Ecosystem Revitalization @ Route 66, Albuquerque, New Mexico
Section 1135 Project

Technical Appendices

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Section 1.

Introduction and Background

1.0 Introduction – Purpose and Need

1.1 Study Authority

This feasibility study is being conducted under the authority of Section 1135(b) of the Water Resources Development Act (WRDA) of 1986 (Public Law 99-662). The objective of this authority is to improve the quality of the environment through modification of the structure or operation of existing water resources projects constructed by the U.S. Army Corps of Engineers (Corps), providing such modifications as are feasible and consistent with the original project purpose. Improvements in ecosystem structure and function in areas adversely affected by such projects are also included in this study.

1.2 Background and Problem Identification

Water resource management activities (for example, diversions, dams, levees, drains, channelization and jetty jack installation) by Federal agencies and other entities, as well as ongoing urbanization, have significantly altered the hydraulic function and ecological health of the Rio Grande within New Mexico. Jemez Canyon and Cochiti dams, operated for flood and sediment control by the USACE, also have contributed to degradation of ecosystem functions and values. These water and sediment control structures were part of flood control and irrigation projects that began in the 1930's. See Figure 1-1 for the Study Area.

These measures, compounded by increased urbanization, have had severe impacts on the Rio Grand Bosque system and its attendant wetland and riparian woodland communities. The result is a river running through a deep and narrow channel surrounded by dense woodland consisting largely of non-native trees that is threatened by wildfire. The quality of the habitat has also decreased significantly due to the lack of diversity in plant life, lack of riparian niches, and the declining health of the native cottonwood overstory. Recognition of the poor state of health of the bosque, the U.S. Army Corps of Engineers and the local sponsor, the Middle Rio Grande Conservancy District, have initiated a restoration plan to address these issues.

1.3 Study Purpose and Scope

The purpose of this Section 1135 Program Technical Appendix is to accompany the feasibility report referred to as the "Detailed Project Report and Environmental Assessment for the Bosque Revitalization at Route 66" to which this report is an appendix. This Technical Appendix contains the findings and supplemental reports of the evaluation of existing conditions of the study area, the analyses of the goals as expressed by the sponsor and integrated with the USACE Section 1135 requirements, and preliminary plans for the proposed project.

The purpose of this study is to determine the advisability of undertaking environmental restoration measures to improve the Rio Grande bosque ecosystem function in central Albuquerque. Potential alternatives include removing jetty jacks and non-native vegetation, such as salt cedar, Russian olive and Siberian elm, enhancing existing high-flow channels, outfall wetlands and other alterations of the floodplain. Improvements of existing facilities for educational, interpretive and low-impact recreational uses have also been considered in the Route 66 Project. The Study began in 2002, and a scoping letter was sent to all relevant Federal, State and local agencies, as well as a number of non-governmental organizations and miscellaneous other stakeholders with ongoing projects in the bosque. A copy of the scoping letter is included in Appendix C of the main document.

Section 2.

Existing Conditions

2.0 Existing Conditions

General-The Study Area is situated in the Albuquerque Basin of the Rio Grande Rift Valley (Crawford et al. 1993. The valley formed as crustal tension beginning in the Tertiary Period (ca. 35 million years ago) along the Rio Grande Rift, created a series of fault-bordered valleys, including the Albuquerque Basin. Volcanism and erosion from adjacent uplands filled the valley with thousands of feet of alluvial sediments, lava, and ash (Chronic 1987). The current floodplain of the Rio Grande in the Study Area consists of fine-grained alluvial silts, sands, and gravels. Soils derived from these deposits in the Study Area are Torrifluvents, Calciorthids and Torriorthents (Soil Conservation Service 1974). Elevation in the Study Area ranges from 4,950 feet to 5,050 feet above mean sea level. Average total annual precipitation at the Albuquerque Airport is 8.70 inches and average annual snowfall is about 10.4 inches. Average total annual precipitation at Bernalillo is 8.86 inches and average annual snowfall is about 6.9 inches.

Geomorphology-Currently within the Study Area, the Rio Grande is predominantly a sand bed river with low, sandy banks. There are numerous sandbars, and the river channel tends to be straight due to jetty jack fields and levee placement (Crawford et. al. 1993). In this area, the river is typified by a uniform channel width averaging approximately 600 feet. Approximately two feet of degradation has occurred in the Albuquerque reach (due to flood control measures upstream) with no significant change in bed material (Mussetter, 2002). The slope of the river bed is less than 0.01 feet per foot (Tashjian 1999). At flows less than the bankfull, the river is establishing a sinuous configuration within the cleared floodway.

The riverbed is changing from one of fine silt particles and sand to coarse sands and gravel. This is a result of the fine sediments becoming trapped by upstream dams and removed in downstream reaches by hungry water. The current place of this transition is just above the Alameda Bridge (personal communication, Drew Baird) which is approximately 7 river miles above the USBOR Study Area. Over time, it is expected that the transitional area will continue to move downstream, accelerating the channel degradation process.

Hydrology- The hydrology of the Middle Rio Grande has been well documented. There are numerous reports that provide a good summary of the data collected. Among these reports are the MRGBBMP and Bio-Park Project (USACE 2003b). These two reports provide the basis for most of the text within this section.

Most of the hydrologic flow data collected within the Middle Rio Grande, as well as throughout the country, is provided by the United States Geological Survey (USGS). The USGS maintains a series of surface water gauging stations to record discharge data over time.

Although considered a perennial river prone to major floods, there are reaches of the Middle Rio Grande that currently experience no surface flow during some summer months in dry climatic periods. It is likely that in certain “dry” years, this was the case prior to man’s settlement of the area as well.

As discussed in Section 2. of the DPR/EA, construction of reservoirs, jetty jack fields, and levees for flood control was initiated beginning in the early 1900s. The Middle Rio Grande hydrology has been altered dramatically by the flood control facilities. A review of annual peak series data also exhibits the influence of flood control. Historical annual peak discharges recorded at the Albuquerque gauge illustrate the effects of regulation on the Rio Grande.

A review of annual peak series data also exhibits the influence of flood control. An earlier study (USACE 2002) presents a discussion of the data collected at the San Felipe gauge. The report states that from 1927 to 1945 floods in excess of 20,000 cfs were experienced approximately every five years. From 1945 to the construction of Cochiti Dam in 1973, floods in excess of 10,000 cfs were fairly common with the exception of drought years. Following construction of Cochiti Dam, regulation has prevented flows from exceeding 10,000 cfs (USACE

2002). While this data is for an area upstream of the Route 66 Project, the flood control activities have has similar affects within the Study Area.

Additional evidence of this fact is presented in a study by the USBOR Flood Hydrology Group (Bullard and Lane, 1993). The goal of this study was to determine the effects of regulation on Middle Rio Grande hydrology. The study developed a procedure to estimate discharge values for regulated (with dam) and unregulated (pre-dam) conditions.

The USBOR Flood Hydrology Group study included flood flow data up through 1988. An independent analysis was conducted as part of the Santa Ana Project (USACE 2002). This new analysis included peak flows through 1996 and served to verify that the data provided by Bullard and Lane is valid for the current conditions.

The last major flood in the Study Area was in 1941, and the existing mature cottonwoods' age structure is heavily weighted toward that season. As a result of higher-than-normal snowfall in 1985, there was an excess amount of water in Cochiti Lake, which allowed limited overbank flooding to occur throughout much of the Study Area for about one week. In 1992, flows of 6,320 cfs inundated a large portion of the bosque between Central Avenue and Bridge Boulevard on the east bank. Since 1941, there have been fourteen years with an annual peak of 7,000 cfs or more at Albuquerque that surely also inundated the overbank locations in the Study Area. Flood control dams have acted to reduce discharges by approximately a factor of two. This is significant in that channel-forming processes are assumed to be dominated by discharges within the range of the recurrence intervals shown on the table. The current effective discharge at the Albuquerque gauge was determined to be 5,500 cfs (USACE 2002).

The actual flood flow capacity of the Rio Grande is determined by the location, size, and strength of the levee system and natural features such as terraces, mesas, and rock outcrops which collectively define the boundaries of the floodway. The channel capacity, on the other hand, is the river channel's bank-to-bank flow capacity within the floodway. In the Middle Rio Grande, water managers extend the concept of channel capacity to include overbank flows to the point where they do not cause damage to the levees or to other structures in the floodway (Crawford et.al 1993). Within the Middle Rio Grande, the reach through Albuquerque has the highest flood flow capacity: 20,000 cfs for sustained (spring) flows and 42,000 cfs for short duration (summer) flows. At the other extreme is the reach in the Corrales area on the east side, and between Albuquerque and Isleta on both sides of the river. In these areas the flood flow capacity is generally only 7,500 cfs (USACE 1989). Recently completed work on the Corrales levee has likely increased this capacity. However, the amount is unidentified.

Although the drainage area increases as one proceeds downstream within the Middle Rio Grande, annual water yield decreases (Graf 1991). From 1895 to 1985 the average annual inflow into the Middle Rio Grande Valley, as measured at the Otowi gauge, is about 1,050,000 acre-feet; at San Marcial the average annual flow is 820,000 acre-feet. This amounts to a decrease of approximately 23 percent (Graf 1991). The difference between inflow and outflow can be accounted for by surface-water evaporation, consumptive use by crops, evapotranspiration by riparian vegetation, and groundwater recharge (Ong et. al 1991). While the magnitude of the average annual yield has likely changed since that study, and the percent reduction in annual yield may have changed, the trend is still apparent today.

Plant Communities-A major change in vegetation dynamics in the bosque ecosystem has been loss of meander cut-off, meander migration, and flood scour processes, which were a driving force in the dynamics of the naturally functioning system. These processes removed existing vegetation and created new sites for founding of plant communities. Sediment deposition in the project area is now restricted to a few, largely ephemeral, mid-channel bars and transitory lateral bars proximal to the river. Meander cut-off and lateral meander migration no longer occur. Bare soil sites are now created primarily through mechanical disturbance or fire, typically in areas no longer subject to periodic inundation and with relatively dry soil moisture regimes (Pittenger 2003,).

Nonnative plant species have become prominent in the bosque. Salt cedar (*Tamarix ramosissima) is* now a prominent colonizer of exposed, bare soil sites in the bosque (Smith *et al.*, 2002). Salt cedar produces seed for several months beginning in spring whereas cottonwood (*Populus deltoides wislizenii)* produces seed only for a short time in the spring and seed remains viable for only about month and a half under ideal conditions (Ware and Penfound 1949, Horton et al., 1960). The flowering and fruiting phenology of salt cedar allows seedlings to establish on and dominate open sites wetted by runoff, rainfall, or river flows during the summer, precluding the possibility for cottonwood establishment on potentially suitable sites the following spring.

Fire was virtually unknown in naturally functioning, low-elevation riparian ecosystems of the Southwest (Busch and Smith, 1993; Stuever, 1997). However, fuel accumulations coupled with mainly human-caused ignitions have introduced fire as a major disturbance mechanism in the *bosque* ecosystem (Stuever, 1997). While cottonwood is highly susceptible to fire-induced mortality, salt cedar re-sprouts vigorously following fire (Busch and Smith, 1993; Busch, 1995). Native cottonwood and willow (*Salix* species) are poorly adapted to fire and lack an efficient post-fire re-sprouting mechanism such as that found in salt cedar (Busch and Smith, 1993). Post-fire soils typically have significantly higher salinity than soils of unburned areas, which may suppress growth of cottonwood and willow seedlings and allow establishment of salt cedar seedlings (Busch and Smith 1993).

Russian olive (*Eleagnus angustifolia) is* established by seed in the understory of mature cottonwood stands and also colonizes openings along the river, often forming dense stands (Hink and Ohmart, 1984; Sivinski *et al.*, 1990). Russian olive is shade tolerant. Seeds germinate in moist to dry sites and the plant sprouts readily from the root crown after damage to or removal of above-ground portions of the plant (Sivinski *et al.*, 1990). Russian olive was present in the bosque in 1981 (Hink and Ohmart, 1984) and continues to increase in the understory of the cottonwoods in the Study Area (Sivinski *et al.*, 1990).

Several other nonnative tree species, in addition to salt cedar and Russian olive, are at least locally common, if not abundant. These species are Siberian elm, tree of heaven (*Ailanthus altissima*), and Russian mulberry (*Morus alba* var. *tatarica*). All three species are shade-tolerant and readily colonize disturbed sites (Crawford et al., 1996; Sivinski et al., 1990). Siberian elm was rare in the bosque in 1981 when it was found only at very low densities, ranging from less than 1.2 trees/ha (0.5 trees/ac) to 7.4 trees/ha (3 trees/ac; Hink and Ohmart, 1984). However, Siberian elm had become increasingly abundant by 1990 (Sivinski *et al.* 1990) and is now very common in the overstory. This species produces large seed crops and is ubiquitous in the Study Area as seedlings, saplings, and mature trees. It sprouts readily from the root crown. Siberian elm seed will germinate under normal rainfall conditions and does not require moist or saturated soils (Sivinski et al., 1990). Tree of heaven and Russian mulberry are more localized in their distribution in the Study Area than salt cedar, Russian olive, or Siberian elm. Both of these species typically colonize disturbed areas, such as along levees and in severely burned sites (Sivinski et al., 1990).

The following description of vegetation in the Study Area uses plant community designations developed by Hink and Ohmart (1984) and mapping by Sivinski and others (1990), updated with mapping completed in 2002 (U.S. Bureau of Reclamation) and observations made in the field in spring 2003. Hink and Ohmart (1984) defined six structure types based on vertical foliage density. Structure type I consists of tall trees (ca. 50 ft) with a relatively dense understory of saplings and shrubs. Type II structure is also composed of tall trees but with little or no sapling and shrub understory. Type III structure consists of mid-size trees (less than 30 ft) and dense understory vegetation. Type IV structure is characterized by open stands of mid-sized trees with widely scattered shrubs and sparse herbaceous growth. Type V structure is dense, short-stature trees and saplings, to about 15 feet height, often with dense herbaceous growth. Type VI structure is scattered plant growth with foliage not exceeding about five feet in height above the ground. Based on 1990 mapping, vegetation in the project area was dominated by old (structure type I, 51.5%) and very young (structure type VI, 34.3%) stands, with little vegetation in the middle structural categories. Structure type V stands, which have higher density of shrubs and saplings than type VI, covered about 130% of the Study Area. Structure types II, III, and IV combined made up only 0.3% of the

vegetation in the Study Area in 1990. In 2002, the U.S. Bureau of Reclamation resurveyed the area using the Hink and Ohmart methodology. By 2002, non-native species had moved into the understory, and smaller trees grew into Type I, II or III stands and changed the structure types as follows: Type I – 59.4%, Type II – 19%, Type III – 2%, Type IV – 4.5%, Type V – 14.5%, and Type VI – 0.6%. In 2003, part of the Study Area was burned in a fire (south of I-40 on both sides of the river) and efforts to thin other areas of the bosque within the Study Area were undertaken as a fire prevention strategy. Based on the changes from the fire and thinning that occurred, structure types were converted as follows: Type I – 0%, Type II – 74%, Type III – 2%, Type IV – 4.5%, Type V – 14.5%, and Type VI – 5%. This is the current status in the Study Area.

Type II stands in the project area consists of mature, closed canopy stands dominated by Rio Grande cottonwood (*Populus deltoides wislizenii*) and Siberian elm. Cottonwood dominated 89.4% of the type II stands, while Siberian elm was the dominant overstory tree in at least 10.6% of the type II stands. However, Siberian elm was present in the overstory and understory of all cottonwood-dominated type II stands in the project area. Much of the non-native understory of Russian olive, salt cedar and Tree of heaven was removed during the thinning in 2003-2004. Other nonnative trees found in the Study Area as minor components of the vegetation were Russian mulberry, northern catalpa (*Catalpa speciosa*), black locust (*Robinia pseudo-acacia*), Osage orange (*Maclura pomifera*), and green ash (*Fraxinus pennsylvanica*). Most of these species were left during thinning efforts.

Although typically not as abundant as nonnative species, native shrubs and trees were also found in the understory of type II stands. Gooding's willow (*Salix goodingii*) and New Mexico olive (*Forestiera neomexicana*) were found scattered throughout the project area in type II stands. These species were locally common, often at well-lighted sites in canopy gaps and along the edges of closed-canopy stands. Golden currant (*Ribes aureum*) was also locally common in dense patches. Virginia creeper (*Parthenocissus inserta*) was common throughout the understory and false indigo bush (*Amorpha fruticosa*) was found scattered throughout the understory of type II stands. The recently thinned type II stands were sparse in understory vegetation, but Russian olive, salt cedar and Siberian elm sprouts are prevalent along with the native understory shrubs listed above. The remaining type V and VI stands were dominated by saplings of tree species or by riparian shrubs. Cottonwood-dominated type V and VI stands occurred at two sites, both of which were pole planting areas.

By July 2004, understory thinning for fire prevention had converted most of the type I stands to type II stands, which are characterized by little understory vegetation. Type VI stands (open areas) increased in coverage as a result of mechanical clearing**.**

Water Quantity- It is estimated that the average annual water loss due to evapotranspiration (ET) in the Middle Rio Grande riparian corridor accounts for 20-50% of that reach's total water depletion (Dahm et.al., 2002). Bosque ET appears to be higher in dense stands of salt cedar and Russian olive than it is in less dense stands of salt cedar and mature cottonwood stands with few understory trees (Dahm et.al., 2002). The project area contains large areas that are predominantly Structure Types I and IV with understories comprised mostly of salt cedar. It has been estimated that ET in the most dense portions of the project area equals approximately 562.6 acre feet annually.

Water Quality- Water quality in the Rio Grande in the Study Area is characterized by relatively high turbidity and slight to moderate alkalinity (Pierce 1989). Average total suspended and total dissolved solids concentrations in the Rio Grande in the Study Area are about 7,000 mg/l and 250 mg/l, respectively (Crawford et al. 1993). Designated uses for the Rio Grande in the Study Area are irrigation, limited warm water fishery, livestock watering, wildlife habitat, and secondary contact (20.6.4 New Mexico Administrative Code §105). Relevant surface water quality standards for this reach include a maximum average monthly total dissolved solids concentration of 1,500 mg/l when flows are greater than 100 cfs.

Water quality in the Rio Grande through the Study Area is impacted by fecal coliform contamination, municipal point sources, urban runoff, and storm sewers (Surface Water Quality Bureau 2002). There are three major storm sewer outfalls to the Rio Grande in the Study Area. Two of these outfalls are located on the east side of the river between the Bridge Street and Central Avenue crossings. The third outfall is located near the old Atrisco Diversion on the west side of the river between the Central Avenue and I-40 crossings. Contaminants introduced to the Rio Grande from these outfalls include solid waste, oils, pesticide and herbicide residues, phosphorous, nitrogen, and fecal coliform (Tague and Drypolcher, 1979;.

Air Quality-Bernalillo County is currently designated as a "maintenance" area for carbon monoxide (CO) and "attainment" for all other pollutants regulated by National Ambient Air Quality Standards (NAAQS). Prior to 1992, the standards for CO were exceeded on numerous occasions in the Albuquerque metropolitan area. The NAAQS for CO include a maximum 1-hour average concentration of 35 parts per million (ppm) and a maximum 8-hour concentration of 9 ppm. Previous violations of the CO standards were generally attributed to mobile sources (e.g. vehicle exhaust) and residential wood burning. However, as a direct consequence of several national and local air quality improvement strategies, no violations of the CO standards have occurred in the county since 1991 (D. Warren, personal. communication, 11 April 2003).

Another potential pollutant of concern in Bernalillo County is particulate matter, which includes particles smaller than 10 microns (PM_{10}). According to the City's Environmental Health Department, the County has historically recorded exceeding of the federal 24-hour standard for PM_{10}, and in 2002, the County came close to exceeding the annual threshold for PM_{10}. PM_{10} issues in the area are generally attributed to windblown dust arising from lands disturbed by human activities (D. Warren, City of Albuquerque, pers. comm., 11 April 2003). To address the potential concerns associated with PM_{10}, the COA and County have adopted a fugitive dust control ordinance which requires construction activities disturbing more than three-quarters of an acre to obtain a fugitive dust control permit and prepare a dust control plan as part of the project.

Bernalillo County is in attainment for particulate matter smaller than 2.5 microns ($PM_{2.5}$), sulphur dioxide, nitrogen oxide, and lead. Levels of sulphur dioxide and lead are so low that they are not monitored by the county (D. Warren, City of Albuquerque, pers. comm., 11 April 2003).

Noise-The Study Area currently receives noise from a variety of sources both within and outside of the bosque. Current noise sources originating within the bosque are attributable to: 1) machinery and vehicle operation; 2) humans; and 3) wildlife and domestic animals. The first group, machinery, creates the loudest sounds. Noise from machinery is often very loud and continuous over long periods of time in certain areas. In other places, it is relatively low-level and intermittent or does not occur at all. Noise sources emanating from outside the bosque but that can be heard in the bosque include the three sources previously mentioned as well as sounds of traffic on nearby bridges and roads.

Generally, there is a fair amount of noise that is generated by people and machinery within and outside of the bosque on a daily basis, particularly in warmer months when there is more activity in the area. Noise from outside the bosque is somewhat buffered within the bosque in areas of dense vegetation and in areas furthest from roads and bridges.

Section 3.

Description of Preferred Alternative

BOSQUE RESTORATION
Albuquerque, New Mexico

3.0 Description of Preferred Alternative

The Preferred Alternative represents the most cost-effective aggregation of restoration features by Solution Area in the overall Study Area for the Route 66 Project. An Incremental Cost Analysis (Section 5.E. in the Technical Appendix) was used to generate Best Buy Plans from which Best Buy Plan # 5 was selected and combined with the proposed recreational features to become the Preferred Alternative. The ecosystem restoration features of the Preferred Alternative are provided below in **Table 3.1 Summary of Preferred Alternative**. Through implementation of the Preferred Alternative, five out of eleven Solution Areas; totaling approximately 121 acres of bosque, will be restored by enhancing hydrologic function and restoring native vegetation. In addition, recreational use of the bosque would be improved by creating 22,500 linear feet of trails with benches, signs and other interpretive features.

Table 3.1 Summary of Preferred Alternative

Area Solution	Feature	Type	Quantity		Total HUs Created*	Water Feature HUs	Bosque Feature HUs	Shrub Feature HUs
D	1.4	Jetty Jack Removal	87	jetty jacks				
	3.3	Dump Removal	27,906	cubic yards				
	5.4	High-Flow Channel	0.92	acres	0.46			
	7.4	Bosque Patch	8.2	acres	8.2			
	7.5	Bosque Patch	9.61	acres	9.61			
	Totals				**18.27**	**0.46**	**17.81**	**0**
E	1.5	Jetty Jack Removal	278	jetty jacks				
	3.4	Dump Removal	23,477	cubic yards				
	5.5	High-Flow Channel	1.63	acres	1.63			
	6.5	Swales	4	acres	4			
	7.6	Bosque Patch	9.52	acres	9.52			
	7.7	Bosque Patch	8.37	acres	8.37			
	8.15	Shrub Thicket	3.39	acres	3.39			
	8.16	Shrub Thicket	3.17	acres	3.17			
	Totals				**30.08**	**5.63**	**17.89**	**6.56**
F	1.6	Jetty Jack Removal	287	jetty jacks				
	2.3	Vegetation Removal	24.75	acres				
	5.4	High-Flow Channel	0.92	acres	0.46			
	6.6	Swales	2.5	acres	2.5			
	7.8	Bosque Patch	8.98	acres	8.98			
	8.17	Shrub Thicket	3.25	acres	3.25			
	8.18	Shrub Thicket	3.1	acres	3.1			
	8.19	Shrub Thicket	3.05	acres	3.05			
	Totals				**21.34**	**2.96**	**8.98**	**9.4**
H	1.8	Jetty Jack Removal.	80	jetty jacks				
	2.5	Vegetation Removal	25.01	acres				
	3.6	Dump Removal	7,964	cubic yards				
	4.5	Outfall Channel	0.96	acres	0.96			
	5.6	High-Flow Channel	2.56	acres				
	6.9	Swales	1.5	acres	1.5			
	7.11	Bosque Patch	8.72	acres	8.72			
	7.12	Bosque Patch	9.59	acres	9.59			
	8.21	Shrub Thicket	3.31	acres	3.31			
	Totals				**24.08**	**2.46**	**18.31**	**3.31**
J	1.1	Jetty Jack Removal.	355	jetty jacks				
	2.7	Vegetation Removal	27.27	acres				
	3.8	Dump Removal	35,555	cubic yards				
	5.6	High-Flow Channel	2.56	acres	2.56			
	6.3	Swales	5.5	acres	5.5			
	8.23	Shrub Thicket	3.41	acres	3.41			
	8.24	Shrub Thicket	3.32	acres	3.32			
	8.25	Shrub Thicket	3.35	acres	3.35			
	8.26	Shrub Thicket	3.2	acres	3.2			
	8.27	Shrub Thicket	2.69	acres	2.69			
	8.28	Shrub Thicket	2.85	acres	2.85			
	Totals				**26.88**	**8.06**	**0**	**18.82**
	Total HUs: 120.65					**19.57**	**62.99**	**38.09**

* High-Channels that are shared between two Solution Areas are only counted once with respect to Cost and Habitat Units

3.1 Bosque Revitalization at Route 66 Project Design Considerations

The overarching goal of this Section 1135 Project is to improve the Rio Grande bosque ecosystem and function within the project area. In developing the proposed restoration project the following recommendations were considered:

- Increase the number and diversity of native bosque patches
- Improve the diversity and quality of water-related habitat
- Restore fluvial processes
- Increase and extend areas of potential habitat for listed species
- Reduce fire hazard
- Improve recreational facilities and preserve habitat by developing formal trails and closing the many user-made trails through the bosque

The Preferred Alternative, see the summary table (Table 3.1) was developed to address these recommendations through the features described below.

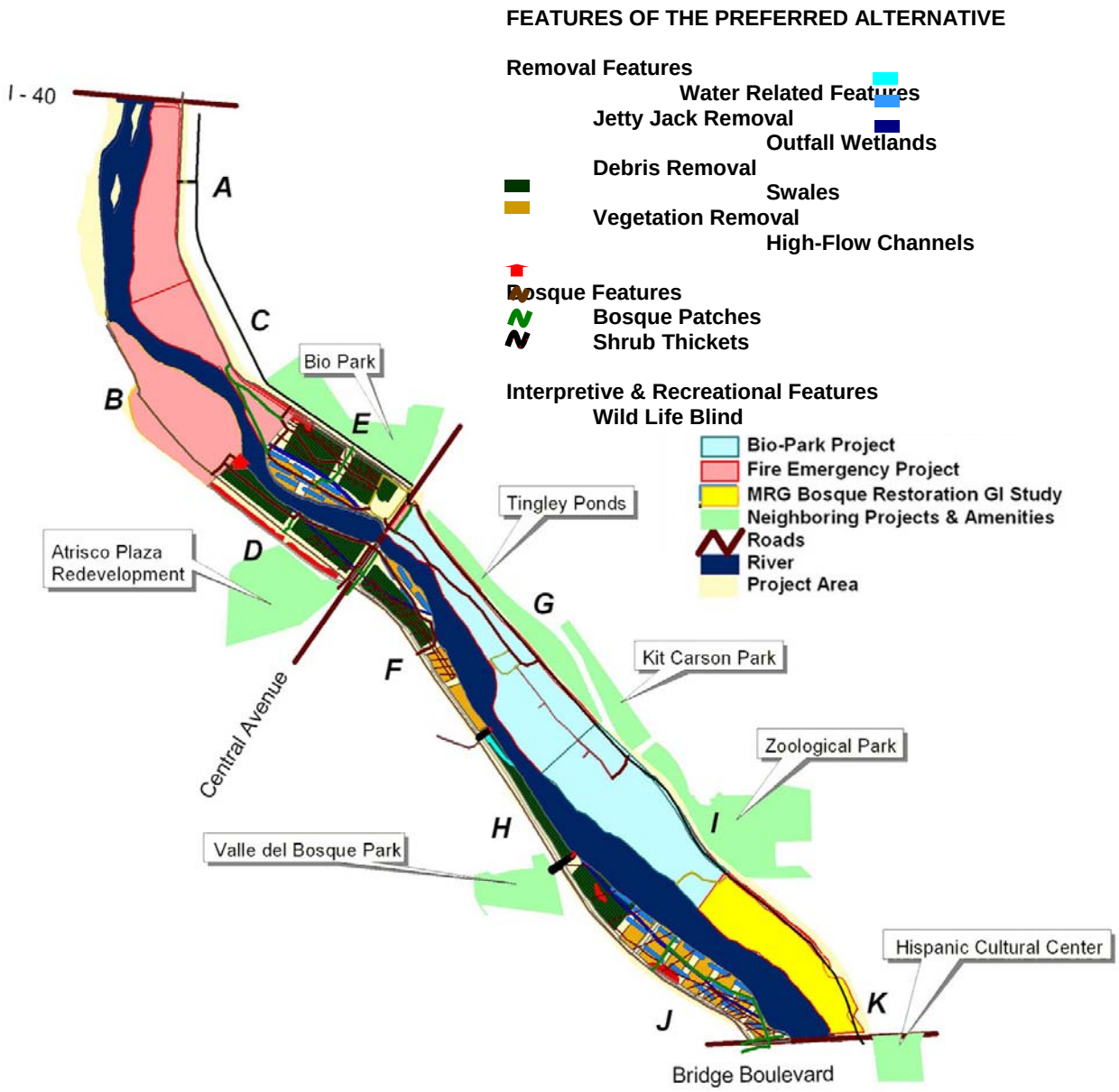
Removal Features

- **Jetty Jacks -** Since their installation, jetty jacks have performed their function of stabilizing the banks of the river and catching sediment. As part of the Study, jetty jacks were analyzed in regard to how essential they were for bank protection and what impact there would be if they were removed. It was determined that some of the jacks still performed an essential function and others are obstacles. The recommendation was to remove the 1087 non-functional jetty jacks in order to facilitate the removal of non-native vegetation and dumped debris. Another important reason for removing the non-functional jetty jacks was to make it easier to mobilize fire fighting and emergency vehicles into the bosque. An added benefit is the removal of dangerous obstacles for recreational users of the bosque.

  Initial analysis indicate that work within the floodplain will not have an adverse impact on the levee system. Future analysis will be done during the pre-construction engineering and design phase to determine impacts on the bridges, which should prove negligible.

- **Non-native vegetation and Dumped Debris -**Over the years approximately 136,000 cubic yards of debris has been dumped in the bosque. Although determined to not hold any hazardous or toxic materials, the debris presents an aesthetic challenge and is thought to encourage continued dumping, therefore the recommendation is for it to be removed.

  Perhaps one of the greatest opportunities of the project is to significantly reduce the non-native vegetation. Approximately 77 acres of non-native vegetation will be removed, thereby decreasing fire hazard and allowing native species to re-establish.



Water-related features

Approximately 19 Habitat Units would be created by the project through development of the three feature types described below. Moist soil areas are critical for catalyzing some of the native revegetation processes of the bosque and improving the overall habitat of the bosque.

- **High-flow Channels -**Three high-flow channels will reconnect the river to the bosque, creating almost six acres of habitat units. The channels will flow creating moist soil conditions for moisture seeking plants and the wildlife they attract. Design of the channels will be coordinated with final alignments of trails to create potential refuge areas by limiting access by recreational users.

- **Outfall Channel** - A single wetland is proposed at the Sunset Irrigation Outfall to take advantage of the opportunity presented by periodic flows during irrigation overflow and cleanout events to create a moist soil substrate for native moisture seeking plants.

- **Swales** - Thirteen habitat units will be provided by the creation of swales in the proposed project to improve and increase habitat in the Study Area. During times of high ground water such as spring run-off and monsoonal rains, these depressions will become ephemerally wet encouraging the establishment of moisture seeking plants such as reeds, sedges, rushes. Coyote willows, peach leaf willows and other bosque shrubs and occasional cottonwoods will thrive on the edges of these moisture rich locations.

Bosque Features

Once the jetty jacks, the debris and the non-native vegetation are removed and moist soil areas are re-established in the Study Area, revegetation can begin. The overall goal of revegetation is to establish a mosaic of shrub thicket, and bosque forest, punctuated by fire break meadows. In order to improve habitat quality, every effort will be made to increase the edge effect and the density of shrub thickets which provide both food and shelter for wildlife.

- **Bosque Forest** - Cottonwoods and mid-canopy trees such as black willow, and peachleaf willow, New Mexico olive and New Mexico locust will be planted. These native trees will revitalize the bosque forest habitat. Continued maintenance will help to ensure that the native trees are not out-competed by salt cedar, Russian olive and Siberian elm trees.

- **Shrub thickets** - Twelve shrub thicket patches are proposed which together add up to almost 38 acres. The patches of shrub thickets are planned to correspond to Hink and Ohmart's vegetation structure V. Most of the shrub thickets will be planted in areas adjacent to the river, on the river bars and along the high-flow channels. The shrub thickets will contain native shrubs such as golden currant, threadleaf sage, amorpha, screwbean mesquite with coyote willows, and seep willows in the moister areas.

- **Water related vegetation** - The water-related features are to be complimented by plantings of native plants. Rushes, salt grass, yerba mansa and other moist soil loving plants will further improve the riparian habitats created by the outfall wetland, and the high-flow channels.

Interpretive and recreational features

The interpretive and recreational features are important, not only for their tremendous potential for educating visitors, but also because over 40,000 linear feet of undesignated trails will be reclaimed and replaced by approximately 22,500 linear feet of new trails. Eight thousand six hundred linear feet will be soft surface and 13,900 linear feet will be stabilized for accessibility. These and the proposed interpretive features will be designed as construction documents are developed, below are brief descriptions of these elements.

- **Stabilized Crusher Fines Trail** - Approximately 6,700 linear feet of stabilized crusher fines trails are proposed. These trails would be the primary circulation system within the bosque and would loop up to the levee. Most of this new trail would be found in the vicinity of Central Avenue, in order to accommodate and limit the impact of primary access points for most users of the bosque in this portion of the Rio Grande Valley State Park.

- **Soft Surface Trail** - Approximately 23,000 linear feet of soft surface trails are proposed. These trails would create loops, and in some cases connect the levee to the river. They would be constructed out of crusher fines to give them a material edge and permanence.

- **Boardwalk** - Two boardwalks are proposed for the Study Area. Both are located on the west side in Solution Area H, which is extremely narrow. These boardwalks would be at the same level as the levees and in the canopy of the bosque. They would extend out to the river, permitting passive recreational and

educational users to access the river and have another kind of experience of the bosque at the tree level without compacting soils or disturbing wildlife.

- **Bridge** - A single drain-crossing bridge is proposed to connect the Bernalillo County Valle del Bosque Park across to the bosque, thereby enabling the park to accommodate parking and more active recreational users.

- **Wildlife Blind** - A single wildlife blind is proposed for the south bank of the wasteway for the Atrisco Header. The soils are often moist in this area, with significant number of birds, and there is a tremendous view out onto the river with the Sandia Mountains in the background.

