SAN JOAQUIN RIVER
NATIONAL WILDLIFE REFUGE PHASE 1:
ANALYSIS OF PROPOSED LEVEE BREACHES

Prepared for

Ducks Unlimited Inc.

and

U.S. Fish and Wildlife Service
Anadromous Fish Restoration Program

Prepared by

Philip Williams & Associates, Ltd.

May 2001

PWA Ref. # 1486

May 21, 2001

Robert Charney
Ducks Unlimited Inc.
Western Regional Office
3074 Gold Canal Drive
Rancho Cordova, California 95670-6116

RE: **San Joaquin River National Wildlife Refuge – Phase 1**
PWA Ref. # 1486

Dear Robert:

We are pleased to enclose our final report for Phase 1 of the above project. This report includes the data report as well as the hydrodynamic analysis of the levee breaching proposed by the U.S. Army Corps of Engineers Non-Structural Alternative for flood management.

We have also forwarded copies of the report to Scott Frazer, SJRNWR Manager, USFWS, Erwin Van Nieuwenhuyse, USFWS AFRP, and Rhonda Reed, CDFG.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Elizabeth Andrews, P.E.
Principal

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1. INTRODUCTION

1.1 CONTEXT AND RATIONALE FOR THE STUDY

As a result of the January 1997 floods several levees failed along the west side of the San Joaquin River in the vicinity of the Tuolumne River confluence. After the flood, the levees were repaired; however, the San Joaquin River National Wildlife Refuge (SJRNWR) worked with the US Army Corps of Engineers (USACE) to plan a non-structural flood management alternative (NSA). This alternative includes breaching existing mainstem San Joaquin River levees on recently acquired Refuge land to protect and restore wetland and riparian habitat. The proposed NSA will provide floodplain inundation behind project levees of up to 3,100 acres of Refuge land in some years.

The focus of this study is to examine habitat effects of proposed levee breaches and NSA refinements with particular emphasis on the needs of fish. The primary analysis tool used in this study was a one-dimensional, looped network hydrodynamic model, MIKE 11. Model results include depth and time of inundation as well as simulated flow on reactivated floodplain at the Refuge.

The study was undertaken under a joint venture between Ducks Unlimited and Philip Williams & Associates, Ltd. (PWA), for the U. S. Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program (AFRP). Funding for the current study was provided by the AFRP.

This report describes the historical setting of the site, the hydrodynamic modeling methodology, evaluation criteria being used to assess the results and finally, the challenges of the project. Evaluation criteria being used include: frequency, duration, depth and area of flooding; potential for fish stranding; and potential for creation of non-native or predator fish species habitat. In addition, potential refinements of the currently proposed NSA are identified.

1.2 LIMITATIONS OF THE STUDY

Phase 1 of the present study represents an initial overview of the proposed non-structural flood management alternative proposed by the USACE. Refinements to the proposed alternative will be made in Phase 2 of the project. The results contained in this report represent the potential conditions of the Refuge under the existing topographical conditions and flow regimes. Modifications to these parameters are likely under proposed Phase 2 alternatives to improve potential habitat conditions at the Refuge.

No hydrodynamic model calibration or validation data were available at the time of this study and therefore the results should be considered with this in mind. In addition, no sensitivity analysis has been conducted in this Phase of the study.

2. FINDINGS AND RECOMMENDATIONS

In this section presents key findings and recommendations, which are described and supported in the remainder of the report.

2.1 FINDINGS

1. The floodplains outside the project levees at the SJRNWR (i.e. Lara, Hagemann, and Vierra Properties) are likely to flood at approximately 16,000 cfs if breaches are made as proposed in the NSA, and are cut to the depth of the adjoining ground elevation.

2. Implementation of the NSA is expected to cause flooding of this SJRNWR floodplain every two to three years, on average, a frequency that is appropriate to achieve anadromous fish habitat enhancement goals.

3. Elevation of the SJRNWR floodplain is lower than the elevation of the breaches, as currently configured and modeled in this study. It is likely that this configuration will result in significant ponding on the floodplain. Model simulations suggest that during a flood similar to the 1994-1995 event, depth of ponding would range from 0 to 4 feet in the floodplain, excluding canals and ditches.

4. Breach 1 is by far the most active breach in the current configuration in terms of bringing water into the Refuge.

5. This model configuration includes berms at West Stanislaus Canal and Hospital Creek. Significant flows through Breach 1 at the south end of the site suggest that the berm at the Canal would breach during flood events, if not breached intentionally prior to the event

6. Breach 3, at the Hagemann plateau, is virtually nonfunctional during all but very large floods such as the 1997 event, if constructed to the elevation of the adjoining ground surface.

7. The key period for active use of the floodplain by Chinook salmon is December through May; late February through April for splittail. Assuming 16,000 cfs threshold criteria, years with floodplain inundation in the twenty-year record examined almost always have two weeks or more of flooding during this time period, though in one year flooding would have ended prior to splittail spawning period in February.

2.2 RECOMMENDATIONS

1. Future simulated NSA alternatives should specifically include facilities to enable floodplains to drain after inundation, and to reduce the potential for fish stranding. In some cases this may include simply lowering the breach elevations; in others, it may mean modeling a culvert or mildly sloped channel through the breach.

2. Future simulated NSA alternatives should explicitly include breaching of the cross-floodplain berms at both West Stanislaus Canal and Hospital Creek, whether or not such breaches are intended as part of the implementation of the alternative.

3. Breach 1 at the upstream end of the project should be significantly enlarged in the model, whether representative of construction plans, or anticipated erosion at this site.

4. It is probably appropriate to eliminate Breach 3 from the NSA, as it provides no value in river-floodplain interaction.

5. While floodplain inundation occurs primarily through Breach 1, all NSA breaches besides Breach 3 are active in river-floodplain exchange during larger flood events.

6. Additional topographic and existing site drainage facility data should be collected and incorporated into the model for future simulation analyses.

7. The model's downstream boundary condition should be moved farther downstream so that it is sufficiently removed from the area of interest.

3. PROJECT OBJECTIVES

The objective of this study is to apply the hydrodynamics model MIKE11 to simulate flow on Refuge floodplains to analyze proposed non-structural alternatives for flood management. This includes identification of areas on the Refuge that will be inundated during flood events, and recommendation of potential modifications to the proposed non-structural alternative for flood management. These recommendations will be further investigated during Phase 2 of this study. Finally this project includes development of habitat evaluation criteria to relate parameters describing floodplain inundation to potential benefits and constraints for habitat restoration with particular emphasis on anadromous fish. These criteria can be applied in Phase 2 to distinguish between potential project refinement alternatives.

4. SETTING

4.1 PROJECT SITE

The SJRNWR is located on the San Joaquin River downstream of the confluence of the San Joaquin and Tuolumne rivers, approximately 9 miles west of the city of Modesto. Levee breach sites identified in the NSA plan prepared by the USACE are located on the San Joaquin River from approximately river mile (RM) 79 to RM 86. Three Reclamation District levees are proposed for modification within the Refuge. A photograph showing the SJNWR as vie wed from the south of the site looking north along the project levee with the river to the east and the floodplain of the Refuge to the west is shown in Figure 1. A map of the site is shown in Figure 2.

Figure 1 – San Joaquin River National Wildlife Refuge – south border of Lara property looking from south to north

