Middle Rio Grande Bosque Restoration Project

Technical Engineering Appendix

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Middle Rio Grande Ecosystem Restoration Project

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I - INTRODUCTION

1-01. Purpose and Scope. This technical appendix present design criteria and construction cost associated with the recommended plan Middle Rio Grande Bosque Feasibility Study. The data, criteria and construction costs presented herein will serve as a basis for plans and specifications for construction of the proposed plan described below.

1-02. Project Authorization. Congressional authority for this feasibility study and the associated technical appendices are derived from Congressional authorizing projects on the Rio Grande, particularly in the Middle Rio Grande (MRG). These authorizations began with the basic flood control authorization for the Middle Rio Grande Public Law No. 228, 77th Congress and follows with Section 401 of the Water Resources Development Act of 1986 (Public Law 99-662) dated 17 November 1986, which authorized the Middle Rio Grande Flood Control Project from Bernalillo to Belen, New Mexico authorizing flood protection but not ecosystem restoration. In 2001 the MRGCD requested initiation of a reconnaissance study by the Corps for ecosystem restoration in the MRG. Authorization for a Reconnaissance study was provided in House of Representatives Resolution 107-258, and included in the Energy and Water Development Appropriations for fiscal year 2002. This resolution states:

> *"The conferees have agreed to provide $350,000 for the Corps of Engineers to initiate and complete a Reconnaissance study to evaluate environmental restoration, recreational and related purposes for the Middle Rio Grande Bosque, Bosque, New Mexico. The conferees are aware of the unique nature of this study and encourage the Corps of Engineers to establish an interstate steering committee to leverage lessons learned from the Rio Salado, Phoenix and Tempe Reaches, Arizona, and Tres Rios, Arizona Environmental projects as well as experience within the Agency."*

A Reconnaissance study was initiated in March 2002. The results and conclusions of the reconnaissance phase were presented in Middle Rio Grande Bosque Restoration Section 905(b) Analysis, U.S. Army Corps of Engineers, Albuquerque District, June 2002. The recommendation of that report states that there was a Federal interest in proceeding to feasibility phase of the General Investigation. A Feasibility Cost Sharing Agreement was signed between the MRGCD, as the non-Federal Sponsor, and the Corps, initiated the feasibility phase of the study in the Fall of 2004.

1-03. Project Description. The recommended plan for the MRGBER includes the Bosque within Corrales which is designated as the *Corrales Bosque Preserve*. The Northern extent of the Corrales Bosque Preserve forms the north boundary of the Study Area, while the southern boundary is formed by the northern limits of the Pueblo of Isleta. The area is defined on the east and west by the flood control levees. The project Area is approximately 26 miles in length along the river and roughly 5,300 acres in size. The project area was divided into five reaches. Reach designation allowed for simplified hydrologic analysis of existing conditions and evaluation of proposed restoration plans. Bridges were used as the boundary of each reach because bridge crossings tend to have the greatest influence on hydrology and therefore make a logical break point. The reach designations are also amenable to consideration of stakeholder interests, vegetative community makeup, and geographic location.

Reach 1 is bounded on the north by the confluence of the Barancas Arroyo and the Rio Grande and the Alameda Bridge to the south. As stated previously, the boundaries for all the reaches to the east and west of the recommended plan are bounded by the flood control levees, which roughly parallels the Rio Grande forming a width of approximately 1,500 feet. Approximately 7,000 feet downstream of the northern boundary of this reach is the first of the features for both sides of the overbank. The proposed plan provides for 9,000 feet of treat/retreat/revegetation for both overbanks along with ---- acres of swales for the left bank and 5,000 feet of bank destabilization and an 8,000 feet of overbank high flow channelization with wetland creation for the right bank. Proceeding 14,000 downstream from these features is the lower sets of features for both overbanks. Water features include the construction of hi-flow channel (4,000 feet), creation of wetlands specifically at the outfall for the right overbank. Several sets of swales (distributed across both banks) are proposed in conjunction with bank destabilization. Existing jetty jacks will be removed and trails created as indicated on sheet C-101.

Reach 2 is bounded on the north by the Alameda Bridge and to the south by the Montano Bridge on the south. Approximately 11,000 feet upstream of the Montano Bridge on the left bank, the recommended plan proposes 3,800 feet of treat/retreat/revegetation with the creation of a wetland approximately ---- in area. Existing jetty jacks will be removed and trails created as indicated on sheet C-102.

Reach 3 is bounded by the Montano Bridge on the north and the Central Bridge on the south. Existing jetty jacks will be removed and trails created as indicated on sheet C-103. Approximately 6,700 feet south of the Montano Bridge on the right bank is a treat/retreat/revegetation area that is approximately 2,600 feet along the Rio Grande. Within this reach is approximately 1,000 feet of bank destabilization for the right side of the bank. Located within this area is an area referred to commonly as the "Oxbow" along the right bank. Water features include the restoration of open water habitat (in the "Oxbow" itself), construction of a water control structure, and reconfiguring the South-end and Namaste outfalls.

Reach 4 is bounded on the north by Central Bridge and extends to the south of the Rio Bravo Blvd Bridge by approximately 8,000 feet. Immediately south of the Central bridge on the left side of the Rio Grande, is 6,700 feet of treat/retreat/revegetation area with an outfall wetland connected to an existing wetland. South of the Rio Bravo Blvd on the left bank of the Rio Grande is an area of treat/retreat/revegetation with 6,000 feet of high flow channel and bank destabilization and an outfall wetland. Existing jetty jacks will be removed and trails created as indicated on sheet C-104.

The northern most boundary of Reach 5 is approximately 8,000 feet south of the Rio

Bravo Blvd and is bounded on the south with the northern boundary of the Pueblo of Isleta, just south of the Interstate 25 Bridge. Both sides of the Rio Grande within this reach have two areas of treat/retreat/revegetation with swales. On the left side are areas of 6,200 and 3,600 feet of area alongside the Rio Grande and the right side two areas of 6,500 alongside the Rio Grande. Existing jetty jacks will be removed and trails created as indicated on sheet C-105.

1-04. Requirements of the Local Sponsor. The local sponsor will be required to provide lands, easements, right-of-way, relocations, and disposal sites for construction of the Middle Rio Grande Bosque Ecosystem Restoration Project. The cost for lands, easements, and rights-of-way includes property currently owned Middle Rio Grande Conservancy District and the City of Albuquerque. All construction access to the sites is by public roadway. All contractor staging is to be within the defined project boundaries. Dredged materials would be stored on project land until used as a portion of construction fill requirements or spoiled in appropriate areas. Excess material would be removed to an appropriate commercial dump site, based on other recent projects (USACE 2004). The value of lands, easements, rights-of-way, relocations, and disposal/borrow areas (LERRD) for permanent easements and the Non-Federal Administration Costs is estimated at $1,316,000. The full Real Estate Plan can be found in the Appendix B.

1-05. Surveys. Formulation for the Middle Rio Grande Bosque Feasibility Study project was accomplished using orthophotographic mapping obtained in March 2007. This mapping was developed at a scale of 1"= 100' with a 1 foot contour interval. Detailed designs for this study are based on a digital terrain model generated from a data base primarily established by photogrammetric methods from vertical aerial photography. The mapping is at a scale of 1"=100' with a 2-foot contour interval.

II-HYDROLOGY, HYDRAULICS & GEOMORPHOLOGY

2-01. Introduction of Analysis for Baseline Conditions. Baseline conditions for the Rio Grande were conducted under the Rio Grande Bosque Restoration Feasibility Study. Applicable elements of that work are included below to provide the necessary background which was used in support of the design development.