- **Benches** - Twenty benches are proposed to provide seating for users of the trail system. The benches are proposed to be set out along the trails and the levee approximately every quarter mile.

- **Signage** - Twenty signs are also proposed to provide educational and interpretive moments as users move through the bosque. They would help people to understand how the bosque functions and what has transpired in this particular portion of the bosque.

- **Seeding with native grasses and forbs**, such as Indian rice grass (Oryzopsis hymenoides), galleta grass (Hilaria jamesii), side oats grama (Bouteloua curtipendula), blue grama (Bouteloua gracilis), sand dropseed (Sporobolus cryptandrus), sun flower (Helianthus annuus) and in wetter areas, yerba mansa (Anemopsis californicus), emory sedge (Carex emoryi), and salt grass (Distichlis stricta). Seeding involves sowing seed via methods such as broadcasting, crimp and drill or hydro-mulching. Other than the gel in the hydro mulch, no irrigation will be applied. Timing of reclamation seeding will be critical to the establishment of the vegetative cover.

- **Bare root container or plug planting with native shrubs**, such as peachleaf willow (Salix amygdaloides), New Mexico olive (Forestiera neomexicana), four wing saltbush (Atriplex canescens), chamisa (Chrysothamnus nauseosus), false indigo (Amorpha fruticosa) golden currant (Ribes aureum), three leaf sumac, woodbine, and in wetter areas, coyote willow (Salix exigua), black willow (Salix nigra var. gooddingii), and Seepwillow (Baccharis salicifolia) will be an important strategy for establishing woody plants. Bare root planting refers to planting a plant with a hydro-gel application on its roots directly in the ground. Container planting refers to planting small plants from containers, and plug planting refers to planting small seedlings. The juvenile plants will be planted as bare root with hydro gel (a.k.a. Dri-Water™). Hydro-gel refers to containers filled with water-absorbing gel particles that absorb water and then slowly release it to plants over time. Containers of gel are placed around the root zone of the plant at the time of planting. Replacements or refills of the containers may be necessary once or twice per growing season during the time of establishment (generally, two years). Coyote willows can also be planted in wet areas as bundles of live sticks.

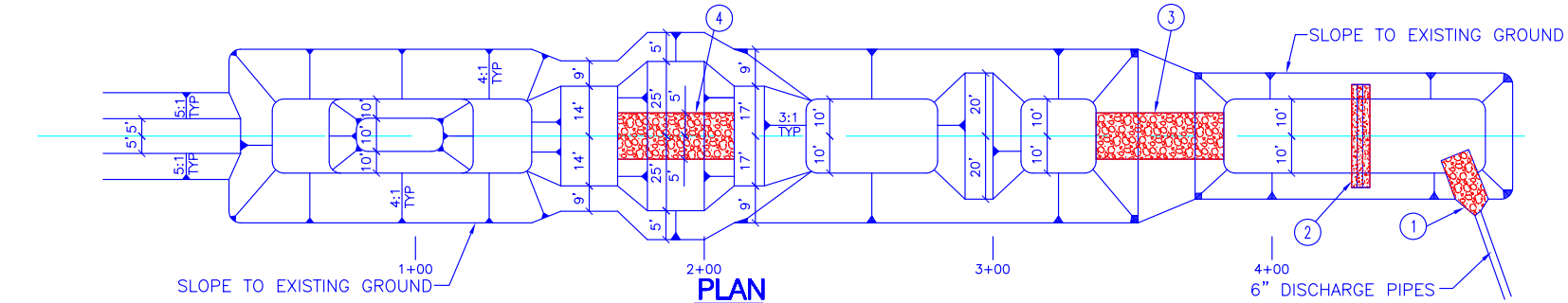
- **Pole planting of native trees**, such as the Rio Grande cottonwood (Populus fremontii var. wislizenii), black willow (Salix nigra var. gooddingii) and peachleaf willow (Salix amygdaloides). Pole planting is the technique most frequently used in the restoration of riparian areas. Many of the pilot projects in the bosque have utilized pole planting, and according to AOSD, they have a 90 percent success rate (conversation with O. Hummel, 2002). Branches of cottonwoods and willows, 10 feet to 15 feet in length, are slipped into holes that have been augered through the soil to the water table. Little maintenance is required beyond taking precautions to protect the young trees from beavers.

Section 4.

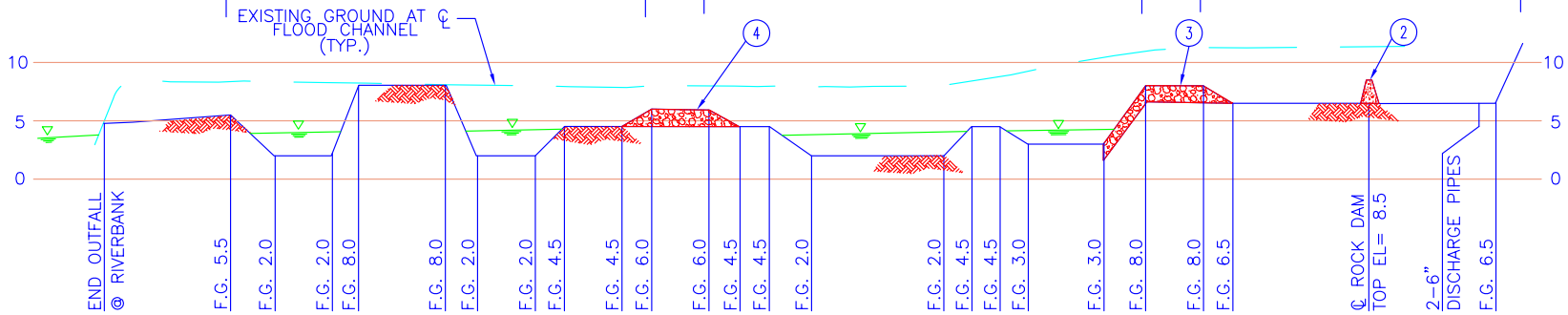
Engineering Analysis (Feasibility Study Level)

The following technical appendix section includes backup documentation of basic conceptual features of the preferred solution. Included are sketches and concept engineering plates for the moist soil depressions (MSD's), high flow channels, and the Sunset Road Irrigation Outfall. These engineering calculation sheets are for those solutions that involve features of excavation, backfill, stabilization, riprap, and piping. These solutions and their locations are described in detail in Section 4: Plan Formulation and Evaluation Process.

4.1 Engineering Plates



PLAN



PROFILE

GENERAL NOTES:

1. TYPICAL POND SIDE SLOPES ARE 4:1, UNLESS OTHERWISE NOTED.
2. EXCAVATION GRADE TOLERANCE IS ± 0.25. HORIZONTAL LOCATION TOLERANCE IS NOT CRITICAL AND WILL BE DETERMINED AT TIME OF CONSTRUCTION.
3. NUMBER OF WETLAND PONDS WILL VARY BY LOCATION.

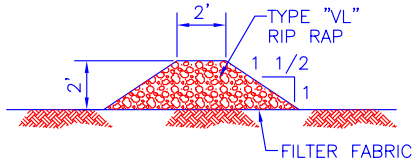
KEYED NOTES:

(1) CONSTRUCT TYPE "VL" RIP RAP, 10'W x 20'L x 24" DEEP AT PIPE OUTFALL.

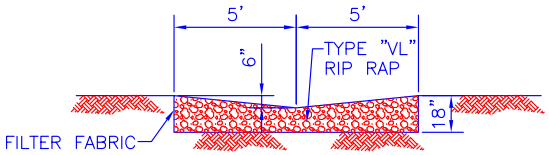
(2) TYPE "VL" RIP RAP DAM 35' LONG X 2' HIGH. (SEE DETAIL A, THIS SHEET.)

(3) TYPE "VL" RIP RAP CHANNEL. (SEE DETAIL B, THIS SHEET.) SLOPE ENDS TO MATCH POND SLOPES, BOTH ENDS.

(4) TYPE "VL" RIP RAP CHANNEL. (SEE DETAIL B, THIS SHEET.)



DETAIL A



DETAIL B

United States Army Corps of Engineers

Dolomite ▲ Riedel

BOSQUE REVITILIZATION @ ROUTE 66	
TYPICAL OUTFALL CONCEPTUAL DESIGN	
DRAWN BY: L.M.R.	DATE: 08/18/2005
CHECKED BY: S.A.	PROJECT NO. 030077.006.-.GAW

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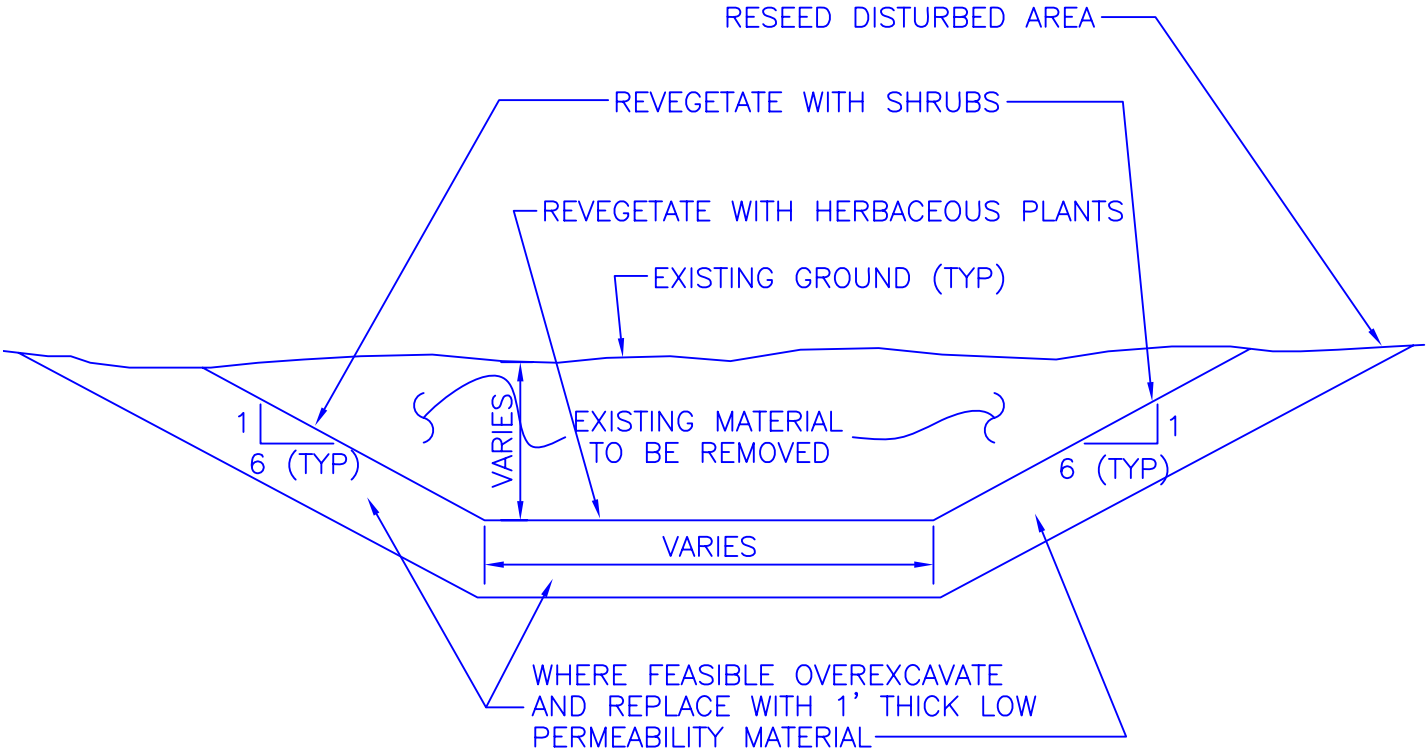
Nov 09, 2005 - 8:16am



TYPICAL SECTION

NOTES

1. EXISTING SAND MATERIAL (TYP) TO BE REMOVED.
2. BANK AREAS TO REMAIN WHERE EXISTING SIDESLOPES AND ACCEPTABLE (NATIVE) VEGETATION ARE ESTABLISHED.

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BOSQUE REVITILIZATION @ ROUTE 66

HIGH FLOW CHANNEL TYPICAL SECTION CONCEPTUAL DESIGN

DRAWN BY:	L.M.R.	DATE:	08/18/2005
CHECKED BY:	S.A.	PROJECT NO.	030077.006.–.GAW

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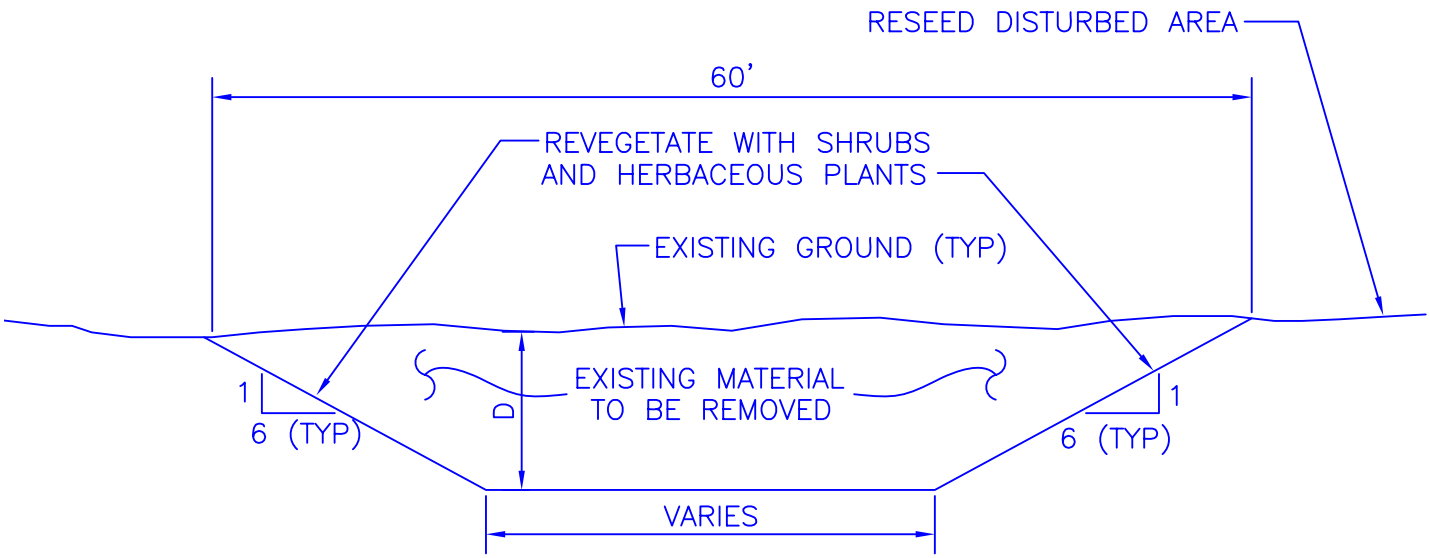

MOIST SOIL DEPRESSION AREA	DEPTH 'D' (FT)
SOUTH PRESERVE 1	6.7
CENTRAL NE	7.5
CENTRAL SW	7.4
SOUTH PRESERVE 2	6.7

TYPICAL SECTION

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BOSQUE REVITILIZATION @ ROUTE 66

MOIST SOIL DEPRESSION TYPICAL SECTION CONCEPTUAL DESIGN

DRAWN BY:	L.M.R.	DATE:	08/18/2005
CHECKED BY:	S.A.	PROJECT NO.	030077.006.–.GAW

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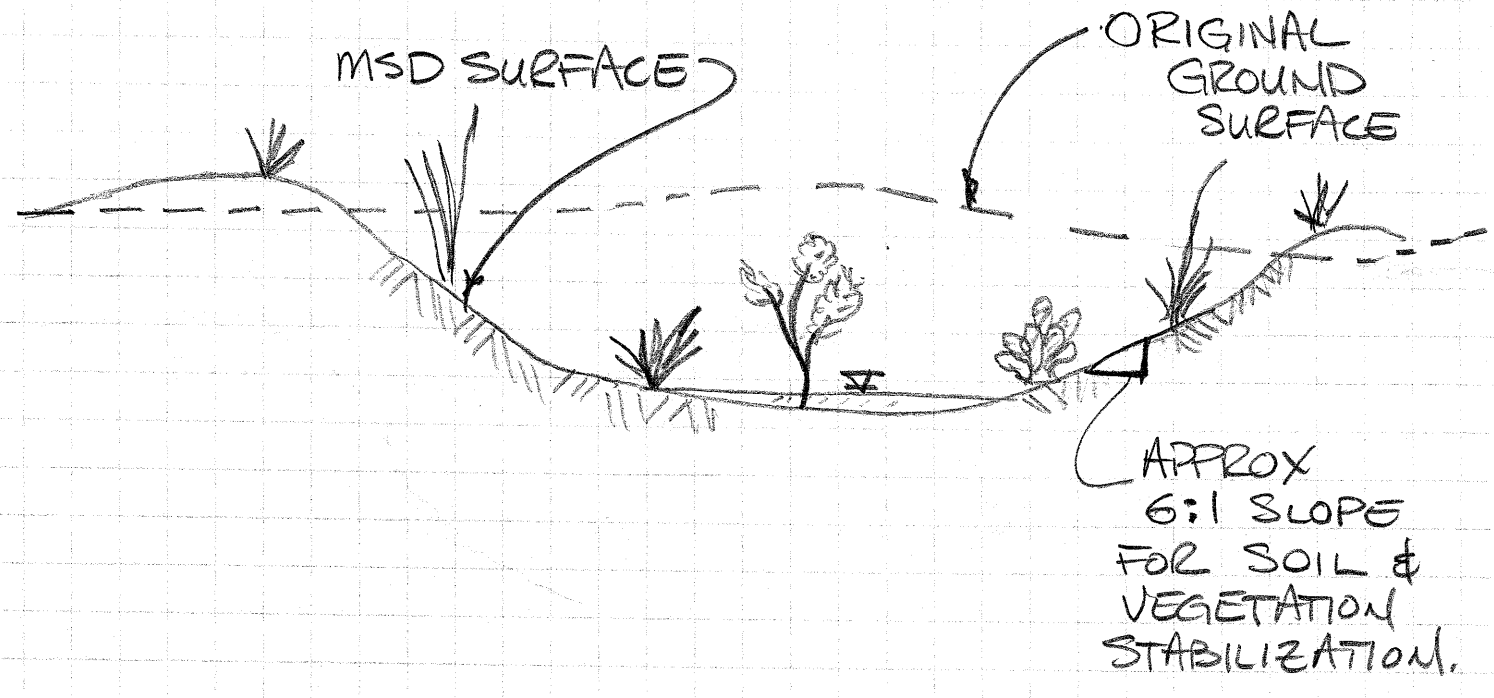
09, 2005 – 8:16am

4.2 Engineering Features – Concept Sketches and Notes

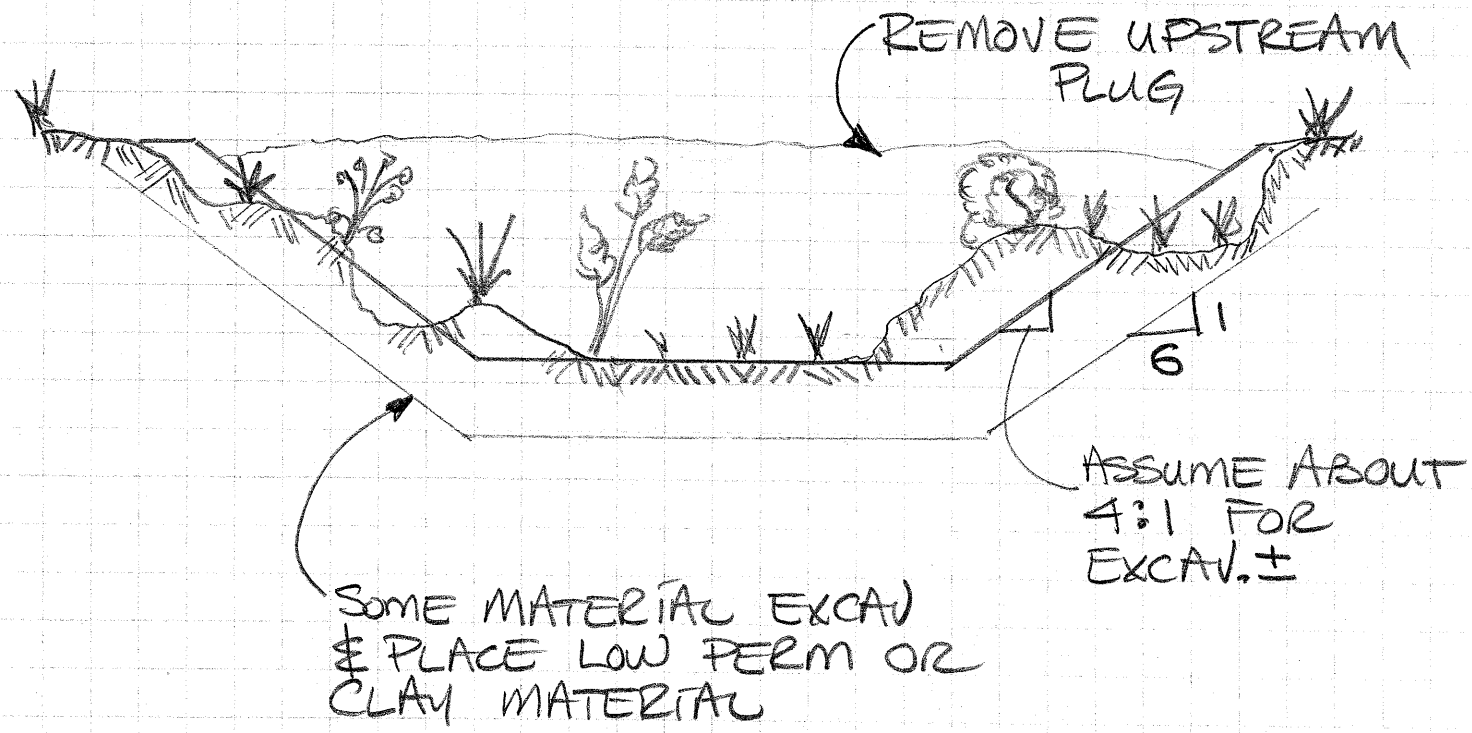
MOIST SOIL DEPRESSIONS (MSD)

CONCEPT PROVIDES SOME DEPRESSION AREAS OR BOWLS TO HOLD SOME MOISTURE FOR SHORT PERIODS. PROVIDES ENHANCED VEGETATION, AND WATER FOR ADDED/IMPROVED HABITAT



HIGH FLOW CHANNEL

PER CONCEPT, THE EXISTING "HIGH FLOW" CHANNELS WILL PROVIDE SOME ADDITIONAL "WET HABITAT" FOR THE PROJECT. THE IMPROVEMENT REQUIRES:

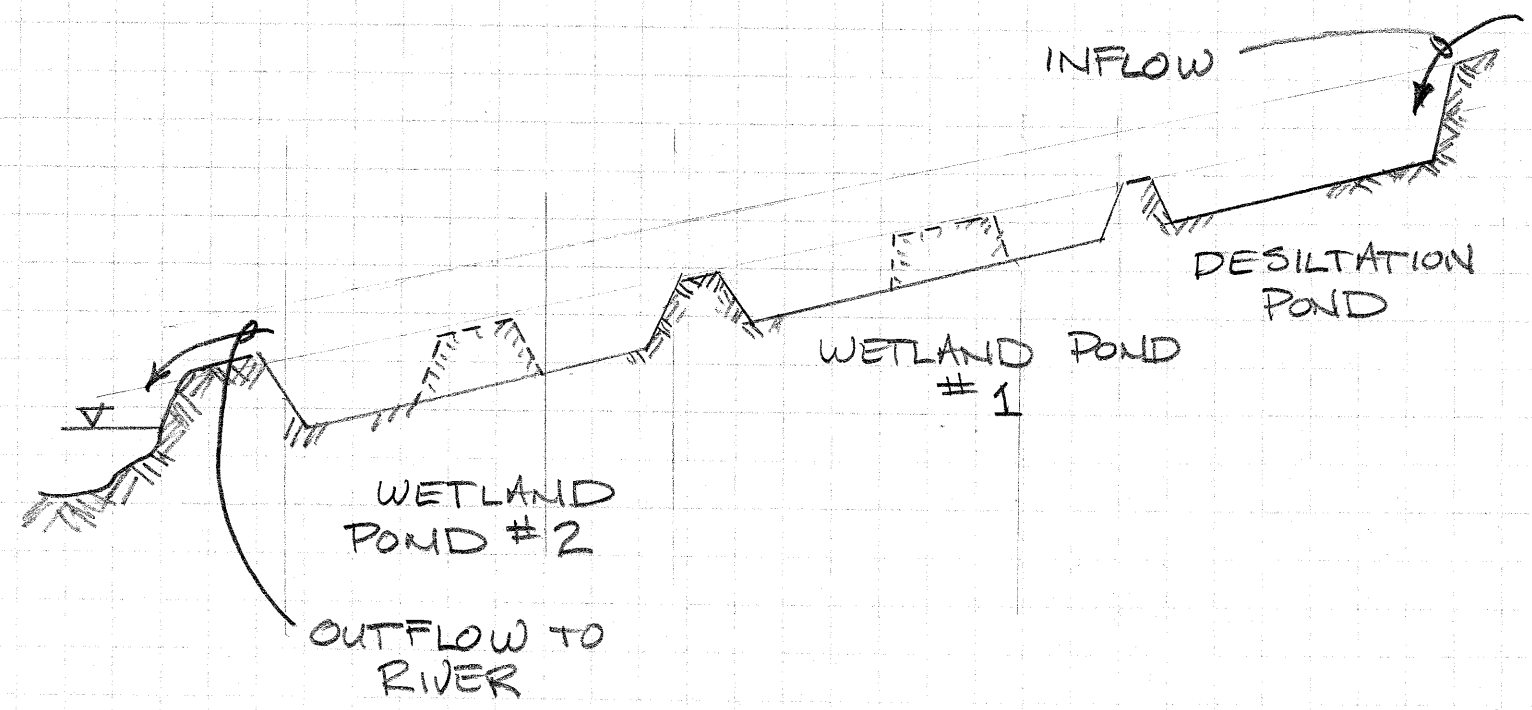


ASSUME REVEGETATION IN CHANNEL AREA & SOME RESEEDING ALONG BANKS.

SUNSET ROAD OUTFALL CHANNEL
OUTFALL WETLAND HABITAT IMPROV.

CONCEPT:

SIMILAR TO OSAGE/LA MEDIA OUTFALL WETLAND PLAN. PROVIDES WETLAND HABITAT.



SUNSET OUTFALL WILL HAVE TYPICAL DEWATERING, BACKFILL & COMPACTION, RIP-RAP, LINER, FILTER FABRIC AND MINOR HYD STRUCTURE. AREA IS ALREADY EXCAVATED SO ONLY 25% OF EXCAVATION VOLUME REQD FOR NEWLY CONSTRUCTED PONDS IS ASSUMED.

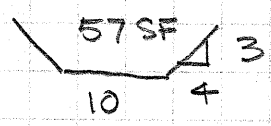
QUANTITIES COMPUTED BASED ON OSAGE/LA MEDIA CONCEPT.

SUNSET ROAD OUTFALL QUANTITIES
"CONCEPT"

① DEWATERING - APPROXIMATE LENGTH FOR DEWATER ≈ 600 LF

② SEDIMENTATION POND - EXCAVATION
120' x 40' x 2' VOL = 360 CY

OUTFALL - EXCAVATION



x 100 LF VOL = 220 CY

WETLAND PONDS - EXCAVATION
150' x 70' x 2 VOL = 780 CY.

TOTAL EXCAVATION = 360 + 220 + (3 x 780)
= 2920 CY

EXCEPT THAT THIS AREA IS ALREADY EXCAVATED. ASSUME ABOUT 25% WILL NEED TO BE RE-EXCAV, MOVED, ETC

VOL = .25 x 2920 = 730 CY

③ BACK FILL & COMPACTION
"ISLANDS" IN PONDS
40' x 20' x 2' VOL = 60 CY
TYPICAL EMBANKMENT
70' x 2' x 70' VOL = 375 CY
FOR 3 AREAS (DESILT + 2 ea WETLAND PONDS)

(60 + 375) x 3 = 1305 CY

Section 5.

Literature Cited

Assessment of Ecological Processes, Historical Reference Conditions, and Existing Ecological Situation for the *Bosque* Ecosystem Restoration at Route 66 Project, Rio Grande from I-40 to Bridge Street, Albuquerque, Bernalillo County, New Mexico

21 August 2003

Prepared for:
Bohannan-Huston, Inc. and the
U.S. Army Corps of Engineers, Albuquerque District

Prepared by:
John Pittenger

Blue Earth Ecological Consultants

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1.0 ECOLOGICAL PROCESSES

Riparian plant communities are typically described in terms of their structure (*e.g.* Hink and Ohmart, 1984; Szaro, 1990; Milford *et al.*, 2003). Structure, with respect to vegetation, comprises the plant species present, their relative abundance, and their spatial relationships, such as vertical height and horizontal coverage (Rejmánek, 1977). The structure of riparian vegetation is an expression of ecological processes that create and maintain environmental gradients such as soil moisture, duration of inundation, sediment deposition, and light levels. These gradients in turn influence the distribution and abundance of individual plant species (Gleason, 1926; Austin, 1987). Discussion of the processes that create a mosaic of riparian vegetation patch types is necessary to adequately describe probable historic, natural vegetation conditions and assess existing vegetation patterns in the context of ecosystem restoration.

1.1 Major Ecological Processes Influencing Riparian Vegetation

Important native woody riparian plant species in the project area are Rio Grande cottonwood (*Populus deltoides wislizenii*), Goodding's willow (*Salix gooddingii*), and *Salix exigua*, coyote willow (Hink and Ohmart, 1984; Durkin *et al.*, 1995). Studies related to ecological processes that influence riparian vegetation specific to the project area are few (*cf.* Crawford *et al.*, 1993). However, riparian plant communities dominated by *Populus* and *Salix* are widespread in alluvial river ecosystems throughout the world and there is a considerable body of literature pertaining to ecological processes that influence these communities. Because of the similarity in dominant woody species composition, this information is applicable to the project area.

Three interrelated processes, all associated with surface water flow (Poff *et al.*, 1997), exert major influences on riparian vegetation in alluvial river systems (Brinson *et al.*, 1981: 17-26; Malanson, 1993:75-114). These three processes are:

> ***Channel dynamics***, or fluvial-geomorphic processes, that include sediment movement and storage, bar formation, meander migration, and channel abandonment;
>
> ***Moisture regime*** including soil moisture, saturation, hydroperiod (*i.e.* duration of inundation), and depth to ground water; and
>
> ***Flooding*** including physiological and mechanical effects on plants as well as channel dynamics (*e.g.* avulsion) and moisture regime (*e.g.* inundation) effects.

The influence of these three processes on the structure of riparian vegetation in meandering, alluvial stream systems is discussed below.

1.1.1 Channel Dynamics Channel dynamics in alluvial, meandering river systems are the patterns of erosion and deposition that create morphological features such as point bars, cut banks, meander scrolls, oxbows, and mid-channel bars (Allen, 1965). Point bars and cut banks develop from lateral and downstream migration of meanders. Sediment is eroded from cut banks and is deposited on bars. Erosion at cut banks functions to remove riparian vegetation and change sunlight, soil, and water table conditions along the cut-bank edge (Kupfer and Malanson, 1992). Mid-channel bars are sediment deposits initiated by channel obstructions or disequilibrium between sediment supply and sediment transport capacity (Leopold *et al.*, 1964: 295). The rate of meander migration is a major determinant of the proportion of floodplain riparian vegetation in various successional states, and thus of vegetation diversity (Johnson *et al.,* 1976).

Deposition of sediments on point bars and mid-channel bars provides bare soil sites for establishment of pioneer species such as cottonwood and willow. *Populus* and *Salix*, under favorable soil moisture conditions, have long been known to rapidly colonize bare depositional sites in the active floodplain of alluvial rivers (*e.g.* Watson, 1912; Ware and Penfound, 1949; Noble, 1979; Harris, 1987; Karrenberg *et al.*, 2002). Shull (1922) noted formation of a mid-channel bar in the Mississippi River by deposition, beginning in 1919, of what was locally known as "cottonwood soil" (*cf.* p. 202, a "light-colored sandy silt"). Over a period of six years a dense stand of cottonwood developed on the newly-deposited sediments. Cottonwood and willow seedlings comprised initial plant communities on barren first-, second-, and third-level topographic surfaces of the South Canadian River in Oklahoma (Hefley, 1937) and on point-bar deposits in the Missouri River (Johnson *et al.*, 1976). Hughes (1990) described *Populus ilicifolia* as an important component of pioneer vegetation on bare surfaces of point bars in the Tana River, a large alluvial stream in southeastern Kenya.

Bare-soil mesic or hydric sites may also be created by cut-off sections of channel bends abandoned by meander migration, typically referred to as oxbows (Leopold *et al.* 1964: 317). Similar to sediment deposits, recently-formed oxbows provide bare, open sites for establishment of cottonwood and willow (Brady *et al.*, 1985; Shankman, 1993). Oxbows may contain standing water if they intersect the local ground water table or if they receive frequent surface-water input. In these situations, submerged or emergent hydrophytic plant species typically become established (Van Cleave, 1935; Hefley, 1937). Meander scrolls are remnant point-bar deposits of past meander migration. These features are evidenced by sequential ridges and depressions on the floodplain surface. The topographic diversity of meander scrolls effects depth to the water table and soil moisture regimes, which in turn influences riparian plant community composition, as discussed below.

1.1.2 Moisture Conditions Soil moisture levels and depth to ground water on floodplain sites are influenced primarily by surface topography, the variation of which is created through fluvial-geomorphic processes (Malanson, 1993: 99; see above). The limits of riparian vegetation are controlled by depth to the water table (Hughes, 1990). Moisture in upper soil layers is a primary influence on establishment of tree species while ground water levels are important for their persistence (Dawson and Ehleringer, 1991).

Soil moisture has a major influence on seed germination and seedling survival of *Populus* (Moss, 1938; Bradley and Smith, 1986; Mahoney and Rood, 1993) and *Salix* (Taylor *et al.*, 1999; Dixon, 2003).

Moisture gradients are a major determinant of the distribution of riparian plant species (Weaver, 1960; Bush and Van Auken, 1984; Tanner, 1986). For example, Jackson and Lindauer (1978) documented five community types on the floodplain of the South Platte River in northeastern Colorado. They described a community dominated by *Salix exigua* on the most hydric sites, where soils were 90% sand and the water table was four to 20 cm (1.6 to 7.9 in) below the surface. A mixed *Populus sargentii-Salix exigua* community was found on the next, less-hydric topographic level. The third topographic level of the floodplain was dominated by open- and closed-canopy stands of cottonwood. The fifth community type was found on the highest topographic surface, elevated one to two meters (3.3 to 6.6 ft) above the surrounding floodplain. This community was treeless with scattered shrubs and dominated by grasses such as sand dropseed (*Sporobolus cryptandrus*), saltgrass (*Distichlis stricta*), and wheatgrass (*Agropyron smithii*).

