HYDRAULIC ANALYSIS OF RIPARIAN HABITAT CONSERVATION ON THE SACRAMENTO RIVER FROM PRINCETON TO BEEHIVE BEND

HYDRAULIC MODELING OF THE SACRAMENTO RIVER, FROM RM 163 to RM 176

GLENN AND COLUSA COUNTIES, CALIFORNIA

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1.0 INTRODUCTION

The purpose of this project was to analyze the hydraulic effects of riparian habitat conservation and restoration in the overbank areas within the levees of the Sacramento River Flood Control System (SRFCS). The area involved in this study is referred to by The Nature Conservancy as the Beehive Bend Sub-Reach, and extends from the town of Princeton (River Mile (RM) 163) to the upstream limit of the left levee (RM 176), in Glenn and Colusa Counties, California. The study area is shown in **Figure 1**.

Three hydraulic model runs were developed for this project. Model Run 1 simulates existing conditions and was used to evaluate the impacts of the other model runs. Model Run 2 was developed to determine the potential hydraulic impacts to the SRFCS levees from maximum riparian habitat conservation and restoration and to determine any especially sensitive areas. Model Run 3 was completed with the intent of developing a realistic landcover configuration that maximized riparian vegetation, minimized hydraulic impacts on the SRFCS levees, and that could be sustained with minimum maintenance.

This project was authorized by The Nature Conservancy (TNC), Sacramento River Projects Office, in Chico, California. The hydraulic analysis was performed by the Sacramento office of Ayres Associates.

2.0 HYDRAULIC MODEL DEVELOPMENT

The U.S. Army Corps of Engineers (USACE) computer program, HEC-RAS, was used for the hydraulic analysis in this study. A previous HEC-RAS model developed for the Sul Norte project (JSA and Ayres Associates, 2000), was used to simulate the river reach from RM 167 to RM 172. This original model was extended downstream to RM 163 near Princeton and upstream to RM 176 at the limit of the left levee.

Cross sections of the river and floodplain were taken from topographic and hydrographic survey data of the Sacramento River and associated floodplains developed in 1997 by the U.S. Army Corps of Engineers (USACE) for the Sacramento and San Joaquin Rivers Comprehensive Study. Structural information of the bridge at Highway 162 was obtained from the California Department of Transportation and supplemented by field investigation.

3.0 DESCRIPTION OF HYDRAULIC MODELS

3.1 Model Run 1

Model Run 1 reflects existing conditions and was used as a base to evaluate the impacts of Model Runs 2 and 3.

Model Run 1 was based on 1997 land use conditions estimated from aerial photographs taken in 1997 and provided by TNC. The Department of Water Resources document entitled "1997 Sacramento River Atlas" (DWR, 1999) was also used to estimate land use. A map of the study area with existing land use conditions is presented in **Figure 2**. Cross sections used in the HEC-RAS model and River Miles are also shown in this figure.

Manning's Roughness Coefficients were used to reflect the different types of land use in the hydraulic models. Ayres Associates performed a field investigation to verify land use types and densities for use in estimating Manning's Roughness Coefficients. Various documents (listed in the References section) were used to estimate roughness values.

Stream flow data from the Butte City gage, located in the middle of the study reach at approximately RM 168.5, was used to calibrate the HEC-RAS model. The gage data was obtained from the California Department of Water Resources' California Data Exchange Center's web page. The 1998 peak flow and stage were used for calibration. The peak discharge in 1998 was 151,000 cubic feet per second (cfs), with a corresponding water surface elevation of 92.48 feet. Manning's Roughness Coefficients were estimated based on the field investigation and refined in the calibration run to match a stage of approximately 92.5 feet with a flow of 151,000 cfs at the Butte City gage. The Manning's Roughness Coefficients listed in **Table 1** reflect the final values used in the model after the calibration process.

Table 1. Manning's Roughness Coefficients	
Description of Land Use	**Value**
Main Channel	0.030
Riparian Vegetation	0.160
Prune and Young Walnut Orchard	0.100
Mature Walnut Orchard	0.080
Cultivated Fields (Fallow)	0.035
Open Space	0.035
Gravel / Sand Bars	0.040
Grass / Sedge and Sparse Shrubs	0.040

The HEC-RAS model from the Sul Norte study (JSA, Ayres Associates, 2000) was incorporated into this model. As a result of extending the Sul Norte HEC-RAS model, recalibration was required and the Manning's Roughness Coefficient for the orchard land use was divided into two different values depending on tree size and density. The final Manning's Roughness Coefficients for the calibrated model are presently somewhat lower than what was used for orchard in the Sul Norte report. This change however, does not impact any of the conclusions in the Sul Norte report.

The final calibrated HEC-RAS model was then run with the design flow (150,000 cfs) to compute the water surface profile for existing conditions.