In order to define the baseline conditions, Mussetter Engineering, Inc. (MEI) was retained by the U.S. Army Corps of Engineers (Corps), under contract (Contract DACW47-02-D-005, Delivery Order 0006) to perform hydraulic modeling using the FLO-2D model in support of the Middle Rio Grande Bosque Restoration Feasibility Study. The FLO-2D modeling is intended to provide assessment of overbank flows and the resulting area of inundation, as well as hydraulic data to facilitate an analysis of sediment transport conditions and geomorphic processes along the reach. Results from this analysis were used to evaluate various riparian and wetland restoration alternatives. This report summarizes the analysis of the baseline conditions, which is the first phase of the modeling project under this task order. The analysis included (1) development of the hydrologic scenarios, (2) FLO-2D model development, model verification and application, and (3) a baseline channel-stability analysis. The report is entitled, "FLO-2D Model Development – Existing Conditions and Restoration Alternatives 1 to 5, Albuquerque Reach, New Mexico" by Mussetter Engineering, Inc. dated October 2008. This report is included in the **H&H Appendix** and provides the results of the detailed analysis described above.

A summary of results which are applicable to the habitat restoration project taken from the report are provided below.

2-02. Hydrology. The scope of work for the Rio Grande Bosque Restoration Feasibility Study specifies that the following four hydrologic events (or hydrologic scenarios) are to be modeled in evaluating baseline conditions and other project alternatives that will be developed as the project progresses:

1. The active channel-full flow.
2. A representative post-Cochiti annual spring runoff hydrograph.
3. A 10,000-cfs post-Cochiti flow hydrograph - proposed operational discharge. The discussion regarding the 10,000 cfs flow is not included since it is not applicable to the development of the Habitat Restoration Project.
4. The 100-year post-Cochiti flood-flow hydrograph.

Only hydrologic scenarios 1 and 2 will be discussed further in this report as they are most important to the DDR for the habitat restoration project.

<u>The active channel-full flow, Hydrology Scenario 1</u>

Based on field observations during the 2005 runoff season, the active channel-full flow in this reach is close to 6,000 cfs, somewhat higher than the ±5,000 cfs that was originally specified in the scope of work. The discharge for Hydrology Scenario 1 was therefore increased to 6,000 cfs. This scenario was modeled as a steady-state condition, because the primary purpose is to evaluate the extent and location of overbank flooding that would occur under a sustained discharge at this level. This discharge has a peak flow recurrence interval of about 2.3 years, and mean daily flow exceedence probability of 1.2 percent (i.e., it occurs 4 to 5 days per year, on average).

A representative post-Cochiti annual spring runoff hydrograph, Hydrology Scenario 2

A representative post-Cochiti annual spring runoff hydrograph with a maximum mean-daily flow of 3,770 cfs was developed for evaluating the various riparian and wetland restoration alternatives. To develop the representative hydrograph, mean daily flow values for each of 29 post-Cochiti annual hydrographs were plotted.

Because the individual hydrographs peak at different times each year, the timing of each of the annual hydrographs was adjusted by centering the hydrographs so that the rising and falling limbs match as closely as possible to prevent over estimating the hydrograph volume, particularly on the rising and falling limbs. A 50-percent exceedence hydrograph was computed based on these translated hydrographs and yielded a peak discharge of 3,770 cfs (A log-Pearson III frequency analysis of the annual peak flows that was performed for this evaluation indicates that the peak mean daily flow of 3,770 cfs shown in Figure 1 corresponds to a recurrence interval of about 1.4 years and a mean daily flow exceedence probability of 8.1 percent [i.e., occurs 30 days per year, on average]).

The mean daily flow hydrographs that were developed for this analysis primarily represent snowmelt runoff from the upper part of the basin which typically changes discharge relatively slowly due to the size of the drainage basin and dampening effects of the upstream reservoirs. As a result, the mean daily and instantaneous maximum flows during the snowmelt season are not significantly different; thus, the use of mean-daily flow values for this analysis is believed to be appropriate.

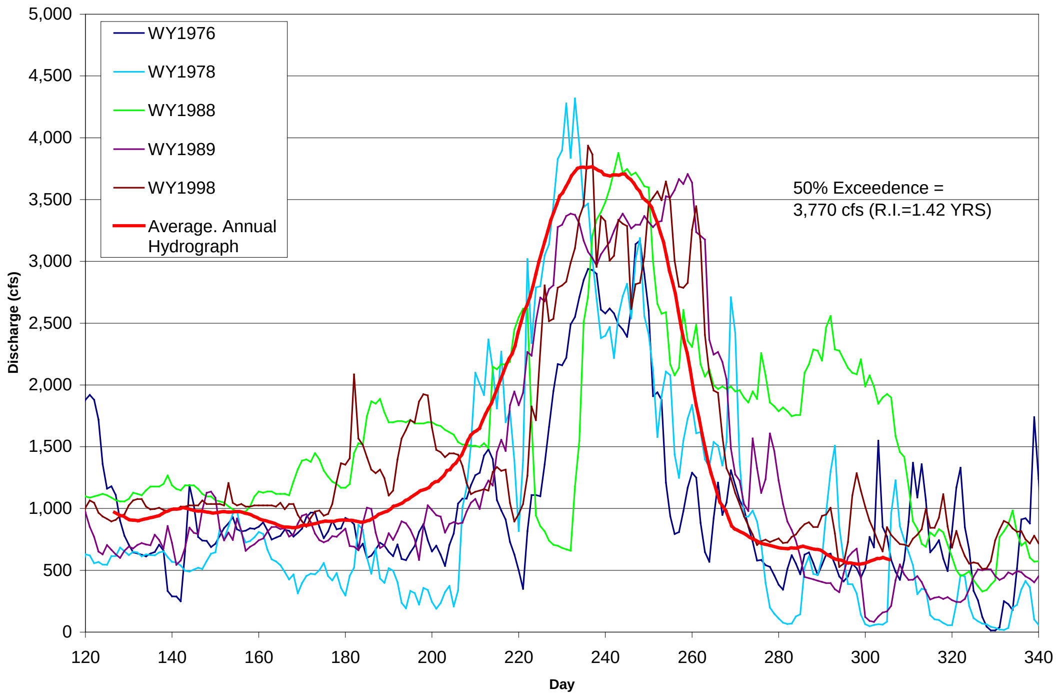

Figure 1 - The representative 50-percent exceedence hydrograph and a comparison with five natural hydrographs with similar peak discharges.

2-03. Hydraulics - Model Calibration and Validation. A detailed discussion of the model development, calibration and validation can be found in the Rio Grande Bosque Restoration Feasibility Study report in the **H&H Appendix** and will not be discussed in detail here. However, comparison of the predicted water-surface elevation at 6,300 cfs from the updated FLO-2D model with the 2005 measured profile shows very good agreement. The performance of the model was also evaluated over a broader range of flows and compared to water surface elevations at four bridges where measured water-surface elevations were available. Based on the results, the updated FLO-2D model appears to be reasonably well validated. The HEC-RAS Hydraulic Model used in support of the Rio Grande Bosque Feasibility Study was also calibrated as part of this effort and has been used in support of the DDR for the habitat restoration project.

2-04. Hydraulics – Rio Grande Bosque Feasibility Study Model Results. The validated FLO-2D model was applied for Hydrology Scenarios 1, 2 and 3, and the results were used to compare the main channel water-surface elevations with the top-of-bank elevations, and to map and evaluate the extent, depth and duration of overbank inundation along the reach (shown in the report in Appendix A). As stated earlier, only scenarios 1 and 2 will be discussed in this report as they most relate to the DDR for the habitat restoration project.

Hydraulics for Hydrology Scenario 1

At 6,000 cfs, which corresponds to the steady-state discharge for the active channel-full flow (hydrology scenario 1), the water-surface elevation is above the top-of-bank at only

two locations:
1. On the left bank just upstream from Central Avenue, and
2. Between Bridge Boulevard and Rio Bravo Boulevard.

Inundation results from Hydrology Scenario 1 are very similar to the 6,300 cfs validation run that was based on measured water surface elevations taken during the 2005 runoff season, with overbank inundation occurring at two locations:
1. Immediately upstream from the Central Avenue Bridge (depth of approximately 0.5 feet), and
2. The right overbank about midway between Bridge Boulevard and Rio Bravo Boulevard (depth of 0.2 to 3.2 feet).