The frequency and duration of inundation, in addition to moisture requirements for establishment and persistence, also influences the structure of riparian vegetation (Wheeler and Kapp, 1978; Kozlowski, 1984). Riparian plant species vary in their tolerance to inundation and resulting anoxic conditions (Amlin and Rood, 2001). Growth and regeneration of many riparian tree species declines with increasing hydroperiod, and permanent inundation results in eventual loss of tree cover in most riparian ecosystems (Hughes, 1990). Seedlings are particularly sensitive to inundation and tolerance of plants generally increases with age (Jones *et al.*, 1994).

Soil composition affects moisture regime. Sands drain quickly and thus anoxic conditions occur only with high water tables or extended inundation. Fine-particle soils, which deposit in areas of very low current velocity, have high water-holding capacity and slow drainage. Fine-grained soils may accumulate at arroyo mouths on the floodplain, behind natural levees, and in oxbows (Hughes, 1990).

1.1.3 Flooding Over-bank flooding may effect riparian vegetation through removal of plants (Stevens and Waring, 1985), inundating floodplain surfaces and replenishing soil moisture, and through channel dynamics such as avulsions, meander migration, and sediment deposition (Malanson, 1993: 107-114). While much attention has been given to infrequent, high-magnitude floods as a driving process in riparian ecosystems (Agee, 1988; Stromberg *et al.*, 1991; Scott *et al.*, 1996), the duration of flood events may be a much more important influence on channel migration rates and vegetation dynamics (Richter and Richter, 2000). Flood events are defined here as river flows that exceed bankfull stage.

Soil moisture and ground water levels are increased by wetting of the floodplain during over-bank flow events (Fenner *et al.*, 1985; Busch and Smith, 1995; Crawford *et al.*, 1996: 294). Duration and frequency of inundation is the primary factor determining nutrient status of floodplain forests (Hughes, 1990) which, in arid and semi-arid regions, results in higher productivity compared to upland sites (Brinson *et al.* 1981).

Forest-floor litter decomposition rates and nutrient cycling were shown to be influenced by floodplain inundation in the Middle Rio Grande (Ellis *et al.*, 1999). Soil nutrients may also be augmented by sediment deposition on the floodplain surface that occurs with over-bank flows (Brinson *et al.*, 1981: 19-20).

Flood events may erode secondary channels on the floodplain, often cutting across point bars, and scour lower-level surfaces of bars. Bare, alluvial sediments in secondary channels provide sites for establishment of *Salix* and *Populus* (Hughes, 1990; Taylor *et al.*, 1999). Deposition of sediments during high-magnitude floods may occur on all floodplain levels, providing new sites for establishment of pioneer species (Baker and Walford, 1995). Regeneration of cottonwood and willow may occur by sprouting from 'flood-trained' and buried saplings or from root-crowns following flooding (Agee, 1988). Infrequent, large floods may change the pattern of river channels through avulsions, where the river shifts course and creates a new channel (Leopold *et al.*, 1964: 84). Wetland vegetation may develop in channel segments abandoned by avulsion where there is interception of ground water or ponding of surface water (Stromberg *et al.*, 1997; Hughes, 1990). Where surface water is absent, the abandoned channel provides an open, bare substrate for colonization by pioneer riparian plant species.

1.2 A Conceptual Model of Vegetation Dynamics in the Bosque Ecosystem

The influence of channel dynamics, soil moisture regime, and flooding on vegetation structure can be summarized and portrayed in a conceptual model. Richter and Richter (2000) developed a conceptual model of riparian vegetation dynamics influenced by geomorphic processes and natural succession for the Yampa River in northwestern Colorado. The model was developed for a meandering reach of the river that flowed through a wide, alluvial valley. The riparian vegetation communities included emergent wetlands, coyote willow stands, and cottonwood forest. The conceptual model developed by Richter and Richter (2000) therefore serves as an appropriate basis for describing riparian dynamics of a naturally functioning reach of the Rio Grande through the project area. For the purposes of the Route 66 Bosque Feasibility Study, Richter and Richter's (2000) conceptual model was modified to describe, in general terms, probable vegetation dynamics in a naturally functioning *bosque* (Figure 1). The boxes represent riparian patch types, while the dashed lines indicate changes driven by fluvial geomorphic processes or channel dynamics. The solid lines indicate changes in patch type driven by biotic succession, modified from Richter and Richter (2000) to reflect characteristics of the *bosque* ecosystem.

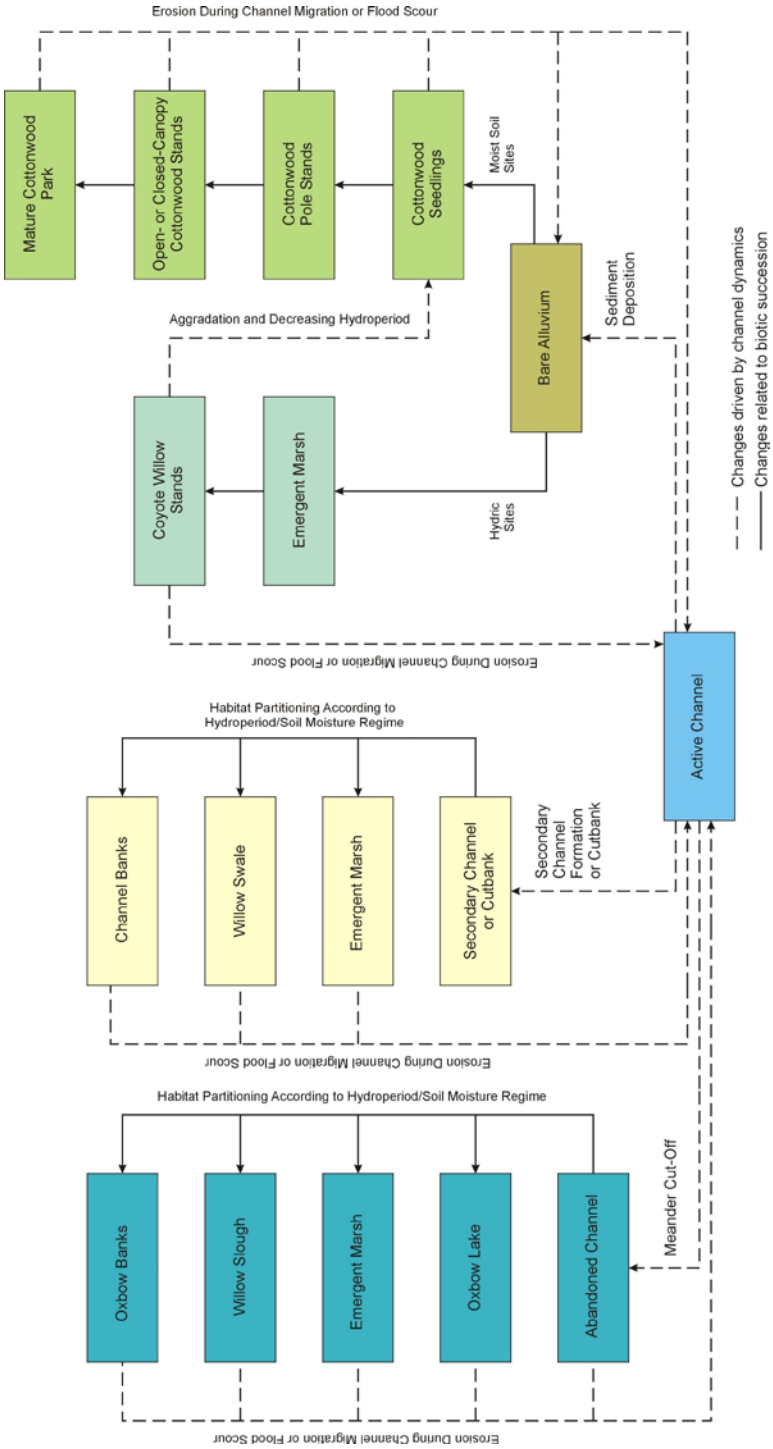


Figure 1. Conceptual model of riparian vegetation patch dynamics in a naturally functioning

Vegetation dynamics are generated from fluvial geomorphic processes, as indicated by the central position of the active channel in the conceptual model. Fluvial geomorphic processes of sediment deposition, secondary channel formation, cutbank erosion, or meander cutoff create sites for pioneer vegetation in meandering reaches (Johnson *et al.*, 1976). In reaches with fixed channel location, floods of high magnitude deposit sediments on the floodplain surface which provides bare, alluvial soils for pioneer species (Baker and Walford, 1995). Beginning on the right side of the model (Figure 1), sediment deposition associated with point bar development, mid-channel bar formation, or floodplain deposition creates surfaces of bare alluvium that are colonized by herbaceous wetland plants (Figure 2) or cottonwood seedlings (*e.g.* Watson, 1912; Hink and Ohmart, 1984: 37). Hydric sites colonized by emergent marsh communities are succeeded by coyote willow stands as the wetland vegetation traps sediment, the point bar surface becomes elevated, and the riverward edge of the point bar extends laterally into the channel (Figure 3). Continued deposition of sediments in the coyote willow stands along with decreasing hydroperiod allows for establishment of cottonwood seedlings. These successional patches and moist soil sites colonized directly by cottonwood seedlings develop into cottonwood pole stands. Cottonwood pole stands are succeeded by closed- and open-canopy cottonwood stands with understories of species less tolerant of inundation (Jackson and Lindauer, 1978). Mature cottonwood stands may develop into a 'park' character with an overstory of large trees, an understory carpeted with herbaceous species, and few woody plants in the understory (Jackson and Lindauer, 1978).

The left portion of the model (Figure 1) depicts vegetation patch development in secondary or abandoned channels or on cutbanks. Secondary channels may form across point bars during scouring high flows (Figure 4), while meander cutoffs result in abandonment of a channel segment. Cutbanks are formed from erosion, often into established riparian forest, on the outside bend of meanders (Figure 5). Succession of patch types in secondary channels, cutbanks, or abandoned channels is influenced largely by soil moisture regimes or hydroperiod, which is the duration of surface water inundation. The San Antonio Oxbow is an example of an emergent wetland community maintained by hydric soil conditions.

Fluvial geomorphic processes can result in conversion of vegetation patches to active channel, as indicated by the dashed lines from patch types back to the active channel in Figure 1. Scour and deposition during flood events can also reset sites back to primary successional stages (*cf.* dashed lines from vegetation patch types back to bare alluvium, secondary channel, and abandoned channel in Figure 1).

In summary, the conceptual model illustrates the processes that, in a naturally functioning system, would result in a mosaic of vegetation patches in the riparian landscape of the *bosque*. Fluvial-geomorphic processes drive creation of bare, open sites available for establishment of native riparian and wetland vegetation. Changes in structure of vegetation patches that are spatially and temporally removed from the disturbances of channel dynamics are driven by biotic succession. Soil moisture regime (*i.e.* soil saturation, hydroperiod, depth to water table) in these patches has a major influence on successional development of riparian and wetland plant communities.

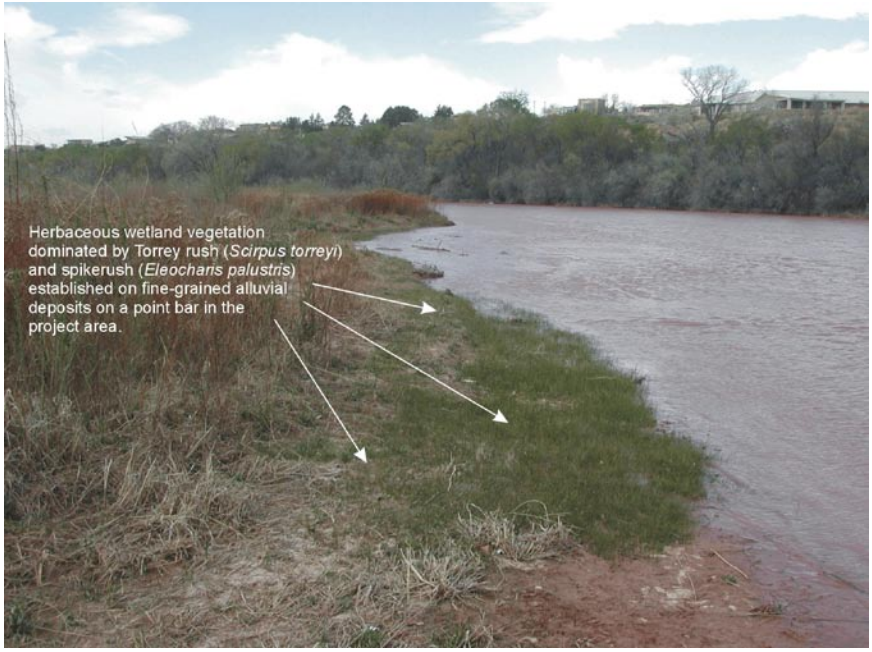


Figure 2. Emergent marsh vegetation patch established on fine-grained alluvial deposits at the edge of a point bar. This pioneer vegetation, once established, begins to trap sediments. The resulting accretion raises the surface elevation of the bar and advances the edge of the bar into the active channel (photo: J.S. Pittenger).

Figure 3. Succession of emergent marsh to coyote willow stand on a point bar. Succession to the coyote willow stand occurs with aggradation of alluvial sediments and decreasing hydroperiod (photo: J.S. Pittenger).

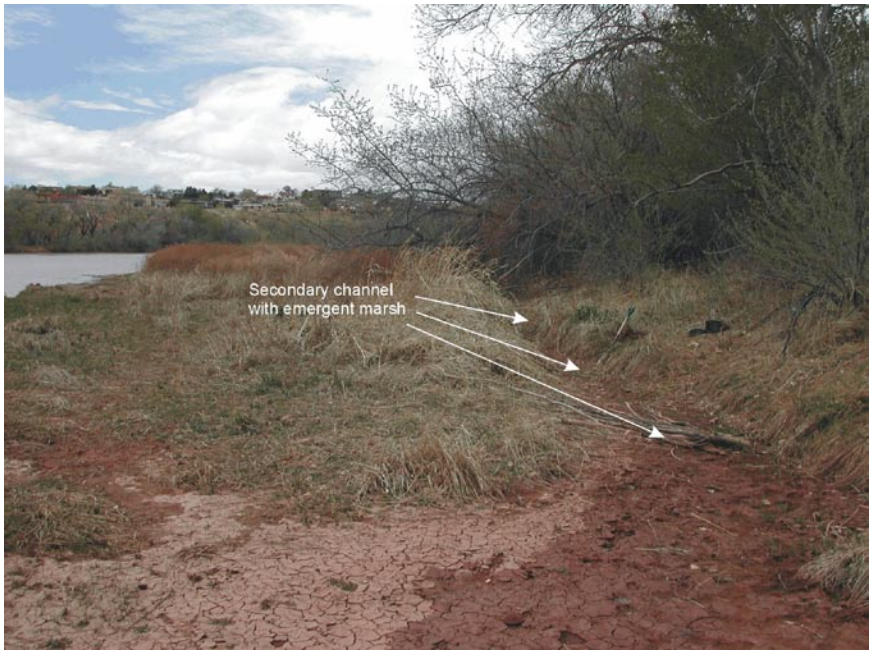


Figure 4. Emergent wetland community established in a small secondary channel. This channel formed at the back of a point bar along the base of the third floodplain level (photo: J.S. Pittenger).

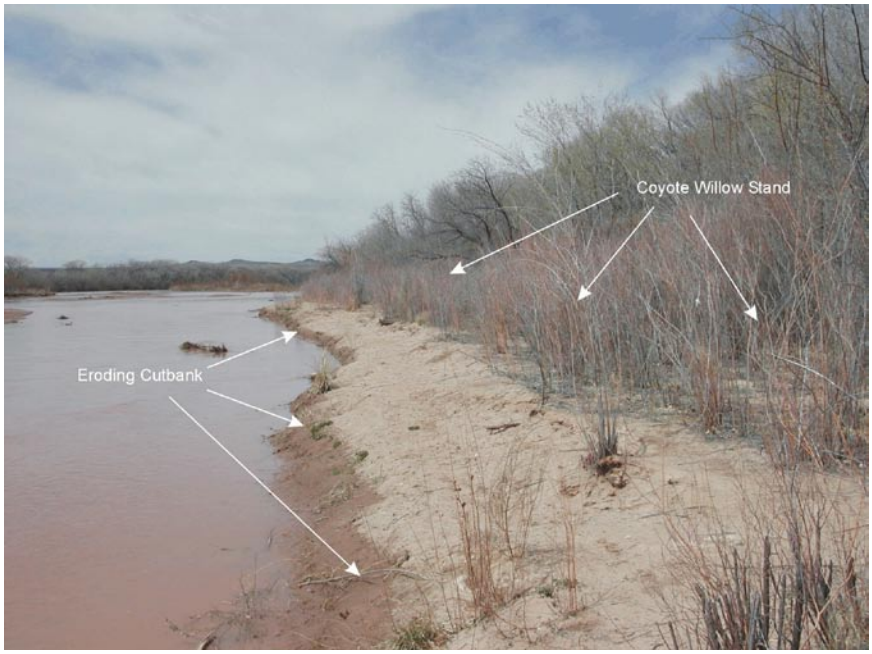


Figure 5. Coyote willow channel bank community on the eroding cutbank of a broad meander during low flow. The cutbank is eroding into established riparian forest on the floodplain. The cutbank erosion creates an edge with different soil moisture, light, and hydroperiod conditions compared to the forest interior (photo: J.S. Pittenger).

2.0 HISTORICAL REFERENCE CONDITIONS

2.1 Natural Reference Condition of the *Bosque* Ecosystem

From the previous discussion of processes operative in a naturally functioning *bosque* ecosystem, a mosaic of vegetation patches can be inferred as the historic condition of riparian vegetation in the project area. This is also implied in the limited amount of historical information available on riparian vegetation in the project area.

Large wetlands and an extensive cottonwood gallery forest occupied the floodplain of the Rio Grande in the project area prior to major modifications of the ecosystem by man. Large cottonwood gallery forests on the east side of the Rio Grande from Tomé northward into Albuquerque were described in the mid-1700s (Scurlock, 1998: 186). In the 1600's the *Bosque Grande de San Francisco Xavier*, an extensive cottonwood gallery forest, occupied the east side of the Rio Grande from Alameda Pueblo downstream to the vicinity of present-day Barelas, where the forest gave way to a complex of wetlands known as the *Esteros de Mejia* (Scurlock, 1998: 185). The wetlands consisted of herbaceous marshes (*cienegas*), "swamps" or sloughs (*esteros*), and open-water ponds (*charcos*). The *Bosque Grande de San Francisco Xavier* was a prominent landscape feature at least into the early 1700s (Scurlock, 1998: 185). Scurlock (1998: 185) noted that the wetlands and *bosque* "were sustained by a high water table and periodic flooding of the Rio Grande." Flooding deposited fine-grained sediments "rich in nutrients" on the floodplain (Scurlock, 1998: 186).

The conceptual model of riparian vegetation dynamics (Figure 1) assumes that the historic character of the Rio Grande in the project area was a meandering stream in a broad, alluvial valley. While the latter characteristic is not in question, the historic morphology of the river in the project area has not been well described. Historic, natural morphology of the Rio Grande has often been described as a braided channel (*e.g.* Crawford *et al.*, 1993: 16). Historic records of the river in locations south of Albuquerque indicate that braided channel morphology may have been the natural condition there (Scurlock, 1998:187-188), possibly due to the influence of sediment input from the Rio Puerco and Rio Salado (*e.g.* Schumm and Meyer, 1979; Bullard and Wells, 1992: 11). However, stream gradient, sediment composition of the banks and channel bed, and historic descriptions of riparian vegetation suggest that morphology of the Rio Grande in the project area was more of a single-thread, broad, meandering channel.

The relationship between channel pattern, channel slope, and bankfull discharge described by Smith and Putnam (1980) can be used to assess probable historic channel morphology in the project area. Channel slope in the reach of the Rio Grande from Cochiti just south of Albuquerque is about 0.00095 m/m (5 ft/mi) and the dominant channel-forming discharge prior to closure of Cochiti Dam was about 170 m^3/s (6,000 cfs; Lagasse, 1981: 29) These slope and dominant discharge conditions are strongly indicative of a meandering channel pattern (Smith and Putnam, 1980). Historic records also imply that the Rio Grande in the project area had a slightly meandering, single-thread channel morphology. The occurrence of large

sloughs or oxbows, recorded in 1630 (Scurlock, 1998: 185), is evidence of meander cutoff, which is a characteristic of meandering stream channels. Well-vegetated, defined river banks, noted in 1782 (Scurlock, 1998: 186), are more consistent with a meandering channel morphology as opposed to braided channels, which typically have highly erodible, shifting banks (Rosgen, 1996). High width:depth ratio, high sediment supply, and dune-antidune bed form are characteristic of meandering channels in fine-grained alluvium (Rosgen, 1996: 5-100).

Major channel realignments from avulsion were relatively infrequent, with eight such events documented over a roughly 200-year period between 1700 and the late 1800s (Scurlock, 1998: 267). However, substantial over-bank flooding (*i.e.* flows greater than 283 m^3/s [10,000 cfs]) occurred with recurrence interval of about 3.8 years, which translates to a probability of occurrence of 25% in any given year, for the period 1895-1953 (Otowi gage, U.S. Geological Survey station number 08313000).

2.2 Changes in Ecological Processes and Vegetation Structure

Substantial, large-scale, human-induced changes in riparian vegetation structure and ecological processes in the project area probably did not occur until arrival of Spaniards in the 1500s (Crawford *et al.*, 1996: 283). Land clearing for irrigated agriculture and diversions from the river likely began to have an effect on the *bosque* ecosystem at least as early as the late 1700s. Direct diversions from the river were indicated by the occurrence of wide, deep irrigation ditches in the Albuquerque area in 1776 (Scurlock, 1998: 186). The number of *acequias* and area of floodplain under irrigated agriculture expanded with an increasing population from 1680 through 1817 (Scurlock, 1998:113- 115). Settlement of the Rio Grande continued as other European immigrants moved into the area, with an estimated 130,000 people living along the river from Santa Fe to Belen by 1830. Population growth resulted in increased water diversions from the river, continued clearing of native vegetation (*cf.* Scurlock, 1998: 202) and expanding irrigated agriculture on the floodplain. By the 1820s, irrigation had resulted in formation of saturated soils and wetlands on the floodplain (Scurlock, 1998: 187) and increasing alkalinity of floodplain soils from irrigation had become problematic by the early 1800s (Scurlock, 1998: 274). Diminished river flows from diversions was noted as early as 1807 (Scurlock, 1998: 187). It appears that much of the *bosque* had been cut down by 1846, when Lieutenant J. W. Abert noted, from his camp on the Rio Grande at Atrisco, that “no wood is to be obtained within less than 9 or 10 miles of Albuquerque” (Scurlock, 1998: 233).

Intensive grazing and logging in the watershed of the Rio Grande increased sediment input into the stream and by 1850 the rate of channel aggradation began to accelerate (Scurlock, 1998: 281). By the early 1900s, concurrent with increased water diversions, aggradation of the river bed resulted in channel widening and formation of large mid-channel bars that were colonized by cottonwood (Scurlock, 1998: 188). It is likely that increased sediment supply caused a major shift in channel morphology and large-scale channel instability (*cf.* Schumm and Meyer, 1979). Flooding increased in frequency and magnitude due to changes in watershed runoff characteristics (Scurlock, 1998: 188). Changes in channel alignment and rapid bank erosion occurred during flood stage because of the aggraded channel and lack of riparian

vegetation, which rendered stream banks susceptible to accelerated rates of erosion (Scurlock, 1998: 188). Aggradation in the Albuquerque reach of the Rio Grande was at a maximum rate of about 0.6 m/50 yrs (2 ft/50 yrs) prior to construction of dams in the drainage basin (Lagasse, 1981: 30). A 1922 U.S. Reclamation Service map of the project area shows extensive sand bars and a paucity of riparian vegetation, much of which is noted as "brush", with very little indication of cottonwood forest (Figure 6). An enormous sand bar shown on the west side of the river north of the present-day Central Avenue bridge measured about 792 m (0.49 mi) wide by 2,225 m (1.38 mi) long (Figure 6).

Wetlands and alkali deposits in areas waterlogged by irrigation covered a substantial portion of the Middle Rio Grande Valley by the early 1920s (Van Cleave, 1935; Scurlock, 1998: 281). Construction of drainage ditches in 1925 and diversion and flood control dams and levees beginning in 1930 began to lower the high water table and established a defined floodway. The average width of the floodway area between the levees was 457 m (1,500 ft; Lagasse, 1981: 29), compared to a historic floodplain width in the project area of about 4,000 m (13,120 ft; U.S. Reclamation Service topographic map, 1922).

Closure of Jemez Canyon Dam in 1953 and Cochiti Dam in 1973 initiated major channel changes in the Albuquerque reach by reducing sediment load and decreasing peak flows (Lagasse, 1981; Bullard and Wells, 1992). Channelization of the river and installation of fields of Kellner jacks was completed from 1953 to 1959 (Lagasse, 1981). Channelization created a relatively straight channel and the fields of Kellner jacks initiated massive sediment deposition adjacent to the channel. These management actions defined a fixed plan form, narrowed active channel. As a result of flow regulation, sediment reduction, and channel modification, the channel width decreased, sinuosity increased, and the channel began to incise (Lagasse, 1981; Scurlock, 1998: 282). Two exotic phreatophytes, salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*), were becoming increasingly common in the riparian plant communities of the Rio Grande in the project area in the mid-1930s (Van Cleave, 1935). Siberian elm (*Ulmus pumila*) was introduced into the Albuquerque area in the 1920s (Scurlock, 1998: 287).

The riparian ecosystem of the Rio Grande in the project area had been changed dramatically from natural conditions by the early to mid-1900s. Only remnants of the *Bosque Grande de San Francisco Xavier* remained in 1922 (Figure 6). The portion of the *Esteros de Mejia* in the project area had apparently been reduced to one small wetland on the east side of the Rio Grande north of Barelas (Figure 6). Some ponds associated with ditches located on the floodplain east of the river likely supported wetland vegetation (*cf.* Figure 6, north of Bluehers Garden). Also, an old channel named "Palmer Slough" on the east side of the river may have contained remnant wetland habitat. Large tracts of the floodplain in the project area classified as "alkali" in 1922 were zones of high alkalinity resulting from waterlogging and saturation of soils (Scurlock, 1998: 274). These areas were classified as wet meadows by Van Cleave (1935) and were dominated by sedge (*Carex* sp.), spikerush (*Eleocharis* sp.), bulrush (*Schoenoplectus [Juncus]* sp.), inland saltgrass (*Distichlis spicata*), and yerba mansa (*Anemopsis californica*). However, by the mid-1930s much of the hydric floodplain community had been eliminated by drainage and lowering of the water table (Van Cleave, 1935). Salt cedar and Russian olive were common components of riparian plant communities by 1935 (Van Cleave, 1935).

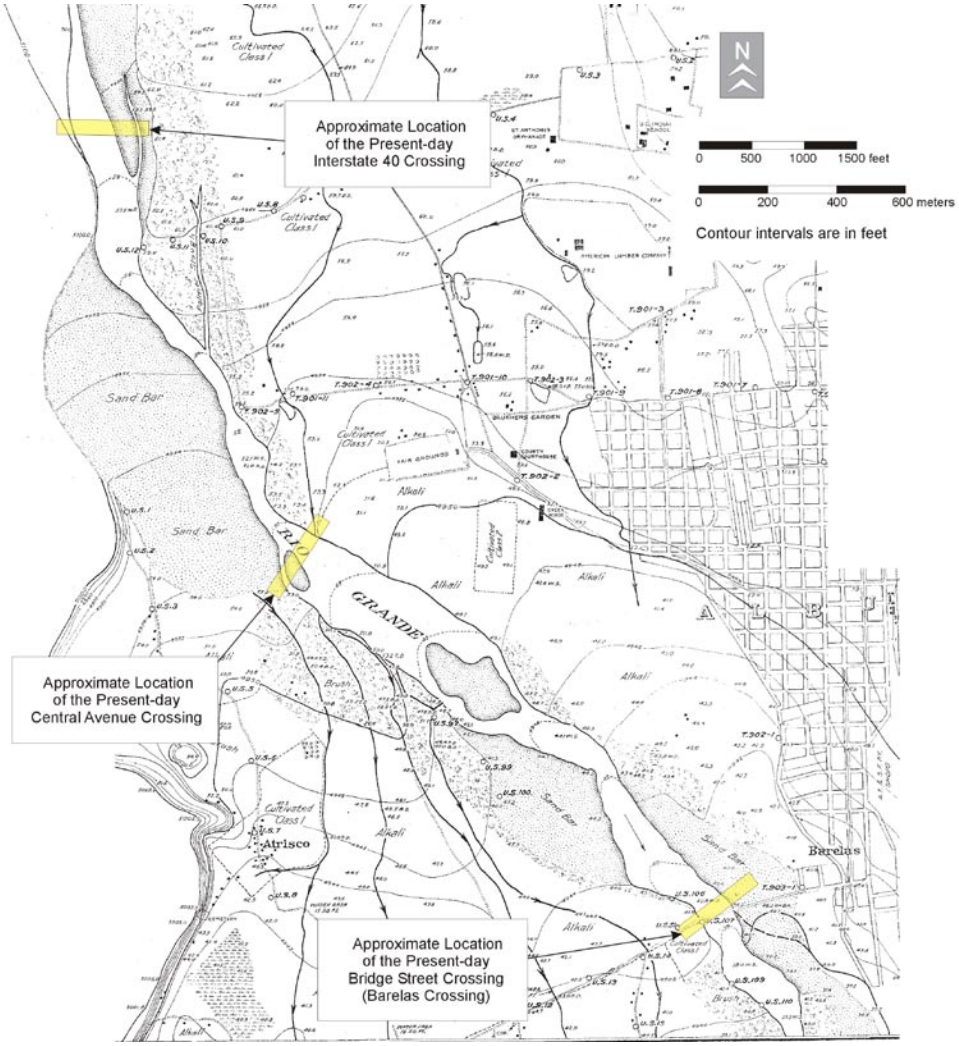


Figure 6. Excerpt from a 1922 U.S. Reclamation Service topographic map showing the project area.

In summary, man-induced changes in fluvial geomorphic processes that influence vegetation dynamics in the *bosque* were initiated at least as early as the late 1700s. These processes were progressively altered from the natural condition through the 1800's and into the mid-1900s, when imbalances between sediment supply and discharge and removal of riparian vegetation apparently created very unstable dynamics in the riverine and riparian ecosystems. Channelization, levee construction, Kellner jetty installation, sediment retention in reservoirs, and flow regulation reversed the processes of aggradation and channel widening. These river management measures also created a fixed channel plan form and a narrower floodplain that was less frequently inundated or disconnected entirely from the river. The result has been disruption or termination of major processes depicted in the conceptual model of dynamics in a naturally functioning *bosque* ecosystem (Figure 1).

3.0 EXISTING ECOLOGICAL SITUATION

Substantial impacts from man, starting about 250 years ago, resulted in compounding rates of change in structure and vegetation dynamics to the point that the *bosque* ecosystem is now on the verge of irreversible conversion (Crawford *et al.*, 1996). A similar pattern of loss of alluvial forests through channelization, flow regulation, and levee construction since the 17th century is well documented in Europe (Décamps *et al.*, 1988). Decline of natural riparian structure and function of the *bosque* ecosystem was recognized in the 1980s as a major ecological change in the Middle Rio Grande Valley (Hink and Ohmart, 1984; Howe and Knopf, 1991).

3.1 Altered Vegetation Dynamics in the Existing Bosque Ecosystem

Loss of conditions necessary for regeneration of native riparian plants and increasing abundance of nonnative species was identified in river systems throughout the western U.S. beginning in the mid-1970s, with main-stem impoundments typically identified as the primary factor driving alteration of ecosystem structure and function (Fenner *et al.*, 1985; Howe and Knopf, 1991). Impoundments alter the hydrograph and reduce sediment supply in downstream reaches and cause channel incision and narrowing of the floodplain (Williams and Wolman, 1984). Installation of Kellner jetty fields, levee construction, sediment and vegetation removal, and irrigation diversions have exacerbated these effects in the project area (Crawford *et al.*, 1993: 42-50). Changes wrought by impoundments and channel modifications in the project area have created a riparian ecosystem organized by autogenic factors, including plant succession and invasion by nonnative species, and novel allogenic factors such as fire. Conversely, the naturally functioning *bosque* ecosystem was structured largely by fluvial gemorphic processes (*cf.* Déscamps *et al.*, 1988; Figure 1).

A major change in vegetation dynamics in the *bosque* ecosystem has been loss of meander cut-off, meander migration, and flood scour processes (Figure 7), which were a driving force in the dynamics of the naturally functioning system (Figure 1). These processes removed existing vegetation and created new sites for founding of plant communities. Sediment deposition in the project area is now restricted to a few, largely ephemeral, mid-channel bars and transitory lateral bars proximal to the river. Meander cut-off and lateral meander migration no longer occur (Figure 7). Bare soil sites are now created primarily through mechanical disturbance or fire, typically in areas no longer subject to periodic inundation and with relatively dry soil moisture regimes.