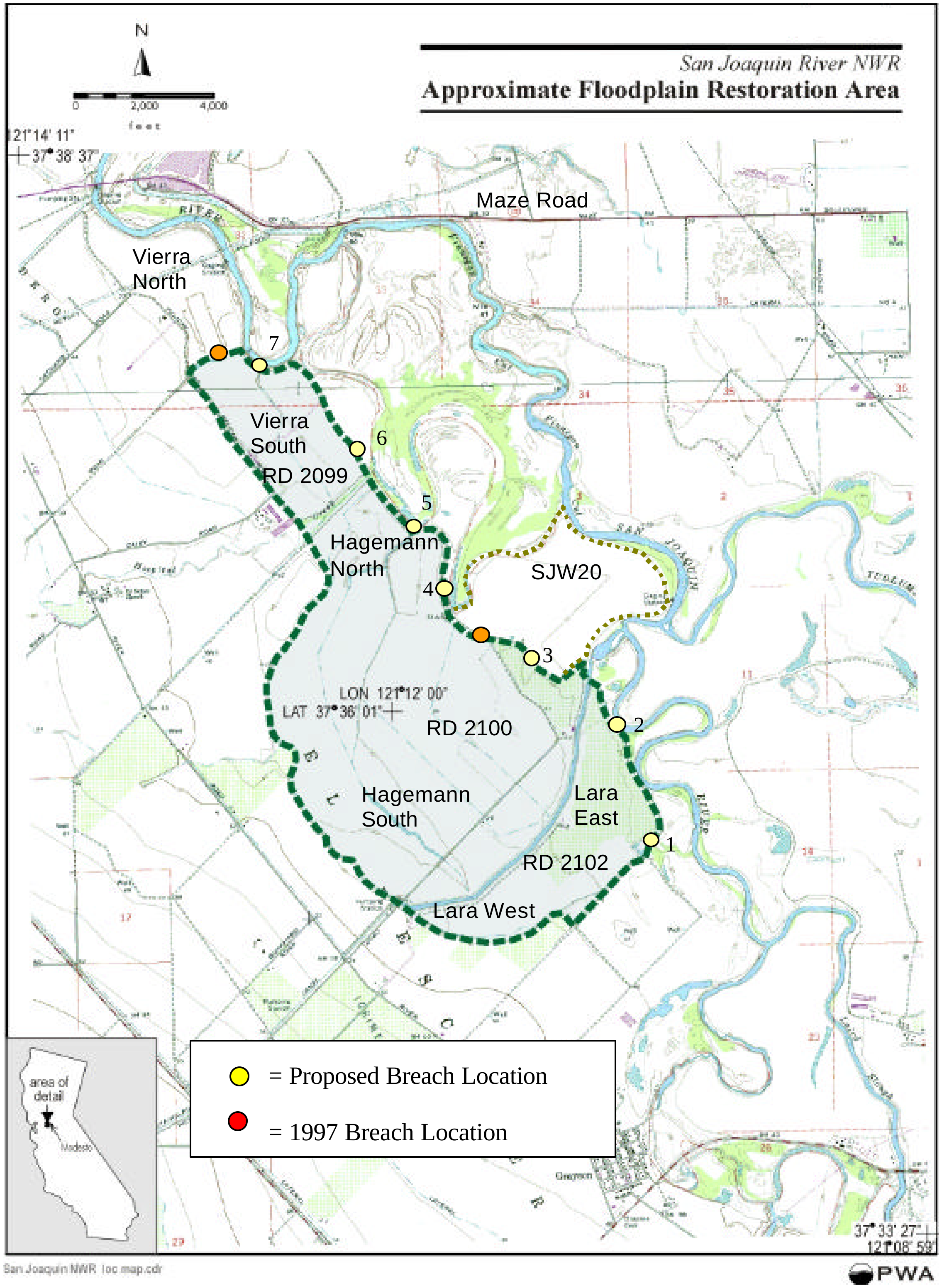


Figure 2 – Boundaries of SJRNWR, levee breach locations, and reclamation districts

4.2 PROJECT HISTORY

4.2.1 Historic Land Use

The SJRNWR has historically been used for livestock grazing and cultivated agriculture including orchard and row crops. Agricultural development and channel alterations in the SJRNWR are evident in documents from the early 1900's. In 1926, the West Stanislaus Irrigation District developed a canal system that included a diversion at the site of the SJRNWR. Irrigation systems on Refuge lands were also constructed around this time (Griggs, 2000).

4.2.2 Flood Setting

Precipitation in the San Joaquin Valley occurs primarily from November to April with very little precipitation occurring during summer months. Snow pack accumulates on the east side of the basin above an elevation of about 5,000 feet; snowmelt generally begins to affect runoff by April. Two types of floods may be identified in the basin: rainfall floods during late fall and winter and snowmelt floods during spring and summer. Highest peak discharges are due to floods driven by rainfall runoff; however their duration tends to be lower than floods driven by snowmelt.

Prior to construction of Friant Dam, very high late spring and early summer flows declined gradually over summer to reach minimum flow levels in the fall and early winter. Today, the system is highly regulated by storage reservoirs, and is further affected by groundwater withdrawals, diversions for irrigation, power, municipal supply, and imported water. During summer months, base flow is low, and consists mainly of return water from irrigated areas. In winter and early spring, higher flows still occur; however, levees currently prevent most of the SJRNWR from flooding. Channel design flow at Maze Road Bridge is 46,000 cfs. Levees begin to fail, or are overtopped when flows exceed 40,000 cfs. Out of channel flows may have occurred in 1938 (41,600 cfs), and did occur in 1969 (41,800 cfs), 1983 (38,400 cfs), and 1997 (59,300 cfs) (USACE, 2000).

4.2.3 Purchase of Study Site

In 1999, the USFWS purchased 3,166 acres of flood-prone farmland consisting of three properties located on the west bank of the San Joaquin River between RM 77 and RM 84, near the confluence of the Tuolumne River with the San Joaquin River. Levees protecting these parcels had failed in 1983 and 1997. One of the principal reasons for the purchase of the land, which became a significant portion of the West Unit of the SJRNWR, was to provide a demonstration of a non-structural flood control alternative. Plans for the site include breaching of levees to allow floodwaters from the river to spread over its former floodplain. It is intended that such levee breaches would relieve pressure on the other local levees as well as surrounding communities during high flows.

4.2.4 Non-Structural Alternative for Flood Control

In February 1998, the USACE, USFWS and the Reclamation Board (RCB) signed an outline of issues and preliminary agreements regarding a non-structural flood control alternative. In this agreement, the USACE provided recommendations to the RCB and USFWS for breaching of levees at the seven locations shown in Figure 2, including a one-dimensional steady-state hydraulic analysis of the expected flood impacts of the proposed breaches through the project reach, using the HEC-RAS numerical model. The study analyzed conditions for the project design flood of 46,000 cfs. The project design level of protection is approximately 60 year with New Melones Reservoir. The project design profile allows a 3-foot allowance for freeboard. Results of the USACE study are summarized in Table 1.

The USACE proposed seven breach locations as shown earlier in Figure 2, two locations in each of the levee systems of RD's 2099 and 2102 and three locations in the levees of RD 2100. Breach locations were chosen at known structurally weak areas of the project levees and at topographically low areas along the line of the project levees.

Table 1 – Results of the USACE Non-Structural Alternative Analysis

Reclamation District	**Area** (Acres)	**Floodplain Elevation** (Feet)	**Project Levee Crown** (Feet)	**Project Flood Water Surface Elevation** (Feet)	**Area Inundated** (Acres)
2099	530	20.0 to 25.0	40.5 to 41.5	37.0 to 38.5	530 Complete inundation of district. Occasional inundation to adjacent properties
2100	1,535	20.0 to 40.0	41.0 to 43.5	38.0 to 40.5	1,535 Complete inundation of district. Minor inundation (15 acres) to adjacent properties
2102	400	30.0 to 40.0	43.5 to 46.0	40.5 to 42.3	400 Complete inundation of district. No inundation to adjacent landowners

5. METHODOLOGY

The primary objective of this analysis is to develop a model to examine effects of proposed levee breaches on anadromous fish habitat. The analysis will also be used to identify potential refinements to the current NSA that may provide improved habitat conditions. The primary analysis tool being used for this investigation is a hydrodynamic model capable of simulating water flow over the floodplain during flood events. This tool will be used in a subsequent phase of work in conjunction with habitat criteria that have been developed for the evaluation of simulated flood conditions. A five-year simulation period (1993 to 1998) was chosen to include the 1997 flood and also to encompass a range of hydrologic conditions.

5.1 HYDRODYNAMIC MODEL

To determine if restoration areas will provide appropriate habitat, a hydrodynamic model is being used to simulate flow under a levee breach scenario. The approach taken in this modeling study has been to model the system using a one-dimensional looped network hydrodynamic model that describes floodplains as separate channels, each with its own hydrodynamic characteristics. This approach allows simulation of velocity and depth in the floodplain as well as in the main channel.

The numerical model MIKE 11 is being used to simulate system hydrodynamics. This commercially available model has been used to simulate behavior of both simple and complex rivers and floodplain systems (DHI, 2000). MIKE 11 uses an implicit finite difference scheme for computation of unsteady flow based on the Saint Venant Equations.

One of the major advantages of using a looped network system is the ability to describe separate flow patterns and flow exchange in the floodplain. The modeling area is typically divided into major channels and floodplains depending on topography, cross-section shape and estimated flow patterns. Interaction between individual branches is accomplished through connecting channels to describe flow over banks or levees. A schematic of the MIKE 11 looped network developed for the study site is shown in Figure 3.

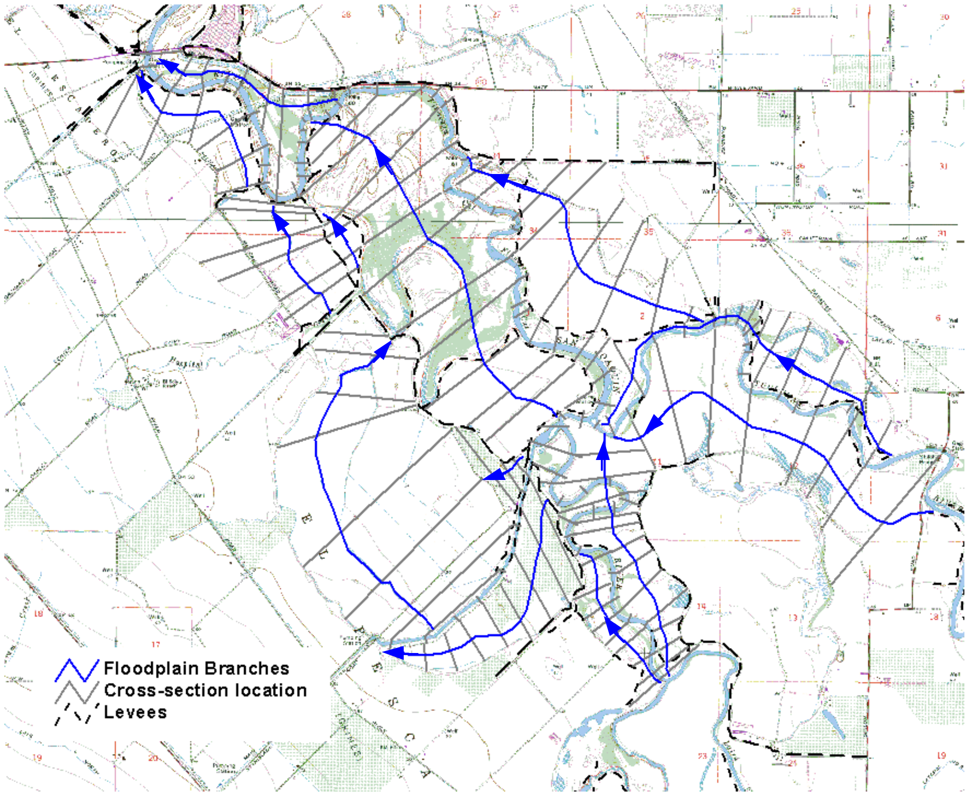


Figure 3 – Schematization of San Joaquin River National Wildlife Refuge for Floodplain Modeling