3.2 Model Run 2

The purpose of Model Run 2 was to determine if there would be significant hydraulic impacts to the SRFCS levees within the Beehive Bend Sub-Reach with full participation in Sacramento River Conservation Area (SRCA) riparian habitat programs (SRAC, 1998), and if so, are there specific areas that are especially sensitive. The planting configuration for this model is shown in **Figure 3**. The configuration is based on an independent analysis conducted by TNC to determine areas where the property owners might likely participate in the riparian habitat programs. This independent analysis was based on existing land ownership patterns within the SRCA and the results will be published elsewhere. The likely program participants are located within Zone I, as shown in **Figure 3**. Zone I includes land within the inundated area for the 2.5-year flood recurrence interval (DWR, 2000) and soils of capability class III or greater. Zone II includes area within the SRFCS levees but outside of the 2.5-year inundated area with class I and II soils. Model Run 2 reflects the area within Zone 1 as being comprised of full riparian vegetation, and the area within Zone II as being planted to orchards. The model was not intended to be a restoration design. Due to soil type, topography, and groundwater conditions, riparian vegetation would not naturally occur at the modeled density in the study area.

3.3 Model Run 3

The purpose of Model Run 3 was to design a riparian vegetation conservation and restoration configuration that could be implemented with less than significant impacts on the levees and channel. An iterative design approach was used in a joint effort of TNC ecologists and Ayres Associates engineers. The preferred land cover configuration included a mix of riparian vegetation, orchard, and grass/sedge meadow and was developed in order to minimize hydraulic impacts while providing environmental benefits. The appropriate land covers (i.e. riparian vegetation, orchard) were designed based on the existing vegetation, soil types and availability of groundwater so that no higher hydraulic friction would naturally occur, except if management input (i.e. irrigation, fertilizer) takes place. For the river reach upstream and downstream of Sul Norte, an iterative process was used to change area from the existing land use to riparian vegetation, orchards, and grass/sedge. For the Sul Norte area, the planting configuration is based on the preferred alternative from the Sul Norte Report (JSA, 2000) which included the east and west third of the right overbank area being planted to full riparian vegetation and the middle third being planted to grass and sparse shrubbery. These resulting vegetation limits can be seen in **Figure 4**.

The conservation and restoration configuration presented in Model Run 3 could only be achieved by a combination of natural recruitment, revegetation and retention of existing riparian vegetation, and the willing participation of landowners in the study reach.

4.0 EVALUATION CRITERIA

The criteria used to evaluate Model Runs 2 and 3 involved changes in freeboard, changes in water surface elevation, and changes in main channel velocity. The following is a discussion of methodology used for this evaluation.

4.1 Freeboard

The Reclamation Board's minimum freeboard criteria was used for this study. The Reclamation Board has jurisdiction within the designated floodway, and regulates any "encroachment" within the floodway. An encroachment is defined in the California Code of Regulations (CCR) Title 23 as "any obstruction or physical intrusion by construction of work or devices, planting or removal of vegetation, or by whatever means for any purpose into…[the designated floodway]."

The primary measure by which the Reclamation Board evaluates the effects of encroachments is freeboard, the difference between the water surface elevation and the top of levee elevation. The State of California (CCR Title 23) mandates a minimum of three feet of freeboard for any flood control levee, and 4 feet of freeboard for any flood control levee within 100 feet of a bridge. It is possible the levees are higher in a particular segment of a river and may have freeboard that exceeds the minimum requirements, however, any increase in water surface elevation may still be of concern.

4.2 Water Surface Elevation

For evaluating increases in water surface, this study used the Federal Emergency Management Agency (FEMA) guidelines. FEMA criteria allows encroachments into the floodway if it has been demonstrated through hydraulic analysis that the proposed encroachment will not increase flood levels by more than a designated height. FEMA guidelines require that the water surface elevations increase by no more than one foot.

4.3 Velocity

Significant changes in velocity have the potential to change erosion and deposition patterns. Ayres Associates is unaware of any established criteria for effects on velocity. Our judgement is to allow no more than a 0.5 ft/s of increase in the maximum velocity through this reach for the design flow.

However, for the Sacramento River, most of the sediment transport occurs when the main channel is at bank-full flow, just before the overbank areas are inundated. There are no planting changes being made in the main channel for Model Runs 2 and 3, and therefore, sediment transport during the main channel bank full flow will remain unchanged as compared to Model Run 1 (existing conditions).

5.0 RESULTS OF HYDRAULIC MODELING

The results of the hydraulic analysis for Model Runs 1, 2, and 3 are summarized below. Results for Model Runs 2 and 3 are as compared to Model Run 1 (existing conditions).

5.1 Model Run 1

Model Run 1 reflects existing conditions and was used to evaluate the impacts of the other model runs. Water surface elevations and freeboard information for Model Run 1 are shown in **Table 3**. Water surface profiles are shown in **Plate 1** and freeboard profiles are shown in **Plate 2**. The minimum amount of freeboard is 4.98 feet and occurs at cross section 437+21.