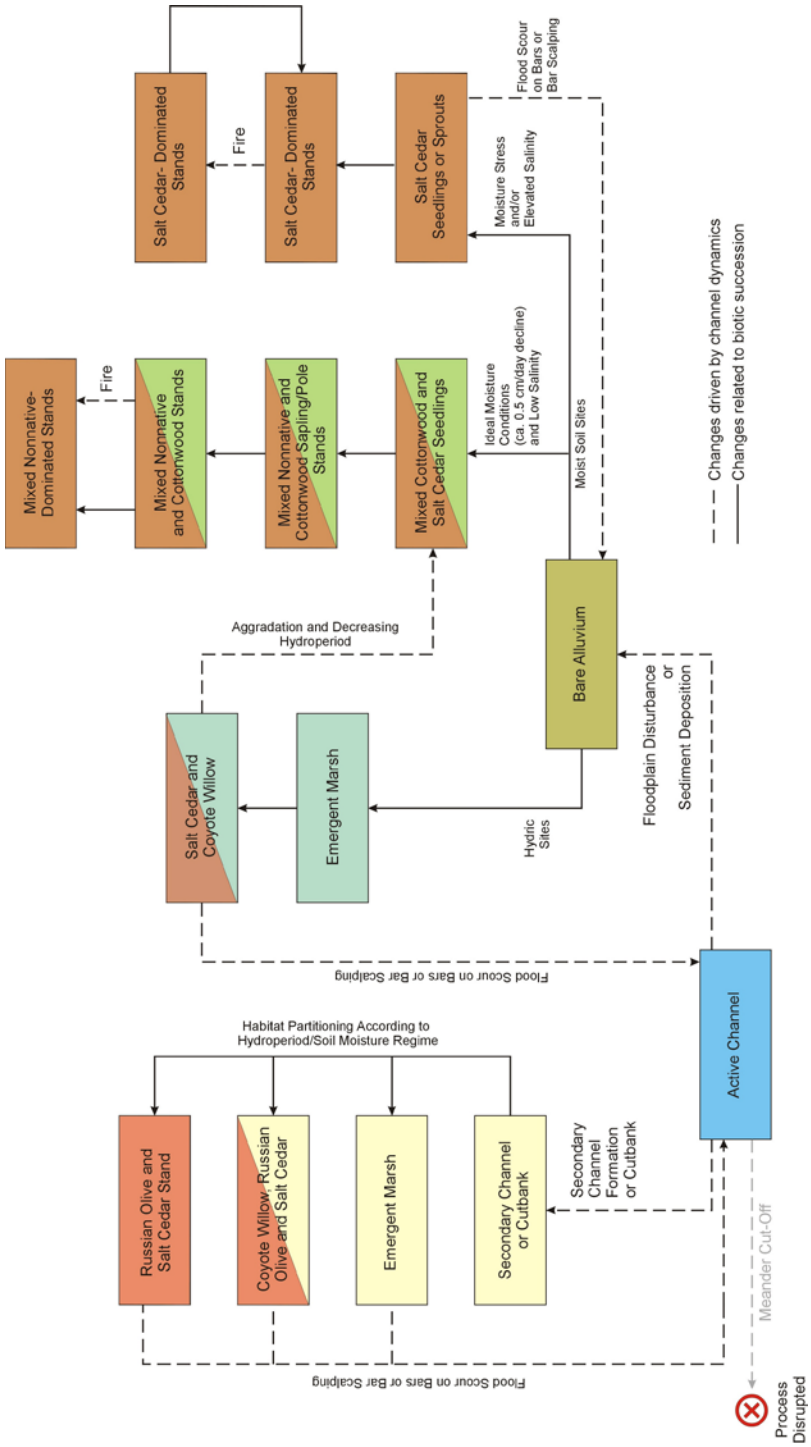


Figure 7. Conceptual model of altered riparian vegetation patch dynamics in a modified

Salt cedar is now a prominent colonizer of exposed, bare soil sites in the *bosque* (Smith *et al.*, 2002; Figure 7). While individual cottonwood seedlings have a greater competitive effect relative to salt cedar seedlings under ideal soil moisture conditions (Sher *et al.*, 2000), the competitive effect is lost under conditions of water stress (Segelquist *et al.*, 1993) or elevated salinity (Busch and Smith, 1995: 363). Salt cedar produces seed for several months beginning in spring (Ware and Penfound, 1949; Horton *et al.*, 1960) and therefore colonizes bare, moist-soil sites throughout the summer. Cottonwood, on the other hand, produces seed only for a short time in the spring and seed remains viable for only about month and a half under ideal conditions (Horton *et al.*, 1960). The flowering and fruiting phenology of salt cedar allows seedlings to establish on and dominate open sites wetted by runoff, rainfall, or river flows during the summer, precluding the possibility for cottonwood establishment on potentially suitable sites the following spring. Salt cedar also becomes established in the understory of mature cottonwood stands in the project area where there is sufficient light (Crawford *et al.*, 1996: 295).

Fire was virtually unknown in naturally functioning, low-elevation riparian ecosystems of the Southwest (Busch and Smith, 1993; Stuever, 1997). However, fuel accumulations coupled with mainly human-caused ignitions have introduced fire as a major disturbance mechanism in the *bosque* ecosystem (Stuever, 1997). While cottonwood is highly susceptible to fire-induced mortality (Stuever, 1997), *Tamarix* re-sprouts vigorously following fire (Busch and Smith, 1993; Busch, 1995; Figure 7). *Populus* and *Salix* are poorly adapted to fire and lack an efficient post-fire re-sprouting mechanism such as that found in *Tamarix* (Busch and Smith, 1993).

Post-fire soils have significantly higher salinity than soils of unburned areas, which may suppress growth of *Populus* and *Salix* seedlings and allow establishment of salt cedar seedlings (Busch and Smith, 1993). Salt cedar has a higher salinity tolerance than *Salix* and *Populus* and adjusts to high salinity sites through accumulation of salts and osmotic adjustment, whereas willow and cottonwood exclude ions at the root endodermis (Busch and Smith, 1995: 363). Salt cedar uses the absorbed ions to maintain turgor pressure at low water potential and also exudes salts through special glands, allowing it to tolerate higher salinities and water stress than *Populus* and *Salix* (Busch and Smith, 1995: 363). Halophytes, such as salt cedar, may salinize soils when well-supplied with moisture to reduce water uptake and transpiration (Busch and Smith, 1995).

Russian olive is established by seed in the understory of mature cottonwood stands and also colonizes openings along the river, often forming dense stands (Hink and Ohmart, 1984; Sivinski *et al.*, 1990: 9). Russian olive is shade tolerant. Seeds germinate in moist to dry sites and the plant sprouts readily from the root crown after damage to or removal of above-ground portions of the plant (Sivinski *et al.*, 1990: 9). Russian olive was present in the overstory in 1981 (Hink and Ohmart, 1984: 36) and continues to increase in the overstory of the *bosque* in the project area (Sivinski *et al.*, 1990: 9).

Several other nonnative tree species, in addition to saltcedar and Russian olive, are at least locally common, if not abundant, in the overstory. These species are Siberian elm, tree of heaven (*Ailanthus altissima*), and Russian mulberry (*Morus alba* var. *tatarica*). All three species are shade-tolerant and

readily colonize disturbed sites (Crawford *et al.*, 1996: 289; Sivinski *et al.*, 1990: 9-10). Siberian elm was rare in the *bosque* in 1981 when it was found only at very low densities, ranging from less than 1.2 trees/ha (0.5 trees/ac) to 7.4 trees/ha (3 trees/ac; Hink and Ohmart, 1984: 41-42). However, Siberian elm had become increasingly abundant by 1990 (Sivinski *et al.* 1990: 10) and is now very common in the overstory. This species produces large seed crops and is ubiquitous in the project area as seedlings, saplings, and mature trees. It sprouts readily from the root crown. Siberian elm seed will germinate under normal rainfall conditions and does not require moist or saturated soils (Sivinski *et al.*, 1990: 9-10). Tree of heaven and Russian mulberry are more localized in their distribution in the project area than salt cedar, Russian olive, or Siberian elm. Both of these species typically colonize disturbed areas, such as along levees and in severely burned sites (Sivinski *et al.*, 1990: 10).

3.2 Existing Riparian Vegetation and Wetlands Conditions

The following description of vegetation in the project area uses plant community designations developed by Hink and Ohmart (1984) and mapping by Sivinski and others (1990), updated with observations made in the field in spring 2003. Hink and Ohmart (1984: 37-39) defined six structure types based on vertical foliage density. Structure type I consists of tall trees (ca. 15.2 m [50 ft]) with a relatively dense understory of saplings and shrubs. Type II structure is also composed of tall trees but with little or no sapling and shrub understory. Type III structure consists of mid-size trees (less than 9.1 m [30 ft]) and dense understory vegetation. Type IV structure is characterized by open stands of mid-sized trees with widely scattered shrubs and sparse herbaceous growth. Type V structure is dense, short-stature trees and saplings, to about 4.6 m (15 ft) height, often with dense herbaceous growth. Type VI structure is scattered plant growth with foliage not exceeding about 1.5 m (5 ft) in height above the ground.

Based on 1990 mapping, vegetation in the project area was dominated by old (structure type I, 51.5%) and very young (structure type VI, 34.3%) stands, with little vegetation in the middle structural categories (Figure 8A). Structure type V stands, which have higher density of shrubs and saplings than type VI, covered about 13.9% of the project area. Structure types II, III, and IV combined made up only 0.3% of the vegetation in the project area in 1990 (Figure 8A). Mechanical clearing of the forest understory north of the Central Avenue crossing converted about 25.5 ha (63 ac, *ca.* 13% of the project area) of type I stands to type II stands in the spring of 2003 (Figure 9).

Type I and II stands in the project area consist of mature, closed canopy stands dominated by Rio Grande cottonwood (*Populus deltoides wislizenii*) and Siberian elm. Cottonwood dominated 89.4% of the type I and II stands, while Siberian elm was the dominant overstory tree in at least 10.6% of the type I and II stands (Figure 8B). However, Siberian elm was present in the overstory and understory of all cottonwood-dominated type I and II stands in the project area. Nonnative plants were dominant in the understory of type I stands throughout the project area. Most (71.1%) of the type I stands, including those recently converted to type II stands, had a Russian olive-dominated understory, while salt cedar was the second most common understory dominant, occurring in 28.9% of the type I stands (Figure 8C). Other nonnative

Figure 8. Vegetation cover in the 198.3 ha (490 ac) project area. Structure type composition of the vegetation, as mapped in 1990, is shown in (A). Dominant overstory tree species and understory species in type I stands are shown in (B) and (C), respectively. Early succession vegetation coverage is shown in (D), with the proportion of those areas dominated by herbaceous plants or bare ground shown in (E). The area of early succession stands dominated by saplings of various tree species is shown in (F).

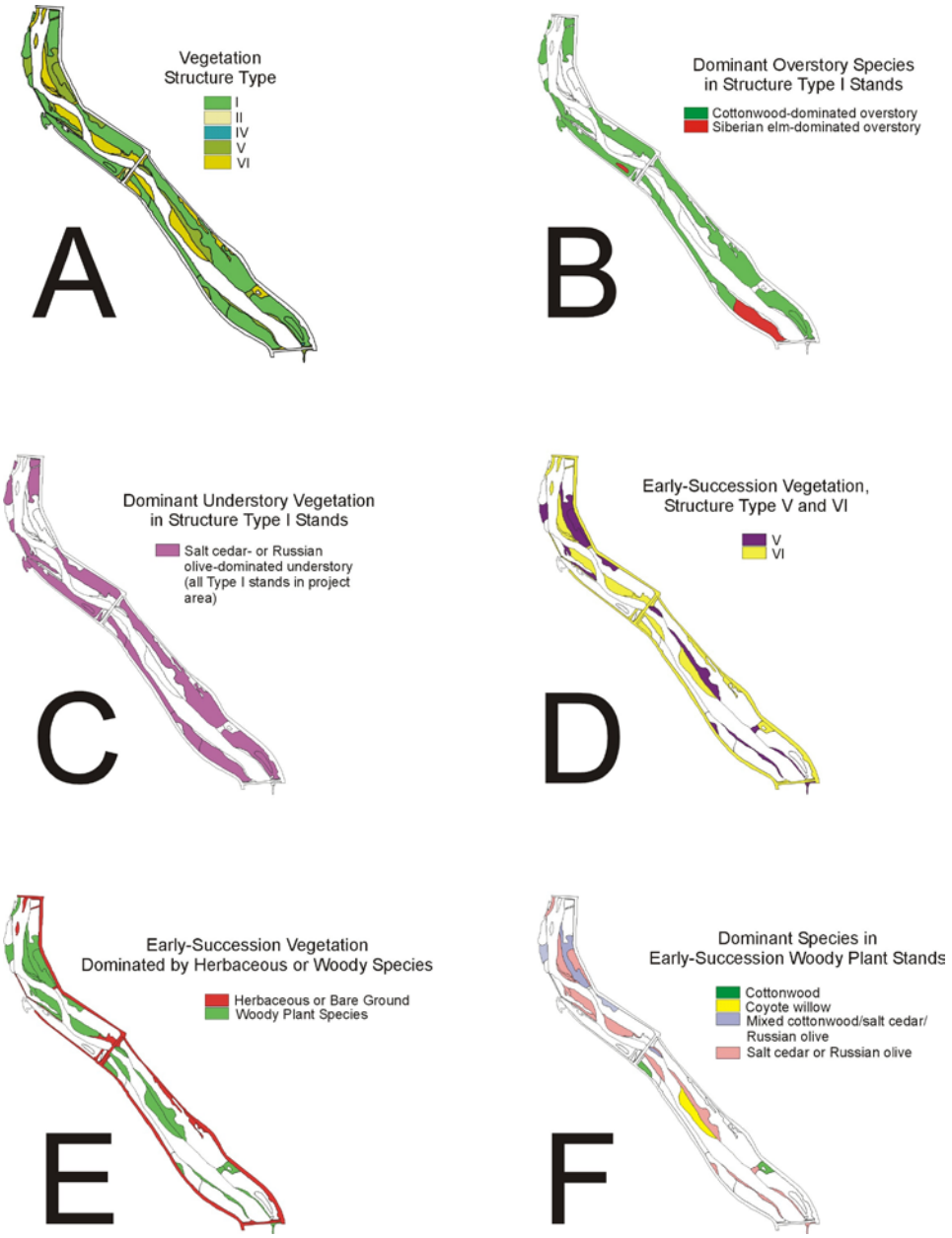


Figure 9. Type I stand converted to a type II stand by mechanical clearing of the understory in spring 2003. This stand is located on the west side of the Rio Grande north of the Central Avenue crossing (photo: J. S. Pittenger).

Figure 10. Russian olive sprouting from the root crown about two weeks after mechanical clearing (photo: J. S. Pittenger).

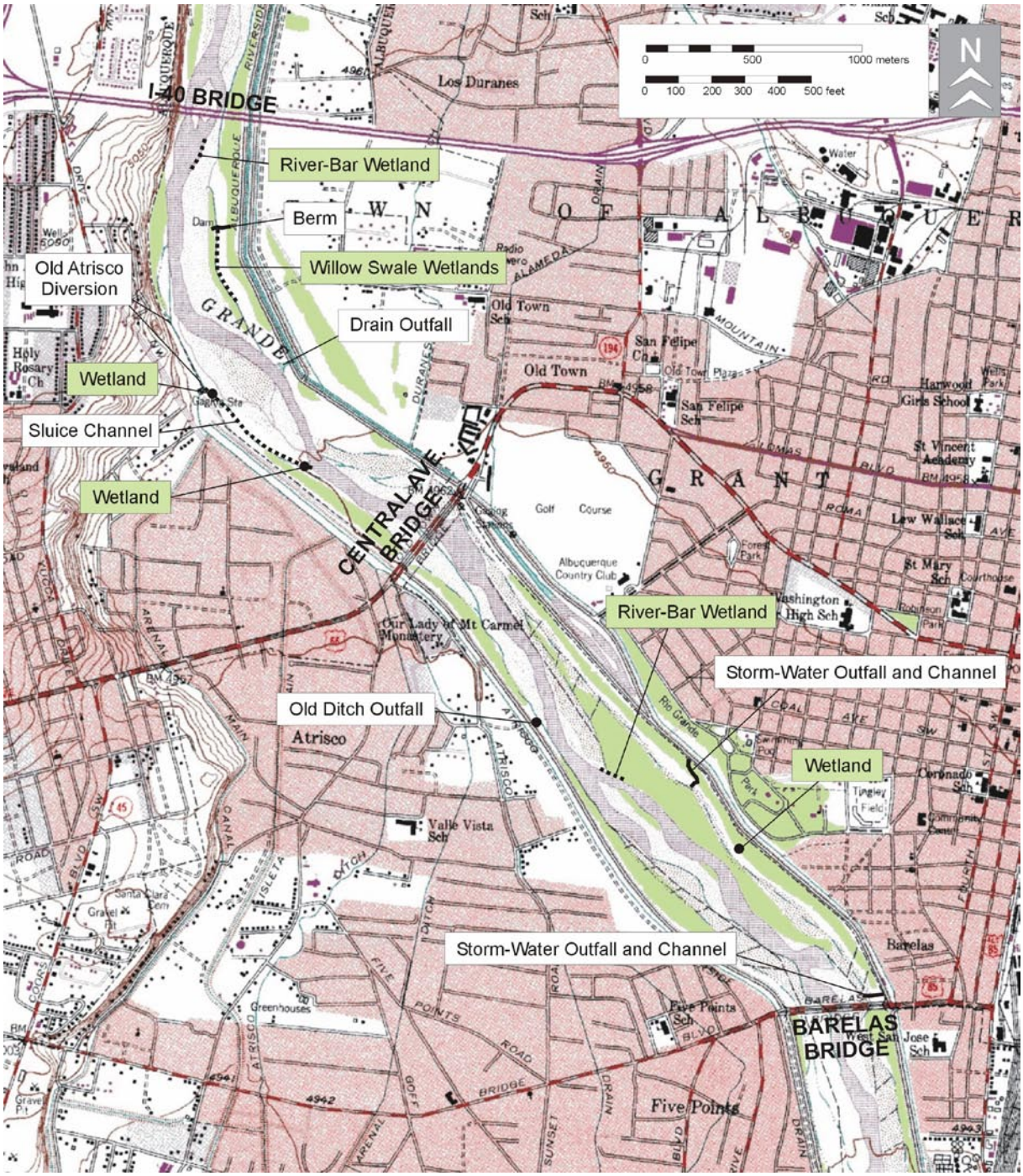
trees found in the project area as minor components of the vegetation were Russian mulberry, northern catalpa (*Catalpa speciosa*), black locust (*Robinia pseudo-acacia*), Osage orange (*Maclura pomifera*), and green ash (*Fraxinus pennsylvanica*).

Although typically not as abundant as nonnative species, native shrubs and trees were also found in the understory of type I stands. Goodding's willow (*Salix gooddingii*) and New Mexico olive (*Forestiera neomexicana*) were found scattered throughout the project area in type I stands. These species were locally common, often at well-lighted sites in canopy gaps and along the edges of closed-canopy stands. Golden currant (*Ribes aureum*) was also locally common in dense patches. Virginia creeper (*Parthenocissus inserta*) was common throughout the understory and false indigo bush (*Amorpha fruticosa*) was found scattered throughout the understory of type I stands. The recently-created type II stands north of the Central Avenue crossing were largely devoid of understory vegetation. However, within the span of a week or two, Russian olive and Siberian elm had begun sprouting from the root crown of cut trees in treated stands (Figure 10). Type V and VI areas, or early-succession vegetation, covered 48.3% of the project area (Figure 8D). Much of this area (44.8%) was dominated by herbaceous plants or bare ground and included the levee roads, cleared and mowed utility corridors, recently burned and cleared sites, or newly-established mid-channel bars (Figure 8E). The remaining 55.2% of the type V and VI stands were dominated by saplings of tree species or by riparian shrubs (Figure 8F). Half of the woody type V and VI stands were dominated by Russian olive. Early-succession, salt cedar-dominated vegetation was found in one large stand on an established point bar on the east bank between the I-40 and Central Avenue crossings (Figure 8F). Another established bar on the east bank between the Central Avenue and Bridge Street crossings was dominated by coyote willow (Figure 8F). Each of these stands comprised about 11% of the woody type V and VI vegetation. Cottonwood-dominated type V and VI stands occurred at two sites, both of which were pole planting areas (Figure 8F).

Only two small patches of vegetation were mapped as structure type III or IV in 1990. A 0.12 ha (0.3 ac) patch of scattered, mid-size cottonwood trees with a sparse Russian olive understory was located just north of the Bridge Street crossing on the east side of the river (Figure 8A). The other patch was a 0.44 ha (1.1 ac) stand of scattered mid-size cottonwood with a dense Russian olive understory on the north side of the Central Avenue crossing on the west side of the river. A third, previously unmapped area with structure type III vegetation was found on the east side of the river between the I-40 and Central Avenue crossings during field reconnaissance. This area consisted of a stand of coyote willow in a broad, shallow swale through the center of the *bosque*.

Jurisdictional wetlands were found at six locations in the project area (Figure 11). Jurisdictional wetlands were present in at least portions of the willow swale on the east side of the river between the Central Avenue and I-40 crossings. These wetlands were characterized by shallow depth to water (Figure 12), saturated soils near the surface, organic-streaked sandy soils below about 25.4 cm (10 in), and vegetation dominated by coyote willow, cottonwood, inland saltgrass, and Russian olive. A recreational trail was located through the center of the willow swale.

Figure 11. Location of wetlands in the project area.



Two small wetlands were found in the old Atrisco Diversion sluice channel on the west side of the river between the Central Avenue and I-40 crossings (Figure 11). These wetlands were dominated by coyote willow, horseweed (*Conyza canadensis*), and water bentgrass (*Agrostis semiverticillata*; Figure 13). Two wetlands were found along the margins of established river bars (Figure 11). These wetlands were dominated by herbaceous species such as Torrey rush (*Juncus torreyi*), redroot flatsedge (*Cyperus erythrorhizos*), common spikerush (*Eleocharis macrostachya*), American three-square (*Scirpus americanus*), hardstem bulrush (*Schoenoplectus acutus*), water bentgrass, and dock (*Rumex hymenosepalus*). These wetlands had saturated soil in the upper 30.5 cm (12 in) and sandy soils with organic streaking. The sixth wetland in the project area was an excavated depression in the upper floodplain with saturated soils, vegetation dominated by common spikerush, rush (*Juncus* sp.), hardstem bulrush, American three-square, and coyote willow. Jurisdictional wetlands were also present on mid-channel bars in the Rio Grande. These wetlands were not delineated as the project does not involve any work in the river channel.

Figure 12. Soil was saturated at a depth of 30.5 cm (12 in) in the coyote willow swale. Free water was found at a depth of 51 cm (20 in) on 15 April 2003.

Figure 13. Small wetland at the upper end of the Old Atrisco Diversion sluice channel.

3.3 Existing Fish and Wildlife Conditions

An estimated 407 species of vertebrates may occur in aquatic, wetland, or riparian habitat in Bernalillo County, based on a query of the Biota Information System of New Mexico (version 1/00). This estimate includes 24 species of fish, 11 amphibian taxa, 39 species of reptiles, 279 species of birds, and 54 mammalian taxa (Appendix A). Birds are the most important group, based on number of taxa, comprising 69% of all vertebrate species in the estimate.

Common fish species in the project area include river carpsucker (*Carpiodes carpio*), flathead chub (*Platygobio gracilis*), mosquitofish (*Gambusia affinis*), and red shiner (*Cyprinella lutrensis*; Platania, 1993). Less common fish species in the project area include longnose dace (*Rhinichthys cataractae*), channel catfish (*Ictalurus punctatus*), fathead minnow (*Pimephales promelas*), white sucker (*Catostomus commersoni*), and Rio Grande silvery minnow (*Hybognathus amarus*).

Of the 18 herptile species found in the *bosque* ecosystem during pitfall trapping, Hink and Ohmart (1984: 73) found only three to be widespread and common. These species were eastern fence lizard (*Sceloporus undulatus*), New Mexico whiptail (*Cnemidophorus neomexicanus*), and Woodhouse's toad (*Bufo woodhousii*). Herptile abundance and diversity was found to be greatest in habitats that lacked dense canopy cover and that were characterized by sandy soils and sparse ground cover (Hink and Ohmart, 1984: 76). Many of the species taken in the *bosque* were representative of drier upland habitats. Also, sampling method did not adequately represent aquatic or wetland-associated species. Hink and Ohmart (1984: 79-85) did describe a distinct assemblage of species associated with denser vegetation cover in mesic or hydric habitats, which included tiger salamander (*Ambystoma tigrinum*), western chorus frog (*Pseudocris triseriata*), bullfrog (*Rana catesbeiana*), northern leopard frog (*Rana pipiens*), Great Plains skink (*Eumeces obsoletus*), New Mexico garter snake (*Thamnophis sirtalis dorsalis*), western painted turtle (*Chrysemys picta bellii*), and spiny softshell turtle (*Trionyx spiniferus*). Eastern fence lizard, painted turtle, bullfrog, and New Mexico garter snake were observed in the project area in spring 2003.

Common small mammals in the project area are white-footed mouse (*Peromyscus leucopus*), western harvest mouse (*Reithrodontomys megalotis*), house mouse (*Mus musculus*), tawny-bellied cotton rat (*Sigmodon fulviventer*), and rock squirrel (*Spermophilus variegatus*; Hink and Ohmart, 1984; Campbell *et al.*, 1997). Large mammals found in the project area include beaver (*Castor canadensis*), raccoon (*Procyon lotor*), and muskrat (*Ondatra zibethinus*) in aquatic and wetland habitats and porcupine (*Erethizon dorsatum*), long-tailed weasel (*Mustela frenata*), striped skunk (*Mephitis mephitis*), rock squirrel, Botta's pocket gopher (*Thomomys bottae*), coyote (*Canis latrans*), and common gray fox (*Urocyon cinereoargenteus scottii*) in riparian woodlands (Hink and Ohmart, 1984; Campbell *et al.*, 1997). Small mammals were found to be more abundant in moister, densely vegetated habitats and those with dense coyote willow than at drier sites (Hink and Ohmart, 1984: 89). Hink and Ohmart (1984: 99) described assemblages of small mammals associated with different habitat types. Crawford's desert shrew (*Notiosorex crawfordi crawfordi*) and white-footed mouse were associated with moist forest and woodland

habitats. Well-vegetated, grassy habitats and emergent wetlands were occupied by western harvest mouse, plains harvest mouse, house mouse, tawny-bellied cotton rat, and New Mexican jumping mouse (*Zapus hudsonius luteus*). Deer mouse (*Peromyscus maniculatus*) was associated mainly with dry cottonwood forest habitat. Open salt cedar habitat had four small mammal species typically found in dry upland habitats: silky pocket mouse (*Perognathus flavus*), Ord's kangaroo rat (*Dipodomys ordii*), Merriam's kangaroo rat (*Dipodomys merriami*), and northern grasshopper mouse (*Onchomys leucogaster*).

Hink and Ohmart (1984: 102) recorded 277 species of birds in the *bosque* ecosystem during their two-year study. Highest bird densities and species diversity were found in edge habitat vegetation with a cottonwood overstory and an understory of Russian olive or coyote willow in structure types I, III, and IV (Hink and Ohmart, 1984: 107). Emergent marsh and other wetland habitats also had relatively high bird density and species richness. Common species in cottonwood habitats in spring and summer included mourning dove (*Zenaida macroura*), black-chinned hummingbird (*Archilochus alexandri*), Gambel's quail (*Callipepla gambelii*), northern flicker (*Colaptes auratus*), ash-throated flycatcher (*Myiarchus cinerascens*), European starling (*Sturnus vulgaris*), American robin (*Turdus migratorius*), northern oriole (*Icterus galbula*), black-headed grosbeak (*Pheucticus melanocephalus*), lesser goldfinch (*Carduelis psaltria*), rufous-sided towhee (*Pipilio erythrophthalmus*), blue grosbeak (*Guiraca caerulea*), yellow-billed cuckoo (*Coccyzus americanus*), lazuli bunting (*Passerina amoena*), indigo bunting (*Passerina cyanea*), and brown-headed cowbird (*Molothrus ater*).

Thirteen bird species were found to be limited in distribution to particular habitats during the summer, or breeding season. Nine of these species were associated with aquatic or wetland habitats: pied-billed grebe (*Podilymbus podiceps podiceps*), snowy egret (*Egretta thula brewsteri*), Virginia rail (*Rallus limicola limicola*), sora (*Porzana carolina*), American coot (*Fulica americana americana*), killdeer (*Charadrius vociferus vociferus*), spotted sandpiper (*Actitis macularia*), yellow-headed blackbird (*Xanthocephalus xanthocephalus*), and black phoebe (*Sayornis nigricans semiatra*). The other four species were strongly associated with cottonwood forest habitat: great-horned owl (*Bubo virginianus*), hairy woodpecker (*Picoides villosum*), Lewis's woodpecker (*Melanerpes lewis*), and mountain chickadee (*Poecile gambeli gambeli*). Thirty of the 46 species of breeding birds found in the *bosque* used cottonwood forest habitat. No bird species showed a strong preference for Russian olive stands (Hink and Ohmart, 1984: 117). However, when Russian olive was present as a component of the understory in cottonwood stands, it appeared to influence the quality of those stands for birds.

More recent bird sampling in Rio Grande Valley State Park found 62 species in winter and 90 during the breeding season (Stahlecker and Cox, 1997: 7). The 10 most common species in winter 1996-1997 were dark-eyed junco (*Junco hyemalis*), American crow (*Corvus brachyrhynchos*), American goldfinch (*Carduelis tristis*), white-crowned sparrow (*Zonotrychia leucophrys*), American robin, Canada goose (*Branta canadensis*), red-winged blackbird (*Agelaius phoeniceus*), mallard (*Anas platyrhynchos*), European starling, and house finch (*Carpodacus mexicanus*). Of the 90 bird species found in summer in Rio Grande Valley State Park, only 31 were found in the project area, of which 15 were considered to be nesting there (Stahlecker and Cox, 1997: 10). The ten most common species in the *bosque* in summer 1997 were black-

chinned hummingbird, red-winged blackbird, black-headed grosbeak, spotted towhee (*Pipilio maculatus*), brown-headed cowbird, mourning dove, Bewick's wren (*Thryomanes bewickii*), black-capped chickadee (*Poecile atricapillus*), house finch, cliff swallow (*Hirundo pyrrhonota*), and European starling (Stahlecker and Cox, 1997: 11). The greatest number of species and highest bird density in both winter and summer was found in emergent marsh habitat (Stahlecker and Cox, 1997: 9-10). The most abundant bird species found along the river in winter were mallard, Canada goose, and wood duck (*Aix sponsa*), which were also found breeding throughout Rio Grande Valley State Park, although in lesser numbers, in summer (Stahlecker and Cox, 1997: 12-13).

Red-tailed hawk (*Buteo jamaicensis*) and Cooper's hawk (*Accipiter cooperii*) were reported as common raptors along the river in winter (Stahlecker and Cox, 1997: 15-16). Cooper's hawk and great-horned owl also occur as nesting birds in the project area (William DeRagon, biologist, U.S. Army Corps of Engineers, pers. comm.). Twenty-eight stick nests were found in the project area. All of the stick nests were located in Rio Grande cottonwood. None was found in Siberian elm. Stick nests in the project area are used by great-horned owl, Cooper's hawk, red-tailed hawk, and crow.

3.4 Existing Special-Status Species Conditions

Forty-six special status species are known from Bernalillo County (Table 1). Protection from harm, harassment, or destruction of habitat is afforded to species protected under the federal Endangered Species Act. The New Mexico Wildlife Conservation Act and New Mexico Endangered Plant Species Act protect state-listed species by prohibiting take without a permit from the New Mexico Department of Game and Fish or New Mexico Forestry and Resources Conservation Division.

The general vegetation type that each species is known from is listed in Table 1 in the “Habitat” column. Fourteen species that are known to occur in plains mesa grassland in riparian, aquatic, or wetland habitat and whose known distribution includes the project area were considered as potentially affected by the proposed action. Five of these 14 species are listed or candidates for listing under the federal Endangered Species Act: Rio Grande silvery minnow (*Hybognathus amarus*, endangered); bald eagle (*Haliaeetus leucocephalus*, threatened); whooping crane (*Grus americana*, endangered); yellow-billed cuckoo (*Coccyzus americanus occidentalis*, candidate); and southwestern willow flycatcher (*Empidonax traillii extimus*, endangered).

Of the remaining nine species, four are state-listed: neotropic cormorant (*Phalacrocorax brasilianus*, state threatened); common black-hawk (*Buteogallus anthracinus anthracinus*, state threatened); Bell’s vireo (*Vireo bellii*, state threatened); and New Mexican meadow jumping mouse (*Zapus hudsonius luteus*, state threatened). The last five species are federal or state species of concern: flathead chub (*Platygobio gracilis*); black tern (*Chlidonias niger surinamensis*); Yuma myotis (*Myotis yumanensis yumanensis*); occult little brown bat (*Myotis lucifugus occultus*); and Pecos River muskrat (*Ondatra zibethicus ripensis*).

Table 1. Special status plant and animal species that occur in Bernalillo County.

Status is: federal endangered (**FE**); federal threatened (**FT**); federal proposed as threatened (**FPt**) or endangered (**FPe**); federal candidate (**FC**); federal species of concern (**FS**); state endangered (**SE**); state threatened (**ST**); and state species of concern (**SS**). The state species of concern category also includes plants that have status pursuant to the New Mexico Natural Heritage Program criteria, as indicated on the New Mexico Rare Plant List.

Habitat is coded as: **TUN** =alpine tundra; **SCF** = subalpine coniferous forest; MCF =Rocky Mountain upper or lower montane coniferous forest; **SMG** = subalpine-montane grassland; **PJW** = piñon-juniper woodland; **MSC** = montane scrub; **PMG** = plains-mesa grassland; **DGR** = desert grassland; **BDS** = Great Basin desert scrub; and **CDS** = Chihuahuan desert scrub. Special habitats are coded as: **Rip** = riparian; **Wet** = wetlands; **Aq** = aquatic; **Rck** = rock outcrops, rocky areas or cliffs; **Sand** = sand dunes or sandy soils; **Lime** = limestone cliffs or terraces.