The HEC-RAS study simulated results for a single, steady flow, and was intended to evaluate severe flood conditions (i.e. flow at the capacity of the levee system). Although HEC-RAS is capable of simulating both steady and unsteady flow, the earlier HEC-RAS simulated steady flow. This study utilizes the hydrodynamic model MIKE 11 is a dynamic model that simulates conditions during both the rising and falling limbs of the hydrograph, as well as at the peak flow period. A measured hydrograph for water year 1994-1995 will be presented in this report to demonstrate results of MIKE 11 simulations. MIKE 11 model results simulate time-varying inundation of the floodplain, during both the rising and falling limbs of the flood hydrograph and include depth, duration of inundation and flow in the floodplain.

6. DATA REQUIREMENTS

6.1 HYDROLOGIC DATA

A five–year simulation period (1993 to 1998) was chosen for simulation. This period was chosen because it included high and low flow periods, as well as the 1997 El Nino flood. Flow hydrographs were obtained at the upstream model boundaries on the San Joaquin River at Patterson from the Department of Water Resources (DWR) and at the Tuolumne River near Modesto (USGS # 11290000). Stage data as well as stage discharge relationships at Maze Road Bridge, the downstream boundary, were obtained from DWR.

6.2 TOPOGRAPHIC DATA

The USACE has conducted hydrographic, topographic and photogrammetric surveys of the study region, including the mainstem of the San Joaquin and Tuolumne Rivers. This data was collected as part of the development of basin-wide hydraulic modeling by the USACE and is available to the public as part of the Sacramento and San Joaquin River Basins Comprehensive Study (SSJCS). Data collection was conducted under the SSJCS to create a digital terrain model (DTM), representing the topographical surface above and below the waterline along the river and the immediate floodplain either side of the river (usually to the toe of the project levee). Topography of floodplains and Refuge lands was supplemented by the U.S. Geological Survey (USGS) 30-meter digital elevation model (DEM) data, and private surveys.

6.3 DATA GAPS AND INADEQUACIES

Often the greatest challenge of a modeling project is not the modeling exercise itself, but selection of the appropriate model, one whose limitations and strengths are aligned with project objectives. Provided that the appropriate model has been chosen, the accuracy of any model simulation is a function of the availability and quality of input data, as well as appropriate choices of system schematization, and model assumptions.

The model used in this study, MIKE 11, is designed for floodplain analysis. Its formulation and design are in many ways quite suitable for this application. However, the performance of even the best-suited and well-chosen model is severely limited by the availability of input data. Required data include hydrodynamic information at model boundaries, topographic information both in the main channel and on floodplains, and system information such as bcation and operation of canals, pumps, weirs, gates, and other structures. In this case, model implementation has been somewhat limited with respect to all these factors. Model boundaries were set as far as twenty miles upstream of the Refuge, further than is desirable, because flow information was not available within the Refuge. Topographic information within the main stem of the San Joaquin and Tuolumne Rivers, as well as on floodplains immediately adjacent to the rivers was readily available from the USACE Sacramento and San Joaquin Basins

Comprehensive Study. The availability of this data has significantly contributed to the success of this project. However, topographic information on the Refuge floodplain was limited to the USGS quad sheets and 30-meter DEMs. Refuge floodplains are extremely flat, and cannot be well defined using this data set. Field surveys will be necessary in order to accurately characterize topography on Refuge floodplains.

6.3.1 Hydrologic Data

Hydrologic information is required at any location where water leaves or enters the boundaries of the model (e.g. upstream boundary, downstream boundary, tributaries and diversions). Ideally, model boundaries would be defined just upstream and downstream of the SJRNWR sufficiently removed from study boundaries in order to minimize any artificial influence. The nearest suitable upstream gage for the flow boundary on the San Joaquin River is located approximately 20 miles upstream of the confluence of the Refuge, at Patterson, necessitating extension of the model domain a significant distance upstream of the Refuge boundary.

6.3.2 Topographic Data

The hydrodynamic model is severely limited by the coarseness of USGS data that describes the floodplain outside the boundaries of the SSJCS DTM. Limited surveys are available for non-project levees and canals and have been incorporated into the dataset. However, further refinement of model topography could dramatically increase the ability of the hydrodynamic model to accurately simulate flow in the Refuge, particularly on the floodplains.

6.3.3 Levee and Drainage Network

The USGS 30-meter DEM information can provide only limited representations of levee geometry and floodplain topography, including drainage features. For this phase of analysis, no explicit representation of existing culverts or pumps was included in the model. These elements could greatly affect the time period during which ponding would persist. In addition, they would reduce potential concerns about fish stranding. Model representation of levee and drainage features is severely limited by lack of topographic and drainage structure data. Phase 2 of this study should include collection of suitable data and incorporation of it into the model data set.

7. MODEL DEVELOPMENT

7.1 MODEL BOUNDARIES

The hydrodynamic model was divided into two regions. The region referred to as the study area encompasses the Tuolumne River from Shiloh Bridge to the confluence with the San Joaquin River, the San Joaquin River from Laird Slough to Maze Road Bridge, and all associated floodplains, including those within the SJRNWR. Areas upstream of the study area were also included with the model in order to extend the model area to locations where flow records were available; however, model geometry was not developed as fully in these upstream regions as is was in the study area. The extended model area included the Tuolumne River upstream of the study area to the gage at Modesto, and the San Joaquin River upstream of the study area to the gage at Patterson Bridge. A simple schematic of model boundaries is shown in Figure 4.

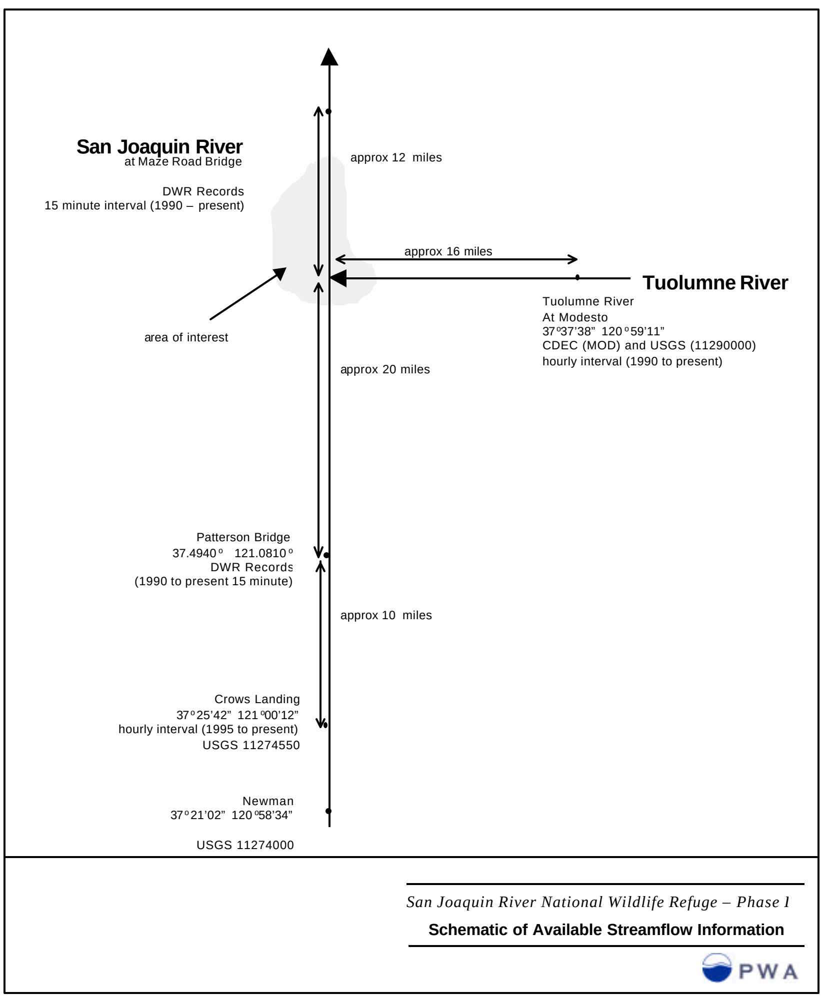


Figure 4 – Schematic of model regions and streamflow information

7.1.1 Topography for Extended Model Area

Main channel geometry for the San Joaquin and Tuolumne Rivers upstream of the study area were obtained from the USACE in HEC-RAS format and converted to a format suitable for use in MIKE 11. These cross-sections extended from Patterson Bridge at the upstream boundary of the model on the San Joaquin River, to Laird Slough, and from Modesto on the upstream boundary of the Tuolumne River to Shiloh Bridge. Cross-sections derived from this geometry were visually inspected for consistency prior to simulation.

