SECTION 8

PROJECT FUNCTIONALITY EVALUATION

This section details hydraulic modeling of the 100-year flood, including the proposed modifications to approximately 105 miles of the Rio Grande floodway between Percha Dam in New Mexico and the American Diversion Dam in El Paso, Texas. This modeling effort is based on the USACE (Albuquerque District, Hydrology and Hydraulics Section) hydrologic and hydraulic analyses of the current conditions of the same area.

The proposed modifications are presented in Section 7, Description of Alternatives. A comparison between the current conditions and the proposed modifications conditions is described. The levee areas where the 100-year computed water surface elevation encroaches on the design freeboard or overtops the levee are identified. Locations where water velocities may result in levee erosion have also been determined. Based on those results, flood control management actions are included in each alternative.

8.1 Previous USACE Model

The USACE performed the hydrologic and hydraulic analyses of the 100-year flood of approximately 105 miles of the Rio Grande floodway between Percha Dam in New Mexico and the American Diversion Dam in El Paso, Texas. The USACE identified the levee areas where the 100-year computed water surface elevation encroaches the freeboard or overtops the levee (USACE 1996)

8.1.1 Hydrologic Modeling

The USACE generated the 100-year flood discharges at selected locations along the Rio Grande using standard hydrologic procedures and the USACE program HEC-1.

The 100-year storm developed for the study area represented a summer thunderstorm rain flood, which generated the greatest peak flows in the study reach of the river. A storm centered below Caballo Dam was assumed. A 100-year 24-hour duration uniform rainfall of 2.39 inches and a NRCS Type IIa distribution were used. The USACE report provides detailed analysis of the methods used in generating the 100-year flood discharges.

Table 8.1, adopted from the USACE report, lists these peak discharges at the selected stations between Percha Diversion Dam and American Diversion Dam. Figure 8.1 is a graphical representation of these data.

Hydraulic Modeling

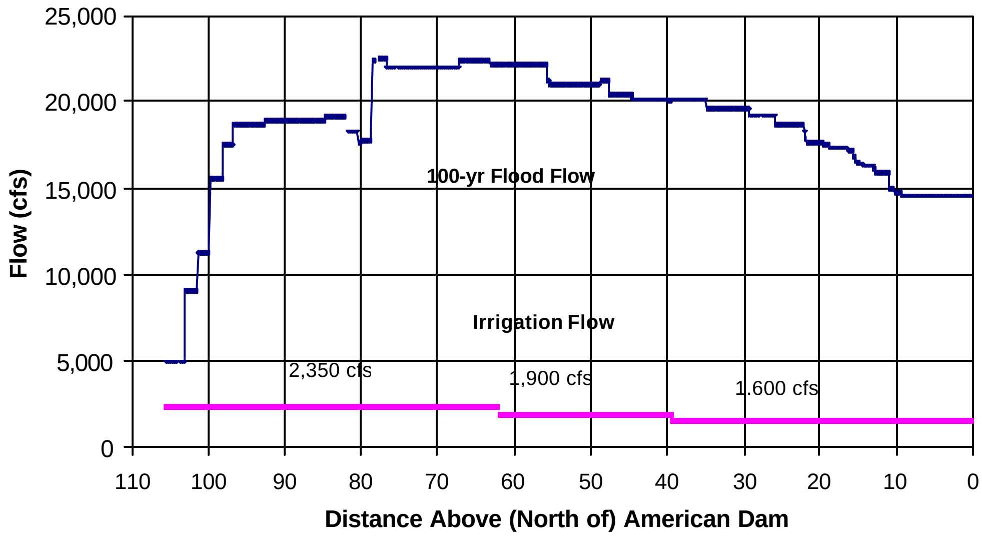
The USACE generated the 100-year flood water surface elevations at selected locations along the Rio Grande using standard hydrologic procedures and the USACE computer program HEC-2.