Common Name	Scientific Name	Status		Habitat
Plants (5)				
Santa Fe milkvetch	*Astragalus feensis*	-	SS	PMG,PJW
La Jolla prairie clover	*Dalea scariosa*	-	SS	CDS,DGR
Sapello Canyon larkspur	*Delphinium sapellonis*	-	SS	MCF
Sandia alumroot	*Heuchera pulchella*	-	SS	MCF/Lime
Plank's catchfly	*Silene plankii*	-	SS	PJW-MCF/Rck
Invertebrates (3)				
slate millipede	*Comanchus chihuanus*	FS	SS	PMG
Socorro mountainsnail	*Oreohelix neomexicana*	-	SS	PJW
southwestern pearly checkerspot butterfly	*Charidryas acastus sabina*	FS	-	CDS-PJW
Fishes (3)				
Rio Grande chub	*Gila pandora*	-	SS	PMG-MCFAq
Rio Grande silvery minnow	***Hybognathus amarus***	**FE**	**SE**	**CDS-PMG/Aq**
flathead chub	***Platygobio gracilis***	**FS**	**-**	**CDS-MCF/Aq**
Birds (19)				
neotropic cormorant	***Phalacrocorax brasilianus***	**FS**	**ST**	**DGR-MCF/Aq**
bald eagle	***Haliaeetus leucocephalus***	**FT**	**ST**	**CDS-MCF/Rip**
northern goshawk	*Accipiter gentilis*	FS	SS	MCF
common black-hawk	***Buteogallus anthracinus anthracinus***	**FS**	**ST**	**CDS-MCF/Rip**
ferruginous hawk	*Buteo regalis*	FS	SS	DGR,PMG
American peregrine falcon	*Falco peregrinus anatum*	FS	ST	CDS-MCF/Rck
arctic peregrine falcon	*Falco peregrinus tundrius*	FS	-	CDS-MCF/Rck
whooping crane	***Grus americana***	**FE**	**SE**	**CDS-PMG/Rip**
mountain plover	*Charadrius montanus*	FPt	SS	DGR,PMG
black tern	***Chlidonias niger surinamensis***	**FS**	**SS**	**DGR-MCF/Aq,Wet**
yellow-billed cuckoo	***Coccyzus americanus occidentalis***	**FC**	**-**	**DGR-MCF/Aq,Wet**
burrowing owl	*Athene cunicularia hypugaea*	FS	-	CDS-PMG
Mexican spotted owl	*Strix occidentalis lucida*	FT	SS	MCF,SCF
white-eared hummingbird	*Hylocharis leucotis borealis*	-	ST	PJW-MCF/Rip
southwestern willow flycatcher	***Empidonax traillii extimus***	**FE**	**SE**	**CDS-MCF/Rip,Aq**
loggerhead shrike	*Lanius ludovicianus*	FS	SS	CDS-PMG
Bell's vireo	***Vireo bellii***	**FS**	**ST**	**CDS-PJW/Rip**
gray vireo	*Vireo vicinior*	FS	ST	PJW
Baird's sparrow	*Ammodramus bairdii*	FS	ST	DGR,PMG

Table 1, continued

Common Name	Scientific Name	Status		Habitat
Mammals (16)				
western small-footed bat	*Myotis ciliolabrum melanorhinus*	FS	SS	PJW-MCF/Rip
Yuma myotis	***Myotis yumanensis yumanensis***	**FS**	**SS**	**DGR-MCF/Rip,Aq**
occult little brown bat	***Myotis lucifugus occultus***	**FS**	**SS**	**CDS-SCF/Rip,Aq**
long-legged myotis	*Myotis volans interior*	FS	SS	MCF/Aq
fringed myotis	*Myotis thysanodes thysanodes*	FS	SS	DGR-MCF/Rck
spotted bat	*Euderma maculatum*	FS	ST	PJW-MCF/Rip
Townsend's big-eared bat	*Corynorhinus townsendii*	FS	SS	CDS-MCF
big free-tailed bat	*Nyctinomops macrotis*	FS	SS	PJW-MCF/Rck
Gunnison's prairie dog	*Cynomys gunnisoni*	-	SS	DGR,PMG,SMG
Botta's pocket gopher	*Thomomys bottae connectens*	-	SS	PMG-PJW
Pecos River muskrat	***Ondatra zibethicus ripensis***	**FS**	**SS**	**CDS-PJW/Aq**
New Mexican meadow jumping mouse	***Zapus hudsonius luteus***	**FS**	**ST**	**CDS-SCF/Rip**
red fox	*Vulpes vulpes*	-	SS	PJW-TUN
ringtail	*Bassariscus astutus*	FS	ST	PJW-SCF/Rck,Rip
black-footed ferret	*Mustela nigripes*	FE	SS	DGR,PMG
western spotted skunk	*Spilogale gracilis*	-	SS	CDS-MCF

3.4.1 Rio Grande Silvery Minnow Rio Grande silvery minnow historically occurred in the Rio Grande drainage in New Mexico and Texas (Lee *et al.*, 1980: 177; Propst, 1999: 26). The species was historically one of the most abundant and widespread fishes in the Rio Grande drainage (Bestgen and Platania, 1991). In New Mexico, historic range of the species included the Rio Chama from Abiquiu to the Rio Grande confluence, the main stem of the Rio Grande from Velarde downstream to the New Mexico-Texas state line, and the Pecos River downstream from Santa Rosa (Sublette *et al.*, 1990: 131). Rio Grande silvery minnow was extirpated from the from the Rio Grande downstream of the Pecos River by 1961 and from the Pecos River proper by the mid-1970s. The species was also extirpated from the Rio Grande upstream from Cochiti Dam and downstream from Elephant Butte Reservoir. Currently, Rio Grande silvery minnow is present only in the Rio Grande between Cochiti Reservoir and the upper end of Elephant Butte Reservoir, which represents less than 10% of its historic distribution (Bestgen and Platania, 1991; Propst, 1999: 26). Abundance of Rio Grande silvery minnow has declined markedly from 1994 to the present time and the population has become concentrated in the reach of the Rio Grande between San Acacia Diversion Dam and the headwaters of Elephant Butte Reservoir.

Rio Grande silvery minnow is a pelagic-broadcast spawner, producing nonadhesive, semi-buoyant eggs (Platania and Altenbach, 1998). Spawning is initiated by elevated stream discharge and occurs primarily in the late spring and early summer, when water temperatures are 20°C (68°F) to 24°C (75°F; Propst, 1999: 27). Females may produce three to 18 clutches of eggs, each clutch numbering from 200 to 300 eggs. Eggs develop as they drift downstream and hatching typically occurs about four days after fertilization,

being dependant on water temperature. After hatching, larvae continue to drift for another one to three days, after which they move into slow-velocity habitats such as backwaters. Growth to maturation occurs in about two months. Rio Grande silvery minnow typically live only about one year, with less than 10% of the adult population surviving to up to two years (Platania and Altenbach, 1998; Propst, 1999: 27). Habitat used by adult Rio Grande silvery minnow is characterized by silty to sandy substrate, depths of 0.2 m (8 in) to 0.8 m (2.6 ft), and slow to moderate current velocity, 0 cm/sec (0 ft/sec) to 30 cm/sec (0.98 ft/sec; Dudley and Platania, 1997). Habitats with slow current velocity and associated cover are used in winter. Rio Grande silvery minnow feeds on algae and detritus (Propst, 1999: 27; U.S. Fish and Wildlife Service, 1999: 20). Major threats to persistence of Rio Grande silvery minnow include diminution of river flows and dewatering by surface water diversions and dam regulation, modification of aquatic habitats that result in faster current velocities and narrower channels, and introduction of nonnative fishes (U.S. Fish and Wildlife Service, 1999: 1-2). Recovery of Rio Grande silvery minnow requires stabilizing the population in the middle Rio Grande and reestablishing the species in suitable habitats within its historic range (U.S. Fish and Wildlife Service, 1999: 42).

Rio Grande silvery minnow occurs in the Rio Grande in the project area, which is also includes designated critical habitat for the species (68 Federal Register 8087: 8135). Fish obtained from recent salvage operations conducted during river drying events and captive propagation have been planted in the Albuquerque area in an attempt to restore the population in that reach (J. Brooks, U.S. Fish and Wildlife Service, pers. comm., 18 July 2003). Releases of captive-reared Rio Grande silvery minnow have been made at Alameda Bridge, which is about 13.6 km (8.5 mi) upstream from the project area.

3.4.2 Flathead Chub Flathead chub occurs in west central North America from the lower Mississippi River and tributaries of the South Canadian River in Oklahoma, north to Lake Winnipeg and Saskatchewan and Mackenzie river drainages in Canada. In New Mexico, the species is native to the Rio Grande, Pecos, and Canadian drainages including the Dry Cimarron drainage. The status of populations of flathead chub is expanding in the Rio Grande drainage and stable in the Pecos and Canadian (including the Dry Cimarron River) drainages. Flathead chub is found in perennial streams and is associated with main-channel habitats characterized by shifting sand substrates and typically turbid water (Sublette *et al.*, 1990). Flathead chub is abundant in the Rio Grande in the project area (U.S. Fish and Wildlife Service, 1999: 15).

3.4.3 Neotropic Cormorant Neotropic cormorant occurs from southern New Mexico to southern Louisiana, southward through Central America and parts of the Caribbean region to southern South America. Vagrants occur elsewhere, including further north in the United States (American Ornithology Union, 1983). In New Mexico, the species breeds and is variably resident in the Rio Grande Valley at Elephant Butte and Caballo lakes. It also occurs regularly at Bosque del Apache National Wildlife Refuge (Hubbard, 1978). All of these locations are key habitat areas where the species is known to breed. The species also occurs occasionally as non-breeding individuals in the Rio Grande Valley northward to the Bernalillo area, southward to Las Cruces, and in the Gila Valley. It is a vagrant, non-breeding bird to

southern Hidalgo County, near Alamogordo (Otero County), and in the lower Pecos River Valley south of Bitter Lake National Wildlife Refuge (New Mexico Department of Game and Fish, 1988). In New Mexico, neotropic cormorants are generally found on larger bodies of water such as reservoirs, where they prey on fish (Hubbard, 1978). They nest near or over water, in vegetation such as snags or trees. Stahlecker and Cox (1997: 25) reported double-crested cormorant (*Phalacrocorax auritus*) in the project area in winter and summer, but no neotropic cormorants. Neotropic cormorant may occur in the project area but are unlikely to breed there due to lack of suitable lacustrine habitat.

3.4.4 Bald Eagle Bald eagle migrates and winters from the northern border southward regularly to the Gila, lower Rio Grande, middle Pecos, and Canadian river valleys (Hubbard, 1985a). Some areas removed from water harbor concentrations of eagles, such as the Mogollon plateau and the region between the Pecos River and the Sacramento, Capitan, Manzano and Sandia mountain ranges. Summering or breeding eagles are rare and have only been documented from a few locations. Key habitat areas include winter roost and concentration localities, such as at Navajo Lake, the Chama Valley (Rio Arriba County), Cochiti Lake (Sandoval County), the northeastern lakes (Raton to Las Vegas), the lower Canadian River valley, Sumner Lake, Elephant Butte Lake, Caballo Lake, and the upper Gila Basin (Hubbard, 1985a). Any nesting or summering areas are considered key habitat for the species. Bald eagles are typically associated with water and riparian habitat. These eagles night-roost in groups in sheltered, forested habitats, such as canyons (New Mexico Department of Game and Fish, 1988). Suitable foraging habitat is characterized by open expanses of water with abundant prey (*e.g.* waterfowl, fish) and large trees or snags for perch sites.

The primary cause for the decline of bald eagles in the past was the ingestion of hydrocarbon pesticide residues in prey, which results in thinning of the eggshells and consequent reproductive failure. Some eagle populations in the United States have recovered in recent years, almost certainly due to the banning of DDT and related chemicals. There are few data to suggest the presence of a historic breeding population in New Mexico, much less to account for its apparent extirpation (Hubbard, 1985a). Winter and migrant populations have increased in New Mexico, apparently as the result of reservoir construction and the expansion of fish and waterfowl populations. January aerial surveys of seven regularly-sampled sites showed bald eagle counts averaging 231 birds in 1979 to 1986, with the adults constituting 44% to 64% of the birds counted (Hubbard *et al.*, 1986). The main threats to wintering populations are habitat loss and degradation, including declines in prey and roost site availability. Disturbance, contamination, and illegal taking are also threats to bald eagles (New Mexico Department of Game and Fish, 1988). The most significant steps toward the conservation of this species are ones aimed at habitat maintenance and enhancement. In New Mexico, optimal habitats center on riparian and lacustrine environments where food, shelter, and potential nest sites are in the greatest supply.

Bald eagle may occur in winter along the Rio Grande, particularly to the north and south of the project area (Stahlecker and Cox, 1997: 17). No winter roosts are known from the project area, likely due to unsuitable conditions created by the existing level of human disturbance (Stahlecker and Cox, 1997: 22).

3.4.5 Common Black-Hawk Common black-hawk is known to breed in southwestern New Mexico, east-central to southeastern Arizona, western Texas, and the lower Rio Grande valley and Gulf of Mexico coast in southeastern Texas (Clark and Wheeler, 1987: 48). Most birds migrate south to winter, although some winter records are reported from southern Arizona and the Gulf coast in Texas. In New Mexico, common black-hawk breeds along the lower elevations of the Gila, San Francisco, and Mimbres rivers (Hubbard and Eley, 1985). The species has also been reported as breeding along the Rio Grande north to Albuquerque (Hundertmark, 1974) and, more recently, from the Hondo Valley in Lincoln County (D. W. Stahlecker, pers. com.).

Common black-hawks are a large-bodied raptor with body length of 51 cm (20 in) to 58 cm (23 in) and a wingspan of 122 cm (48 in) to 127 cm (50 in). Body plumage is black, wings are wide, and there is a broad white band across the tail, which is black with a white tip. The tail is short and fan-shaped and there are white spots at the base of the outer primaries. This hawk is closely associated with riparian areas and forages mainly on fish, insects, crayfish, amphibians, and reptiles but occasionally takes small mammals and birds (Clark and Wheeler, 1987: 47; Alsop, 2001: 163). The species typically nests in large cottonwood trees in well-developed riparian woodlands or forests (Millsap, 1981; Schnell, 1979). Nests are constructed of sticks and are typically located in the crotch of a tree, located 4.57 m (15 ft) to 30.48 m (100 ft) above the ground. One to three eggs are laid and there is a single brood per year. Common black-hawk is usually active during the day, when individuals can often be observed soaring (Alsop, 2001: 163).

Common black-hawks are sensitive to human disturbance and are declining in North America, with an estimated 250 nesting pairs (Alsop, 2001: 163). It is estimated that up to 80 breeding pairs occur in southwestern New Mexico (New Mexico Department of Game and Fish, 1996). It is likely loss or fragmentation of large blocks of mature riparian forest habitat has reduced the number of breeding pairs in the state (New Mexico Department of Game and Fish, 1988). Only one occurrence of nesting common black-hawk has been reported from the vicinity of the project area in the last 14 years. That report was from the east side of the river south of the Rio Bravo crossing (Stahlecker and Cox, 1997: 17).

3.4.6 Whooping Crane Although whooping crane now occurs in New Mexico as a result of the Grays Lake National Wildlife Refuge experiment, the only indication of prior occurrence is unverified reports from near Hatch in Doña Ana County in the mid-1850's, near Portales in Roosevelt County in 1938, and Union County in the 1960's (Allen, 1952). Birds from Idaho migrate to New Mexico in the autumn, and most winter in the central Rio Grande valley (Hubbard, 1985b). Occasional birds occur in the nearby Las Uvas valley (Doña Ana and Luna counties) and probably near Deming. A vagrant was also present in migration near Las Vegas. Possible records elsewhere (*e.g.* Clayton) cannot be verified and are probably unlikely. Whooping cranes forage in agricultural fields, primarily where there is waste grain or sprouting crops, and roost on sandbars in the Rio Grande (Hubbard, 1985b).

The principal use areas of the Rocky Mountains whooping crane population include the middle Rio Grande valley of New Mexico, the lower San Luis valley of Colorado, and summering areas in southeastern Idaho and western Wyoming. Southeastern Arizona, northeastern Utah, southwestern Montana, northwestern Colorado, and northern New Mexico are only occupied temporarily during migration or infrequently by a single whooping crane in summer or winter. The portion of the middle Rio Grande valley involved includes a few miles on either side of the Rio Grande ranging from the town of Belén to Bosque del Apache National Wildlife Refuge. The middle Rio Grande area is used as a wintering grounds from November to February. In February and March whooping cranes migrate to south-central Colorado where they spend 4 to 6 weeks in the San Luis valley before continuing north into southeastern Idaho and western Wyoming. The whooping cranes spend April to September on their summer grounds in southeastern Idaho and western Wyoming. In September and October, before migration, they flock with sandhill cranes (*Grus canadensis*) at Grays Lake and other wetlands and pastures before migrating southeast through northeastern Utah and western Colorado. They migrate through northern New Mexico and arrive at the wintering area in early November (U.S. Fish and Wildlife Service, 1996). Whooping crane has not been reported from the project area. Sandbar habitat in the channel of the Rio Grande may provide some suitable roosting habitat; however, forage areas are lacking in the vicinity of the project area. Therefore, whooping crane is unlikely to be found in the project area.

3.4.7 Black Tern Black tern occurs irregularly in summer in northern New Mexico, the Rio Grande Valley, and the Pecos Valley. This tern migrates statewide and is considered rare to fairly common locally. Black tern occurs most frequently in summer in the San Juan Valley, Jicarilla Apache Indian Reservation, the middle Rio Grande Valley, and at Bitter Lake National Wildlife Refuge (Hubbard, 1978). The species winters along Atlantic and Pacific coasts from Panama south to Peru and Suriname (Erlich *et al.*, 1988: 188). Black terns breed and forage in vegetated marshes with some areas of open water (Bent, 1964; DeGraaf *et al.*, 1991; Finch, 1992). The species is a colonial nester and typically produces one brood per year. Nest success is often quite low (Erlich *et al.*, 1988: 188). Nests are constructed of dried herbaceous plant material and are located in palustrine emergent wetlands on the ground (Alsop, 2001: 314). Black terns prey primarily on aquatic invertebrates such as insects, crayfish, and small molluscs but also may eat small fish. Black tern is not known from the project area and suitable emergent palustrine wetland habitat is not present there.

3.4.8 Yellow-Billed Cuckoo The breeding range of yellow-billed cuckoo extends from California and northern Utah eastward to southwestern Quebec and south to Mexico. Yellow-billed cuckoo has declined precipitously throughout its range in southern Canada, the United States, and northern Mexico. The number of breeding birds has declined by about 42% in the eastern United States (Elphick *et al.*, 2001: 335). It is nearly extinct west of the Continental Divide, having disappeared from British Columbia in the 1920's, from Washington in the 1930's, from Oregon in the 1940's, and from northern-most California in the 1950's. It is extremely rare in the interior West. Its only remaining western "strongholds" are three small populations in California, scattered populations in Arizona (especially on the San Pedro

River) and New Mexico (especially the Gila River), and an unknown number of birds in northern Mexico (Center for Biological Diversity, 2000). The species winters in South America (DeGraaf *et al.*, 1991).

Yellow-billed cuckoo nests in dense riparian shrub habitat in stands typically at least 10 ha (25 ac) in size (Elphick *et al.*, 2001: 335). They arrive in New Mexico beginning in late April and early May and nest from late May through August (Howe, 1986). Mature cottonwood forest with well-developed willow understory appear to be important characteristics of habitat for yellow-billed cuckoo (Buffington *et al.*, 1997; Gaines and Laymon, 1984). While willows appear to be a preferred nest tree, the species will also nest in dense salt cedar stands (Howe, 1986). Nests are constructed of sticks and are located in dense foliage. Yellow-billed cuckoo may nest up to three times a year, with a clutch size of two to six eggs. They may occasionally parasitize nests of other birds, particularly when food is abundant. Yellow-billed cuckoo feeds primarily on caterpillars but will also consume bird eggs, frogs, lizards, berries, and other fruits (Erlich *et al.*, 1988). Yellow-billed cuckoo forages primarily in the foliage layer of shrubby and woody vegetation. Populations fluctuate markedly in response to variation in caterpillar abundance. Population declines resulting from loss or disturbance of riparian habitat have been consistently reported in the West (Finch, 1992). The greatest factors affecting the yellow-billed cuckoo have been the invasion of exotic woody plants into Southwest riparian systems and clearing of riparian woodlands for agriculture, fuel, development, and attempts at water conservation (Howe, 1986). Both Hink and Ohmart (1984) and Stahlecker and Cox (1997) reported yellow-billed cuckoo as a nesting bird in the *bosque* of the Middle Rio Grande, although none of these reports were from the project area. Habitat potentially suitable for nesting of yellow-billed cuckoo is present in the project area, primarily in the form of dense salt cedar stands.

3.4.9 Southwestern Willow Flycatcher Southwestern willow flycatcher is found in the U.S. from May until September. It winters in southern Mexico, Central America, and northern South America (Unitt, 1987). In New Mexico, southwestern willow flycatcher is distributed in nine drainages (Gila, Rio Grande, Rio Chama, Coyote Creek, Nutria Creek, Rio Grande de Ranchos, Zuni, Bluewater Creek, and San Francisco). As of 1996, it was estimated that there were only about 400 southwestern willow flycatchers in New Mexico, representing about 42% of the total population of the subspecies (Finch and Stoleson, 2000). Southwestern willow flycatcher occurs in riparian habitats along rivers, streams, or other wetlands, where dense growths of willows (*Salix* sp.), *Baccharis*, arrowweed (*Pluchea* sp.) saltcedar or other plants are present, often with a scattered overstory of cottonwood (Unitt 1987; Sogge *et al.*, 1997; Finch and Stoleson, 2000). These riparian communities provide nesting and foraging habitat. Throughout the range of *E. t. extimus*, these riparian habitats tend to be rare, widely separated, small and often linear locales, separated by vast expanses of arid lands. The southwestern willow flycatcher is endangered by extensive loss and modification of suitable riparian habitat and other factors, including brood parasitism by the brown-headed cowbird (*Molothrus ater;* Unitt, 1987). Stahlecker and Cox (1997: 17, 23) did not find southwestern willow flycatcher in the project area in 1997 nor did they find habitat suitable for the species there (Stahlecker and Cox, 1997: 22). Surveys conducted in 2002 and 2003 did not find any migratory or nesting southwestern willow flycatcher in the project area (William DeRagon, biologist, U.S. Army Corps of Engineers, pers. comm.).

3.4.10 Bell's Vireo Bell's vireo breeds from southern California, the Southwest, and the central Great Plains and the adjacent Midwest southward to northern Mexico. The subspecies *V. b. arizonae* occurs in parts of the southwestern United States and Sonora, while the subspecies *V. b. medius* occurs to the east (Oberholser, 1974). In New Mexico the subspecies *V. b. arizonae* summers locally in the lower Gila Valley and in Guadalupe Canyon (Hidalgo County), with occasional birds in the lower San Francisco Valley and at San Simon Cienaga in Hidalgo County (Hubbard, 1985c). *V. b. medius* summers very locally in the lower Rio Grande (and as a vagrant north to Albuquerque) and the lower Pecos valleys. Key habitat areas are all sites at which breeding populations of this species are found, including, in addition to the above, Rocky Arroyo and Rattlesnake Springs in Eddy County. Reports from northeastern New Mexico have not been verified to date. In New Mexico, Bell's vireo characteristically occurs in dense shrubs or woodland along lowland stream courses, with willows (*Salix* spp), mesquite (*Prosopis* spp.), and seepwillows (*Baccharis glutinosa*) being characteristic plant species (Hubbard, 1985c). These vireos feed on insects, moving slowly about for the most part, gleaning food from branches and leaves. The bird itself is inconspicuous, but the song draws attention to its presence. The nest is a cup of grasses and other plant parts, slung between twigs or small stems not far above the ground. This is generally the only vireo breeding along lowland streams, although other species occur there in migration. Gray vireo (*V. vicinior*) may breed on nearby slopes. Bell's vireo has not been documented as a breeding bird in the project area and habitat suitable for the species is not found there.

3.4.11 Yuma Myotis Yuma myotis is typically found in grassland, woodland and riparian habitats from 1,220 to 2,130 m (4,000 to 7,000 ft) elevation. This species is most common in desert areas and is closely associated with open water (Schmidly, 1991). Yuma myotis forages at the water surface. Railroad bridges and buildings are common summer retreats for this bat (Findley *et al.*, 1975). Females give birth to one young each year, which are raised in nursery colonies that roost in buildings, mine tunnels, and under bridges (Schmidly, 1991). Nursery colonies are highly sensitive and are quickly abandoned if disturbed. Yuma myotis diet consists primarily of moths, beetles, and midges (Schmidly, 1991). Yuma myotis may occur in the project area. The species was collected at Corrales and several other locations along the Rio Grande upstream and downstream from the project area (Findley *et al.*, 1975: 30).

3.4.12 Occult Little Brown Bat This species, like *M. yumanensis*, is a "water" bat in that most specimens have been taken in the vicinity of large permanent water sources such as streams, drainage ditches, or lakes (Findley *et al.*, 1975). Areas where such bodies of water are lacking support these animals only as transients. Vegetation zone seems unimportant in determining their distribution (Findley *et al.*, 1975), although nursery colonies of up to several hundred individuals frequently roost under exfoliating bark of old growth ponderosa pine snags. This species is insectivorous, foraging at the water surface. Occult little brown bats mate in fall and fertilization occurs in spring (Barbour and Davis, 1967; Humphrey and Cope, 1976). Young are born in May or June. As with Yuma myotis, occult little brown bat may occur in the project area.

3.4.13 Pecos River Muskrat Muskrats are found throughout North America wherever there is adequate water and emergent vegetation (Hall, 1981). The historic range of the Pecos River muskrat includes areas within New Mexico and Texas. Muskrats occur in marshes and drainage ditches along the Rio Grande, Pecos, and San Juan rivers. A seemingly isolated colony was reported from tributaries of the upper San José near Grants. In the San Francisco and Gila river drainages the only records of these animals are skulls found in a cave near Reserve. Muskrats occur all over the state up to 3,048 m (10,000 ft) elevation in mountain lakes (Findley *et al.*, 1975); however, the current distribution of this subspecies is largely unknown. Campbell and others (1997) observed muskrat tracks at an island near Montaño Bridge and at the Rio Bravo Bridge crossing, which is the south end of the project area.

3.4.14 New Mexican Jumping Mouse Meadow jumping mouse occurs from Alaska to Labrador southward to British Columbia and the southwestern United States, Oklahoma, Alabama, and Georgia. The subspecies *Z. h. luteus* is endemic to New Mexico and Arizona (Hafner *et al.*, 1981). In New Mexico, meadow jumping mouse occurs locally in the San Juan, Jemez, and Sacramento mountains and in the central-northern and the central Rio Grande Valley (Hafner *et al.*, 1981). The species has also been recorded once in the Sangre de Cristo Mountains at Williams Lake in Taos County and near Belen (Morrison, 1988). Key habitat areas include along the Rio Cebolla in the Jemez Mountains, the vicinity of Española, Isleta Marsh in Bernalillo County, Bosque del Apache National Wildlife Refuge, and the Cloudcroft area. The species may also still persist where previously taken, including near El Rito (Rio Arriba County) and Socorro. The species characteristically is found in mesic habitats dominated by rank, herbaceous vegetation. In both the Jemez Mountains and the Rio Grande Valley, Morrison (1985, 1988) found that preferred habitat for the meadow jumping mouse included permanent streams, moderate to high soil moisture, and dense and diverse stream side vegetation consisting of grasses, sedges, and forbs. At Bosque del Apache National Wildlife Refuge, meadow jumping mice were associated with a grass and perennial forb community with at least 65% vegetative cover (Zwank, 1994).

New Mexican jumping mouse was collected by Hink and Ohmart (1984) along the Rio Grande only at Isleta Marsh, which is south of the project area. More recent sampling in the project area failed to find the species there (Campbell *et al.*, 1997). Potentially suitable habitat for New Mexican jumping mouse in the project area is restricted a few small wetlands adjacent to the river. However, because these wetlands are inundated quite frequently, it is unlikely that they could support a population of New Mexican jumping mouse.

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APPENDIX A

Species potentially occurring in riparian, wetland, or aquatic habitats of the Rio Grande in Bernalillo County.

Dorosoma cepedianum	Gizzard Shad
Oncorhynchus mykiss	Rainbow Trout
Salmo trutta	Brown Trout
Campostoma anomalum	Central Stoneroller
Ctenopharyngodon idella	Grass Carp
Cyprinus carpio	Common Carp
Gila pandora	Rio Grande Chub
Hybognathus amarus	Rio Grande Silvery Minnow
Platygobio gracilis	Flathead Chub
Cyprinella lutrensis	Red Shiner
Pimephales promelas	Fathead Minnow
Rhinichthys cataractae	Longnose Dace
Carpiodes carpio carpio	River Carpsucker
Catostomus commersoni	White Sucker
Ameiurus melas	Black Bullhead
Ameiurus natalis	Yellow Bullhead
Ictalurus punctatus	Channel Catfish
Gambusia affinis	Mosquitofish
Lepomis cyanellus	Green Sunfish
Lepomis macrochirus	Bluegill
Micropterus salmoides salmoides	Largemouth Bass
Pomoxis annularis	White Crappie
Perca flavescens	Yellow Perch
Stizostedion vitreum	Walleye

Ambystoma tigrinum	Tiger Salamander
Bufo cognatus	Great Plains Toad
Bufo punctatus	Red-spotted Toad
Bufo woodhousii	Woodhouse's Toad
Hyla arenicolor	Canyon Tree Frog
Pseudacris triseriata	Western Chorus Frog
Scaphiopus couchii	Couch's Spadefoot
Spea bombifrons	Plains Spadefoot

Spea multiplicata	New Mexico Spadefoot
Rana catesbeiana	Bullfrog
Rana pipiens	Northern Leopard Frog

Chelydra serpentina serpentina	Snapping Turtle
Chrysemys picta bellii	Western Painted Turtle
Terrapene ornata	Ornate Box Turtle
Trachemys scripta elegans	Red-eared Slider
Kinosternon flavescens flavescens	Yellow Mud Turtle
Trionyx spiniferus	Spiny Softshell Turtle
Crotaphytus collaris	Collared Lizard
Gambelia wislizenii	Longnose Leopard Lizard
Holbrookia maculata	Lesser Earless Lizard
Phrynosoma modestum	Roundtail Horned Lizard
Sceloporus undulatus	Eastern Fence Lizard
Urosaurus ornatus	Northern Tree Lizard
Eumeces multivirgatus epipleurotus	Many-lined Skink
Eumeces obsoletus	Great Plains Skink
Cnemidophorus exsanguis	Chihuahuan Spotted Whiptail
Cnemidophorus grahami	CO Checkered Whiptail
Cnemidophorus tigris	Western Whiptail
Cnemidophorus velox	Plateau Striped Whiptail
Arizona elegans	Glossy Snake
Coluber constrictor	E. Yellowbelly Racer
Diadophis punctatus	Ringneck Snake
Elaphe guttata	Great Plains Rat Snake
Heterodon nasicus	W. Hognose Snake
Hypsiglena torquata	Night Snake
Lampropeltis getula splendida	Desert Kingsnake
Lampropeltis triangulum	Milk Snake
Masticophis flagellum	Coachwhip
Masticophis taeniatus taeniatus	Desert Striped Whipsnake
Pituophis melanoleucus	Gopher Snake
Rhinocheilus lecontei	Texas Longnose Snake
Tantilla nigriceps	Plains Blackhead Snake
Thamnophis cyrtopsis cyrtopsis	W. Blackneck Garter Snake
Thamnophis elegans	Wandering Garter Snake

Thamnophis marcianus marcianus	Checkered Garter Snake
Thamnophis sirtalis dorsalis	New Mexico Garter Snake
Tropidoclonion lineatum	Lined Snake
Leptotyphlops dulcis dissectus	Texas Blind Snake
Crotalus atrox	W. Diamondback Rattlesnake
Crotalus molossus molossus	Blacktail Rattlesnake

Icterus bullockii	Bullock's Oriole
Icterus galbula	Baltimore Oriole
Vireo cassinii	Cassin's Vireo
Vireo plumbeus	Plumbeous Vireo
Gavia immer	Common Loon
Podilymbus podiceps podiceps	Pied-billed Grebe
Podiceps nigricollis californicus	Eared Grebe
Aechmophorus occidentalis	Western Grebe
Aechmophorus clarkii	Clark's Grebe
Phalacrocorax auritus	Double-crested Cormorant
Phalacrocorax brasilianus	Neotropic Cormorant
Botaurus lentiginosus	American Bittern
Ixobrychus exilis exilis	Least Bittern
Ardea herodias	Great Blue Heron
Egretta thula brewsteri	Snowy Egret
Butorides virescens	Green Heron
Nycticorax nycticorax hoactli	Black-crowned Night Heron
Plegadis chihi	White-faced Ibis
Anser albifrons frontalis	Greater White-fronted Goose
Chen caerulescens hyperborea	Snow Goose
Chen rossii	Ross's Goose
Branta canadensis	Canada Goose
Aix sponsa	Wood Duck
Anas crecca carolinensis	Green-winged Teal Duck
Anas platyrhynchos	Mallard Duck
Anas acuta	Northern Pintail Duck
Anas discors discors	Blue-winged Teal Duck
Anas cyanoptera septentrionalium	Cinnamon Teal Duck
Anas clypeata	Northern Shoveler Duck
Anas strepera	Gadwall Duck

Anas americana	American Wigeon Duck
Aythya valisineria	Canvasback Duck
Aythya americana	Redhead Duck
Aythya collaris	Ring-necked Duck
Aythya marila nearctica	Greater Scaup Duck
Aythya affinis	Lesser Scaup Duck
Bucephala clangula americana	Common Goldeneye Duck
Bucephala albeola	Bufflehead Duck
Lophodytes cucullatus	Hooded Merganser Duck
Mergus merganser americanus	Common Merganser Duck
Cathartes aura	Turkey Vulture
Pandion haliaetus carolinensis	Osprey
Ictinia mississippiensis	Mississippi Kite
Haliaeetus leucocephalus	Bald Eagle
Circus cyaneus hudsonius	Northern Harrier
Accipiter striatus velox	Sharp-shinned Hawk
Accipiter cooperii	Cooper's Hawk
Accipiter gentilis	Northern Goshawk
Buteogallus anthracinus anthracinus	Common Black-hawk
Parabuteo unicinctus harrisi	Harris's Hawk
Buteo platypterus platypterus	Broad-winged Hawk
Buteo swainsoni	Swainson's Hawk
Buteo albonotatus	Zone-tailed Hawk
Buteo jamaicensis	Red-tailed Hawk
Buteo regalis	Ferruginous Hawk
Buteo lagopus johannis	Rough-legged Hawk
Aquila chrysaetos canadensis	Golden Eagle
Falco sparverius sparverius	American Kestrel
Falco columbarius	Merlin
Falco peregrinus anatum	American Peregrine Falcon
Falco mexicanus	Prairie Falcon
Phasianus colchicus	Ring-necked Pheasant
Meleagris gallopavo	Wild Turkey
Callipepla squamata pallida	Scaled Quail
Callipepla gambelii	Gambel's Quail
Rallus limicola limicola	Virginia Rail

Porzana carolina	Sora
Fulica americana americana	American Coot
Grus canadensis	Sandhill Crane
Grus americana	Whooping Crane
Charadrius alexandrinus nivosus	Western Snowy Plover
Charadrius vociferus vociferus	Killdeer
Himantopus mexicanus	Black-necked Stilt
Recurvirostra americana	American Avocet
Tringa melanoleuca	Greater Yellowlegs
Tringa flavipes	Lesser Yellowlegs
Tringa solitaria	Solitary Sandpiper
Actitis macularia	Spotted Sandpiper
Numenius americanus americanus	Long-billed Curlew
Calidris mauri	Western Sandpiper
Calidris bairdii	Baird's Sandpiper
Gallinago gallinago delicata	Common Snipe
Scolopax minor	American Woodcock
Larus delawarensis	Ring-billed Gull
Larus argentatus smithsonianus	Herring Gull
Sterna forsteri	Forster's Tern
Chlidonias niger surinamensis	Black Tern
Columba livia	Rock Dove
Columba fasciata fasciata	Band-tailed Pigeon
Zenaida asiatica	White-winged Dove
Zenaida macroura	Mourning Dove
Coccyzus americanus occidentalis	Yellow-billed Cuckoo
Geococcyx californianus	Greater Roadrunner
Tyto alba pratincola	Barn Owl
Otus flammeolus	Flammulated Owl
Otus kennicottii	Western Screech Owl
Bubo virginianus	Great-horned Owl
Glaucidium gnoma californicum	Northern Pygmy Owl
Athene cunicularia hypugaea	Burrowing Owl
Strix occidentalis lucida	Mexican Spotted Owl
Asio otus	Long-eared Owl
Asio flammeus flammeus	Short-eared Owl