7.1.2 Topography Within Study Area

Floodplain and main channel geometry within the study area was extracted digitally from a DTM created by PWA from SSJCS and USGS data. Cross-sections were visually inspected for accuracy prior to incorporation into the hydrodynamic model. Floodplain sections were further organized into a series of inter-connected branches to represent the conveyance capacity of the floodplain. The designation of these floodplain branches is shown in Figure 5.

7.2 CALIBRATION AND VALIDATION

In addition to flow estimates at the model boundaries, calibration data is also required for good confidence in model predictions. Model calibration is an essential process to establish appropriate values for parameters in the model's mathematical formulation (e.g., Manning's 'n'). The process of calibration is to fit the model to the system being modeled, trying to match model simulation with observed data. The "goodness" of fit of a calibration exercise is often a function of the objective of the modeling study. Ideally, flow depth and velocity information would be available for calibration purposes within the model domain, including the Refuge floodplain. Once levees have been breached, depth and velocity could and should be monitored to improve model description of this complicated system if further modeling is appropriate. Presently, such calibration data is not available.

Model validation is the process of comparing model results to historic data. Ideally, a calibrated model is compared with one or more sets of independent field data, preferably under a variety of field conditions. In this case the validation data set would be very similar to the calibration data set; it would include measurements of both flow and stage discharge on model floodplains, as well as in the main channel. Such data is not presently available as discussed above. This model has not been calibrated nor has it been validated.

Lack of hydrodynamic data for model validation and calibration are significant limitations in this study. However, calibration and validation data sets will only be available after levees are breached.

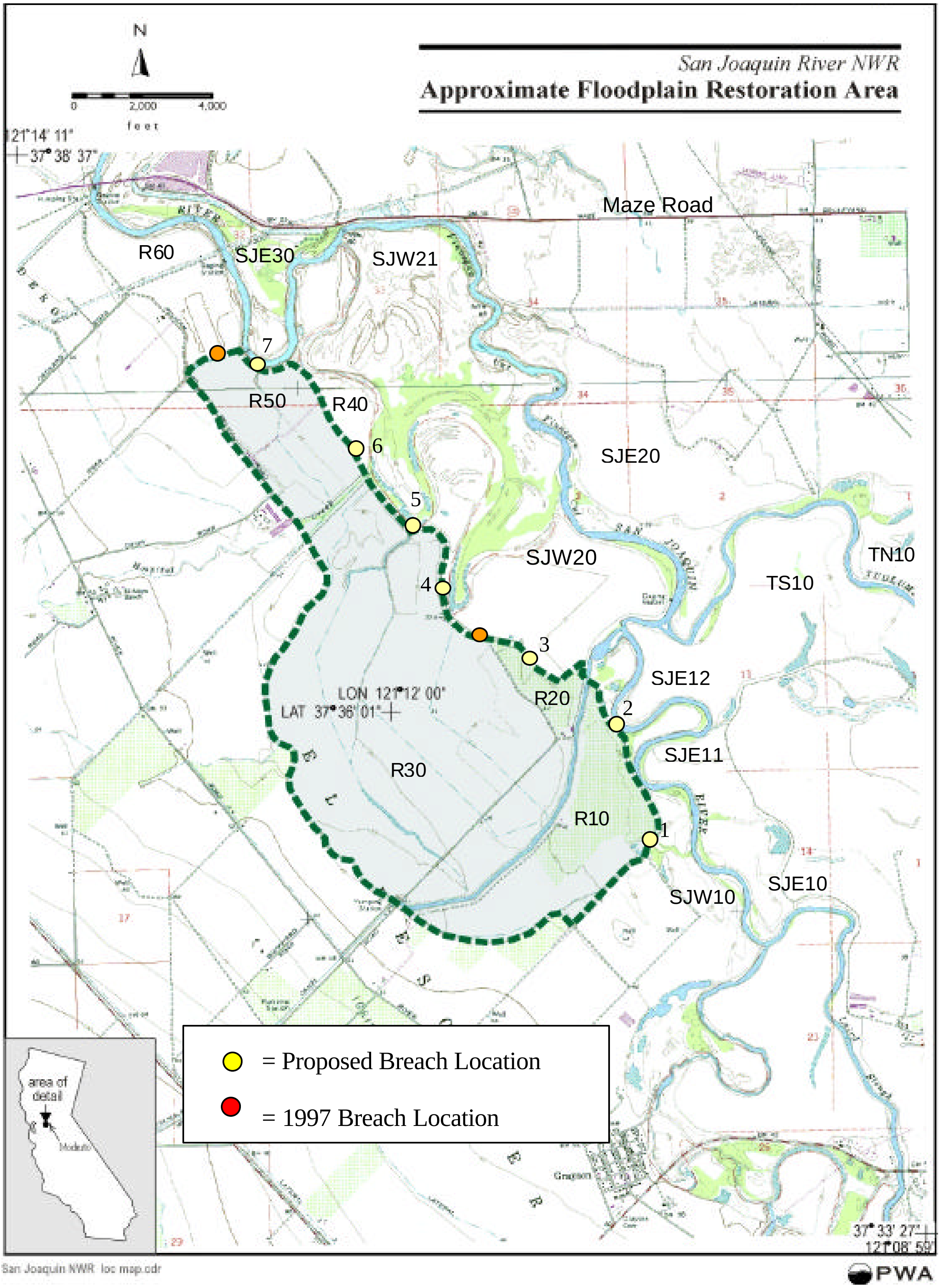


Figure 5 – Designation of floodplains in study region

8. MODEL OF PROPOSED NON-STRUCTURAL ALTERNATIVE

8.1 MODEL RESULTS

Model results suggest that with the proposed breaches, the west floodplain (i.e., SJW 20 as noted in Figure 2) of the San Joaquin River will begin to flood at when flows at Maze Road Bridge reach 9,000 cfs, and that the Refuge will begin to flood when flows at Maze Road Bridge exceed 16,000 cfs.

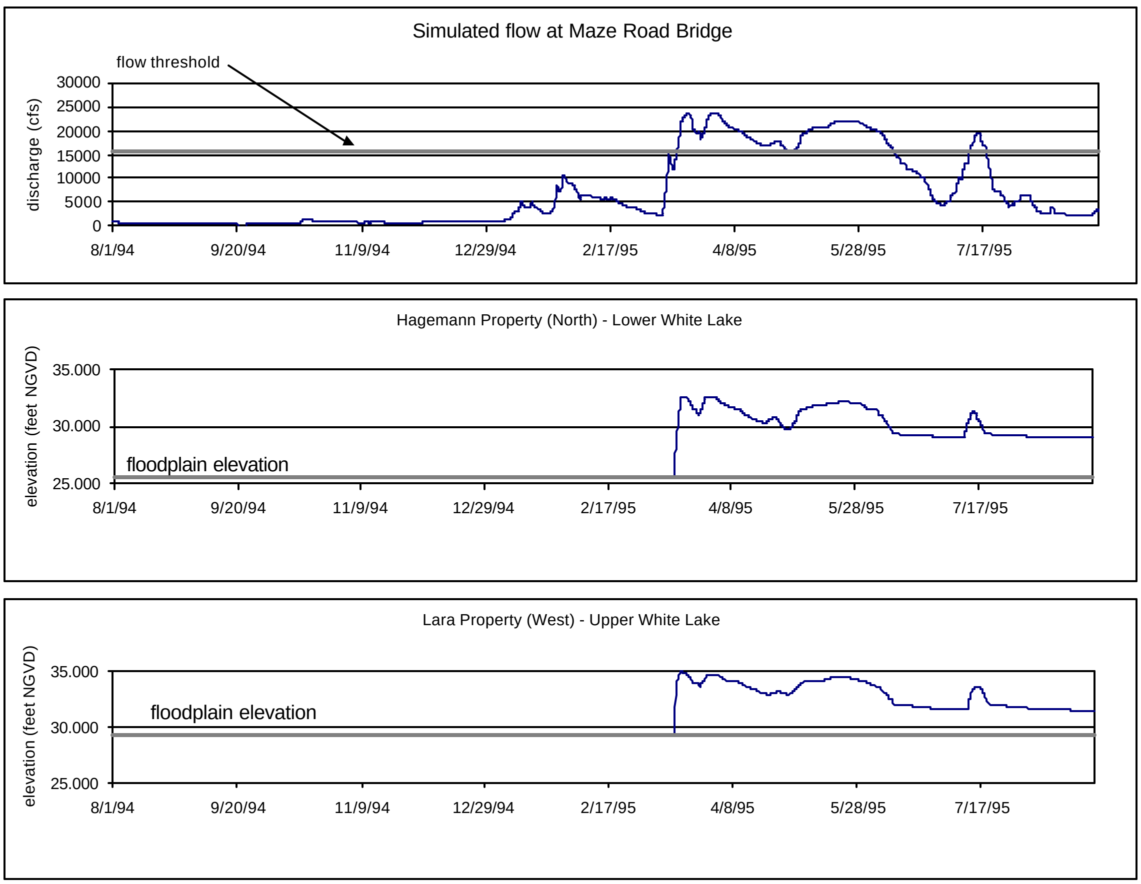
8.1.1 Inundation of Refuge Areas

Model results for the 1994-1995 water year have been grouped into sets of two figures, shown below as Figure 6 and Figure 7. In each set, computed flow at Maze Road Bridge is shown in the top graph with a horizontal line indicating the flow threshold of 16,000 cfs. Beneath the flow graph, several time series graphs show water surface elevation at particular locations. Each time series graph represents water surface elevation at a particular model cross-section. In these figures the elevation of the floodplain has been chosen as the lowest point in the cross-section, outside of any ditch. Elevations are in feet (NGVD 1929 vertical datum).