Table 8.1 Design Flows for Irrigation and 100-Year Flood

Miles Above American Dam	Irrigation Design Flow (cfs)	100-yr Flood Flow (cfs)
105.4	2,350	5,000
102.9	2,350	9,100
101.4	2,350	11,300
99.8	2,350	15,600
98.1	2,350	17,600
96.6	2,350	18,700
92.4	2,350	18,900
84.8	2,350	19,100
81.8	2,350	18,300
80.4	2,350	17,700
80.0	2,350	17,800
78.5	2,350	22,400
78.0	2,350	22,500
76.6	2,350	22,000
67.2	2,350	22,400
63.3	2,350	22,400
63.0	2,350	22,200
55.7	1,900	21,300
55.3	1,900	21,000
48.7	1,900	21,300
47.6	1,900	20,500
44.6	1,900	20,100

Miles Above American Dam	Irrigation Design Flow (cfs)	100-yr Flood Flow (cfs)
39.9	1,900	20,000
39.3	1,600	20,100
34.8	1,600	19,600
29.2	1,600	19,200
25.9	1,600	18,700
22.1	1,600	18,300
22.0	1,600	17,900
21.8	1,600	17,700
19.6	1,600	17,600
18.8	1,600	17,400
16.4	1,600	17,100
15.7	1,600	16,800
15.4	1,600	16,600
15.2	1,600	16,500
15.0	1,600	16,400
14.4	1,600	16,300
13.1	1,600	16,100
12.8	1,600	15,900
10.9	1,600	15,000
10.3	1,600	14,800
9.2	1,600	14,600
0.2	1,600	14,300

Figure 8.1
Design Flows for Irrigation and 100-year Flood



8.1 Design Flows for Irrigation and 100-Year Flood

8.1.2 Conclusions and Recommendations

In its 1996 report, the USACE recommended the following:

- All levee closure devices should be inspected to insure they would operate correctly in case of flood emergencies. In many cases, several existing closure devices in the study reach have been tampered with and remain permanently open.
- There are five bridges (Brickplant, Courchesne, Borderland, Canutillo, and Tonuco) in which the 100-year flood overtops the roadway elevation. These bridges should be replaced in order to pass the 100-year flood without overtopping. The Tonuco Bridge is an abandoned bridge in the northern reach of the study area and should be removed from the floodway. At this time, the New Mexico Highway Department is only planning to replace the Courchesne Bridge.
- The eastern portion of Canutillo, TX is partly protected from flooding by the Atchison, Topeka, and Santa Fe Railroad embankment which acts as the east levee. The railroad embankment extends for about 5 miles; however, the protection is discontinuous due to uncontrolled openings in the railroad embankment. To successfully contain river flood stages within the floodway, the openings must be eliminated. This can be accomplished on an emergency basis by sandbagging the openings or by building stop-log structures at each opening. Both of these methods require extensive manual labor and coordination during an emergency situation; therefore, the measures are not considered viable solutions unless an extensive flood warning system is implemented.

A recommended structural solution would involve both an earthen levee and concrete floodwall. The floodwall, beginning approximately at river mile 9.9 and extending to river mile 11.3, is necessary due to the constricted flow area that exists; the levee-to-levee width in this reach is only 310 feet to 350 feet. This river section currently represents the hydraulic constriction in the study reach, and the levee-to-levee width cannot be reduced by a new earthen levee section without adversely increasing the water surface elevation upstream. The recommended 7,500-foot-long floodwall would vary in height from 8 to 10 feet, without freeboard, and the structure would be located riverside and immediately adjacent to the Atchison, Topeka, and Santa Fe Railroad embankment (the existing east river levee). To accommodate local drainage, the flood wall must tie into the drainage control structures at appropriate locations. Downstream of river mile 10.8 and upstream of river mile 12.2, the levee-to-levee width expands to approximately 500 feet, allowing the floodwall to transition to an earthen levee.