Hydraulics for Hydrology Scenario 2

The profile plots in Appendix A indicate that the water-surface is below the top-of-bank at the modeled cross sections along the entire reach at 4,000 cfs. No overbank inundation occurs under Hydrology Scenario 2 (average annual hydrograph), because the peak discharge of 3,770 cfs is substantially less than the channel capacity along the entire reach.

2-05. Sediment-Continuity Analysis. To facilitate the sediment-transport and channel-stability analysis, the study reach was subdivided into five subreaches that are consistent with the subreaches used for the ecological analysis (see Table 1 and Figure 2 below). Within these subreaches, the geomorphic and hydraulic characteristics of the channel are generally consistent. Reach-averaged hydraulic conditions were developed from the model output for each sub-reach.

Table 1- Summary of subreaches defined for the channel-stability analyses

Subreach	Subreach Length (ft)	Main Channel Top width (ft)*	Limits
1	10,760	710	Southern boundary of the Pueblo of Sandia to Alameda Blvd.
2	22,190	650	Alameda Blvd. Bridge to Montano Blvd. Bridge.
3	23,430	500	Montano Blvd. Bridge to Central Avenue Bridge
4	32,190	545	Central Avenue Bridge to the South Diversion Channel
5	25,640	550	South Diversion Channel to the northern boundary of the Pueblo of Isleta

*at the active channel-full flow of 6,000 cfs

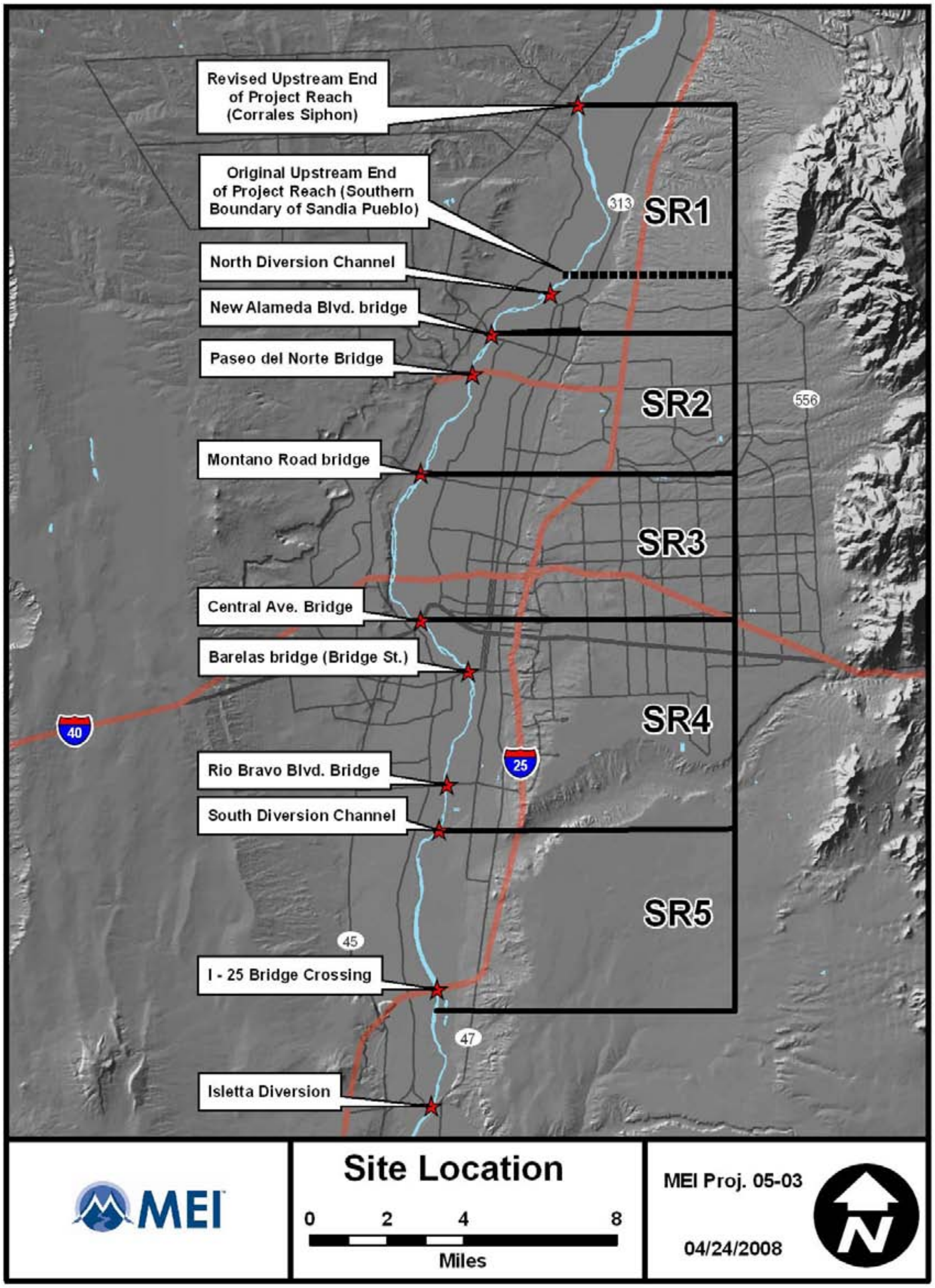

Figure 2- Location map showing the project reach and subreach boundaries.

A baseline sediment continuity analysis was performed to evaluate the potential for aggradation or degradation in response to both an individual short-term hydrograph and longer-term flows (50-year project life) with the present channel configuration and reservoir operations. In general, the analysis was conducted by estimating the bed-material transport capacity of the supply reach and each subreach within the study area for each hydrology scenario and comparing the resulting capacity with the supply from the upstream river and tributaries within the reach. Hydrology Scenario 2 (mean annual runoff) was used for the individual hydrograph, and the mean daily flow-duration curve from the Central Avenue gage for the post-Cochiti Dam period was used for the long-term analysis.

For the average annual hydrograph with no sediment input from the tributaries, Subreaches 1 and 4 are net aggradational (0.04 and 0.05 feet, respectively), Subreaches 3 and 5 are net degradational (-0.06 and -0.04 feet, respectively), and Subreach 2 is approximately in balance with the upstream supply (-0.01 feet).
- (Figure 3)

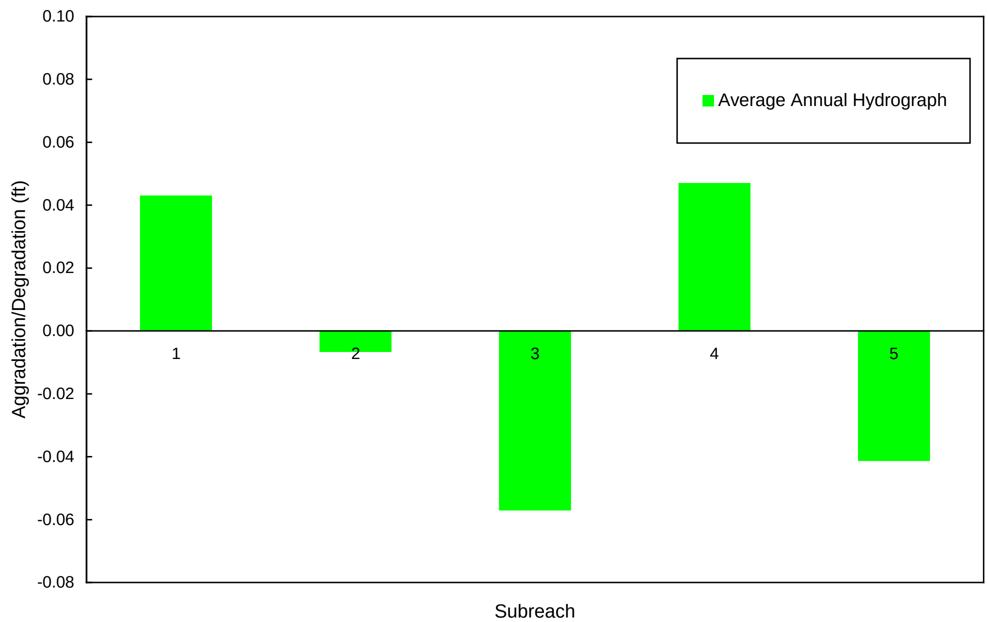

Figure 3 - Computed average annual aggradation/degradation depths for each subreach