As river flows exceed the threshold of 16,000 cfs, water surface elevation exceeds the height of the base of project levee breaches, and floodplains become inundated. Because floodplain elevations are in many cases lower than the base of the levees, and no new or existing culverts connecting floodplains to the river were modeled, water remains trapped in the floodplains as the hydrograph recedes, effectively isolating floodplains from the river. Fish, which arrive in the floodplain having traveled with floodwaters during high flow event, will become stranded in these isolated ponds unless some connection is maintained between the floodplain and the river. Model simulations suggest that during an event similar to the 1994-1995 flood depth of ponding in the SJRNWR floodplain would range from 0 to 4 feet, excluding ditches.

8.1.1.1 Upper and Lower White Lake

Figure 6 shows water surface elevations in Upper and Lower White Lakes (located near the east end of the Lara Property and North end of Hagemann property, respectively). It is likely that these two lakes were one much larger body of water in prehistoric times (Griggs, 2000). Once levee breaches are in place, each of these lakes may remain flooded through the summer and into early fall. Because no evaporation, percolation, or structural drain systems are included in the current model configuration, even where such structures currently exist, ponding shown in these figures probably over estimates the elevation of water remaining in the floodplain after spring flooding. It is likely that without a drain system, the old lake beds will remain inundated until the following winter.



Source: Mike11 Model Results
Notes: WY 1994-1995 Run 1994C

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Model Simulation of Flow and Water Surface Elevation

PWA

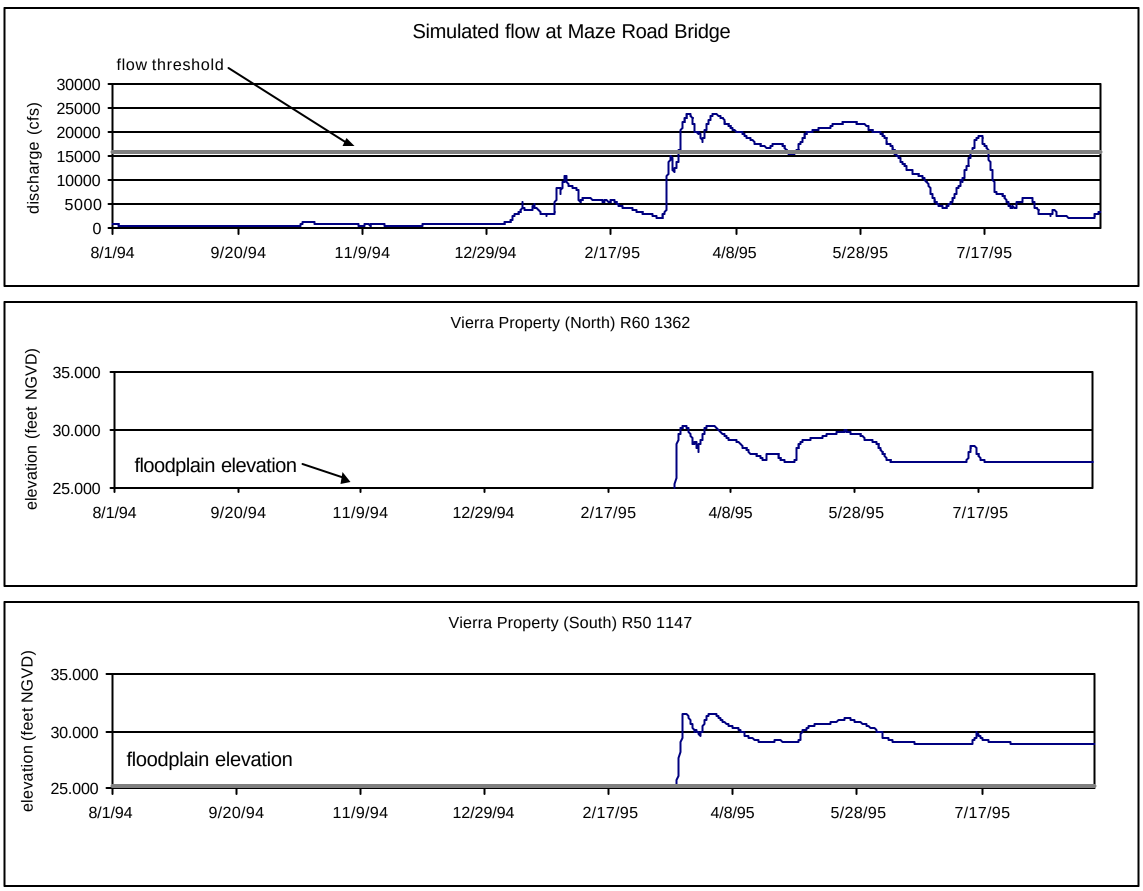
Figure 6 – Water surface elevation near Upper and Lower White Lakes

More southern regions of the former Hagemann property will be subject to only minor inundation unless the West Stanislaus Main Canal is breached and a connection is maintained between the Lara and

Hagemann properties. The Hagemann plateau, labeled R20 in Figure 5, will rarely inundate, and was not shown as flooded during the simulated 1994-1995 event.

8.1.1.2 Vierra Property

Most of the Vierra property is inundated at flows exceeding 16,000 cfs, and without drainage or losses would remain inundated well into the following season. Model improvements, especially improved topography, will help to more clearly characterize this region.



Source: Mike11 Model Results
Notes: WY 1994-1995 Run 1994C

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Model Simulation of Flow and Water Surface Elevation

PWA

Figure 7 – Water surface elevation at northern and southern regions of Lara property

8.2 CORRELATION WITH FLOW REGIME

Flooding occurs in the Refuge when flows at Maze Road Bridge exceed around 16,000 cfs. It is useful to put this information in context with the historic flow regime of the San Joaquin River.

8.2.1 Exceedance Frequency

Although flow data is available at Maze Road Bridge, the period of record is relatively short. Longer flow records are available at the Vernalis gage. The Vernalis gage is downstream of the confluence of the San Joaquin and Stanislaus Rivers. A synthetic data set was obtained by performing a simple subtraction of the Stanislaus River hydrograph from the Vernalis hydrograph (daily flows). In order to determine if this approximation was valid, a simple r^2 correlation was computed comparing the shorter period of record at the Maze Road Bridge with the synthetic data set. This correlation yielded a high correlation, $r^2 > 0.95$. Yearly maximum flows were then computed from this data set.

Figure 8 is a plot of computed exceedance frequency for yearly maximum flows. The figure indicates that the threshold flow of 16,000 cfs is exceeded approximately 30% of the years, indicating that the Refuge will flood once every two to three years. Flooding on the floodplain immediately adjacent to the San Joaquin River (SJW 20) occurs at a lower flow, around 9,000 cfs. Yearly maximum flows exceeded 9,000 cfs roughly 45% of the years in the period of record.

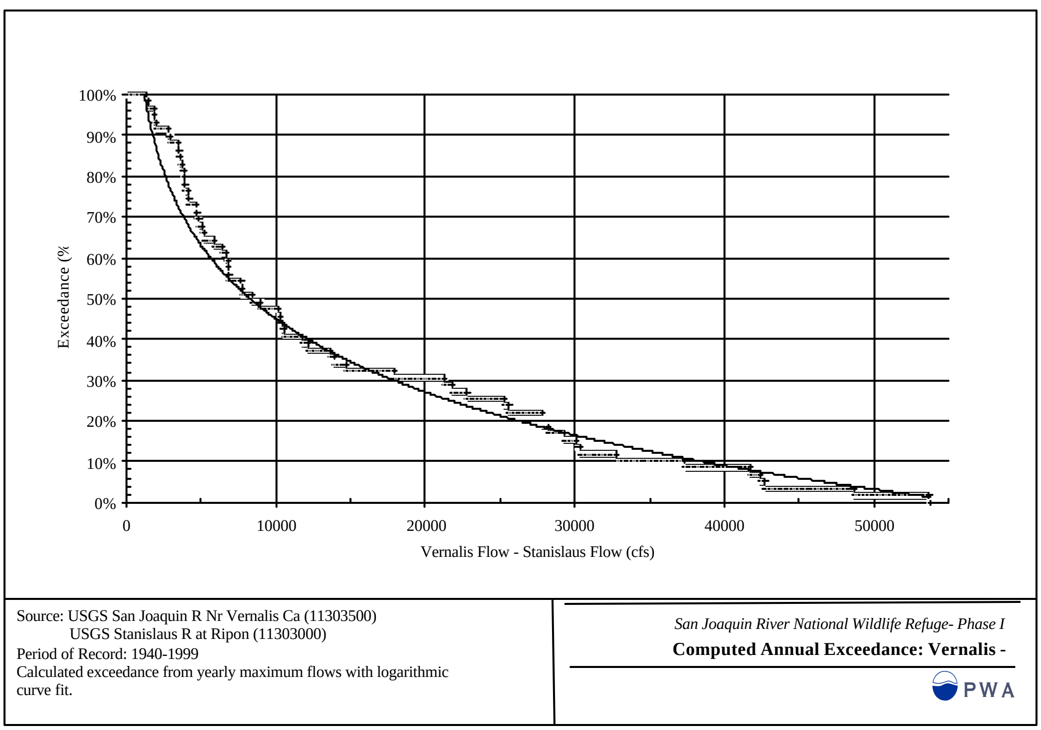


Figure 8 – Computed annual exceedance frequency from yearly maximum flow data

8.2.2 Identification of Years During Which Threshold Flow Was Exceeded

The figure below is a bar graph that shows the number of days in a particular year that the flows at Maze Road Bridge (represented by the synthetic data set) were greater than or equal to 16,000 cfs. Although this graph does not imply that the days during which this flow was met or exceeded occurred consecutively, large flows tend to be the result of storm events and as such are generally consecutive.