The west-side levee should incorporate a flood wall extension for the same constricted area (river mile 10.8 to river mile 12.2) to contain the increased water surface elevation resulting from the decrease in effective flow area with the east-side flood wall in place. The west-side flood wall would consist of a vertical wall partially embedded in the existing levee crown. A floodwall extension is possible on the west side because, unlike the east-side levee, the west-side levee does not serve the dual propose of railroad embankment and flood control levee. The existing levee section should be checked for through seepage and underseepage and for embankment and foundation stability. Some methods of controlling seepage and improving embankment stability could eliminate the economic advantage of the flood wall in comparison to an earthen levee enlargement.

8.2 Modeling of Enhancements

This section details the hydraulic modeling of the 100-year flood including the proposed modifications presented in Section 7, Description of Alternatives. The levee areas where the 100-year computed water surface elevation encroaches on the freeboard or overtops the levee are identified.

8.2.1 Revisions to USACE Model Cross Sections

Parsons ES obtained the geometric, the 100-year flood hydrologic, and hydraulic input data used in this modeling analysis from the USACE through the USIBWC. Parsons ES imported the USACE HEC-2 hydraulic input data files that included the cross section geometry into HEC-RAS (Version 2.2). Then the geometric files were modified to accommodate enhancements proposed for the Project. Cross sections representing the proposed Courchesne Bridge were also included in the model.

The cross sections were modified to include the set back of levees at 3 sites that include property outside the USIBWC right-of-way. These sites contained river channels or other features prior to the Canalization Project construction that make them attractive for environmental enhancement. A total of 115 acres were encompassed by the setbacks modeled. Although areas outside the right-of-way are an element of Alternative 4, the modeling results presented also apply to Alternatives 2 and 3 in terms of identifying the need for levee reconstruction. This is considered valid because the water elevations are not greatly affected between alternatives by the limited levee setbacks considered.

8.2.3 Channel Roughness Coefficient

The HEC-RAS model incorporates a channel roughness coefficient (Manning's "n" value) of 0.02 and overbank roughness coefficients that range from 0.03 to 0.15. The "n" values for the channel and overbank areas subject to enhancements were determined based on land cover (Chow 1959). Table 8.2 displays the values and conditions of Manning's "n" used for this modeling effort.

Table 8.2 Manning's "n" Values

Land Type	Manning's "n" Value
Rio Grande channel	0.02
Overbank Areas	
Mowed brush	0.03
Agriculture	0.04
Wetlands	0.05
Shrubs	0.10
Trees	0.15

Table C.1 in Appendix C shows the selected "n" values used in this modeling effort for the modified cross sections. Table C.1 also lists the "n" values for the left bank, channel, and right bank used by the USACE in its HEC-2 model and those used in the HEC-RAS model. Table C.1 lists whether or not changes in the cross sections occurred.

8.2.4 Model Results for Enhancements and Conclusion

Since design and construction data for the levees are lacking, the structural integrity of the entire system is uncertain. However, portions of the levees that are deficient in elevation relative to a predicted water surface level were identified. In addition, portions of the levees subject to excessive erosive forces due to high water velocities were identified.

Figure 8.2 shows a schematic representation of the model results with 0.1-mile sections color coded where potential problems exist. Results of the HEC-RAS model for the 100-year flood conditions are summarized in Table 8.3. Detailed results for each cross section are given in Table C.2, Appendix C which lists the cross section numbers, left and right top of levee elevations, left and right freeboard, and the computed water surface elevation.

Table C.2 identifies cross sections where the 100-year flood computed water surface elevation encroaches upon the 3-foot levee freeboard or overtops the levee. Areas where water edge velocities exceed 3 feet per second and 4 feet per second are also shown. Water velocities at the edge of the floodway near the channel are critical due to the erosion potential. Velocities of 3 and 4 feet per second were chosen as screening levels due to the lack of information on the construction of the levees.