On a long-term, average annual basis including sediment input from the tributaries, Subreaches 1, 3 and 5 are net degradational (average of -0.11, -0.12, and -0.05 feet, respectively). Subreach 2 is approximately in balance with the upstream supply (-0.01 feet, on average) and Subreach 4 is net aggradational (average of about 0.11 feet).
- (Figure 4)

The long-term average annual results indicate that as much as 5 feet of degradation could occur in Subreaches 1 and 3, and a similar amount of aggradation could occur in

Subreach 4 over a 50-year period. However, the channel will also respond to the sediment imbalance by alterations in the bed-material gradation, and potentially changes in width. As a result these estimates represent an upper limit of the vertical response, and the actual amount of aggradation/degradation will likely be much smaller.

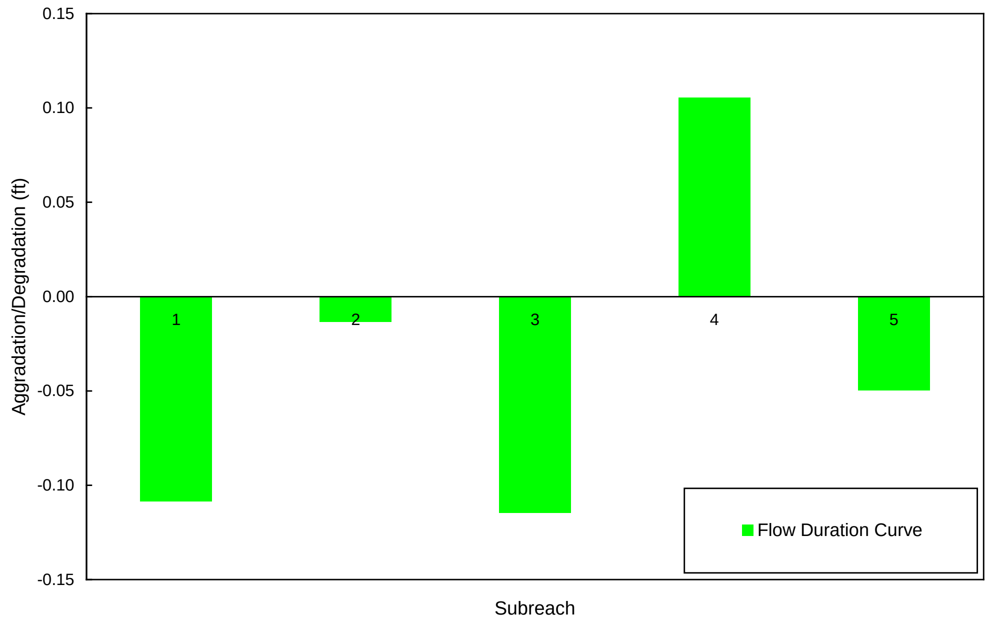

Figure 4 - Computed aggradation/degradation depths for each subreach for the flow-duration curve

2-06. Rio Grande Bosque Feasibility Habitat Restoration Project – Project Features. The Rio Grande channel bank is approximately 5 feet above the river bed through the project reach at most sites. This reach "appears to be disconnected or less responsive to river flow. Water table depths as well as the lack of spatial and temporal variation in the water table indicate efforts to establish new cottonwoods by seed or pole planting will likely fail without periodic overbank flooding" (Eichhorst et al., 2001). Since the bank is approximately 5 feet above the river bed, bankfull flows of approximately 6000-7000 cubic feet per second (cfs) still would not provide overbank flooding at many sites. This is supported by the Rio Grande Bosque Feasibility Study results presented earlier as well as observations made during high flows in the spring of 2005. Therefore, a reconnection between the overbank area and the river is needed to provide flooding internal to the Bosque. In this case, high flow channels are proposed to do that. The proposed channels will have a bottom width of approximately 10 feet with 3 to 1 side slopes (3 horizontal to 1 vertical). The channels will also include embayment areas. They will be located at the upstream channel confluences and at the downstream channel confluences with the Rio Grande. These embayment areas are planned to be 140 feet wide and would be cut into the bank by approximately 70 feet. These embayments will hold water whenever the Rio Grande is flowing at 500 cfs or greater. When the Rio Grande is flowing at less than 500 cfs it is assumed that these areas will be similar to sand bars. At the high point of each channel will be a grade control structure comprised of a one foot thick rip rap blanket 60 feet in length for the full width of the channel to maintain the design intent.

River water is proposed to move through the channels at depths which vary from 0.5' to 3' depending on the flow rate of the Rio Grande. The orthophotography shows that at many of these channel locations, the overbank areas are lower than the existing bank and excavation of the bank would provide a connection. These channels will therefore overbank at a lower flow rate than the Rio Grande active channel and provide inundation and connectivity for the Bosque at these locations. A representative post-Cochiti annual spring runoff hydrograph with a peak mean-daily flow of 3,770 cfs was used for evaluating restoration alternatives. The preliminary design is based on a flow rate in the Rio Grande of 3500 cfs which is representative of the flow rate taken from the average annual hydrograph that would be sustained for a minimum duration of 14 to 21 days. However, they could begin to flow when the Rio Grande discharge reaches 3,000 cfs. The water surface elevation (WSEL) in the Rio Grande for that flow rate (3500 cfs) was used as the basis for setting the invert elevation for the habitat restoration project channels. This allows for flow through the habitat restoration project channels of approximately 10 cfs with velocities that vary between one (1) and two (2) fps. Under these conditions water depth in the habitat restoration project channels would vary from one half (.5) to one (1) foot. Several trail crossings of these channels occur within the project area. These trail crossings will be accommodated using clear span bridges with hand rails that will provide safety to the public while allowing channel flows to pass unobstructed. The representative post-Cochiti annual spring runoff hydrograph and the HEC-RAS hydraulic model used to determine the WSEL in the Rio Grande was developed as part of the Rio Grande Bosque Feasibility Study as described above.

2-07. HEC-RAS Hydraulic Modeling Procedure and Results. The Rio Grande Bosque Restoration Feasibility Study HEC-RAS model is based on the 2002 US Bureau of Reclamation Rio Grande Aggradation-Degradation Study Cross Sections (Range Lines).

The modeling reach is from Range Line 340 (North end of Corrales just below Rio Rancho Waste Water Treatment Plant) to Range Line 632 (Downstream of Interstate Highway 25 and upstream of AT&SF RR Crossing in Isleta Pueblo). The 2002 Cross Sections used are based on NAVD88 Datum and the cross sections taken through this reach were flown on 25 January 2002. The flow in the Rio Grande measured at the Albuquerque Gage on that date was 321 cfs. The bridges through this reach were either surveyed or verified from as-built drawings and converted to NAVD88 Datum. This model was then calibrated to water surface elevation surveys conducted during spring 2005 high flow data that was collected by Tetra Tech Inc. under contract to the Albuquerque District USACE. Additional flow measurements were made at various flow rates at four bridges over the Rio Grande to further aid in calibrating the model. These bridges were at Alameda Boulevard, Central Avenue, Bridge Street, and Rio Bravo Boulevard. Water surface elevations were taken upstream and downstream on each bridge at various flow rates. This model will be referred to as the Rio Grande HEC-RAS Model.