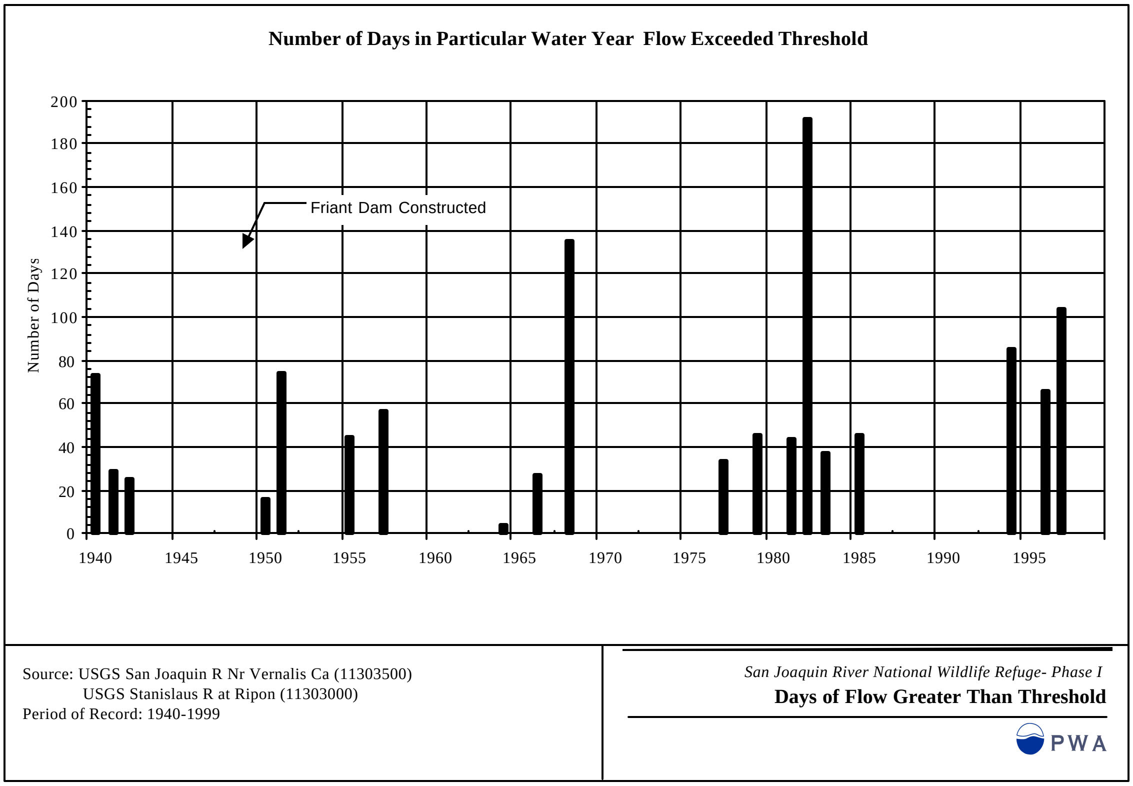
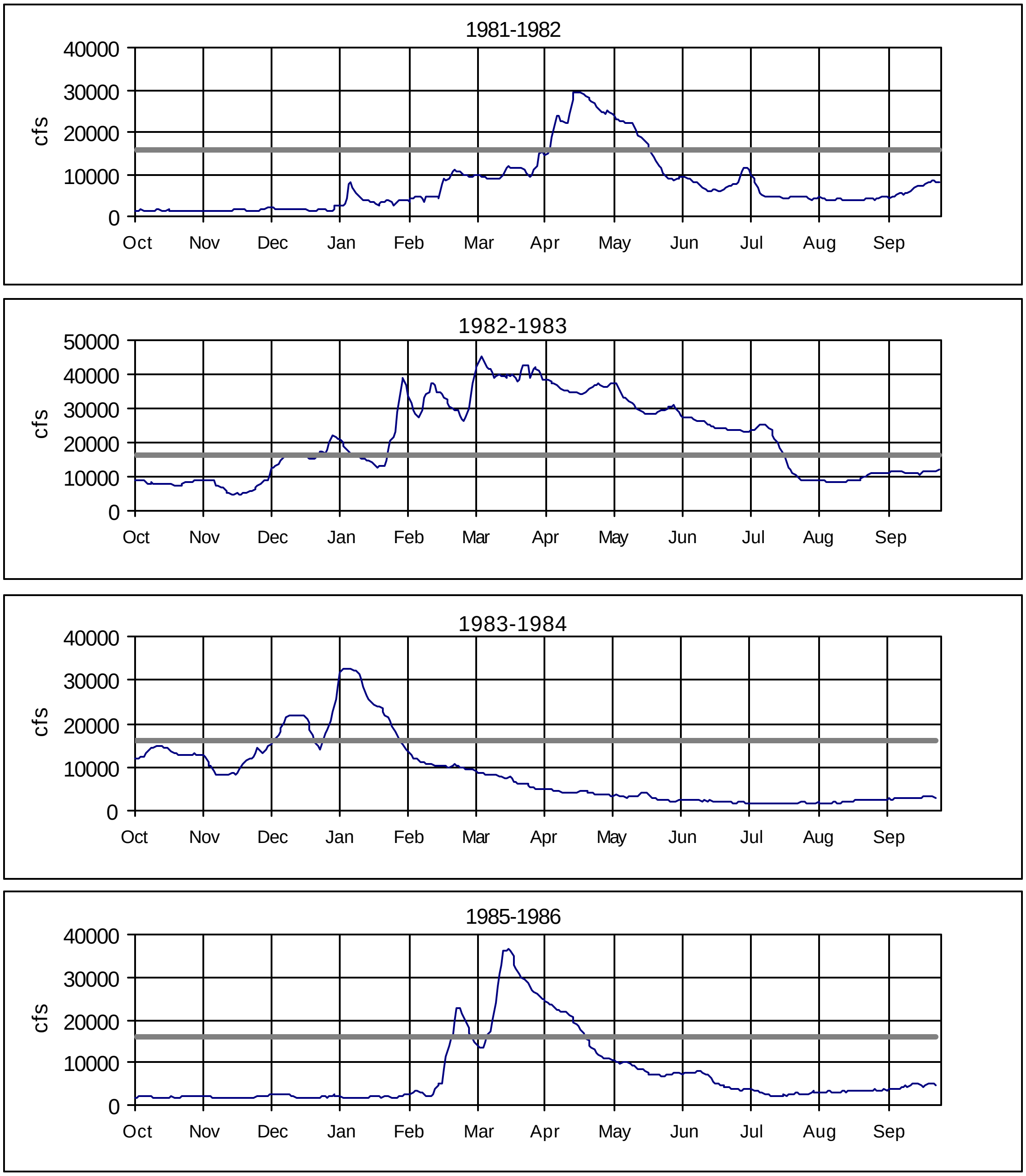


Figure 9 – Number of days that synthetic data set exceeded the flow threshold

8.2.3 Flow Records and Timing

Individual years since 1980 during which flow exceeded the threshold of 16,000 cfs are plotted below. The figures provide an indication of the variation in timing of expected floodplain inundation. Figure 10 shows hydrographs for water years 1981, 1982, 1983, and 1985. Figure 11 shows hydrographs for water years 1994, 1996, and 1997. In addition to these two sets of flow figures, the first and last day that the threshold flow was met, as well as the total days that the flow exceeded the threshold flow are summarized in Table 3.