Aegolius acadicus acadicus	Northern Saw-whet Owl
Chordeiles minor	Common Nighthawk
Phalaenoptilus nuttalli nuttalli	Common Poorwill
Caprimulgus vociferus arizonae	Whip-poor-will
Cypseloides niger borealis	Black Swift
Aeronautes saxatalis saxatalis	White-throated Swift
Archilochus alexandri	Black-chinned Hummingbird
Stellula calliope	Calliope Hummingbird
Selasphorus platycercus platycercus	Broad-tailed Hummingbird
Selasphorus rufus	Rufous Hummingbird
Ceryle alcyon	Belted Kingfisher
Melanerpes lewis	Lewis's Woodpecker
Melanerpes formicivorus formicivorus	Acorn Woodpecker
Sphyrapicus varius varius	Yellow-bellied Sapsucker
Sphyrapicus thyroideus nataliae	Williamson's Sapsucker
Sphyrapicus nuchalis	Red-naped Sapsucker
Picoides scalaris	Ladder-backed Woodpecker
Picoides pubescens leucurus	Downy Woodpecker
Picoides villosus	Hairy Woodpecker
Picoides tridactylus dorsalis	Three-toed Woodpecker
Colaptes auratus	Northern Flicker
Contopus cooperi	Olive-sided Flycatcher
Contopus sordidulus	Western Wood Pewee
Empidonax traillii	Willow Flycatcher
Empidonax traillii extimus	SW. Willow Flycatcher
Empidonax minimus	Least Flycatcher
Empidonax hammondii	Hammond's Flycatcher
Empidonax oberholseri	Dusky Flycatcher
Empidonax wrightii	Gray Flycatcher
Empidonax occidentalis	Cordilleran Flycatcher
Sayornis nigricans semiatra	Black Phoebe
Sayornis phoebe	Eastern Phoebe
Sayornis saya	Say's Phoebe
Myiarchus cinerascens cinerascens	Ash-throated Flycatcher
Myiarchus tyrannulus magister	Brown-crested Flycatcher
Tyrannus vociferans vociferans	Cassin's Kingbird

Tyrannus verticalis	Western Kingbird
Tyrannus tyrannus	Eastern Kingbird
Tyrannus forficatus	Scissor-tailed Flycatcher
Tachycineta bicolor	Tree Swallow
Tachycineta thalassina lepida	Violet-green Swallow
Stelgidopteryx serripennis	N. Rough-winged Swallow
Riparia riparia riparia	Bank Swallow
Petrochelidon pyrrhonota	Cliff Swallow
Hirundo rustica erythrogaster	Barn Swallow
Cyanocitta stelleri macrolopha	Steller's Jay
Cyanocitta cristata	Blue Jay
Aphelocoma californica	Western Scrub Jay
Aphelocoma ultramarina arizonae	Mexican Jay
Gymnorhinus cyanocephalus	Pinyon Jay
Nucifraga columbiana	Clark's Nutcracker
Pica pica hudsonia	Black-billed Magpie
Corvus brachyrhynchos	American Crow
Corvus cryptoleucus	Chihuahuan Raven
Corvus corax sinuatus	Common Raven
Poecile atricapillus	Black-capped Chickadee
Poecile gambeli gambeli	Mountain Chickadee
Baeolophus ridgwayi	Juniper Titmouse
Auriparus flaviceps ornatus	Verdin
Psaltriparus minimus	Bushtit
Sitta canadensis	Red-breasted Nuthatch
Sitta carolinensis nelsoni	White-breasted Nuthatch
Sitta pygmaea melanotis	Pygmy Nuthatch
Certhia americana	Brown Creeper
Salpinctes obsoletus obsoletus	Rock Wren
Catherpes mexicanus conspersus	Canyon Wren
Thryomanes bewickii	Bewick's Wren
Troglodytes aedon parkmannii	House Wren
Troglodytes troglodytes	Winter Wren
Cistothorus palustris	Marsh Wren
Cinclus mexicanus unicolor	American Dipper
Regulus satrapa	Golden-crowned Kinglet

Regulus calendula calendula	Ruby-crowned Kinglet
Polioptila caerulea amoenissima	Blue-gray Gnatcatcher
Polioptila melanura melanura	Black-tailed Gnatcatcher
Sialia sialis	Eastern Bluebird
Sialia mexicana bairdi	Western Bluebird
Sialia currucoides	Mountain Bluebird
Myadestes townsendi townsendi	Townsend's Solitaire
Catharus ustulatus	Swainson's Thrush
Catharus guttatus	Hermit Thrush
Turdus migratorius	American Robin
Dumetella carolinensis ruficrissa	Gray Catbird
Mimus polyglottos leucopterus	Northern Mockingbird
Oreoscoptes montanus	Sage Thrasher
Toxostoma rufum longicauda	Brown Thrasher
Toxostoma curvirostre celsum	Curve-billed Thrasher
Toxostoma dorsale crissale	Crissal Thrasher
Anthus rubescens	American Pipit
Bombycilla cedrorum	Cedar Waxwing
Phainopepla nitens lepida	Phainopepla
Lanius excubitor invictus	Northern Shrike
Lanius ludovicianus	Loggerhead Shrike
Sturnus vulgaris	European Starling
Vireo bellii	Bell's Vireo
Vireo solitarius	Solitary Vireo
Vireo gilvus swainsonii	Warbling Vireo
Vireo olivaceus olivaceus	Red-eyed Vireo
Vermivora peregrina	Tennessee Warbler
Vermivora celata	Orange-crowned Warbler
Vermivora ruficapilla ridgwayi	Nashville Warbler
Vermivora virginiae	Virginia's Warbler
Parula americana	Northern Parula
Dendroica petechia	Yellow Warbler
Dendroica pensylvanica	Chestnut-sided Warbler
Dendroica caerulescens caerulescens	Black-throated Blue Warbler
Dendroica coronata	Yellow-rumped Warbler
Dendroica nigrescens	Black-throated Gray Warbler

Dendroica townsendi	Townsend's Warbler
Dendroica virens virens	Black-throated Green Warbler
Dendroica graciae graciae	Grace's Warbler
Dendroica palmarum	Palm Warbler
Dendroica striata	Blackpoll Warbler
Mniotilta varia	Black-and-white Warbler
Setophaga ruticilla tricolora	American Redstart
Protonotaria citrea	Prothonotary Warbler
Helmitheros vermivorus	Worm-eating Warbler
Seiurus aurocapillus cinereus	Ovenbird
Seiurus noveboracensis	Northern Waterthrush
Oporornis tolmiei	Macgillivray's Warbler
Geothlypis trichas	Common Yellowthroat
Wilsonia citrina	Hooded Warbler
Wilsonia pusilla	Wilson's Warbler
Cardellina rubrifrons	Red-faced Warbler
Myioborus pictus pictus	Painted Redstart
Icteria virens auricollis	Yellow-breasted Chat
Piranga flava	Hepatic Tanager
Piranga rubra	Summer Tanager
Piranga ludoviciana	Western Tanager
Cardinalis cardinalis	Northern Cardinal
Cardinalis sinuatus sinuatus	Pyrrhuloxia
Pheucticus ludovicianus	Rose-breasted Grosbeak
Pheucticus melanocephalus	Black-headed Grosbeak
Guiraca caerulea interfusa	Blue Grosbeak
Passerina amoena	Lazuli Bunting
Passerina cyanea	Indigo Bunting
Passerina ciris pallidior	Painted Bunting
Pipilo chlorurus	Green-tailed Towhee
Pipilo maculatus	Spotted Towhee
Pipilo fuscus	Canyon Towhee
Aimophila ruficeps	Rufous-crowned Sparrow
Spizella arborea ochracea	American Tree Sparrow
Spizella passerina arizonae	Chipping Sparrow
Spizella pallida	Clay-colored Sparrow

Spizella breweri	Brewer's Sparrow
Spizella atrogularis evura	Black-chinned Sparrow
Pooecetes gramineus	Vesper Sparrow
Chondestes grammacus strigatus	Lark Sparrow
Passerculus sandwichensis	Savannah Sparrow
Passerella iliaca	Fox Sparrow
Melospiza melodia	Song Sparrow
Melospiza lincolnii	Lincoln's Sparrow
Melospiza georgiana ericrypta	Swamp Sparrow
Zonotrichia albicollis	White-throated Sparrow
Zonotrichia atricapilla	Golden-crowned Sparrow
Zonotrichia leucophrys	White-crowned Sparrow
Zonotrichia querula	Harris's Sparrow
Junco hyemalis	Dark-eyed Junco
Agelaius phoeniceus	Red-winged Blackbird
Sturnella neglecta	Western Meadowlark
Xanthocephalus xanthocephalus	Yellow-headed Blackbird
Euphagus carolinus carolinus	Rusty Blackbird
Euphagus cyanocephalus	Brewer's Blackbird
Quiscalus mexicanus	Great-tailed Grackle
Quiscalus quiscula versicolor	Common Grackle
Molothrus ater	Brown-headed Cowbird
Icterus spurius	Orchard Oriole
Icterus cucullatus	Hooded Oriole
Icterus parisorum	Scott's Oriole
Carpodacus cassinii	Cassin's Finch
Carpodacus mexicanus frontalis	House Finch
Loxia curvirostra	Red Crossbill
Carduelis pinus pinus	Pine Siskin
Carduelis psaltria	Lesser Goldfinch
Carduelis tristis pallidus	American Goldfinch
Coccothraustes vespertinus	Evening Grosbeak
Passer domesticus	House Sparrow

Didelphis virginiana	Virginia Opossum
Sorex monticolus	Dusky Shrew

Notiosorex crawfordi crawfordi	Crawford's Desert Shrew
Myotis auriculus apache	Southwestern Myotis Bat
Myotis thysanodes thysanodes	Fringed Myotis Bat
Myotis volans interior	Long-legged Myotis Bat
Myotis californicus	California Myotis Bat
Myotis ciliolabrum melanorhinus	W. Small-footed Myotis Bat
Pipistrellus hesperus	Western Pipistrelle Bat
Eptesicus fuscus pallidus	Big Brown Bat
Lasiurus cinereus cinereus	Hoary Bat
Euderma maculatum	Spotted Bat
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat
Antrozous pallidus pallidus	Pallid Bat
Tadarida brasiliensis mexicana	Brazilian Free-tailed Bat
Nyctinomops macrotis	Big Free-tailed Bat
Sylvilagus audubonii	Desert Cottontail Rabbit
Lepus californicus	Black-tailed Jack Rabbit
Tamias dorsalis dorsalis	Cliff Chipmunk
Spermophilus spilosoma	Spotted Ground Squirrel
Spermophilus variegatus grammurus	Rock Squirrel
Thomomys bottae	Botta's Pocket Gopher
Perognathus flavus	Silky Pocket Mouse
Chaetodipus hispidus	Hispid Pocket Mouse
Chaetodipus intermedius	Rock Pocket Mouse
Dipodomys ordii	Ord's Kangaroo Rat
Dipodomys merriami	Merriam's Kangaroo Rat
Castor canadensis	American Beaver
Reithrodontomys megalotis	Western Harvest Mouse
Peromyscus eremicus	Cactus Mouse
Peromyscus maniculatus	Deer Mouse
Peromyscus leucopus	White-footed Mouse
Peromyscus boylii rowleyi	Brush Mouse
Onychomys leucogaster	N. Grasshopper Mouse
Sigmodon fulviventer minimus	Tawny-bellied Cotton Rat
Neotoma albigula	White-throated Wood Rat
Microtus longicaudus	Long-tailed Vole
Ondatra zibethicus	Common Muskrat
Mus musculus	House Mouse
Zapus hudsonius luteus	New Mexican Jumping Mouse

Erethizon dorsatum	Common Porcupine
Canis latrans	Coyote
Urocyon cinereoargenteus scottii	Common Gray Fox
Ursus americanus amblyceps	Black Bear
Bassariscus astutus	Ringtail
Procyon lotor	Common Raccoon
Taxidea taxus berlandieri	American Badger
Spilogale gracilis	Western Spotted Skunk
Mephitis mephitis	Striped Skunk
Felis concolor	Mountain Lion
Lynx rufus baileyi	Bobcat
Sus scrofa	Feral Pig
Odocoileus hemionus	Mule Deer
Antilocapra americana americana	Pronghorn

Appendix B. Cultural Resources

A CULTURAL RESOURCE SURVEY FOR THE PROPOSED MIDDLE RIO GRANDE BOSQUE RESTORATION PROJECT, BERNALILLO COUNTY, NEW MEXICO

U.S. Army Corps of Engineers, 1135 Middle Rio Grande Bosque Ecosystem Restoration at Route 66

By
Michael P. Marshall

Prepared by Cibola Research Consultants
For Bohannan-Huston Inc.

Cibola Research Consultants Report No. 345
NMCRIS Project No. 82701
N.M. State Permit No. 03-045

May 15, 2003

A Cultural Resource Survey for the Proposed Middle Rio Grande Bosque Restoration Project, Bernalillo County, New Mexico

U.S. Army Corps of Engineers, 1135 Middle Rio Grande Bosque Ecosystem Restoration at Route 66

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May 15, 2003

ABSTRACT

This report presents the results of cultural resource survey and records search for the proposed U.S. Army Corps of Engineers, Albuquerque District, 1135 Middle Rio Grande Bosque Ecosystem Restoration at Route 66 project in Bernalillo County, New Mexico. The proposed undertaking is located along the Rio Grande on lands managed by the Middle Rio Grande Conservancy District and under the joint jurisdiction of the U.S. Bureau of Reclamation, and the U.S. Army Corps of Engineers, Albuquerque District. Much of the land within the project is also within the Rio Grande Valley State Park, which is jointly managed by the City of Albuquerque's Open Space Division and New Mexico State Parks Division. The project will be implemented with Federal funding.

The project includes restoring and improving the bosque ecosystem and enhancing the passive recreational use of the bosque adjacent to the Rio Grande. The project will involve removing old jetty jacks and other post and cable flood control structures, as well as removing fuel material to reduce the chance for large bosque crown fires. The project may also improve bike and pedestrian trails, and will construct observation points and facilities. The project will remove non-native plants and replace them with native species.

The project is located along a 3.1-mile (4.99-kilometer) section of the Rio Grande bosque in Albuquerque, and extends from the Interstate 40 bridge on the north to the Bareles Bridge on the south. The project is confined to the riverside and bosque areas inside riverside drains marginal to the flood control levees. The project area within the levees includes 643 acres (260.22 hectares), which consist of 370 acres (149.74 hectares) within the river channel and active floodplain and 273 acres (110.48 hectares) within the Rio Grande bosque. The cultural resource survey area included the 273 acres within the bosque.

The objectives of the survey were to identify all known and potential cultural resources within the project study area, and to evaluate the possible effect of the proposed bosque restoration project on these resources. In order to accomplish this objective, a comprehensive review of cultural-historical records and archives was completed and previous research in the area was reviewed. An archaeological survey was conducted and seven cultural resources and twenty-one isolated occurrences were identified. The entire area lies within the active and historic floodplain of the Rio Grande, and the types of cultural resources identified are related to bridge crossings, irrigation works and flood control features. A description of these resources is provided and recommendations have been made on the cultural resource management for the area.

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INTRODUCTION

This report presents the results of a cultural resource survey and records search for the proposed U.S. Army Corps of Engineers, Albuquerque District, 1135 Middle Rio Grande Bosque Ecosystem Restoration Project at Route 66. The proposed project is situated within the City of Albuquerque, Bernalillo County, New Mexico (Figures 1 and 2). The proposed improvements are a U.S. Army Corps of Engineers project. Funding for the ecosystem restoration project will be provided by Federal sources. The project is located on lands under the joint jurisdiction of State, Federal and City agencies. Most of the lands are managed by the Middle Rio Grande Conservancy District (MRGCD) under permit from the U.S. Bureau of Reclamation. The water way and wetlands are controlled under Section 404 authority by the U.S. Army Corps of Engineers. Much of the land within the project is also within the Rio Grande Valley State Park, which is jointly managed by the City of Albuquerque's Open Space Division and New Mexico State Parks Division.

The project is confined to a 3.1-mile (4.99-kilometer [km]) section of the Rio Grande bosque in the Albuquerque area, and extends from the Interstate 40 (I-40) bridge on the north to the Barelas Bridge on the south. The project area is located within the riverside drains and includes 643 acres (260.22 hectares). There are 370 acres (149.74 hectares) within the river channel and active floodplain and 273 acres (110.48 hectares) within the Rio Grande bosque. The cultural resource survey area was confined to the 273 acres (110.48 hectares) within the bosque. Aerial photographs indicate that the bosque area was originally within the active floodplain and braided channels of the Rio Grande in the 1930s and 1940s. The occasional massive flooding and periodic inundation of the entire project area has prevented long-term human settlement in the area. However, the bosque has been extensively used for hunting, plant gathering, timber logging and fuel use, and various projects related to bridge constructions, irrigation, and flood control works. Much of the project area is within the Rio Grande Valley State Park and is currently used for recreational purposes. The park is also an important wildlife habitat.

The purpose of the project is to restore and improve the bosque ecosystem and to enhance the passive recreational use of the bosque adjacent to the Rio Grande. The project will involve removing some jetty jacks and other post and cable flood control structures, as well as removing fuel material to reduce the chance for large bosque crown fires. The project may also involve improvements to open space access including bike and pedestrian trails, and the construction of observation points and facilities. Non-native plants will be removed and replaced with native species. The project will be implemented by the U.S. Army Corps of Engineers.

The cultural resource investigation was conducted under New Mexico State Permit No. 03-045. The objectives of the survey were to identify all cultural resources within the project study area, and to evaluate the possible effect of the proposed bosque project on these resources. A comprehensive review of cultural-historical records and historical archives was conducted and previous research in the area was reviewed. A systematic survey of the entire bosque within the riverside drains to the immediate edge of the active river channel was completed.

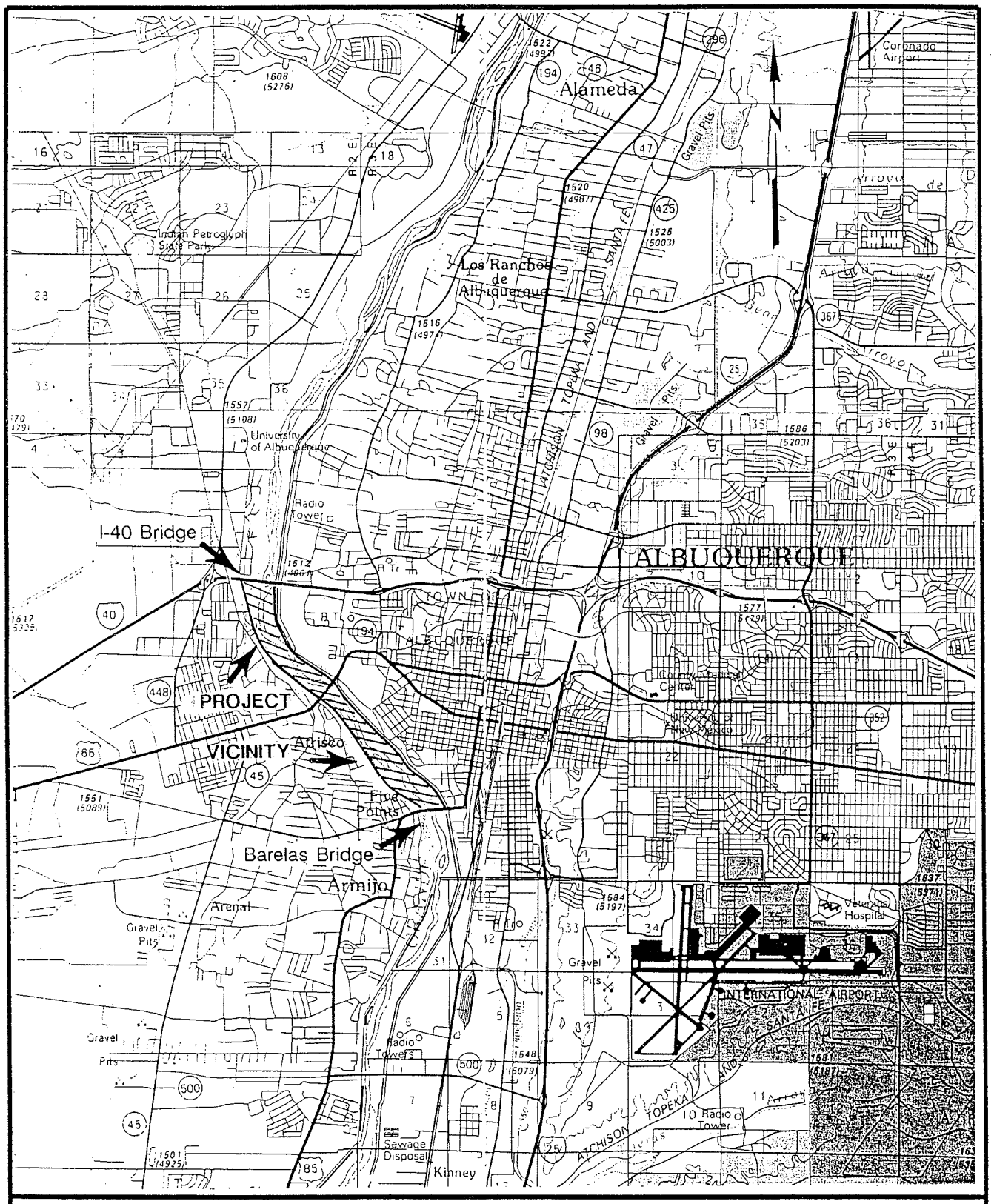

Figure 1. Project Vicinity Map

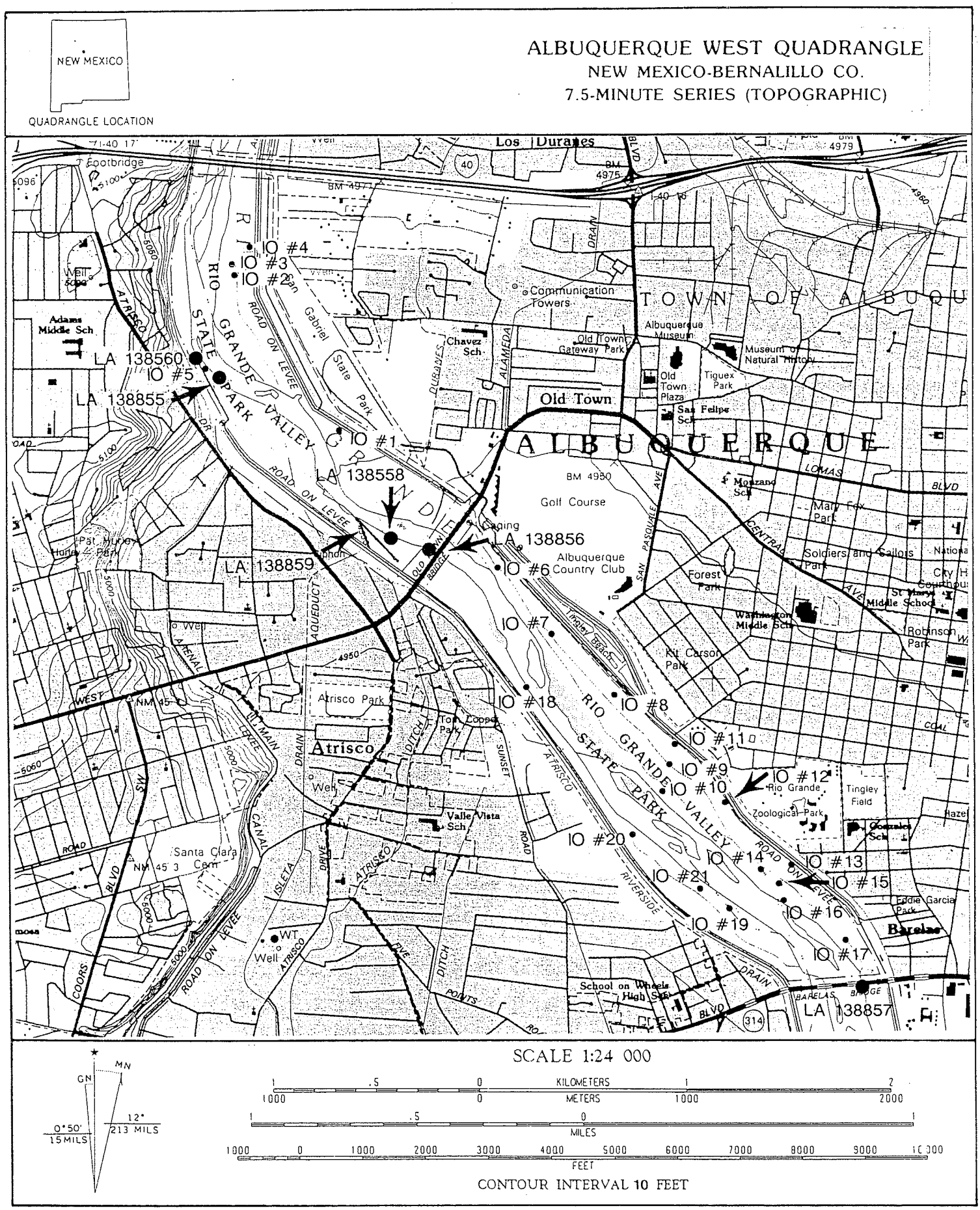

Figure 2. Location of the Project, Cultural Resources and Isolated Occurrences

The cultural resource records search revealed that no cultural properties have been previously identified within the project area. The archaeological survey identified 7 cultural resources including 3 bridge remnants (LA 139208, LA 138856, LA 138857), 1 probable irrigation diversion structure (LA 138858), 1 site with two adjacent segments of pre-MRGCD irrigation canals (LA 138859), 1 flood control structure (LA 138855), and the abandoned Atrisco diversion works (LA 138860). Twenty-one isolated occurrences (IOs) were also identified in the study area, and include 7 fill and dump areas, 7 trash dumps, 4 homeless camps, 2 other temporary log shelters and 1 earth bank feature.

It is recommended that all of the sites be avoided during the project. Three remnants of bridge structures (LA 138856, LA 138857, and LA 139208) and the irrigation diversion structure (LA 138858) are in the active channel of the Rio Grande and will not be affected by the project. Part of the flood control feature (LA 138855) is situated on the west bank of the river near a set of jetty jacks. This area should be avoided by heavy equipment. The two pre-conservancy irrigation canals (LA 138859) are in a bosque area that has been recently cleared of brush and non-native trees by the City of Albuquerque. Further work in this area is unlikely and the canal should not be affected by the ecosystem restoration project. The abandoned Atrisco diversion works (LA 138860) are located along the western edge of the project. The structural features of this complex, which include a header gate, a diversion canal, diversion structures, and a wastewater canal, should not be affected by the project and will remain intact. It is recommended that all of the cultural resources in the project area be identified in the field and designated as protection areas prior to the project implementation. Given this precaution, the project will have no effect on the cultural resources of the area.

This investigation complies with the provisions of the National Historic Preservation Act of 1966, as amended through 1992, and applicable regulations. The report is consistent with federal and state standards for cultural resource management.

PROJECT LOCATION AND PROPOSED UNDERTAKING

The location of the Section 1135 Bosque Ecosystem Restoration project is confined to a 3.1-mile north-south section of the Rio Grande bosque in the Albuquerque area. The project includes the bosque on both sides of the Rio Grande within the riverside drains. It extends from the north side of the Interstate 40 bridge to the south side of the Barelas Bridge at Bridge Street. The entire project is within the City of Albuquerque, Bernalillo County, New Mexico (Figures 1 and 2).

The project area includes approximately 643 acres (260.22 hectares). There are 370 acres (149.74 hectares) within the river channel and active floodplain and 273 acres (110.48 hectares) within the Rio Grande bosque. The cultural resource survey area included approximately 273 acres (110.48 hectares) in the bosque area adjacent to the active riverbed. Much of the area is the active channel and 10-year floodplain of the Rio Grande and is either the flowing riverbed or the recent riverbed floor. The entire Rio Grande

bosque marginal to the riverbed is also within the historic floodplain, but it is wooded and since the 1940s has been subject to only infrequent floods.

The lands are managed by the Middle Rio Grande Conservancy District (MRGCD) and are also under the jurisdiction of the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers. The project is within the Rio Grande Valley State Park, which is jointly managed by the City of Albuquerque's Open Space and New Mexico State Parks Division.

The primary objective of the project is to restore and improve the bosque ecosystem and to enhance the passive recreational use of this urban riverside area. The project will involve removing some of the old jetty jacks and other post and cable flood control structures, and will remove fuel material to reduce the chance for large bosque crown fires. It also will include removing non-native plants such as Salt cedar and Russian olive and will plant native species such as cottonwood. The proposed project will improve wetlands to encourage and sustain various wetland species. In addition, the project may involve improvements to bike and pedestrian trails, the construction of observation points and facilities, and improvements to bosque access. The U.S. Army Corps of Engineers will implement the project.

ENVIRONMENTAL CONTEXT

The project area is located in the northern Mexican Highland Section of the Basin and Range Physiographic Province (Lozinsky et al. 1991). The Albuquerque-Belen Basin is situated within the Rio Grande Rift, and in the Albuquerque area is bounded by the Sandia and Manzano mountains on the east and by the West Mesa and West Mesa volcanic formations on the west (Kelley 1977). The project is situated on the floor of the Rio Grande Valley adjacent to the active river channel and within the historic and modern river floodplain. The project area ranges in elevation from 4,940 to 4,970 feet above sea level. Most of the project area is within a bosque woodland that is composed mostly of cottonwood, willow, Salt cedar, Russian olive, and Siberian elm with lesser growths of Ailanthus, Black locust, and White mulberry. New Mexico privet is one of major brushy plants and various grasses, annual weeds, and riparian plants such as Yerba del Manso are present.

Historical View

In times prior to reclamation efforts and dam construction along the Rio Grande watershed, the channel of the Rio Grande was a wide ever-changing system that often shifted channels within a braided network of waterways. The main channel of the Rio Grande would often shift locations, running along the eastern or western edges of the valley. This pattern of shifting channels affected the location of farmlands marginal to the river and probably accounts for the presence of sister villages or pairs of prehistoric and early historic pueblos, which are found along opposite banks of the river. The populations appear to have shifted from one side of the river to the other, depending on the location of the channel and the availability of farmlands.

In the early 18th century, the historic main channel of the Rio Grande ran along the eastern edge of the valley from Alameda to the Albuquerque area. Maps of the area in 1675 and 1710 show the village of Alameda on the west bank of the river, while a map completed in 1766-68 shows the village on the east bank (Sargeant 1987:39). It appears that a major flood that occurred about 1735 caused the channel to move to the western section of the valley near its present channel. This eastern channel, until the construction of the Alameda dikes in the late 19th-early 20th centuries, often carried high water floods. It is well known that the area was subject to general flooding prior to reclamation efforts, and that this old river channel was responsible for the flooding of downtown Albuquerque in the late 19th-early 20th centuries.

The old paleo-channel along the eastern edge of the valley, when abandoned by the river except during time of high water floods, formed what is known as a "yazoo". A good description of this yazoo is provided by Sargeant (1987: 35).

> "Before the river in the Albuquerque area was confined to its present channel in 1957, the Rio Grande was a meandering braided stream with oxbows, riparian woodland, and numerous marshlands. From time to time, as the aggrading river filled its bed with sediment, it overflowed its banks, and shifted to a new channel with new levees and sand banks higher than the outlying alluvial flats. The low areas on the flats, called yazzos, were filled with water from the arroyos on the east and west mesas. Water was prevented from flowing into the river by the levees and, because of the high water table related to the aggrading riverbed, was not easily absorbed by the saturated ground. Swamps formed where the water did not evaporate."

Floods played a major role in the early settlement and land use of the area, and often caused the abandonment and relocation of pueblo villages and later Hispanic settlements. Several of these settlements were located on slight elevations in the valley floor and were subject to frequent flooding or were on low islands surrounded by floodwaters. Many of the older sites and buildings in the valley floor were destroyed or damaged by floods and others remain buried in the alluvial sediments.

The substrata of soils in the project area are floodplain alluvium that was deposited by Rio Grande river deposits and by lateral arroyo flows from the Sandia Mountain slopes. These include coarse water-deposited sand, fine clay silt, gravel deposits, and occasional aeolian dunes that originated from the river bottom deposits. The alluvial floor of the Rio Grande Valley has been aggrading for centuries, probably since the early Holocene, and as a result, many of the early valley floor surfaces are buried (Kelley 1977), or are exposed only in later channel-cuts. The formation of the valley floor sediments in the project is a bewildering complex of fluvial surfaces, cut and reburied, and a complex network of braided river channels.

Flooding in the Rio Grande Valley, agricultural development, and the more recent urban development in the Albuquerque area have had a considerable effect on the nature, location, and preservation of the cultural resources. Many of the archaeological and older historic sites have been destroyed, buried by fluvial action, or extensively modified by later construction and development. Surface visibility of cultural remains is obscured by these actions and in some areas, buried cultural remains are present. Archaeological investigations and cultural resource management projects in the Rio Grande Valley usually require a combination of historic research, archaeological survey, and test excavation or monitoring activities in order to locate and define the cultural resources. The nature and extent of this search methodology is dependent on the specific location and circumstances of the proposed development. The bosque restoration project is located within the active and historic floodplain of the Rio Grande in an area that has prevented settlement and allowed for only limited farming and grazing uses. A number of bridges and irrigation facilities were built in the area, but floods have destroyed many of these features.

The Rio Grande bosque in the early historic period was dominated by stands of Rio Grande cottonwood and willow thickets and by extensive marshes and swamps populated by sedge, bulrush, cattail, salt grass and other species and may have existed in this composition for nearly a million years (Scurlock 1988a:131). The bosque environment was an important ecozone and resource for Native American populations who inhabited the area, and it probably saw rather extensive use for gathering riparian plants, hunting bosque and riverine animals, and for collecting fuel wood and construction materials. This use likely began in the Paleoindian-Archaic periods. Utilization of the bosque environment probably intensified following the development of hamlet villages as early as 1800 B.C. Use of the bosque environment was more extensive after the florescent development of Rio Grande Pueblo culture, beginning in the 13th century, when large adobe pueblos extended in a chain of a least 80 major villages along the Rio Grande Valley in New Mexico. Native Americans probably set fire to the bosque, clearing the area for fields and this had a major effect on its composition. Nonetheless, it is likely that extensive cottonwood groves extended along the river even during the height of Rio Grande Pueblo civilization, prior to Spanish contact.

The first Europeans to see the Rio Grande Valley near Albuquerque arrived on September 7, 1541 with the Don Francisco Vázquez de Coronado expedition and were the first to describe the valley. They reported that "This river of Nuestra Señora flows through a broad valley planted with fields of maize and dotted with cottonwood grooves. There are twelve pueblos, whose houses are built of mud and are two storeys high" (Bolton 1964:184). Following Spanish colonization in 1598 and during the period from the early Spanish occupations of the 17th century to the first entrance of the Americans in the early 19th century, the Rio Grande bosque experienced considerable use and was extensively harvested for firewood and building materials.