Table 8.3
HEC-RAS Model Results for the 100-Year Flood Conditions With Enhancements

(Combined Length of Right and Left Levees in Miles)

Management Unit	Levee or Right-of-Way Over-topped	Freeboard Less Than 1 foot	Freeboard Less Than 3 feet	Edge Velocity Above 4 ft/s	Edge Velocity Between 3 and 4 ft/s
Upper Rincon	0.2	1.2	4.4	0.2	0.9
Lower Rincon	1.8	1.8	6	1	2.4
Seldon Canyon	2.6	0.1	1	0	0.2
Upper Mesilla	1.2	0.9	3.7	0	1.3
Las Cruces	0	0	4.8	0	1.9
Lower Mesilla	1.2	0.5	18.5	0.9	8.3
El Paso	6.9	4.6	21.9	1.1	7.8
Total Miles	**13.9**	**9.1**	**60.3**	**3.2**	**22.8**

Figure 8.2 Schematic of Hydraulic Model Results

8.2.5 Comparison with Current Conditions

Table 8.4 shows the difference between post-enhancement and current levee overtopping potential. Table C.2 shows the differences in the 100-year flood computed water surface elevation between the USACE's HEC-2 results (current conditions) and the HEC-RAS results (with enhancements). Table 8.4 below shows that proposed enhancements to the floodway areas do not significantly change the current situation of overtopping potential or levee erosion potential throughout the Project for Alternatives 2, 3, or 4. The levee reconstruction required is similar for each alternative.

Table 8.4
HEC-RAS Model Results for the 100-Year Flood Conditions
Changes Due to Enhancements

(Combined Length of Right and Left Levees in Miles)

Management Unit	Levee or Right-of-Way Over-topped	Freeboard Less Than 1 foot	Freeboard Less Than 3 feet	Edge Velocity Above 4 ft/s	Edge Velocity Between 3 and 4 ft/s
Upper Rincon	0.2	0.7	0.5	-0.1	-0.4
Lower Rincon	0.1	0.1	1.3	0.0	-0.5
Seldon Canyon	0	-0.1	-0.3	0.0	-0.1
Upper Mesilla	0	0	0.3	-0.1	-0.5
Las Cruces	0	0	1.3	0.0	-1.2
Lower Mesilla	-0.1	-0.1	3.1	0.1	-3.4
El Paso	0.5	1.8	-0.2	-0.3	-3.9
Total Miles	**0.7**	**2.4**	**6**	**-0.4**	**-10.0**

8.3 Flood Control Remedies and Recommendations

The USACE's recommendations in Section 8.1.2 are still appropriate. However, the New Mexico Highway Department is not planning to replace any bridges except the Courchesne Bridge. The Courchesne Bridge proposed cross section has been included in the HEC-RAS model.

Several options were considered with respect to overtopping of levees or rights-of-way, encroachment on freeboard, or excessive velocities.

- Add levee where none exists;
- Raise or fortify existing levee;
- Set back levee or right-of-way; and
- Implement no additional flood protection measures.

Each of these options was included as part of the overall remedy for flood damage reduction. However, a more detailed flood damage reduction study using a risk-based analysis is required to optimize the overall investment of flood control resources.

The general criteria for selecting a flood damage reduction option was based on protection of existing residential, commercial, or industrial structures. Where flooding would be limited by natural topography to agricultural land, even if flooding included land outside USIBWC right-of-way, no additional flood protection was included.

For most areas with levees, the adjacent land elevations outside the USIBWC right-of-way are relatively flat across the valley floor. Therefore, failure of the levee would subject large areas, including structures, to flooding. In these cases, the remedy was to raise or fortify the levee if modeling data indicated encroachment of the freeboard or excessive water velocities. Table 8.5 shows the miles of levee modifications indicated by the HEC-RAS modeling.