Source: USGS San Joaquin River Near Vernalis CA (11303500) Daily Mean Flows
Notes:

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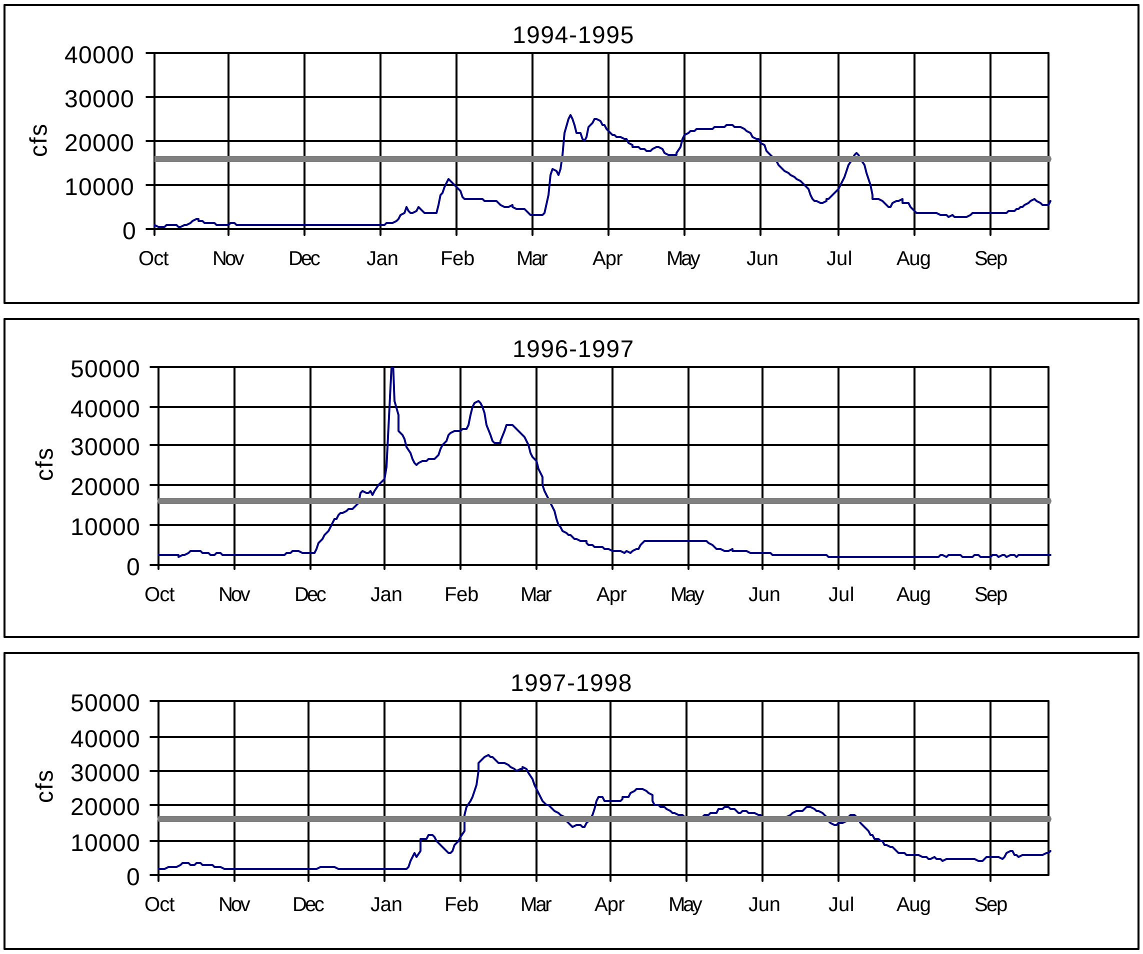
Flow at Vernalis

Figure 10 – USGS Daily Stream Flow at Vernalis: Selected years, 1981-1986



Source: USGS San Joaquin River Near Vernalis CA (11303500) Daily Mean Flows
Notes:

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Flow at Vernalis

PWA

Figure 11 – USGS Daily Stream Flow at Vernalis: Selected years, 1994-1998

8.3 CORRELATION WITH HABITAT EVALUATION CRITERIA

Simulation of hydrologic conditions on the proposed floodplain is a meaningful tool for habitat evaluation only to the extent that linkages between the two are identified. Science that relates inundation conditions to resulting habitat value in rivers of California's Central Valley is extremely young; however, it is of critical importance to planning effective floodplain restoration actions. An important component of this study effort has been to preliminarily identify key floodplain inundation parameters that can be used as indicators of habitat value. These criteria were developed based on consultation with several researchers active in the field as well as from available literature, and may be further revised for use in comparing alternative NSA refinement scenarios in a subsequent phase of the study. Current habitat evaluation criteria are shown in Table 2.

Table 2 – Summary of Habitat Evaluation Criteria

Parameter	Value	Species	Biological Importance
Recurrence Interval	Minimum 2-3 year return period[1]	Splittail	Ensure adequately-frequent spawning
Timing of flooding	Late February →April[1,2,3, 6]	Splittail	principal spawning and rearing months
	May[1,3,6]	Splittail	Spawning and rearing may extend into May
	December →May[1, 7]	Chinook salmon	Rearing habitat for juveniles
	Prior to February[1]	Splittail	May increase habitat value by providing additional forage habitat for adults
	December →May[4]	Phytoplankton Zooplankton	Improved production prior to arrival of juvenile and adult salmon, splittail
Duration of flooding/Mean Hydraulic Residence Time	≥ 2 days[4]	Phytoplankton	Improved production
	14 days – several weeks[2,4]	Zooplankton	Improved production
	≥ 14 days[3, 6]	Splittail, chinook salmon	Adult spawning, incubation and larvae to develop sufficiently to move with receding flow
End of Inundation; connectivity	Avoid non-draining floodplain with depressions greater than 1 feet in depth[1]	Non-native fish	Avoidance of predator or non-native fish and reduction of salmon and splittail stranding.
Velocity and depth	Mean velocity: >0[2,4], < 3 ft/sec[7]	Splittail Chinook salmon	Adult splittail spawning in faster water, juvenile splittail use of slower water; salmon rearing only in moving water; both need flow cues to avoid stranding
	Total surface area between 6 inches and 6 feet depth[2,3,4]	Splittail Salmon	Splittail spawning, splittail and salmon habitat [1,2]

[1] Jones & Stokes Associates. 2000. Functional Relationships for the Ecosystem Functions Model, Sacramento-San Joaquin Rivers Basin Comprehensive Study. Final. (J&S F022). December. Sacramento, CA. Prepared for Sacramento-San Joaquin Rivers Basin Comprehensive Study Team, U.S. Army Corps of Engineers, Sacramento, CA.
[2] Keith Whitener, Project Ecologist, Cosumnes River Preserve, 2001. Personal communication.
[3] Randy Baxter, CA Department of Fish and Game, 2001. Personal communication.
[4] Ted Sommer, Environmental Specialist, CA Department of Water Resources, 2001. Personal communication.
[5] Jones & Stokes, 1999. Use of Restored Floodplain Habitat on the American River by Juvenile Chinook salmon and other Fish Species. June. Prepared for the Sacramento Area Flood Control Agency, Sacramento, CA.

Table 3 shows a summary of flow statistics for years since 1980 in which the threshold flow of 16,000 cfs was exceeded. Beginning of inundation ranges from early December to early April, and extends until at least May, satisfying flood timing criteria for splittail. Inundation ends as early as late December.

Table 3 – Summary Statistics for Years Since 1980 in which threshold flow was exceeded

Water Year	Total Days Q > 16,000 cfs	Days/Event Q > 16,000 cfs	Time Period
1981-1982	44	44	April 8 - May 21
1982-1983	191	1	December 12
		14	December 25 – January 7
		176	January 25 – July 19
1983-1984	37	7	December 10 – December 16
		1	December 18
		29	December 29 – January 26
1985-1986	46	6	February 23 – February 28
		40	March 13 - April 21
1994-1995	85	43	March 17 – April 28
		39	May 3 – June 10
		3	July 14 – July 16
1996 - 1997	66	66	January 1 – March 7
1997 – 1998	104	38	February 5 – March 14
		34	March 29 – May 1
		12	May 16 – May 27
		6	May 29 – June 3
		13	June 18 – June 30
		1	July 13

8.4 LEVEE BREACH LOCATIONS

A large component of this study is to determine the effectiveness of the proposed levee breach locations. Each levee breach was modeled as a fifty foot wide breach with side slopes of 1 vertical on 4 horizontal, each essentially a broad crested weir with a trapezoidal opening. Levee crown elevations were taken from both the DEM and spot elevations reported in the SSJCS. Breach elevation was taken as approximately equal with adjacent ground elevation. For purposes of this study, breaches are numbered from upstream to downstream, as noted in Figure 2.

MIKE 11 results for water surface elevation near each of the levees were compared with the height of each levee breach and each levee crown in order to better understand levee placement. Figure 12 shows water surface elevation and breach heights at proposed breach sites 1 and 2, both within Reclamation District (RD) 2102. The top plot shows water surface elevation at Breach 1, the most upstream of the seven proposed breaches. Most of the flow in the Refuge enters through this location. A smaller amount of flow passes through Breach 2.