Additional HEC-RAS Models were developed for the habitat restoration project channels. The water surface elevations (WSEL) from the Rio Grande HEC-RAS Model were used to provide upstream and downstream WSEL control for the habitat restoration project HEC-RAS Models. The habitat restoration project high flow channels are shown on the project map located in the Feasibility Report.

High flow channels were designed for a target design flow of 3,500 cfs in the Rio Grande. Channel sections will have a bottom width of 10 feet and 3:1 side slopes with a grade control structure of plain rip rap. Bed slopes for the high flow channels are mild, generally ranging from S = .0015 ft/ft up to S = .003 ft/ft. Detailed design for each high flow channel will be provided with final plans. The resulting flow rates in the habitat restoration project channels are approximately 10 cfs with velocities that average one (1) fps. Under this condition water depths in the habitat restoration project channels will vary from one half (.5) to one (1) foot. The channels were also evaluated at flows in the Rio Grande of 6,000 cfs (Rio Grande bank full flow) and 7,750 cfs (100 year regulated peak at Albuquerque). These flows were evaluated for the habitat restoration project channels to determine flow depths and/or channel overtopping. Representative results of these evaluations are summarized in Table 2 as follows:

Table 2 – Summary of Results from HEC-RAS Modeling of High Flow Channels

Rio Grande Flow 3500cfs	**Channel Flow**	**Flow Depth @ High Pt.**	**Average Velocity**	**Channel Overtopping**
Representative Channel 1	10 cfs	.5 feet	1.0 fps	No
Representative Channel 2	10 cfs	.4 feet	1.5 fps	No
Representative Channel 3	10 cfs	.6 feet	1.0 fps	No

Rio Grande Flow 6000cfs	**Channel Flow**	**Flow Depth @ High Pt.**	**Average Velocity**	**Channel Overtopping**
Representative Channel 1	60 cfs	1.6 feet	2.0 fps	Yes
Representative Channel 2	80 cfs	1.4 feet	2.5 fps	Yes
Representative Channel 3	50 cfs	1.4 feet	1.7 fps	No

Rio Grande Flow 7500cfs	**Channel Flow**	**Flow Depth @ High Pt.**	**Average Velocity**	**Channel Overtopping**
Representative Channel 1	100 cfs	2.1 feet	2.5 fps	Yes
Representative Channel 2	130 cfs	1.7 feet	3.0 fps	Yes
Representative Channel 3	85 cfs	1.8 feet	2.0 fps	Yes

The HEC-RAS Models are included in the **H&H Appendix**. The habitat restoration project map is located in the Feasibility Report showing the alignments for the high flow channels and their locations in relationship with the Rio Grande.

2-09. FLO-2D Hydraulic Modeling Procedure and Results. The 250-foot grid

Existing Conditions model was modified to represent each of the restoration alternatives by making appropriate adjustments to the main channel cross sectional geometry, overbank grid elevations, and roughness parameters. Alternatives were developed using various combinations of channel and overbank features. A detailed discussion of the modeling and analysis effort, as well as all alternatives investigated are included in the report entitled, “FLO-2D Model Development – Existing Conditions and Restoration Alternatives 1 to 5, Albuquerque Reach, New Mexico” by Mussetter Engineering, Inc. dated October 2008. This report is included in the H&H Appendix. In developing the restoration alternatives, the following five categories of features were identified:

1. Water Features (300 cfs)
2. Water Features (3,500 cfs) – (High flow channels discussed in previous section)
3. Bank Destabilization
4. Swale Trench Excavation
5. Overbank Treat-Retreat-Revegetation

These features were delineated in their proposed spatial locations on the project mapping and provided to Mussetter Engineering, Inc. (MEI) in ArcGIS shape file format. MEI overlaid the features onto the FLO-2D grid in ArcGIS to determine the grid elements to be modified (**Figure 5**).

The “Water Features (300 cfs)” represent ponds that are disconnected from the main channel and embayments that are directly connected to the main channel. The 300-cfs designation represents the lowest elevation of the feature that corresponds to the channel water-surface elevation adjacent to the feature at a discharge of 300 cfs. **Figure 6** shows a schematic representation of the modifications of the existing conditions FLO-2D grid to represent the delineated channel and overbank restoration features for this type of feature.

In cases where the restoration features encompass more than one grid element, the grid elevations representing the features are sloped in the downstream direction to match the water-surface slope. The pond features are designed to the 300-cfs water-surface elevation and are intended to be sufficiently low to be hydraulically connected to the groundwater. The embayment features are typically located at existing drain returns, and were designed to connect the river to the drains. In addition to changing the grid elevation to represent the 300-cfs water features, the banks of the channel cross sections were lowered to the grid elevation to ensure that flows would be conveyed to the embayment features.

The “Water Features (3,500 cfs)” are typically high-flow channels that follow historic high-flow paths in the overbanks. Based on guidance from the USACE, the grid elevations identified for these features were lowered 1-foot below the corresponding, computed 3,500-cfs water-surface elevation. The channel cross sections at the up- and downstream ends of the features were also lowered to ensure that water would be conveyed from the channel into the features at the upstream end and from the overbank features back to the channel at the downstream end.

The “Bank Destabilization” features are connected directly to the river and were designed to provide habitat along the channel margins. The bank destabilization features were incorporated into the FLO-2D model by lowering the FLO-2D grid elevation and bank elevations in the corresponding channel cross sections to the computed water-surface elevation (WSEL) at 3,500 cfs. The Rio Grande HEC-RAS Model will also be used to verify the final construction elevations for these features at the modeled 3500 cfs WSEL.