5.2 Model Run 2

Model Run 2 was developed to determine the potential hydraulic impacts to the SRFCS levees from maximum riparian habitat conservation and restoration and to determine which areas of the SRFCS levees, if any, are especially sensitive. This model run was developed to serve as an evaluation tool, and was not intended to be a restoration design.

Model Run 2 keeps the design flow within the SRFCP levees and meets the minimum freeboard requirement of 3 feet, however, it does not meet the specified evaluation criteria of no more than one foot of increase in the water surface elevation. Water surface elevations and freeboard information for Model Run 1 (existing conditions) and Model Run 2 are shown in **Table 2**. Water surface profiles are shown in **Plate 1** and freeboard profiles are shown in **Plate 2**.

The minimum amount of freeboard occurs at cross section 241+01 in which case freeboard decreases 1.42 feet from 5.13 feet to 3.71 feet. The range of water surface elevation changes throughout the study reach varied from a maximum increase of 3.56 feet at cross section -46+27 to a minimum increase of 0.87 feet at cross sections 437+21, 446+94, and 456+64.

Channel velocities are shown in **Plate 3**. Channel velocity varies somewhat at individual cross sections, however, the range of velocities within the entire study reach is not significantly changed. Based on the small change in depth and velocity for the design flow, little change in the potential for bed and bank erosion is expected.

For Model Run 2, water surface elevations increased by more than one foot in many areas. Downstream of RM 164 the water surface elevations increased on the order of 3 feet. These increases in water surface elevation may possibly have some effect on the stability of the levees and increase the potential for landside seepage.

The results from Model Run 2 and from other runs (not included in this report) demonstrated that there are three areas sensitive to additional riparian plantings. These areas cause a significant increases in water surface elevation that continues upstream for a considerable distance. These areas are as follows: 1) the levee constriction downstream of RM 164, 2) the highway 162 bridge at RM 168.5, and 3) the east side levee upstream of RM 175.

5.3 Model Run 3

The purpose of Model Run 3 was to design a maximum riparian vegetation conservation and restoration configuration that is fully compliant with the evaluation criteria presented herein and that could be sustained at that level with minimum maintenance.

This design reflects planting a mix of riparian vegetation along with planting of grass/sedge. By converting areas from orchard and other land uses to grass/sedge, water surfaces will be reduced which will compensate for converting other areas to riparian vegetation. The sensitive areas identified in Model Run 2 were considered when developing the planting mix. Water surface elevations and freeboard information for Model Run 1 (existing conditions) and Model Run 3 are shown in **Table 3**. Water surface profiles are shown in **Plate 1** and freeboard profiles are shown in **Plate 2**.

The minimum amount of freeboard occurs at cross section 71+30 in which case freeboard decreases 0.35 feet from 5.24 feet to 4.89 feet. The range of water surface elevation changes throughout the study reach varied from a maximum increase of 0.57 feet at cross section 178+32 to a maximum decrease of 0.59 feet at cross sections 241+01 and 253+48.

Channel velocities are shown in **Plate 3**. As explained in Model Run 2 the increase in velocity is not significant. Since Model Run 3 has less of an impact than Model Run 2, the velocities are not an issue of concern for this design.

The results of Model Run 3 meet all of the evaluation criteria. Although the results show that there is a slight impact when compared to existing conditions in some areas, other areas show a slight benefit. Overall, this alternative imposes very little additional threat to the SRFCS levees, and stays in the FEMA's and the Reclamation Board's regulations.

6.0 CONCLUSIONS

Based on our hydraulic analysis and field review of the project area, Ayres Associates offers the following conclusions:

1. Model Run 2 was developed to determine if the SRFCP levees are sensitive from a hydraulic standpoint to riparian vegetation conservation and restoration. Model Run 2 meets Reclamation Board guidelines, but does not meet FEMA guidelines; greater than 3 feet of freeboard was maintained, however water surface elevations increased by more than one foot in a large portion of the study reach.

2. Model Run 2 also shows that there are three areas particularly sensitive to riparian vegetation conservation and restoration. These are 1) the levee constriction at RM 164, 2) the bridge at RM 168.5 and 3) the east side of the levee upstream of RM 175. These areas appear particularly sensitive to changes in landcover (ie. water surface elevation changes are more dramatic and continue upstream for a considerable distance).

3. The results of Model Run 3 meet all of the evaluation criteria. Model Run 3 results in little change in water surface elevation and in freeboard over Model Run 1 (existing conditions). Throughout the entire river reach analyzed for this project, there is greater than the required three feet of freeboard. This design actually reduces the water surface elevation in some of the study reach to below Model Run 1 (existing conditions).

4. No change in erosion potential along the river banks is expected to occur for a flow of 150,000 cfs as a result of either Model Run 2 or 3.

5. The results of this study are consistent with and include the planting configuration and recommendations in the Sul Norte report (JSA, 2000). The Sul Norte results are unaffected by the analysis presented in this report.

7.0 REFERENCES

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