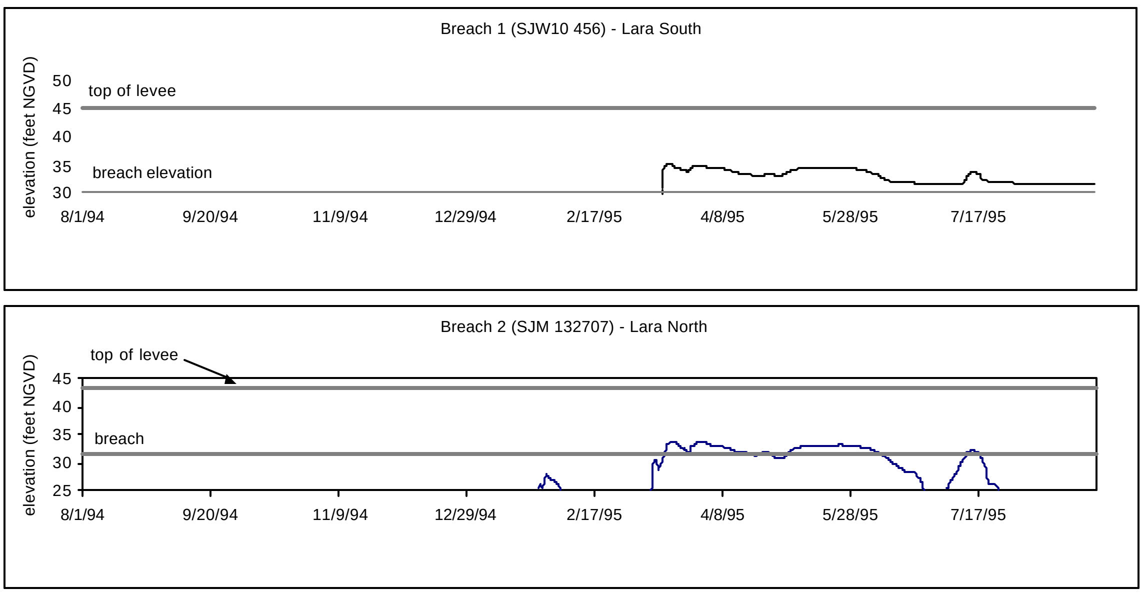

Figure 12 – Water surface elevation at proposed breach sites 1 and 2 (RD 2102)

Figure 13 shows water surface elevation at levee breaches 3 through 5, all within RD 2100, formerly the Hagemann Property. Breach 3 is located on the Hagemann Plateau, a raised plain that is only inundated at high flows. During the 1994-1995 simulation period, the breach at this location never passed flow. As shown in the top plot of Figure 13, the height of the breach opening is around five feet above the maximum elevation of the water surface at this location. Moving downstream, a limited amount of flow passes through Breach 4, as the breach elevation is rarely exceeded. Breach 5, the most downstream of the three breaches in RD 2100, is the most active of the three, with most of the flow at this location passing from the Refuge to the floodplain interior to the levee (i.e. Breach 5 acts as a drain rather than a source of flow).

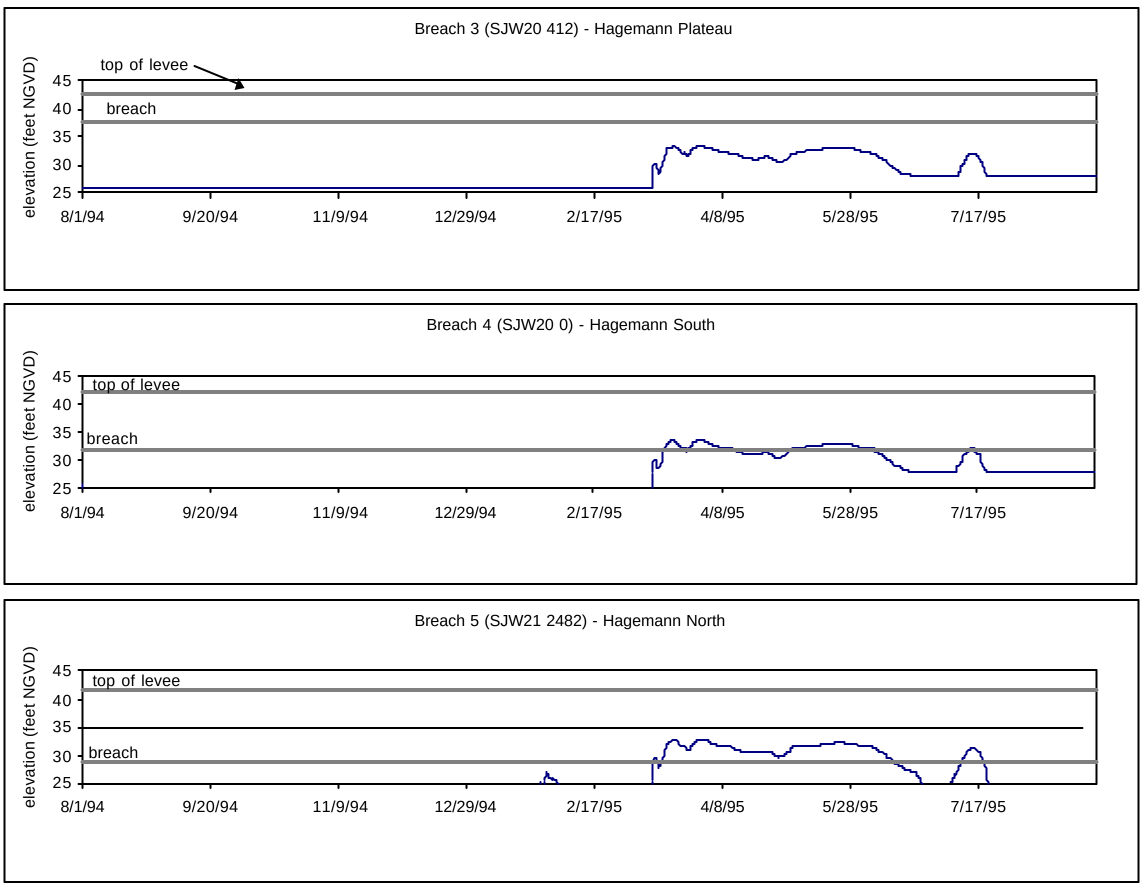

Figure 13 – Water surface elevation at proposed breach sites 3 through 5 (RD 2100)

Figure 14 shows the most downstream of the seven breaches, which are located on the Vierra property. Both of these breaches act primarily to return flow to the river and its floodplains. The Vierra Property presently acts as an independent system in this breach configuration. During the water year 1994, levees isolating Hospital Creek prevented water from the Hagemann property from spilling into the Vierra property (RD 2099).

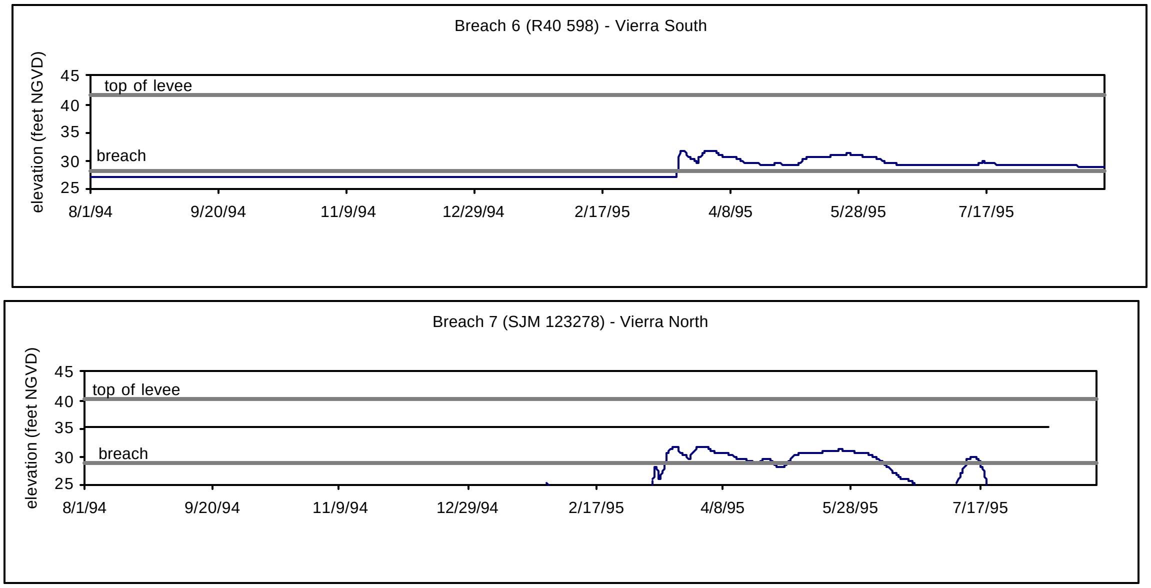

Figure 14 – Water surface elevation at proposed breach sites 6 and 7 (RD 2099)

Of the seven breaches modeled in this study, by far the greatest amount of water passes through Breach 1. One refinement of the project could include enlargement of Breach 2 (either through direct action or erosion) and breaching of the West Stanislaus Irrigation Canal and Hospital Creek berms to allow water to move from RD 2102 into RD 2099, and implementation of some kind of drainage system whereby return flow can more easily pass from RD 2100 and RD 2099 back into the San Joaquin River, to avoid ponding and fish stranding.

9. FURTHER MODEL DEVELOPMENT

9.1 ADDITIONAL PRE-PROJECT ANALYSIS

In a subsequent phase of the study, we hope to conduct the following additional steps in developing analyses to refine the design of the NSA to benefit floodplain habitat:

- refine the hydrodynamic model using improved topographic data;
- refine the habitat evaluation criteria for comparison of alternative NSA scenarios;
- conduct a geomorphic assessment of potential NSA conditions to guide alternative scenario development and comparison of expected outcomes;
- develop alternative NSA scenarios for evaluation using the hydrodynamic model and habitat evaluation criteria.

9.2 IMPLEMENTATION AND MONITORING

Adaptive management is a systematic process for continually improving management policies by learning from the outcomes of restoration programs. It allows resource managers a way to proceed responsibly, improving understanding for future decisions. As restoration takes place, better understanding of habitat use by birds, fish and mammals can improve the development of habitat evaluation criteria. Moreover, it is extremely important to continue to improve our understanding of underlying physical processes, including changes in topography, soils, groundwater levels, as well as flow depth and velocity in order to form a basis for understanding restoration success and failure.

Once implementation of the selected NSA scenario has occurred, monitoring data may become available for model calibration, thereby allowing reassessment of the merits of the implemented project, and further modification of the project, if appropriate, as an adaptive management effort.

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