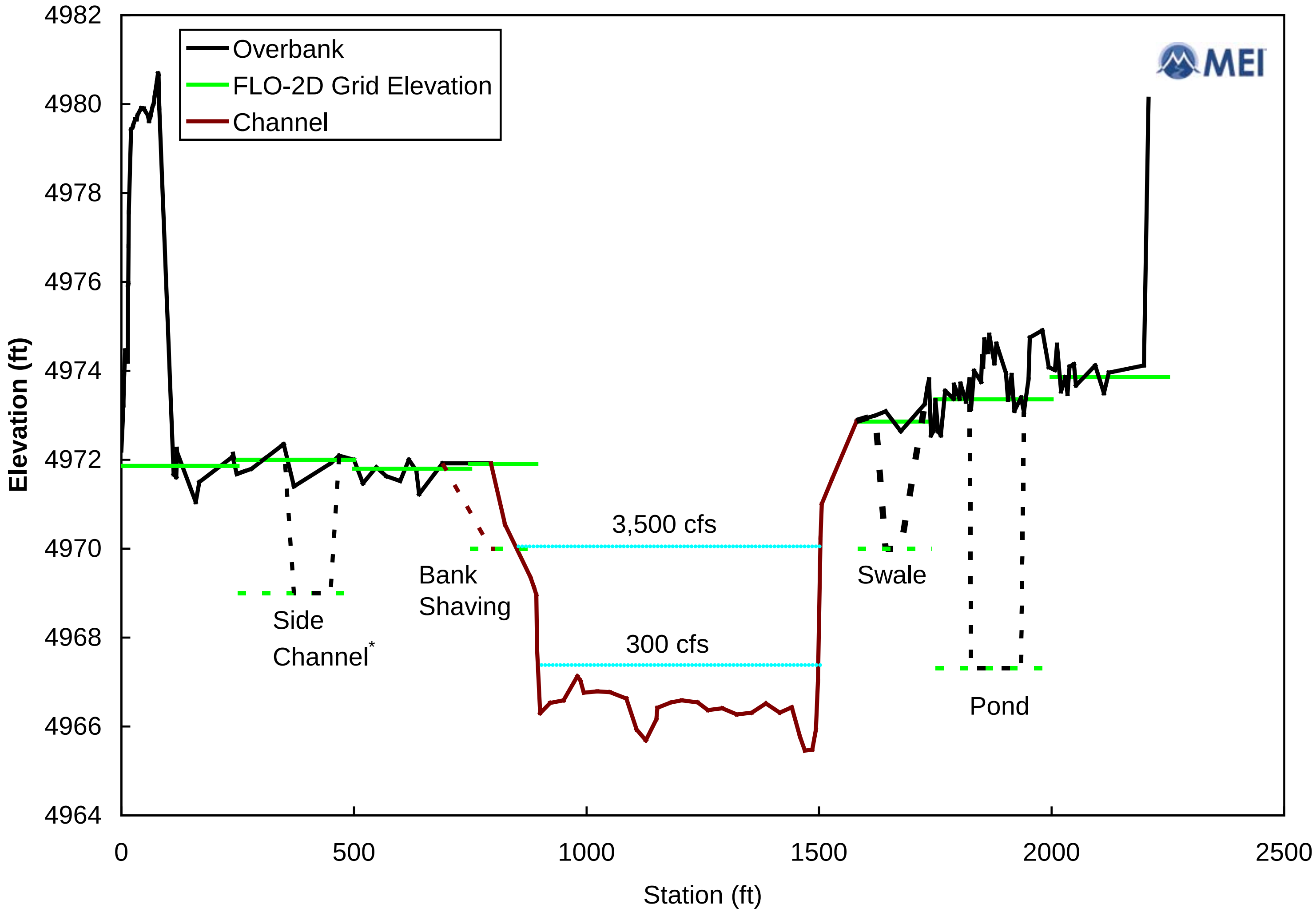

Figure 5- Schematic representation of FLO-2D grid modification to represent proposed alternatives.

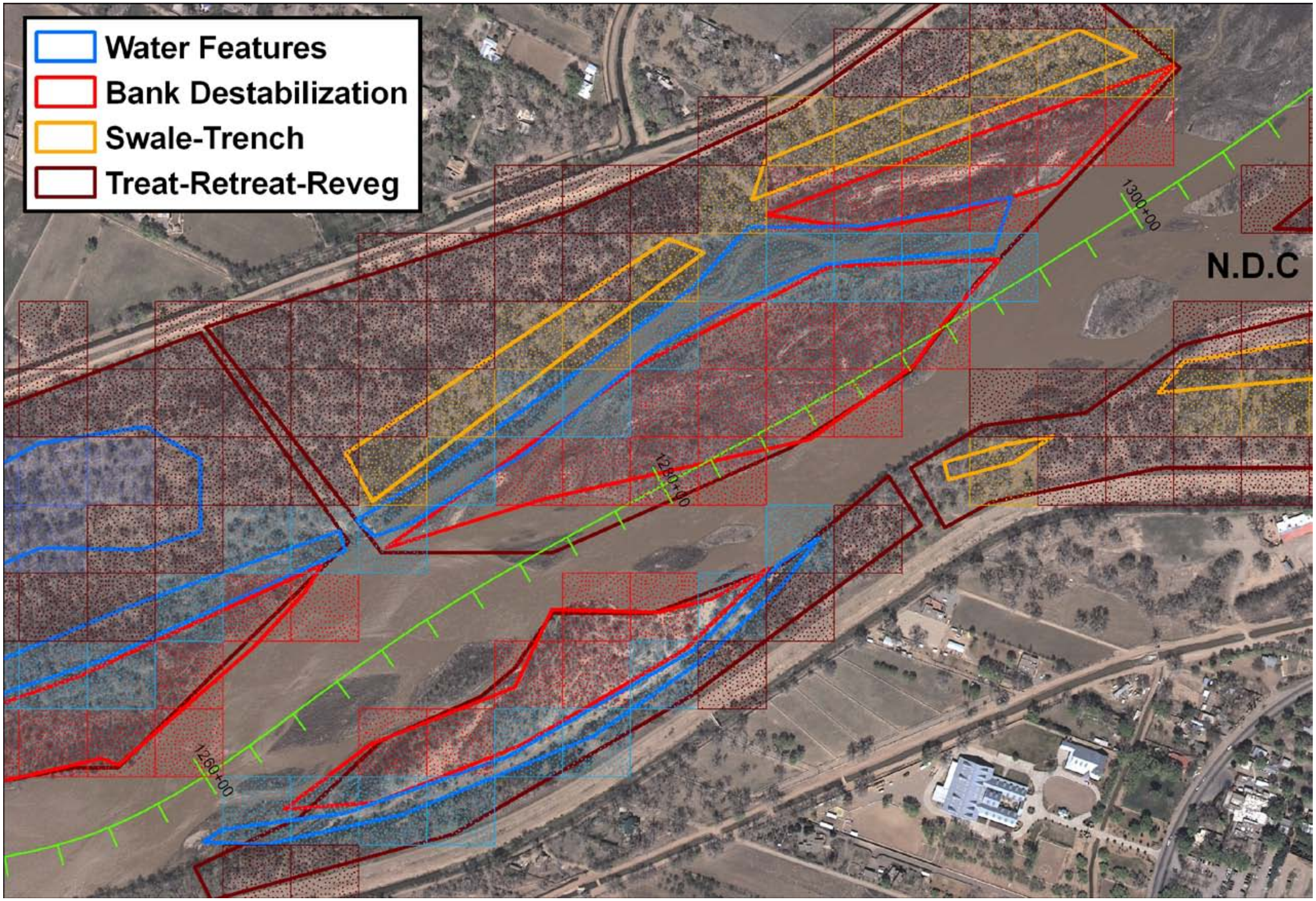

Figure 6 - Example of delineated FLO-2D grid elements used to represent the restoration alternatives in vicinity of the North Diversion Channel.

The channel widening caused by the embayments and bank destabilization features, and the associated increase in overbank flows, causes the channel water-surface elevations along the reach to decrease compared to the existing conditions. As a result, an iterative procedure was used to ensure that the designed restoration features are inundated at the desired 3,500 cfs water-surface elevations. The iteration procedure was conducted by running the Year 0 Restoration Alternatives at a discharge of 3,500 cfs and comparing the resulting water-surface elevation to the elevation of the design feature. If the difference between the design elevation and the predicted water-surface elevation was greater than approximately 0.05 feet, then the elevation of the design feature was adjusted to the new predicted water-surface elevation, and the simulation was re-run with the new design elevations. Typically, only one iteration was required for the design and water-surface elevations to converge within the specified tolerance.

The “Swale Trench Excavation” features are low-elevation features in the overbanks, designed to be connected to the groundwater. They are not hydraulically connected to the main channel when flows are sufficiently low to be contained within the main channel; therefore, no cross-section changes were made for these features.

The “Overbank Treat-Retreat-Revegetation” features represent the ongoing fuel reduction and non-native vegetation removal program that is being conducted. These programs involve clearing and re-vegetation of the overbanks. These features are represented in the FLO-2D model by adjusting the overbank roughness of the grid elements (**Table 3**). No elevation or cross-section adjustments were made for these features.

Table 3- Manning's n-values for delineated features for Years 0, 5, 20, 30, and 50.

Feature	Year 0	Year 5	Year 20	Year 30	Year 50
Water features (300 cfs)	0.040	0.050	0.060	0.060	0.060
Water feature (3,500 cfs)	0.040	0.050	0.060	0.060	0.060
Bank destabilization	0.055	0.100	0.100	0.100	0.100
Swale trench	0.050	0.065	0.100	0.100	0.100
Overbank treat-retreat-revegetation	0.040	0.075	0.085	0.085	0.085

The results of the Flo-2D Modeling including the inundation mapping for the entire reach are provided in the **H&H Appendix**.

Eichorst, K. D., M. C. Steuver, D. C. Shaw, and C. S. Crawford. 2001. Bosque Ecosystem Monitoring Program (BEMP): First Report: 1997-2000. University of New Mexico Open-File Report 01-1. Prepared in cooperation with Bosque School. Albuquerque, New Mexico.