The earliest descriptions of the valley by Americans reveal a river valley near denuded of trees. Josiah Gregg, who visited the valley in 1839, stated, "On the water-courses there is little timber to be found except cottonwood, scantily scattered along its banks. Those of

the Rio del Norte are now nearly bare throughout the whole range of the settlements, and the inhabitants are forced to resort to the distant mountains for most of their fuel" (Gregg 1966:159). Various observers of the valley during the American invasion of 1846 commented on the lack of fuel wood and presence of only scattered cottonwood bosques along the river. There were only a few cottonwoods along the river between Albuquerque and Isleta. However, a fine grove was noted south of Isleta at a place called Bosque (Wizlizenus 1969:34-36). In 1846, Henry Smith Turner also noted that "There is great difficulty in obtaining sufficient fuel for cooking purposes-the men have to go to the distance of several miles to obtain a handful of wood...We occasionally see a grove of cottonwood which is preserved with great care, as it furnished the only material with which carts for the whole country are made. These groves are always private property" (Simmons 1982:19). In 1855, the circuit judge W.W. H. Davis described a bare valley with only an occasional cottonwood grove saying, "..About a mile below Doctor Connelly's (south of Isleta) were passed what is known as the bosque, a large tract of fine timber, mostly cottonwood, something very rare in New Mexico. Wood is exceeding scarce all over the country. The valleys are generally bare of it... The country is said to have been well wooded when the Spanish first settled it, but in many parts it has been entirely cut off, and in some instances without leaving even a single tree for shade" (Davis 1857:356). This appears to have been the general situation of the Rio Grande bosque in the greater Albuquerque area. However, cottonwood bosques were again found by early American observers south of La Joya in the Rio Abajo district, which had been abandoned by Spanish and Pueblos alike since the Pueblo Revolt of 1680. The bosques of the upper river area were also affected by "... the meandering and flooding of the river, which frequently changed its course, resulting in cyclic destruction and regeneration of cottonwood stands" (Crawford et al. 1993:25).

All of the early photographs of the Albuquerque area show an extremely wide and bare riverside, nearly devoid of trees. A photograph of Tingley Beach under construction in 1930 shows no trees whatsoever along the riverside to the west (Biebel 1986:15). Today, much of this barren riverside is forested and is within the Rio Grande bosque study area.

Following the arrival of the railroad in 1880, imported fuels and the use of coal fuel began to increase and somewhat alleviated the use of bosque fuel wood. However, the riverside remained denuded until the 1930s. During the 1920s and 1930s, the riverside was invaded by introduced species such as Salt cedar, Russian olive and occasional elm and Ailanthus. Many of the cottonwood stands were reestablished when they were neglected for fuel wood and building materials. Large stands of cottonwood also became reestablished following the control of the river channel by reclamation efforts over the last 80 or so years. These stands are periodically destroyed by destructive fires caused by the accumulation of fuel wood from Salt cedar, Russian olive and other understory vegetation. It is one of the objectives of the project to remove some of this understory fuel to preserve further destruction to the cottonwood stands.

The invasion of non-native species into the Rio Grande bosque—beginning in the early 20th century—had a major effect on the riverside environment. Many of these species escaped from cultivation in the nearby Albuquerque urban neighborhoods. The non-

native species that have had the most effect on the bosque environment include Salt cedar, Russian olives and to a lesser degree, Siberian elm, Ailanthus, White mulberry, and Black locust.

Tamarisk or Salt cedar (*Tamarix ramosissima*) was native to Asia Minor and was apparently imported into the Southwest in the late 19th century. Nurseries in California offered Salt cedar for sale in the 1860s, and it had escaped from cultivation as early as 1870 (Scurlock 1988a:138). Salt cedar was introduced into the Albuquerque area by at least 1900, and was noted as an Albuquerque ornamental in 1908 (Crawford et al. 1993:30). Many of the older trees today can be found around historic structures and ruins. Based on a botanical survey conducted in 1910-1912, it was commonly cultivated in New Mexico and had begun to escape into the surrounding drainages (Wooton and Standley 1915). The City of Albuquerque and the Forest Service purchased Salt cedar from Stark Brothers Nursery in 1919, and it could soon be found growing along irrigation ditches. Its use in flood and erosion control in the 1920s helped to spread the species. By 1936, it had invaded much of the valley floor and spread over earlier lowland farms (Scurlock 1998:294), and was recognized as a major problem in water conservation. Vast areas of the Rio Grande Valley, especially south of Bernardo, were covered with Salt cedar and it was estimated that by 1947, it dominated 60,640 acres of the Rio Grande Valley and consumed an estimated 238,700 acre feet of water (Scurlock 1988a:138).

Russian olive (*Elaeagnus augustifolia*), a native of the Black Sea coast, was introduced to Mesilla, New Mexico about 1903. It was also identified as a New Mexico ornamental in a 1910-1912 botanical survey (Wooton and Standley 1915), but was not common in "escaped context" until later. It was reported growing on the Rio Grande floodplain in 1929 and 1935 (Scurlock 1988a:138). By 1960, it was a major component of the Rio Grande bosque at Albuquerque. Russian olive is shade tolerate and continues to advance its stands under the cottonwood canopy.

The Tree of heaven (*Ailanthus altissima*) is also seen at locations of early historic structures in the Albuquerque area and in escaped groves in the Rio Grande bosque. This species is a native of China, and was introduced to the eastern U.S. in the late 18th-early 19th century. Ailanthus was noted in the 1910-1912 botanical survey as a common shade tree, especially in the southern part of New Mexico (Wooton and Standley 1915). Ailanthus trees are often found in historic New Mexican communities and are frequently seen by archaeologists in proximity to historic ruins. Ailanthus is found in scattered locations in the bosque study area, and there is a rather large grove located on the west bank south of I-40 below the high western bluffs.

There was no mention of Siberian elms (*Ulmus pumila*) in the 1910-1912 botanical survey of New Mexico (Wooton and Standley 1915). Early photographs of the New Albuquerque Townsite show that cottonwoods were commonly planted for shade adjacent to many of the buildings. However, elms and other species such as Lombardy poplar, Green ash, and Honey locust were purchased by the City of Albuquerque in 1919 to plant in residential areas and parks (Scurlock 1988a:13). The use of elms for shade was

promoted by Albuquerque Mayor Clyde Tingley in the late 1920s and 1930s, and soon dominated the treescape of Albuquerque (Scurlock 1998:287) as it does today.

Another escaped species to enter the bosque, especially near the urban area, is the White mulberry (*Morus alba*) (Crawford et al. 1993:30). A small grove of Black locust trees was found in the east bosque not far south from Central Avenue at GPS Locus: Zone 13, 346868 Easting by 3883888 Northing.

RECORDS SEARCH

A comprehensive records search was completed for the proposed bosque improvement project. This research included a variety of archaeological and historical sources. Numerous source institutions were searched including the New Mexico State Historic Preservation Division (NMSHPD), the Archaeological Records Management System (ARMS), the Museum of Albuquerque, the University of New Mexico Library and Special Collections Division, the City of Albuquerque Special Collections Division, the Earth Data Analysis Center (EDAC), the University of New Mexico Maps and Graphics Information Center (MAGIC), the New Mexico State Highway and Transportation Department (NMSHTD), the Middle Rio Grande Conservancy District (MRGCD), the U.S. Bureau of Reclamation, and other published sources. There is a wealth of archival information regarding the Albuquerque area from 1880 to the present day. However, information on land use during the Spanish Colonial and Mexican periods is confined to brief references to the general area and to the nearby settlements of Albuquerque's Old Town and Los Barelas.

A diverse and varied group of historic and archival records for the project area and vicinity were consulted in this study as part of the historic context and historic bridge survey documentation. Important sources of historic information for the study area are maps and photographic records. Maps that were consulted for the project are listed in the bibliography. Aerial photographic coverage of the project area was obtained from EDAC at the University of New Mexico, and aerial oblique photographs were inspected in the photographic archives at the Museum of Albuquerque. Information regarding the various bridges that spanned the Rio Grande in the project areas was obtained from a variety of historic sources including the NMSHTD Bridge Section in Santa Fe, the Museum of Albuquerque photographic archives, various newspapers and other published sources.

Previous Research

There has been little previous archaeological research within the Rio Grande bosque in the area of the project. Archaeological surveys were completed for the more recent I-40 bridge projects (Koczan 1991, Marshall S. 1991), but no cultural resources were identified. A survey along the Atrisco Riverside Drain, directly adjacent to the project, was completed by Marron and Associates, and Laboratory of Anthropology (LA) site numbers were assigned to the Atrisco Lateral Canal (LA 120397) and the Pajarito Lateral Wasteway (LA 120398) (Berry 1997). An archaeological survey was also completed for the Tingley Beach area directly east of the project (Polk et al. 1999), but no cultural

features other than the park were identified. A Museum of New Mexico site number (LA 6859) has been assigned to the village of Armijo, directly west of the project, but this is a control number for historic records and does not refer to a specific property. An archaeological survey and records search was also conducted for the New Mexico Hispanic Cultural Center, which is directly east of the south end of the project (Marshall 1996). The project is on the grounds of the San Jose School, which is listed on the National Register. The project provides some information on the context of the area and the Barelas Bridge.

STATE AND NATIONAL REGISTER PROPERTIES

There are no historic properties listed on the New Mexico State Register of Cultural Properties or the National Register of Historic Places within the Middle Rio Grande bosque restoration project area. There are numerous historic properties listed on the State and National registers in the nearby Albuquerque area, but none will be affected by the proposed undertaking. The closest nominated property to the project is the West San Jose School (HPD No. 1645), which is 656.17 feet (ft) (200 meters [m]) southeast of the Barelas Bridge. Two alignments of the former U.S. Route 66 highway crossed on bridges over the Rio Grande in the project area. Route 66 crossed over the Barelas Bridge from 1926 to 1937, and over the Central Avenue Bridge from 1937 until it was decertified in 1985. While segments of Route 66 quality for nomination to the National Register of Historic Places, there are no intact historic features or US 66 vintage bridges structures that remain in the area, and it is clear that the present bridges built from 1982 to 1995 are not eligible. Only remnants of the older highway bridges were found, and these do not have the integrity to qualify for National Historic Register nomination.

TRADITIONAL CULTURAL PROPERTIES

There are no known traditional cultural properties or sacred sites within the proposed bosque ecosystem restoration project area. No cultural features or landforms normally identified as traditional or sacred sites were identified. Traditional cultural properties consultations were made by the U.S. Army Corps of Engineers with the various tribal groups recommended by the New Mexico State Historic Preservation Division for Bernalillo County. These tribal groups include: the Hopi Tribe, the Navajo Nation, Isleta Pueblo, Sandia Pueblo, Laguna Pueblo, and the White Mountain Apache. The consultation letters were sent out by John Shelberg of the U.S. Army Corps of Engineers. The results of this consultation will be appended to this report when it is submitted as part of the compliance process.

SURVEY METHODS

Cibola Research Consultants conducted an archaeological survey of the project area during February and March 2003. Prior to the archaeological survey, a series of historic and modern maps and aerial photographs were obtained to assist in understanding the present condition and historic nature of the study area. The historic maps and photographs were utilized during the survey to help locate remnants of old bridges, irrigation facilities and other features. Former floods have removed most of these features. However, the historic maps and photographs helped to identify the former location of the cultural features, so that a more extensive search could be made in these areas.

The archaeological survey of the bosque study area was largely dictated by the nature of the forested environment. In many areas, there are extensive wooded thickets that are largely impenetrable. However, there are numerous trails in and among the thickets that allow access to the general area. Much of the survey included following this maze of trails in and among the thickets.

Those areas of the bosque that are somewhat open, allowed for a more systematic pedestrian transect survey. In these cases, multiple transects of 15-meter intervals were completed. Other open areas included the edge of the river channel and the river floodplain. In these areas, the survey along the riverbank searched for any cultural features that might have been exposed in the floodplain, such as old bridge abutments or irrigation canals.

Given the nature of this forested and closed thicket environment, the survey transects were often quite irregular. The primary objective during the fieldwork was to inspect as much of the bosque floor as possible. This often involved circling around thickets and viewing into the thicket areas from the edges. The survey also included a great deal of back tracking on trail systems. The general orientation and control of the survey area was maintained by the use of hand held GPS units that continued plotting survey locations within each survey tract.

The project area is well defined by the boundaries of the river, the active river channel floodplain, and the riverside drains. Areas of the river channel and adjacent active floodplain were not inspected, except in cases where former bridges were believed to be located. The survey included the level bosque floor and in some areas old, river channels or sloughs that carry water during periods of floods.

The location of the cultural features found in the project area were determined by a GPS unit and each feature was plotted according to Universal Transmercator (UTM) coordinates. The cultural resources that justified inclusion into the New Mexico Cultural Resources Information System (NMCRIS) database were documented and are described in this report. Other minor cultural features such as modern trash dumps or filled areas, homeless camps and other modern features have been identified as isolated occurrences (IOs) and do not justify further consideration.

CULTURAL-HISTORICAL CONTEXT

A detailed cultural-historical overview of the middle Rio Grande Valley area has been completed by the Bureau of Land Management and the U.S. Forest Service (Cordell 1978). A number of observations regarding the culture history of the general area, which have relevance to the bosque restoration project, are presented here.

Prehistoric Overview

No early prehistoric cultural remains have been identified, to date, within the immediate area of the bosque project. Paleoindian and Archaic period cultural remains are rarely found in the Rio Grande valley floor and floodplain. They have either been destroyed or obscured by centuries of flooding and the ever-changing course of the river channel, and by the aggraded character of alluvial sediments in the area. The Rio Grande valley floor environment was probably used during these early periods of human occupation in the region, but due to fluvial processes, such remains are only rarely preserved or exposed.

The few Paleoindian and more common Archaic cultural remains found in the Albuquerque area are located on the bench land adjacent to the river valley and the nearby plains west of the river valley and along the base of the Sandia and Manzano mountains. The only Archaic period components that have been identified in the valley floor project vicinity have been found in excavations at the Chamisal Pueblo site, LA 22765, (Sargeant 1985:5.2) and at the Montano Bridge site, LA 33223, (Gossett and Gossett 1988). The Chamisal component has been dated to 720 B.C.

There is evidence for early sedentary village developments in the Rio Grande Valley that date to the late Archaic period. A pre-ceramic pithouse village of ca. 100 B.C. affinity was partially excavated at the Montano Bridge site (O'Leary and Biella 1987 and Gossett and Gossett 1988). Very little is known about this early period of village culture, but it is possible that such communities existed at least a millennia before the development of recognized early Pueblo village culture. Late Archaic village populations with maize agriculture have been dated along the Rio Puerco Valley from 1170 to 1870 B.C. (Byrd, et al. 1995), and it is probable that similar early village sites once existed along the Rio Grande Valley.

Most of the early Developmental Pueblo sites that have been found in the general project area are located on the bench edges marginal to the river. Rather extensive sets of Basketmaker III and Pueblo I period pithouse sites have been found along the river valley south of Central Avenue on the west bank (Skinner 1965), the west bank north of Corrales (Ward 1986), and on the eastern bench edges south of Sandia Pueblo (Keesling 1980). Puebloan occupations of Pueblo II and III period affinity in the area are characterized by scattered hamlet villages that occur along the valley margins throughout the district (Marshall 1985), and it is probable, despite the absence of known archaeological remains, that the valley floor was also extensively used by these ancestral puebloan populations. The small hamlet settlements appear to have exploited farm lands marginal to the river valley and exploited both riverine and desert plains habitats.

The Pueblo II and III hamlet villages of the area represent a developmental backwater of the more advanced plateau pueblo cultures of the period. However, with the demise of Chacoan civilization and other plateau cultures in the late 12th and 13th centuries, there was a major coalition and centralization of the scattered Rio Grande hamlet settlements. This period of coalition resulted in the nucleation of scattered hamlets into larger village settlements, which are characteristic of the Pueblo IV period. The small and scattered hamlets of the valley edge were abandoned and small adobe pueblos were built along the valley edge and floor. The development of these early adobe pueblos and the emergence of the Rio Grande glazeware ceramic tradition in ca. A.D. 1300, mark the beginning of the Pueblo IV period and the era of Puebloan cultural florescence in the Rio Grande Valley. It is estimated that the Puebloan population of the Middle Rio Grande Valley increased ten-fold in the period from A.D. 1200 to 1500. This increase was apparently due to foreign intrusions from the adjacent plateau, as well as, insitu population growth. The fusion of foreign plateau and indigenous Rio Grande populations in the study area resulted in the eventual development of ancestral Southern Tiwan pueblo culture. It has been estimated that 50 to 75 pueblo villages of Southern Tiwan affinity, both great and small, were built in the Middle Rio Grande Valley during this period.

Many of the large Pueblo IV settlements in the general vicinity of the project, such as Puaray LA 717, Pueblo Maigua LA 716, Pueblo Calabacillas (LA 289) and Piedras Marcadas (LA 290) are built along the edges of the Rio Grande on low benches above the frequently flooded valley floor. However, three large ancestral Tiwan pueblos, Alameda Pueblo (LA 421), Chamisal Pueblo (LA 22765), and Los Poblanos Pueblo (LA 46633), are located on the valley floor in the North Valley area and Amalia Pueblo (LA 719), Shipman Pueblo (LA 720) and others are located in the South Valley floor. Excavations at Chamisa Pueblo and at Los Montanos Pueblos not far north of the bosque project revealed evidence of flooding, and it likely that most of the valley floor and some of the lower valley edge pueblos were flooded. The changing course of the Rio Grande River also affected numerous pueblos and historic villages and, in some cases, probably removed entire settlements. Pueblo IV period glazeware ceramics have been found in the riverbed south of Rio Bravo, indicating that the river changed channel and is now removing pueblo deposits. The precise location of this pueblo has not been identified.

Historic Period

The first contact of Tiwan peoples with European populations occurred on September 7, 1541, when a detachment of Spanish conquistadors of the Coronado expedition arrived in the area. Conflict with the Spanish during the two-year stay of the expedition reduced many of the pueblos to ruins and many of the refugee populations fled to other pueblos and to mountain retreats in the Sandia Mountains. Following the Coronado expedition, the Spanish did not return until 1580 and did not attempt colonization until 1590 and 1598. In the interim, a number of the Tiwan pueblos in the Middle Rio Grande Valley were reoccupied. However, many of the pueblos, including the large complex at Piedras Marcadas (LA 290), were never re-established. Immediate to Spanish contact and colonization, there was a considerable decline in Tiwan and other native populations, probably due to both warfare and the introduction of European diseases.

The first attempt to convert the Pueblo Indians of New Mexico to the Catholic faith was made in 1581 by two priests at the Pueblo of Puaray (LA 717) in the Alameda area. The priests that remained at the pueblo were soon killed by the Tiwan inhabitants. The discovery of their death by the Espejo expedition in December, 1582 resulted in the Spanish execution of Puaray residents and the burning of the pueblo (Kessell 1979:41). However, the Tiwans reoccupied the pueblo and it was visited by the Oñate colonization party in 1598.

Early Spanish occupation of the Middle Rio Grande Valley occurred subsequent to the colonization and a series of estancia settlements were built in the lower river district. Also, located in the Albuquerque area was the mission settlement of San Francisco de Sandia (LA 294), built in 1610, and small *visitas* or chapels were constructed at Alameda Pueblo (LA 421) and Puaray Pueblo (LA 717). The 1680 Spanish census of pueblo populations in the area lists Sandia Pueblo with 3,000 inhabitants, Puaray Pueblo with 200, Alameda with 300 and Isleta with 2000 (Schroeder 1979:244).

The Spanish archives indicate that there were about 17 Spanish estancia settlements in the general Albuquerque area. Most of these early Spanish settlements remain undiscovered or have been destroyed, and none is known in the immediate area of the bosque project. All of these settlements were abandoned during the Pueblo Indian Revolt of 1680 when 21 of 32 missionaries in New Mexico were murdered along with 380 other Hispanic residents. During the Spanish retreat down the Rio Grande to El Paso, many of the pueblos, including Sandia and Puaray, were burned. Alameda Pueblo was also burned during the attempted Reconquest of 1681. As a consequence of the 1680 revolt and Spanish reconquest of 1692, the pueblos of Sandia, Puaray and Alameda were abandoned; the refugees from Sandia having migrated to the Hopi villages to avoid retribution by the Spanish. There is also evidence of fortifications built during this period on high mesas and hills near the Rio Grande Valley and of hidden refugee sites in the nearby Sandia Mountains (Marshall 1985).

Following the Spanish reconquest, there was an attempt by the Spanish to resettle the remaining Tiwa in the area at Alameda Pueblo in 1702. However, in 1709, the 50 Tiwan inhabitants of Alameda Pueblo were moved to the Pueblo of Isleta, where additional Tiwans who had returned from Hopi had settled. The Pueblo of Sandia continued to be abandoned until 1748, when it was resettled by a mixed group of pueblo refugees returning from Hopi, under a petition submitted by Father Menchero. In 1776, Father Dominquez described Sandia Pueblo as inhabited by 275 persons, in two sections; one occupied by Hopi and the other by Tiwas (Adams and Chavez 1956).

The earliest Hispanic reference to the swamplands in the vicinity of Albuquerque and the Los Barelas area was to *"Los Esteros de Mexia,"* in the Oñate records of 1598 (Hammond and Rey 1953). The project area is near the Pre-Revolt period estancia or hacienda of Pedro Varela (Hackett 1937:I: 313-318), from which the nearby community of Los Barelas derives its name. The first mention of the Pedro Varela estancia is made in the Spanish documents of 1662. This estancia, located along the Camino Real wagon road, was one of a group of widely scattered Hispanic settlements that were established

during the early 17th century among Pueblo settlements of Southern Tiwan affinity. The precise locations of these early Colonial period Hispanic settlements are unknown.

During the attempted reconquest of 1692, seventeen abandoned Spanish estancias were noted in the Rio Grande Valley between Isleta and Alameda pueblos (Hackett and Shelby 1942:li, and 380). Albuquerque's Old Town Plaza, founded in 1706, was located near the 17th century *Hacienda de Doña Luisa de Trujillo* (Chavez 1972; Simmons 1982:40; Adams and Chavez 1956:145). This early hacienda might have been in the area of *La Glorieta*, an early 19th century building purchased by Franz Huning in 1861, and now located at 1801 Central NW (Dewitt 1978:36).

Some of the other named estancias in the Albuquerque valley included those of Don Pedro de Chavez, Francisco Gómez, Alonso Garcia, Don Pedro Duran y Chávez, the house of Captain Francisco de Ortega, Juan Dominquez de Mendoza and others. The nature of these early estancia settlements is poorly known, and only a few have been archaeologically identified in the Rio Abajo area (Marshall and Walt 1984 and Marshall 1985). They ranged from small farmsteads to rather large establishments. For example, one estancia settlement south of Albuquerque contained 98 settlers including the extended Mendoza family and various servants and slaves of which 38 were killed in the Pueblo Indian Revolt of 1680. The Alonso Garcia settlement contained 12 Spanish with 22 servants in attendance (Hackett and Shelby 1942:138). Many of these early estancias had buildings constructed around *placitas* or courtyards and incorporated walled corrals (casa-corral structures). Most were constructed of adobe blocks set on masonry foundations. Room sizes were much larger than contemporary pueblo structures. Traces of Spanish majolica, olive jars and copper fragments are often found at early estancias sites, but otherwise, the artifact assemblages contain large numbers of local ceramics and materials native to New Mexico (Marshall 1985).

Atrisco Grant

The lands immediately west of the river in the project area are located on the Atrisco Grant. The Atrisco Grant was given in 1692 to Fernando Duran y Chavez and other residents of the area. The name Atrisco is derived from the Nahuatl word *"Atlixco"* which means "across the water". Nahuatl names were often applied to places and settlements in New Mexico during the early expeditionary and colonization period. These names were given by Indians from the valley of Mexico who accompanied the Spanish during this period and by some of the Spaniards who were familiar with the Nahuatl language.

During the early 17th century, the Estancia de San Antonio, owned by Alonso Garcia de Noriega, was established in the area. This and other early Spanish estancias in the area were linked to the east bank settlements by a ford across the river, later known as the Barelas crossing. These estancias were destroyed during the Pueblo Revolt of 1680.

Resettlement of the Atrisco area by Hispanic populations, following the Atrisco Grant of 1692, was established by at least 1703. In the early 18th century, the area was known as Atrisco de Albuquerque. Baptismal records from the church in Albuquerque refer to

births at Atrisco from as early as 1744. In 1760, there were four small plaza communities on the western floor of the Rio Grande Valley in the Atrisco Grant. These included "San Jose de los Sanchez, perhaps located around the church of the same name on La Vega Road; Los Chavez, at or near modern Armijo; Los Garcias at the intersection of the present Five Points and Atrisco Road; and Los Ranchos de Atrisco, probably situated south of modern Bridge Street along Atrisco Road" (Scurlock 1988b).

Father Dominquez said in 1776 that: "The farmlands in this little place are very sterile because they are sandy, and therefore they are cultivated with great labor, yielding reasonable crops in proportion". He also stated that the Los Ranchos de Atrisco community supported 52 families with 288 persons (Adams and Chavez 1956:154). By 1790, the Atrisco community was said to have considerable livestock, which they grazed on the West Mesa or Llanos de Albuquerque. In 1778 the Atrisco Grant was extended west to the Rio Puerco, and then contained 82,000 acres. The 1790 census listed 223 residents within the Atrisco Grant. The U.S. Census of 1870 lists 740 residents in the Ranchos de Atrisco area (Julyan 1996:25).

Old Town and Post-Revolt Occupations (1706-1846)

The first settlement of Albuquerque, originally spelled *Alburquerque*, was officially founded on March 10, 1705, by Governor Francisco Cuervo y Valdéz a few years after the Reconquest. It was established at the site of the former estancia of Diego de Trujillo, which was occupied in 1632. This estancia was also known as *Paraje de las Huertas*, and following Diego's death was given to his wife Doña Luisa de Trujillo. The area was also called *El Bosque de Doña Luisa* for a cottonwood groove in the area. Governor Cuervo named the new settlement the *Villa de San Francisco Xavier de Albuquerque* after the Duke of Alburquerque, Viceroy of New Spain, and the patron saint of the earlier Trujillo estancia. However, the Viceroy ordered that the name be changed to *San Felipe Neri de Alburquerque* after his majesty's heavenly patron (Chavez 1972, Steele 1983:26). In 1706 the governor stated that the new settlement had 35 families comprising 252 persons, and that a plaza settlement with governmental buildings and a church had been established. However, later investigations in 1712 revealed that the early community consisted of 19 families of 103 persons and 10 soldiers, and that the settlement was scattered over the area of a league.

The dispersed settlement of Albuquerque was exposed to Indian attack. Therefore, in 1779 an order was given for the settlers to construct a defensible plaza around the location of the church. The first church at Albuquerque was built west of the plaza in 1706, and there is reference to continued church construction in 1718 (Chavez 1972:6). It was inspected by Father Dominguez in 1776 (Adams and Chavez 1956), and was described as a small rectangular building. The old church was nearly in ruins in 1790, and a new church was constructed in 1793 on the north side of the plaza at the present location of the San Felipe Neri Church (Steele 1983:26). A description of Albuquerque in 1776 by Fray Francisco Atanacio Domínguez refers to a cluster of 24 houses on the plaza, with a scattering of ranchos along the road north of the plaza that comprised in all 763 persons in 157 families (Adams and Chavez 1956:151). This scattered settlement

pattern probably also extended along Barelas Road to the southwest and Tijeras Canyon Road to the east.

In 1821, Padre Jose Francisco Leyva Y Rosa, pastor of the Albuquerque church, reported that there were 4,075 persons in the jurisdiction of the *Villa of Alburquerque,* all within a series of small settlements scattered north to Sandia Pueblo and south to Isleta. To the north, he identified the communities of Plaza de Los Duranes close to the main plaza, Los Candelarias, Los Griegos, Los Gallegos, Los Poblanos, Los Ranchos, Los Candelaritas, Alameda, Terranante, Los Lunas, Los Pereas, Los Garcias, Los Corrales, San Mateo and Los Gonzales. Many of these settlements were simply a loose scattering of houses and farms. To the south and close to the location of the later New Albuquerque townsite, he states: "On the east side of the river less than a half league south of Alburquerque there is a little plaza called El Estero, and from here a quarter league away follows Los Barelas reaching as far as Los Olguines, which is all a scattered neighborhood, and that is the last thing the sun shines on in that direction of this jurisdiction" (Steele 1995: 171-173). According to Thomas Steele, "San José de los Barelas was a straggle of houses along the present Barelas Road running as far southeast as the present San José Church. When the railroad came in 1880, it chopped the settlement in two, leaving the name 'Barelas' with the part west of the tracks and the name 'San José' and the chapel on the east side" (Steele 1995:176). In the 1860s, San Jose was described as a settlement of 40 to 50 residences (Julyan 1996:314). The scattered settlement of Los Olguines was perhaps also known as *Las Lagunitas*. It was described as being south of San Jose de Las Barelas and without a chapel or patron saint (Steele 1995:32).

San José de Los Barelas

The settlements of El Estero and San Jose de Los Barelas were located east of the bosque project area in the vicinity of present-day Barelas. El Estero (the pool or swamp) was situated near the swampy land of its namesake. Los Barelas appears to have been scattered along Barelas Road for a considerable distance. These communities were probably first established in the 18th century, but are not described as a community in the historic records consulted in this study until the early 19th century. A petition for lands in the Barelas area was made on August 10, 1707 by Antonio Barela to Captain Martin Hurtado, alcalde mayor of Albuquerque. This suggests that the Pre-Revolt period estancia settlement Pedro Varela (Hackett 1937:I: 313-318) may have been re-occupied. Los Barelas is mentioned as a community by 1821 (Steele 1995:171).

The Los Barelas area had long been the ford of the Rio Grande (*El Vado de Barelas*), crossing to the village of Atrisco and points south (Los Padillas, Pajarito, Isleta Pueblo). This ford also provided access to the west side road, which was often more passable than the older east side road (Simmons 1982:167). In 1856, the U.S. Army constructed the first ferry across the Rio Grande. It was launched at a crossing about three miles south of Old Town in the area of present-day Barelas (Simmons 1982:168). This ferry was used to transport people, livestock and wagons across the river until the first bridge was built at the location in 1876.

In 1860, the population of Barelas was 300, in 1870 the population was 350, and in 1880 it was 400 (Wilson 1996b). The construction of the railroad tracks through the valley in 1880 bisected the Barelas fields and disrupted traditional agricultural land use patterns. However, the construction of the railroad roundhouse, and the nearby repair shops, stimulated growth and urban development in the area. Today, the Barelas area consists of the North Barelas neighborhood that extends from Bridge Street to Coal Avenue, and South Barelas, which is scattered in the area south of Bridge Street (Dewitt 1978:53).

CROSSING THE RIVER: FORDS AND BRIDGES

When Will Rogers visited Albuquerque, he commented that the Rio Grande was the only river he ever saw that needed irrigation and folks who visit New Mexico are often disappointed that the mighty Rio Grande, formerly known as Rio Bravo del Norte, is a small chocolate-colored stream. Indeed, in time of drought the Rio Grande often ceased to flow and sank into the sands at Corrales or Belen. However, this lazy little desert river, following a high snow pack in the northern mountains and attended by a warm spring, turned into a raging torrent that filled the lower valley floor with flood waters destroying towns and villages from Bernalillo to El Paso. Indeed, the great flood of 1884 ran at a rate of 100,000 cubic feet per second, and other major floods have been recorded along the river in 1828, 1862, 1865, 1871, 1872, 1874, 1884, 1891,1897, 1903, 1904, 1905, 1906, 1920, 1929, 1937,1941 and 1947 (Ackerly et al.1997:183-184).

Crossing the river during times of normal and low flow was not difficult, and the river was easily forded. However, during the spring melt and times of flood it was impossible to ford. Various fords, ferries, and bridges have existed in the Albuquerque area, and many of these were within the bosque restoration project area. Many early bridges were destroyed by floods, and flooding was common prior to the U.S. Bureau of Reclamation flood control projects of the 1930s. Historical notes regarding the fords, ferries, and bridges that are known to have crossed the Rio Grande in the bosque project area, and are presented in the following discussion.

During the Spanish Colonial period, most travelers were forced to cross the Rio Grande at *vados* or fords. The Vado de Barelas was one of the most frequently used in the Albuquerque area, and was situated near the present-day Barelas Bridge. There were efforts to construct a bridge across the Rio Grande at Belen in 1791, and bridges were built at El Paso del Norte from 1797 to 1819 (Bloom 1925:6). However, floods soon destroyed these structures. The bridges at El Paso were constructed of logs floated on rafts from New Mexico, which was a remarkable feat in itself. However, after these early attempts to bridge the river, there is no evidence to indicate that bridges were built across the Rio Grande until the late 1870s. These structures were constructed in the Albuquerque area and within the bosque restoration project area. There was a request by the New Mexico Territorial Legislature in 1854 that asked the U.S. Congress for funds to build bridges across the Rio Grande at Albuquerque and San Juan Pueblo, but this went unheeded (Simmons 1982:404).

El Vado de Barelas: The Barelas River Ford

The Barelas river ford was first utilized in the early Spanish Colonial period. The location was selected to provide communications between the settlements on the east bank in the Barelas and Albuquerque area with those on the west bank in the Atrisco, Pajarito, and Los Padillas areas. The road going south of Barelas on the east bank towards Isleta was very sandy, making passage extremely difficult, while the road on the west bank, following the general area of present-day La Vega Road and Isleta Boulevard, was more compact and less of an obstacle. The ford itself was a rather wide crossing with a sandy floor, and was impassable during periods of flood or high water.

Below Albuquerque, the Camino Real wagon road "Split into several parallel branches, offering travelers a choice of routes southward. In dry weather, most people took the one descending the east bank of the Rio Grande that lead from the Albuquerque plaza and passed close to Spruce Baird's house. But sometimes, this way proved so sandy that wagons sunk to their axles. When that was the case, many caravans forded the river near Barelas and followed firmer ground on the west shore as far as Socorro, where they re-crossed the river and got back on the main road" (Simmons 1982:167). Travelers who used this ford often sent their baggage across on canoes or rafts and swam their horses and mules across the river.

Lt. Simpson described the ford at Barelas in 1849 saying: "Colonel Washington and staff crossed over to Albuquerque this morning at the ford. The river at this point is probably about three hundred yards wide, the stream rapid, its depth four feet and its bottom of somewhat quicksand character. During the higher stages of the water, the river is too deep to be forded; but, though this is the case at the several fords along its course, boats seem never to be resorted to by the Mexicans. Indeed, I have not seen a single one since I have been in the country" (McNitt 1964:153).

