysis showed 1,500 feet as plausible and therefore it was chosen by USACE for all breaks on the Feather River[10]. A break on the Sutter

[8] *Central Valley Floodplain Evaluation and Delineation Program,* California Department of Water Resources, 2009
[9] *Report of the 1955 Sutter County Grand Jury*, 1956
[10] *Sutter County, California Feasibility Study, Feasibility Scoping Meeting (F3) Milestone Report,* United States Army Corps of Engineers, October 2004

Bypass in 1997 was 1,100 feet long and thus was the basis for the USACE 1,000-ft breach width assumption for Sutter Bypass and Wadsworth Canal breaks.

The levee breaches were simulated by coding a gap into the corresponding lateral weir simulating an 'open hole' in the levee. The breach cut elevation was set to the elevation of the landside toe.

3.6 PONDING LIMITATIONS

To delineate the inundated area for the southernmost portion of the basin, the ponded portion of the floodplain (near the Feather River/Sutter Bypass confluence) was held to a water surface elevation of 51.5-ft (NAVD88), which is the lowest recorded levee crest elevation in basin[11]. The low point is located along the Sutter Bypass approximately 1,500 ft. north of the confluence with the Feather River. In accordance with ULDC Section 7.20, the ponded water surface elevation was limited to the minimum overtopping elevation. This was simulated by coding hydraulic structures into the model that limited the maximum water surface elevation at the southernmost end of the model to 51.5 NAVD88.

Section 7.20 of DWR's *Urban Levee Design Criteria* (ULDC)[12] states:

> *Flood relief structures such as culverts, gates, weirs, pumping plants, and levee relief cuts may be assumed effective and relied upon for performing as designed provided they are identified in an approved flood relief plan in the operation and maintenance manual (and/or in the flood safety plan) for the project.*
>
> *If such a flood relief plan is approved, it may be used to lower the ponded water surface in the flooded areas of the basin based on the hydraulic capacity of the flood relief structure(s) and the most severe levee breach or floodwall failure scenario that is reasonably expected. In the case of levee relief cuts, the ponded water surface may be no lower than the levee crown elevation (due to the higher uncertainty associated with this type of flood relief structure).*

Therefore, because SBFCA is in progress of developing a relief cut plan in accordance with ULDC Section 7.20, the 200-year maximum water surface at the southern end of the Sutter Basin was set to this minimum levee crown elevation assuming that the provisions of ULDC Section 7.20 will be satisfied. Note that the maximum water surface elevation for the Sutter area (the area northwest of Wadsworth Canal) was not held to the lowest levee crown elevation since there is no ongoing work for developing a relief cut plan in this area.

[11] *Urban Levee Geotechnical Evaluations Program LiDAR Survey,* Fugro West, January 2009
[12] *Urban Levee Design Criteria*, California Department of Water Resources, May 2012

4 200-YEAR FLOODPLAIN RESULTS

The 200-year post-project floodplain maps are included on the following pages of this report. In total, four different maps were developed (note that all four maps show the same 200-year residual floodplain):

1) A map of the 200-year residual post-project floodplain for the entire Sutter Basin highlighting depths greater than 3-feet

2) A map of the 200-year residual post-project floodplain for the entire Sutter Basin, with depths shown in 1-foot intervals

3) A zoomed-in map of the 200-year residual post-project floodplain near Yuba City, highlighting depths greater than 3-feet

4) A zoomed-in map of the 200-year residual post-project floodplain near Yuba City, with depths shown in 1-foot intervals

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200-year Residual Floodplain from Cherokee Canal not addressed or shown

200-year Residual Floodplain from the Butte Sink not addressed or shown

BIGGS

GRIDLEY

LIVE OAK

YUBA CITY

SUTTER

RM 87.48

RM 84.0

RM 17.0

Post-FRWLP Residual Floodplain (from 2012 Interior Drainage Analysis)

Post-FRWLP Residual Floodplain (from 2012 Interior Drainage Analysis)

Floodplain for Sutter Bypass RM 87.48 Levee Breach

Post-FRWLP Floodplain for Southern Subbasin

Breach Locations
FRWL Project
SBFCA Boundary
City Boundary
General Plan Boundary

200-year Floodplain Depth (ft)

0 - 3
3.01 - 20.2

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SUTTER BUTTE FLOOD CONTROL AGENCY

SUTTER BASIN 200-YEAR POST-FRWL PROJECT RESIDUAL FLOODPLAIN DEPTHS GREATER THAN 3 FT

200-year Residual Floodplain from Cherokee Canal not addressed or shown

200-year Residual Floodplain from the Butte Sink not addressed or shown

BIGGS

GRIDLEY

LIVE OAK

YUBA CITY

SUTTER

RM 87.48

RM 84.0

RM 17.0

Post-FRWLP Residual Floodplain (from 2012 Interior Drainage Analysis)

Post-FRWLP Residual Floodplain (from 2012 Interior Drainage Analysis)

Floodplain for Sutter Bypass RM 87.48 Levee Breach

Post-FRWLP Floodplain for Southern Subbasin

Breach Locations
FRWL Project
SBFCA Boundary
City Boundary
General Plan Boundary

200 year floodplain
Depth (ft)

- 0 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 10.00
- > 10.00

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SUTTER BUTTE FLOOD CONTROL AGENCY

SUTTER BASIN 200-YEAR POST-FEATHER RIVER WEST LEVEE PROJECT RESIDUAL FLOODPLAIN DEPTHS

SUTTER

YUBA CITY

RM 87.48

RM 84.0

RM 17.0

Breach Locations
FRWL Project
SBFCA Boundary
City Boundary
General Plan Boundary

200-year Floodplain
Depth (ft)
0 - 3
3.01 - 20.2

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SUTTER BUTTE FLOOD CONTROL AGENCY

200-YEAR POST-FRWLP RESIDUAL FLOODPLAIN DEPTHS GREATER THAN 3 FT NEAR YUBA CITY

SUTTER

YUBA CITY

RM 87.48

RM 84.0

RM 17.0

Breach Locations
FRWL Project
SBFCA Boundary
City Boundary
General Plan Boundary

200 year floodplain
Depth (ft)

- 0 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 10.00
- > 10.00

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SUTTER BUTTE FLOOD CONTROL AGENCY

200-YEAR POST-FRWLP RESIDUAL FLOODPLIAN DEPTHS NEAR YUBA CITY