III. GEOTECHNICAL

3.1. Geotechnical Information

3.1.1. Regional and site geology. Middle Rio Grande Bosque Restoration project boundaries fall within the Albuquerque Basin, along the Rio Grande. The Albuquerque Basin is bounded by the Sandia, Manzanita, and Manzano uplifts on the east, by the Lucero uplift and Puerco platform on the west, and by the southern end of the Naciemento uplift on the northwest. Small volcanoes and fissure flows mark the boundaries at several locations. The age of the rocks in the mountains ranges from Pre- Cambrian to Pennsylvanian. The Sandia Mountains are composed primarily of Precambrian granite overlain by an eastward dipping sedimentary sequence of Pennsylvanian age limestone. The western face of the Sandia Mountains is partially buried by alluvial fans to the west. The basin is filled with poorly consolidated Cenozoic deposits whose constituents were eroded from the uplands. These sediments have formed coalescing alluvial fans. The sediments that make up the fans are angular to subangular pieces of limestone that are deposited with sands, silts, and clays. The soil also contains large limestone cobbles and boulders. The fans generally grade into finer materials as one move westward toward the center of the basin. Sediments deposited along the floodplain of the Rio Grande consist primarily of silts and sands with clay and rounded gravels. These sediments have been transported from both the headlands to the north along the Rio Grande and from the Sandia Mountains to the east and were deposited/reworked in the area of Albuquerque. The stratigraphic relationships between different depositional environments are complex and soil/sediment types are not consistent over short ranges.

3.1.2. Exploration. Exploration was not completed specifically for this project, however explorations completed for the Rio Grande Floodway, Albuquerque Unit Evaluation Report (2009) lie in the same general region and are presented here. Sixty-three soil borings were advanced between June 8, 2006 and June 23, 2006 along the Phase II and Phase III portions of the Albuquerque Unit levees. Soil boring locations were chosen to give an overall condition of the levee and not isolate the worst locations. Spacing and locations of soil borings attempted to follow guidance presented in ETL 1110-2-569 “Design Guidance for Levee Underseepage”. Funding constraints and accessibility issues limited the number soil borings and their locations. Borings conducted on the crest of the levee were advanced to 30’ depth, except for soil borings 8HSA-63, 8HSA-65, and 8HSA-67 which were advanced to 45’, 40’, and 40’ respectively. Soil borings located at the toes of the levee were advanced to 15’ depth. Standard Penetration Tests (SPTs) were performed starting from the surface and at 2.5’ intervals to the bottom of the borehole. N values were recorded for each SPT, N values were used to determine relative density or consistency of the soils encountered. Soil samples recovered from each SPT, if possible, were sent to Amec’s soils laboratory for analysis. Lab analysis performed on soil samples included sieve analysis, Atteberg limits, and gravimetric moisture content. Soil samples were classified based on the Unified Soil Classification System. Boring locations map, boring logs, and laboratory analysis for the Phase II and Phase III Albuquerque Unit levees are provide in the Geotechnical appendix of this report.

3.1.3. Selection of preliminary design parameters. Applicable design parameters likely include shear strength parameters, such as friction angle and cohesion and permeability parameters. As values for these parameters will vary widely based on soil types, expected ranges are shown below:

Appropriate soil strength and permeability parameters were estimated using borehole profile gradations and correlations based on soil types from Table 3-1 “Typical Engineering Properties of Compacted Materials” in UFC 3- 220-03FA “Soils and Geology Procedures for Foundation Design of Buildings and Other Structures”.

3.1.4. Geophysical investigations. No geophysical investigations were performed.

3.1.5. Groundwater. No project specific groundwater studies were performed, however the groundwater table is this region is known to vary from near surface to approximately eight to ten feet below surface elevations depending on topography and season.

3.1.6. Recommended instrumentation. No instrumentation is recommended.

3.1.7. Seismic Analyses. As seismic design will not be required for this project, no seismic analyses were performed.

3.1.8. Preliminary foundation design and slope stability analysis. Foundations were not evaluated for the alternative selected. Foundations are minimal for the alternative selected. Slopes cut to 3 horizontal to 1 vertical are expected to be adequate.

3.1.9. Excavatability. Soils expected to be encountered during construction include sands, silts and clays and are expected to be relatively easy to excavate. Rock is not expected to be encountered and blasting will not be permitted. Dewatering efforts will be necessary for implementing portions of the alternative selected.

3.1.10. Anticipated construction techniques, limitations, and problems. Traditional machine excavation is expected to be used for project features, with adequate dewatering as required.

3.1.11. Potential borrow sites and disposal sites. Borrow material is not expected to be required. Disposal sites shall be per environmental requirements.

Parameter	Units	Value
Friction Angle	degrees	27-33
Cohesion	psf	0-150
Permeability	cm/s	10^{-8} - 10^{1}

3.1.12. Potential sources of concrete materials and results of materials investigations. Concrete materials, if required, are locally available at a variety of concrete plants.

3.1.13. Stone Slope Protection. Stone slope protection sources are not available on site and will have to be purchased locally as required.

3.2. Design Concerns. Soils on site are not ideal for water retention structures, but for the features proposed by the alternative selected, soils are expected to be suitable. Water levels in and around project features will be largely driven by seasonal ground water levels and periodic overbanking of the Rio Grande during spring run-off. Impacts to flood damage reduction structures due to activities associated with the Bosque Restoration Feasibility Projects have been evaluated. Water (head) at longer durations, at lower flows against a flood damage reduction structure could be considered a negative impact to the structure. The hydraulic modeling for the selected alternative indicates the majority of the projects do not cause an increase in the inundation duration at a lower flow. Projects which do cause longer durations at lower flows adjacent to the structures will require additional analysis during design to predict possible impacts to the structures. Negative impacts to the flood damage reduction structures may require additional protections added to the structure prior to the completion of the restoration project impacting it. The maximum design effort, but not the selected alternative, may cause negative impacts to flood damage reduction structures at various locations across the project reach. During bank full and the 100 year snowmelt flow levels, the levee is inundated at depths up to 4 feet for periods greater than 100 days in numerous areas. This may require protections added to the levee prior to the construction of the proposed feature creating the inundation. The selected design alternative does not create any inundation issues not already existing during bank full flows. It does create inundation areas not already existing during the 100 year snow melt flow, in some areas 3 feet deep for more than 50 days. Again, the inundated levee regions may require protections prior to construction of the proposed features causing the inundation, especially in areas where inundation can be expected to last several days or weeks.

3.3. Additional Exploration and Testing. The soils exploration and boring presented herein is not project specific and provides a general description of soils in the project reach. If features in the project are expanded to include berms, levee embankments, foundations or other earth structures not currently included in the project additional sampling and testing will be required. This will likely include drilling, SPT sampling, soil classification, Atterburg limits, shear strength and permeability testing. However, for the current project features, additional sampling is expected to be minimal.

3.4. Laboratory Program. No project specific laboratory testing was completed. Boring logs which include laboratory soil classification from the Albuquerque Unit.

IV- ENVIRONMENTAL ENGINEERING

4-01. The Middle Rio Grande Bosque Feasibility Study was planned in compliance with environmental engineering factors listed in ER 1110-2-1150. Since the project focus is ecosystem restoration, design of alternatives focused on the least impact to the environment while providing high quality habitat. The following sections describe how construction of the Proposed Action can be implemented to follow the ER.

4-02. Use of environmentally renewable materials. Part of implementation of the project includes planting of native vegetation. Native trees require protection of the bottom 5 feet. Trees should be protected with natural material that will grow with the tree and naturally disintegrate. Where possible, when soil is being excavated to create wet habitat, the top layer of soil can be saved and used to replant/reseed areas disturbed during construction (if it contains native vegetation).

4-03. Design of positive environmental attributes into the project. Since the project is an ecosystem restoration project, all attributes are designed to be positively environmental and improve the existing ecosystem.