Table 8.5 Flood Control Measures for Deficient Levees

(Combined Length of Right and Left Levees in Miles)

Management Unit	Set back Right-of-Way	None	Add levee	Set Back Levee	Raise Levee
Upper Rincon	3.4	26.6	0	0	0
Lower Rincon	0	4	0.6	5.8	1.6
Seldon Canyon	0	14.1	1.3	0	0
Upper Mesilla	0	6.2	0	0	3.1
Las Cruces	0	0	0	0	5.2
Lower Mesilla	0	1	0	3.1	16.9
El Paso	0.7	2.3	7.2	0	28.6
Total Miles	**4.1**	**54.2**	**9.1**	**8.9**	**55.4**

The set back of levees was a component of several enhancement sites in order to encompass additional acreage for riparian or uplands habitat. Water surface elevations at some sites will be reduced because of the wider floodway. The flood control benefits of levee setbacks are based on the attenuation of peak flows within the retention volume of the expanded floodway. These benefits are a function of the timing and duration of the peak flow and the position of the setback relative to flood prone areas or deficient levees. A more detailed flood damage reduction study would be needed to evaluate the dynamic behavior of the peak flood flows and the optimum location of floodway detention volume provided by levee setbacks.

Aerial photographs of the floodplain near deficient levees were reviewed to identify agricultural land adjacent to the existing right-of-way that could be incorporated into flood control strategies. These areas could be enclosed within a realigned levee and subjected to the flooding during the 100-year event. The areas could be purchased by USIBWC or could continue in agricultural production with the owner granting a flood easement. These candidate areas are not included in the alternatives identified for the EIS because they could not be evaluated for flood control purposes within this study. Table 8.6 lists the cross section number (miles above American Dam), area, and modified levee length for these flood control sites.

Table 8.6 Candidate Flood Control Sites

Miles from American Dam	Side (Looking Downstream)	Area (acres)	Modified Levee Length (ft)
96	Left	35	4,300
91	Left	75	6,100
83.4	Right	110	7,500
79.8	Right	125	7,600
77.5	Right	165	7,500
76.3	Left	55	3,300
75.3	Left	195	12,000
52.6	Left	45	4,000
50.6	Right	120	9,500
47.8	Left	55	5,500
45.5	Left	75	7,200
43.4	Left	45	4,600
41.9	Left	235	12,600
Total		**1,335**	**91,700**

8.4 Assumptions and Limitations of the Model

It is imperative to understand the results of the model within its limitations. HEC-RAS is currently capable of performing one-dimensional water surface profile calculations for steady-state conditions with gradual changes in flow due to inflows from tributaries. The model is capable of modeling flow in both natural and constructed channels. The following assumptions are implicit in the analytical expressions used in the current version of the program:

1. Steady-state conditions;
2. Flow is gradually varied where tributaries enter the main channel;
3. Flow is one-dimensional; and
4. River channels have less than 1:10 slopes.

Flow conditions are assumed to be steady state because time-dependent terms are not included in the energy equation. Flow within the main channel is assumed to be gradually varied at tributary inflow locations because the mathematical equations used are based on the premise that a hydrostatic pressure distribution exists at each cross section. At locations where the flow is rapidly varied (at hydraulic structures such as bridges, culverts, and weirs), the program switches to the momentum equation or other empirical equations. Flow is assumed to be one-dimensional (i.e., velocity components in directions other than the direction of flow are not accounted for) because the mathematical equations used are based on the premise that the total energy head is the same for all points in a cross section. Small channel slopes are assumed because the pressure head in the mathematical equations used is represented by the water depth measured vertically. The program for this study does not have the capability of dealing with movable boundaries (i.e., sediment transport), or hydrograph routing, which would allow varying discharge rates to be calculated as the floodplain cross section varies.

The topographic information available is limited to the digital elevation model, which the USACE produced for the 1995 study. This information was compiled for the USIBWC right-of-way and extends outside the right-of-way for only a very limited distance. The topographic information does not include potential floodway areas located beyond this limited distance from the right-of-way. This precludes modeling the flood control effect of potential levee setbacks significantly outside the right-of-way.