4-04. Inclusion of environmentally beneficial operations and management for the project. Operations and management of the project should be mainly by the natural environment itself (the river, rain water, etc.). Project features have been designed to be fairly self-sustainable. When maintenance is required, it should be very light with limited equipment needs (even only shovels in some cases). Vegetation shall be planted correctly using the latest methods to allow for the greatest success and minimal to no maintenance.

4-05. Beneficial uses of spoil or other project refuse during construction and operation. Spoil will be created during excavation of water features within the project. Spoil can be used to build up access roads and/or be placed at the toe of the levee for reinforcement. This use of spoil has been employed in other similar projects with great success.

4-06. Energy savings features of the design. Construction of the project requires very little electrical power operated equipment. All construction can be implemented with gas powered equipment such as front end loaders, bobcats, trucks, etc. This equipment should be utilized in the most efficient manner possible.

4-07. Maintenance of the ecological continuity in the project with the surrounding area and within the region. This is one of the main goals of the project since it is an ecosystem restoration project. Features have been designed to fit in with existing habitat that does not require restoration.

4-08. Consideration of indirect environmental costs and benefits. Indirect costs and benefits were considered during the NEPA evaluation of the proposed action. Indirect benefits include improved habitat quality that provides an improved quality of life for adjacent property owners as well as wildlife. Indirect environmental costs are incurred during construction by an increase in noise and decreased air quality in the vicinity of equipment under operation. These indirect costs are temporary during construction only.

4-09. Integration of environmental sensitivity into all aspects of the project. Environmental sensitivity during construction is incorporated by implementing Best Management Practices (BMP's) throughout the duration of construction. Typical BMP's for work within the bosque would include (but not be limited to):

- All equipment would be inspected at least twice a day to ensure that oils, fuels, or lubricants are not leaking. All servicing and fueling of equipment would be conducted in a designated area hydrologically isolated from surface waters. Additionally, emergency spill kits would be placed in the designated fueling area to absorb and contain any accidental spills of fuels, lubricants, or other chemical contaminants.
- All herbicides would be applied according to manufacturer's specifications and label instructions.
- BMPs shall be enforced to prevent erosional inputs into the lake or wetlands. These BMPs shall include, but shall not be limited to: the use of silt fences adjacent to the lake or wetlands to prevent erosion into these waterways; fueling of vehicles shall not take place inside the wetlands; and equipment and vehicles shall be cleaned prior to entering and leaving the work site.
- A 401 water quality certification would need to be obtained from the New Mexico Environment Department. All requirements of this certification shall be adhered to during construction.
- Construction-related effects to air quality would be minimized by: 1) requiring the contractor to have emission control devices on all equipment; and 2) employing the use of Best Management Practices to control wind erosion, including wetting of soils within the construction zone and compliance with local soil sedimentation and erosion-control regulations. Construction and operation of the recommended plan would conform with air quality control regulations as established by the Clean Air Act and the New Mexico Air Quality Control Act.
- BMPs to minimize air quality disturbance shall be employed. These include tracking out of material by covering trucks to avoid fugitive dust violations; maintaining and sweeping public trails to keep them free of debris and dust; and wetting down work areas.
- All work areas shall be continually wet down to minimize dust. Any sediment deposited on the paved trail due to construction shall be swept as needed.
- All work shall be conducted outside of the bird breeding season to avoid destruction of active nests and mortality of young birds. Work shall only take place in the bosque September 1 through April 30.
- In order to minimize the potential for disturbing Bald Eagles utilizing adjacent habitat, the following guidelines shall be employed: If a Bald Eagle is present within 0.25 mile of the project area in the morning before activity starts, or arrives during breaks in project activity, the contractor is required to suspend all activity until the bird leaves of its own volition, or a USACE biologist, in consultation with the USFWS, determines that the potential for harassment is minimal. If this occurs, the contractor shall contact the Contracting Officer's Representative. However, if an eagle arrives once activity is underway, or if an eagle were beyond 0.25 mile of the site, activity will not be interrupted.

- If any previously-unrecorded cultural resources are encountered during construction, work at that location would stop and the USACE and State Parks archaeologists would be contacted.
- Construction contracts would require that construction equipment and activities comply with state and local noise control ordinances to minimize noise increases.
- In order to reduce the potential to transfer non-native vegetation seed, all equipment should be cleaned with a high pressure water hose before entering the site, between sites, and before leaving the site.
- The Contractor shall clean all previously used construction equipment prior to bringing it onto the project site. The Contractor shall ensure that the equipment is free from soil residuals, egg deposits from plant pests, noxious weeds, and plant seeds. The Contractor shall consult with the USDA jurisdictional office for additional cleaning requirements.
- Construction shall follow any other regulations required by Clean Water Act (CWA) 404 or other.

4-10. Environmental Review Guide for Operations. Respect to environmental problems that have become evident at similar existing projects, there are none.

4-11. Incorporation of environmental compliance measures into the project design. Any specific terms and conditions specified in the Biological Opinion or Fish and Wildlife Coordination Act Report (CAR) from the U.S. Fish and Wildlife Service shall be followed. This information will be provided to the Contractor. Any specific terms and conditions resulting from comments during public review of the Environmental Assessment shall be followed. This information will be provided to the Contractor. This includes any guidelines per CWA 404, 401 State Water Quality or other.

V-COST ESTIMATE

5-01. The estimated total cost for the Middle Rio Grande Ecosystem Restoration Project is $26,216,000 and is based on January 2010 prices. Of this amount, $24,900,000 is the Federal share while $1,316,000 is Non-Federal cost. Summary and detailed cost estimates are shown following this summary in MCACES Cost Estimate format. The Projects Costs shown below have been indexed for inflation (%) from the date of the MCACES of January 2010 to ?????. Federal and Non-Federal cost estimates contain Engineering and Design, Supervision and Administration and a contingency factor of ??%.

Table 4- Costs

Middle Rio Grande Bosque Feasibility Study-Cost Sharing October 2008 Price Level			
Item	Federal Cost	Non-Federal Cost	Total Cost
Ecosystem Restoration (ER)			
PED	$1,701,000	$0	$1,701,000
LERRD	$0	$1,315,974	$1,315,974
Ecosystem Restoration	$18,900,000	$0	$18,900,000
Subtotal	$20,601,000	$1,315,974	$21,916,974
Interest During Construction (48 months, 4.625%)	$2,035,400	$0	$2,035,400
Total ER Cost	$22,636,400	$1,315,974	$23,952,374
Recreation			
PED	$170,100	$0	$170,100
LERRD	$0	$0	$0
Recreation Features	$1,890,000	$0	$1,890,000
Subtotal	$2,060,100	$0	$2,060,100
Interest During Construction (48 months, 4.625%)	$203,500	$0	$203,500
Recreation Subtotal	$2,263,600	$0	$2,263,600
Total Project First Cost	**$24,900,000**	**$1,315,974**	**$26,215,974**
Annual Cost	$1,285,706	$67,950	$1,353,656

VI-DESIGN AND CONSTRUCTION SCHEDULE

6-01. General

Table 5- Schedule Prior to Design

Item	Date
Approve Feasibility Study	18 Nov 20010
Negotiate PPA	19 Nov 2010
Sign PPA	5 May 2011

6-02 Design. The Albuquerque District upon signing of the PPA will begin with the design of Reach 1. The plans and specifications will include the completion of design and the design documentation report for features associated with each reach. The schedule for the reaches is listed below.

Table 6- Schedule for Design

Reach	Beginning Date	Completion Date
1	August 2010	May 2011
2	August 2011	May 2012
3	August 2011	May 2012
4	August 2012	May 2013
5	August 2012	May 2013

6-03. Construction. Environmental considerations allow for construction to occur during the period of 1 September through 30 May, therefore some reaches will take two periods to complete construction.

Table 7- Schedule for Construction

Reach	Construction Award	Duration
1	August 2011	12 months
2	August 2012	12 months
3	August 2012	12 months
4	August 2013	24 months
5	August 2013	24 months