Barelas Ferry

The Barelas ford was the most frequently crossed ford identified in the Albuquerque area in the Colonial and Mexican period records. However, its use was highly dependent on the level of the river flow, and during the flood season, it was impassable. In 1856, the U.S. Army operated a ferry across the Rio Grande at Albuquerque. It was launched at a crossing about three miles south of Old Town Plaza in the area of the present Barelas Bridge (Simmons 1982:162). The ferry was used to transport people, livestock and wagons across the river until the first bridge was built about 1876. The ferry was owned by the military, but operated by local employees. "Around the docking site on the east bank, a small community of Los Placers grew up. It later was washed away by one of the Rio Grande's spring floods" (Simmons 1982:168).

The ferry was described in the Santa Fe Weekly Newspaper of November 5, 1870 as "an exceedingly primitive craft, being a low, narrow barge, evidently of considerable age, and somewhat shaky as to its deck timbers. The motive power.... consisted of two brunettish individuals, who after depositing their garments upon the prow, took to the water, rope in hand, and drew us across the main force" (Simmons 1982:168).

W.W. H. Davis in 1855 described the U.S. military ferry at Barelas saying "It was near mid-afternoon when we resumed the road. We drove down the Del Norte three miles to the government ferry, where we crossed to the west bank of the river. The ferry is kept by an old Mexican in the employ of the quarter-master's department for twenty-five dollars per month, but who is allowed to charge for the ferrying of citizens. The means of crossing was a rickety old scow that could accommodate but one wagon at a time. The passage was somewhat difficult on account of the high wind, but we made the opposite shore in safety" (Davis 1982: 390).

Old Town Ferry and Tom Post Pontoon Bridge

The Old Town ferry across the Rio Grande was established prior to its purchase by Tom Post in 1874 (Simmons 1982:203). Rafts and canoes were often used to cross the river, and there is reference to eight rafts carrying Navajos and Navajo wagons across the river at Albuquerque in 1868 (Simmons 1982:194). Tom Post opened Post's Exchange Hotel in 1875 at Old Town Plaza, and was soon considering the construction of a toll bridge across the Rio Grande west of the plaza. In 1876, Mr. Post constructed a pontoon bridge across the river, which was the first bridge across the Rio Grande in the Old Town area. It had a two-story house, a store, and a toll station at the east end of the bridge. According to Simmons (1982:204), the bridge was located in the area of the present Central Avenue Bridge, and was destroyed by floods prior to 1880. However, no maps or photographs of this bridge have been found, and its precise location needs to be verified.

In September of 1876, an Albuquerque newspaper reported that "the Rio Grande has been bridged at this place....Traffic, even freighters, will now flow up and down the river unchecked." The owner, Thomas Post, stated "although passengers will pay toll it will be a decided improvement over crossing in a single boat." In the event of high water, three extra pontoons were reserved for extending the span (Ream 1974).

A bridge is shown, seemingly along the Central Avenue alignment, on the 1886 Bird's Eye View of Albuquerque, but the toll house is on the west side of the river. The Bird's Eye View fails to show the Perea Road Bridge to the north, which was probably extant at the time, and leaves some doubt as to which bridge is represented in the illustration. There are no bridges shown near Old Town on the 1883 Town of Albuquerque Grant map (Figure 3). Two roads are shown on the 1883 Bernalillo quadrangle leading from Traction Park at Old Town across the Rio Grande (Figure 4), suggesting the presence of a bridge structure at this time. However, later records (Yeo 1910; Burkholder 1928) fail to describe a bridge on the Central Avenue alignment. The first modern highway bridge was constructed at this location in 1930.

Old Town Perea Road Bridge

One of the first bridges built across the Rio Grande near Old Town Plaza was located on the former Perea Road alignment (now Mountain Road) northwest of the Old Town plaza. It was built by the Albuquerque Bridge Company. The company was formed in 1879, and was operated by the founding fathers of New Town, Elias Stover (president), Franz Huning (vice-president) and William Hazeldine (secretary). Construction of the bridge began in 1881, and the bridge was opened on December 12, 1882.

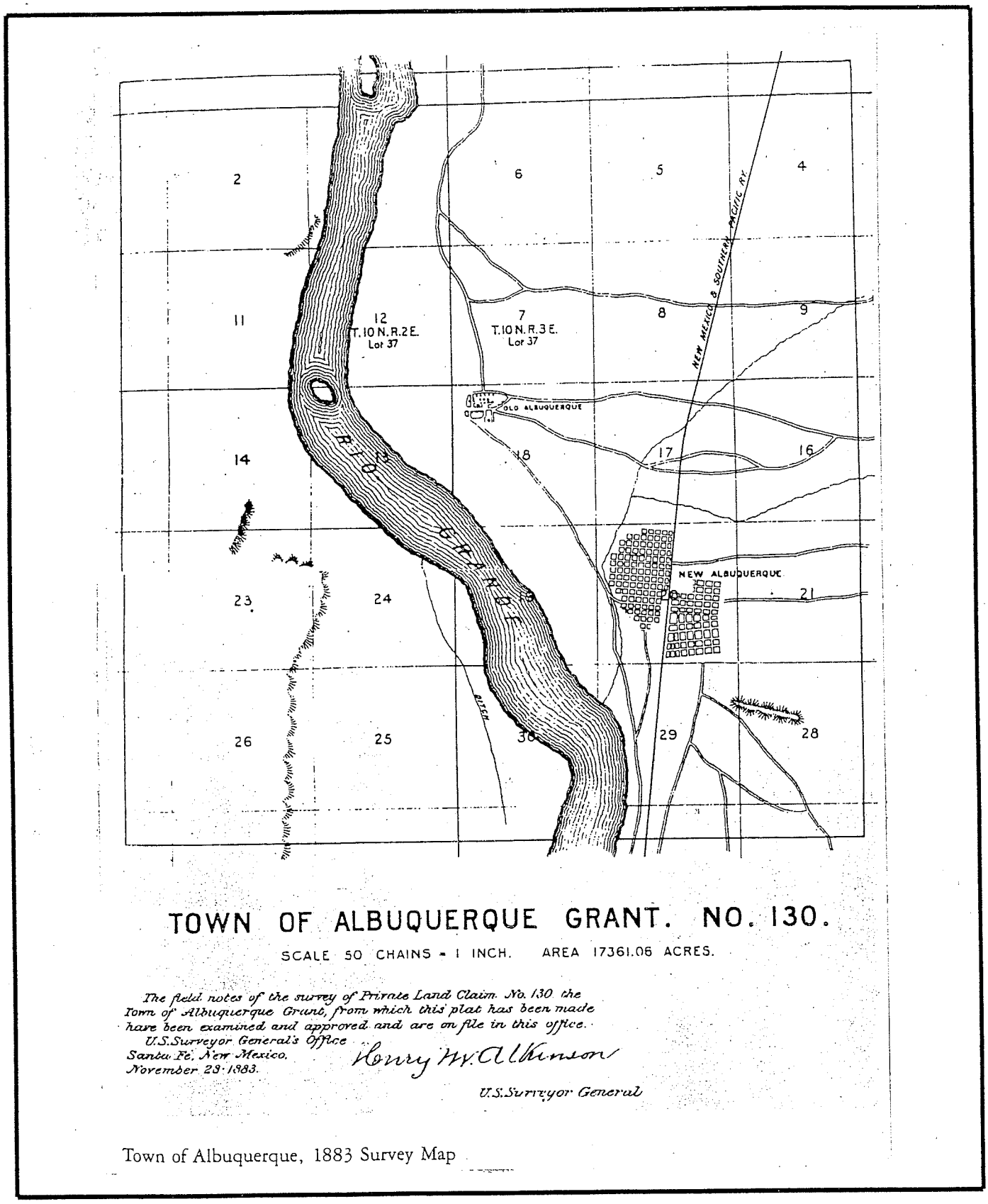

Figure 3. 1883 Town of Albuquerque Grant Map

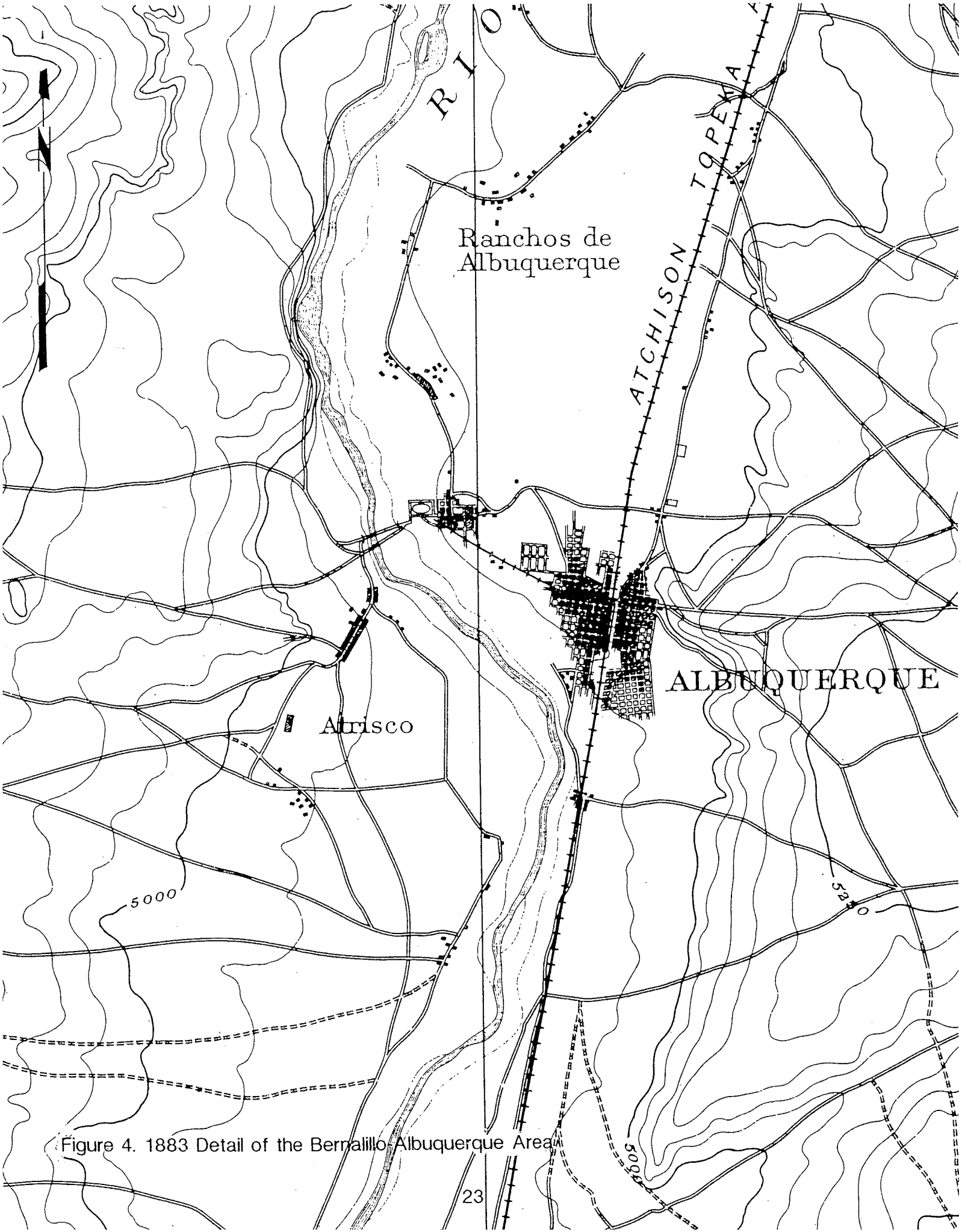

Figure 4. 1883 Detail of the Bernalillo-Albuquerque Area

The bridge was built at a cost of $22,000 dollars and had a 600-ft span across the river and a 500-ft span across the marshlands approaching the river. It had a toll house at the center of the bridge, where fees of five cents a person were collected (Simmons 1982:278). All traffic across the bridge walked, and no trotting was allowed. Any faster pace was fined. The toll bridge was not a successful business venture because people usually forded the river during the dry season and during high water, when it was most needed, floods damaged the structure and it could not be used (Rebord 1947:18).

Maintenance of the bridge caused costly repairs due to high waters. The bridge was damaged in the flood of 1884, when 170 feet of the western end was washed away (Simmons 1982:300). The bridge was rebuilt, but the structure was finally swept away during the flood of 1891. The 1884 flood was sufficient to cause a 500-ft westward shift of the main river channel at the Albuquerque Bridge (Carter 1953:20). This bridge, like many of the early New Mexico timber structures, rested on shallowly planted piers, not like the pile-driven decks of the later structures. This, together with the low elevation of the bridge deck and the closely spaced timber spans, made bridges vulnerable to floods. David Kammer explains "The cluster of closely planted piers, decks only a few feet above normal water flow, and modest earthen approaches rendered ...bridges and their approaches vulnerable to the boulders, trees, drowned livestock and other debris rushing downstream during floods. Roots and snags pummeled the piers, or, often worse, became trapped between the piers and the low-clearance bridge deck, damming the river. As pressure rose, bridge portions often gave way" (Kammer 1996:E-9 and E-10).

Two photographs of the Perea Road Bridge are curated by the Museum of Albuquerque and one is illustrated in Figure 5. An illustration of the bridge was also made (Ritch 1883) and shown in Figure 6.

The 1881 plat map of the Albuquerque area fails to show the bridge, but illustrates the river island where the bridge was built (Figure 7). However, the bridge is shown in an 1884 (Ross) schematic map of Albuquerque (Figure 8). The bridge was north of Old Town Plaza, and was located on the Perea Road alignment. The 1884 Ross map shows that the bridge crossed over on an island in the riverbed. It is probable that the toll house was located on the island. This island is also shown on the 1883 Town of Albuquerque Grant map (Figure 3), but the bridge, which existed at the time, is curiously not shown.

Archaeological survey of the bosque floor in the area of this bridge alignment was made in an attempt to locate the remnants of the old bridge. A high sand bank is present on the immediate east edge of the present river channel, which appears to have been the island. East of this sand bank is a lowland bosque that was a former river channel. A thorough search along the east bank and bosque floor failed to reveal any evidence of the bridge. However, from the east edge of the river a structural remnant of the bridge was seen on the west bank and was subsequently located. This remnant of the bridge is identified as LA 139208, and is described in the site files.

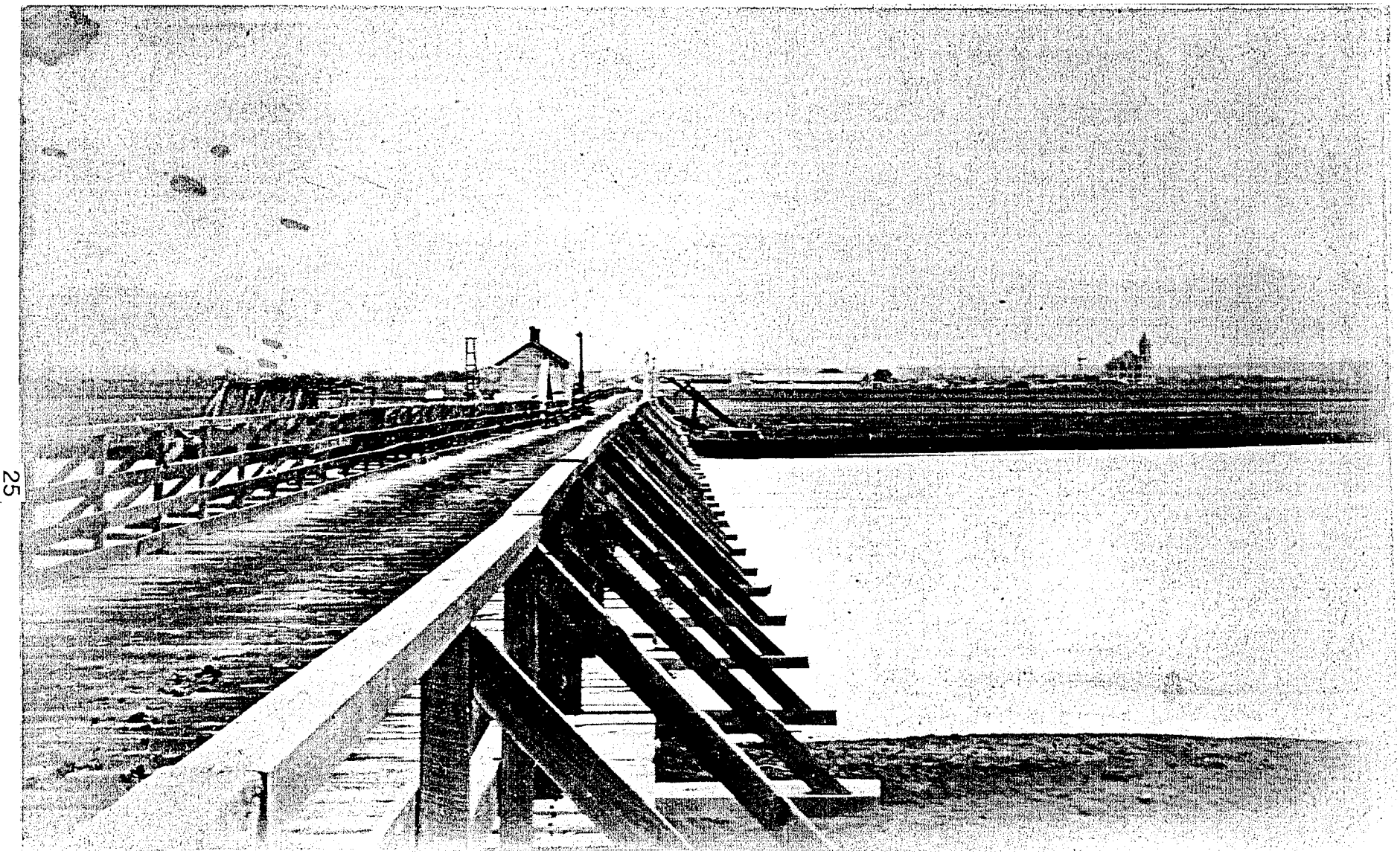

Figure 5. Perea Road Bridge Alignment at Old Town (ca. 1881-1891). Museum of Albuquerque Collections No. 1978.50.098

RIO GRANDE BRIDGE AT ALBUQUERQUE.—(1,600 feet long.)

Figure 6. Illustration of the Perea Road Bridge at Albuquerque (Ritch 1883)

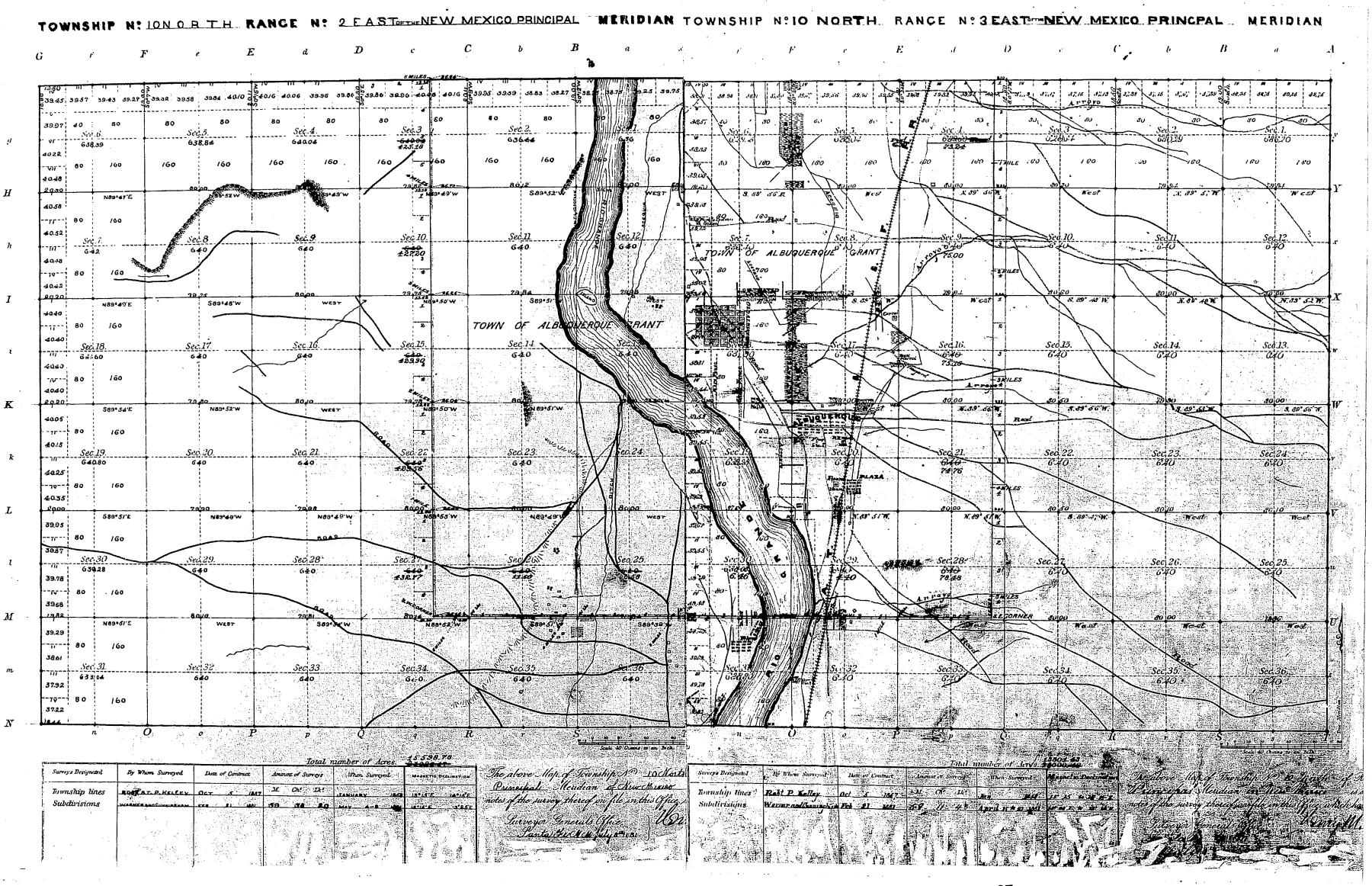

Figure 7. 1881 Plat Map of the Albuquerque Area

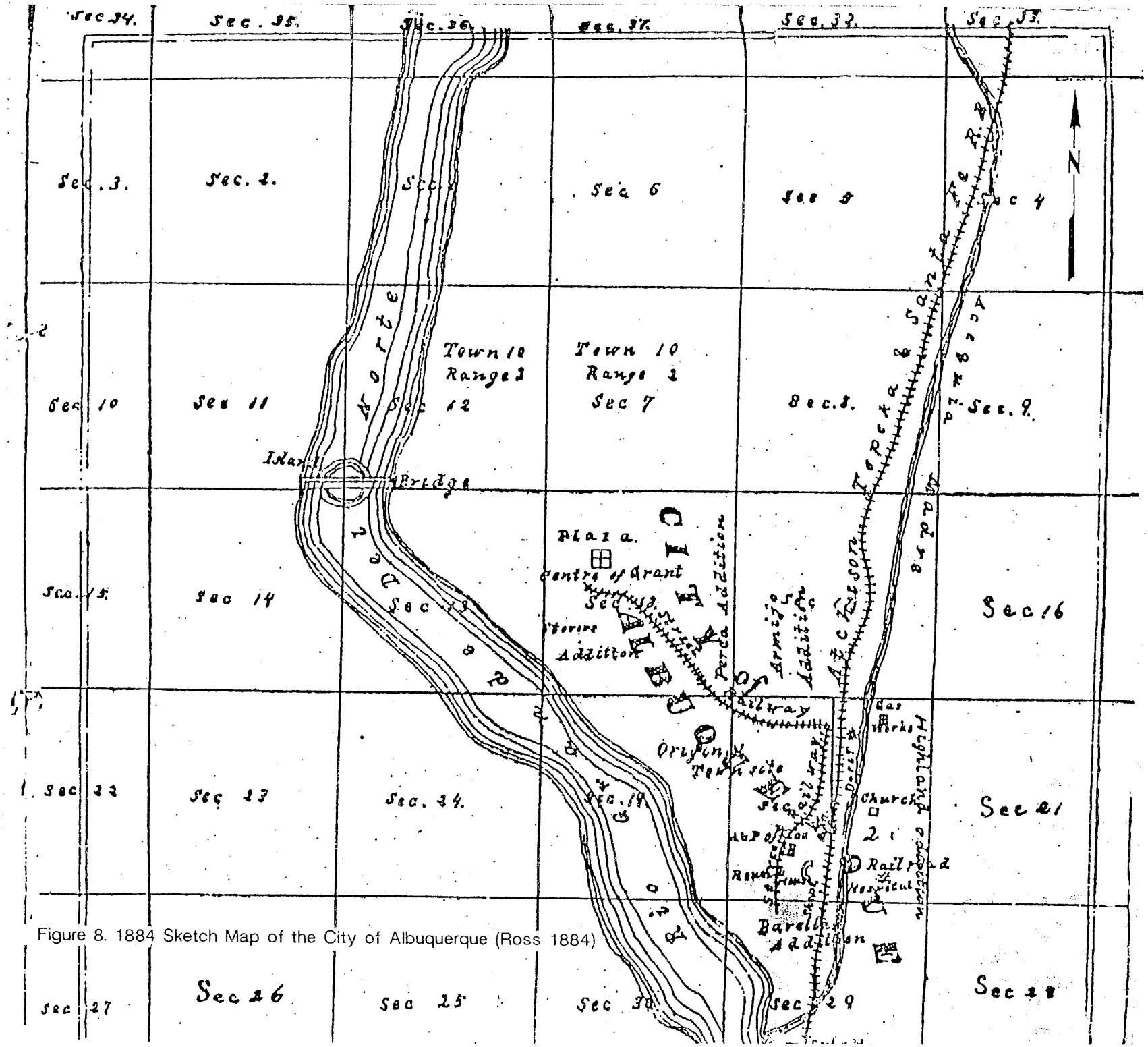

Figure 8. 1884 Sketch Map of the City of Albuquerque (Ross 1884)

Barelas Bridges

The first bridge at Barelas was built in 1876, the same year that Tom Post constructed his pontoon bridge near Old Town. There is reference to the formation of the Albuquerque Bridge Company in January 1864, but no evidence to indicate that any construction proceeded from this incorporation (Ream 1975). The first Barelas Bridge was a wood construction that was destroyed by the flood of 1884. A photograph of an early pony-truss bridge at Albuquerque (Figure 9) may be the early Barelas Bridge. This bridge was replaced by the second Barelas Bridge, which was a lumber-beam truss construction with cable pinning built on rather narrow iron pilings (Figure 10). The 1898 Willets map of Albuquerque shows the Barelas Bridge, and identifies it as the "New Bridge" This second bridge was damaged by a flood in 1904.

The third Barelas bridge was an iron truss construction that was built in 1910. It was an 18-span bridge built at a cost of sixty thousand dollars (Fitzpatrick and Caplin 1975:46). This bridge had a less massive and more open truss appearance. Two sections of this bridge were washed away by a flood on June 4, 1912 (Figure 11). The bridge was under repair in December 1912. According to Roy Stamm, the two sections of the bridge were still out in 1913 when he made one of the first flights over Albuquerque. Flying down the river, they were unable to gain altitude as they flew through the gap of the missing bridge sections (Stamm 2000:192).

The flood of 1912 caused major damage to the third Barelas Bridge. The west approach to the bridge was damaged on May 24, 1912 and on June 4, the newspaper headlines read: "River took bridge last night-two spans of the new structure at Barelas swept into the torrent after piers had settled to the water's edge"(Wiley 1972). A makeshift extension was completed in the fall that allowed the bridge to be crossed, but the destroyed truss sections were still under reconstruction in December of 1912. Cobb Studio's photograph of the iron truss bridge repair is on file at the Museum of Albuquerque (1990.03.029). This bridge is illustrated on the 1927 Middle Rio Grande Conservancy District maps, and it is listed in 1928 as a steel truss highway bridge 1565 feet in length, which was the longest of 15 bridges between Cochiti and San Marcial (Burkholder 1928:90).

The fourth Barelas Bridge, which was concrete, was built adjacent and south of the old iron truss construction in ca. 1928 (Figure 12) (Kammer 1996: Figure 11). Remnants of the pilings for this structure were found under the south side of the present bridge and are identified as site LA 138857. The 1928 Barelas highway bridge (NMSHTD Bridge No. 9) (Figure 13) was 29.3 ft in width and 1,553 feet in length. It consisted of 62 simple spans, each 25 ft long, and it had timber piles and caps and a concrete deck. Both the iron truss and new concrete highway bridge remained in use for a period. However, the truss construction was subsequently dismantled, although the foundations of the truss structure remained in place and are visible in a 1953 photograph (Museum of Albuquerque Photo No. 1990.05.108).

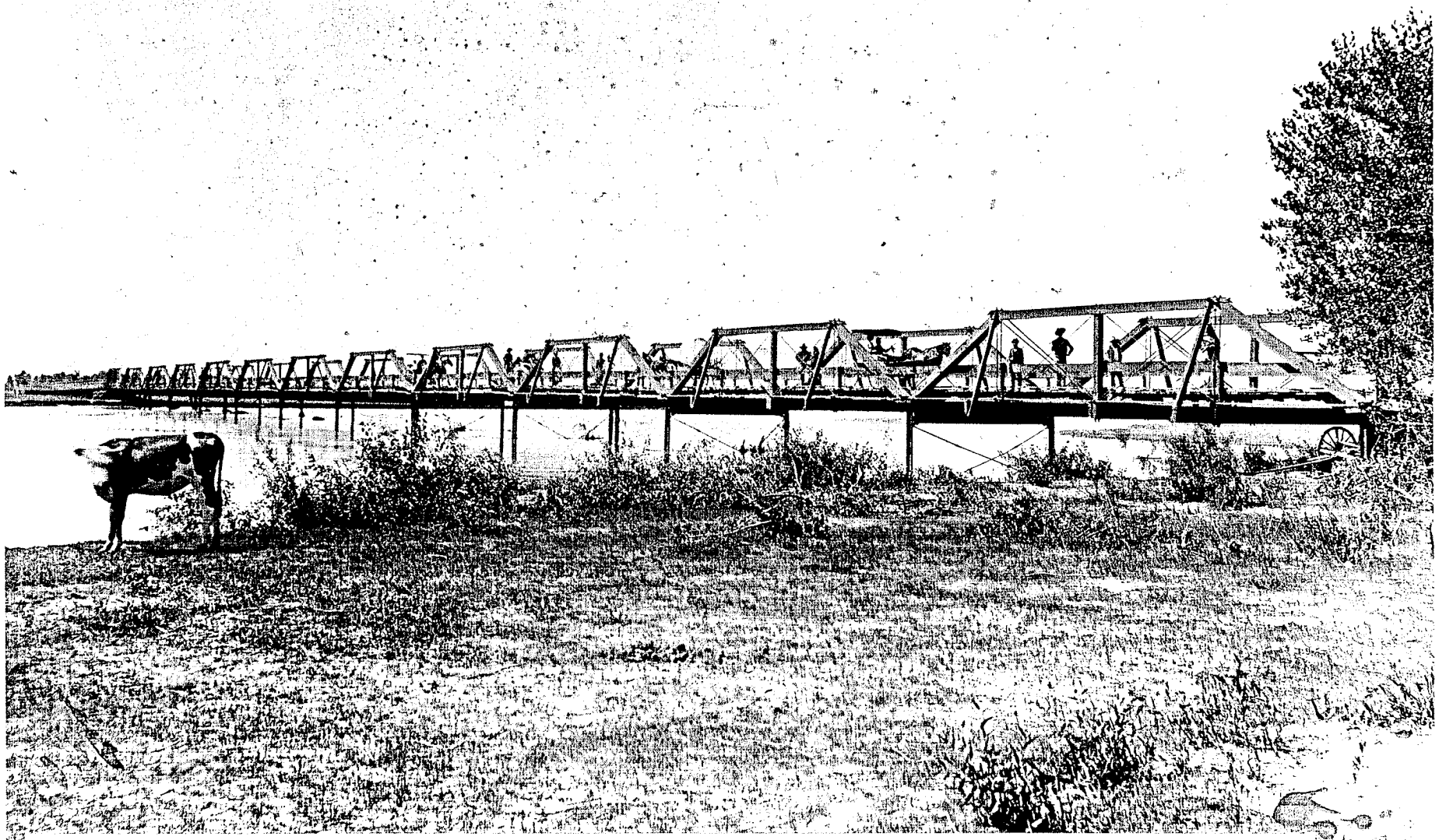

Figure 9. Pony-truss Bridge at Albuquerque, Probably at the Barelas Crossing, ca. Late 1870s or Early 1880s (Museum of Albuquerque).

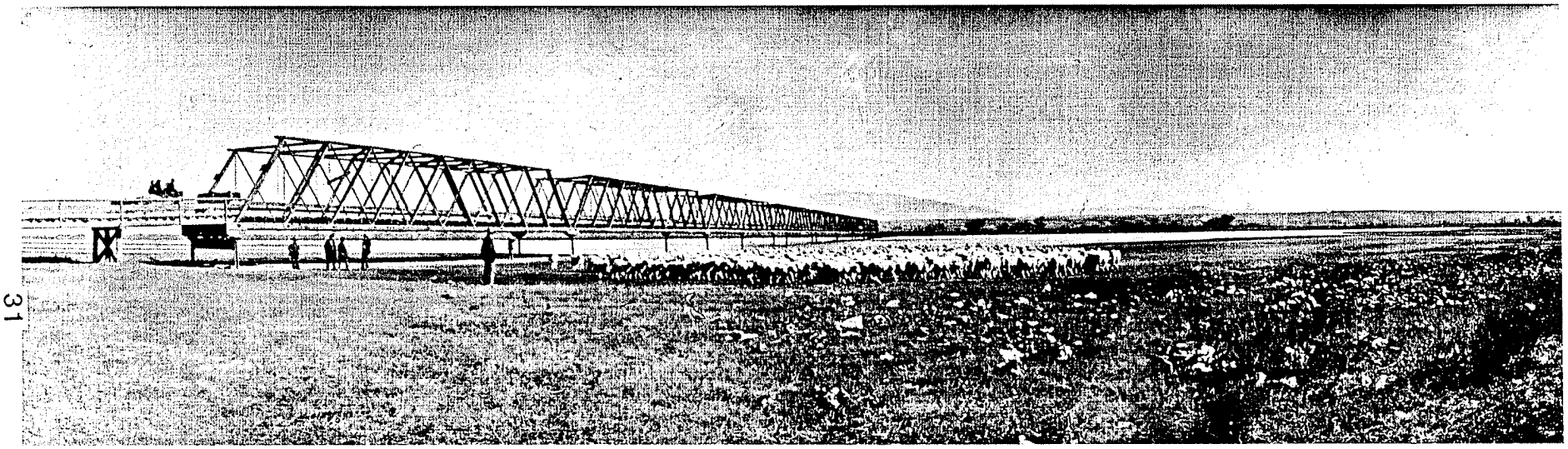

Figure 10. Iron Truss Bridge at Barelas (ca. 1902) View to the East. Museum of Albuquerque Collections No. 1999.017.020.

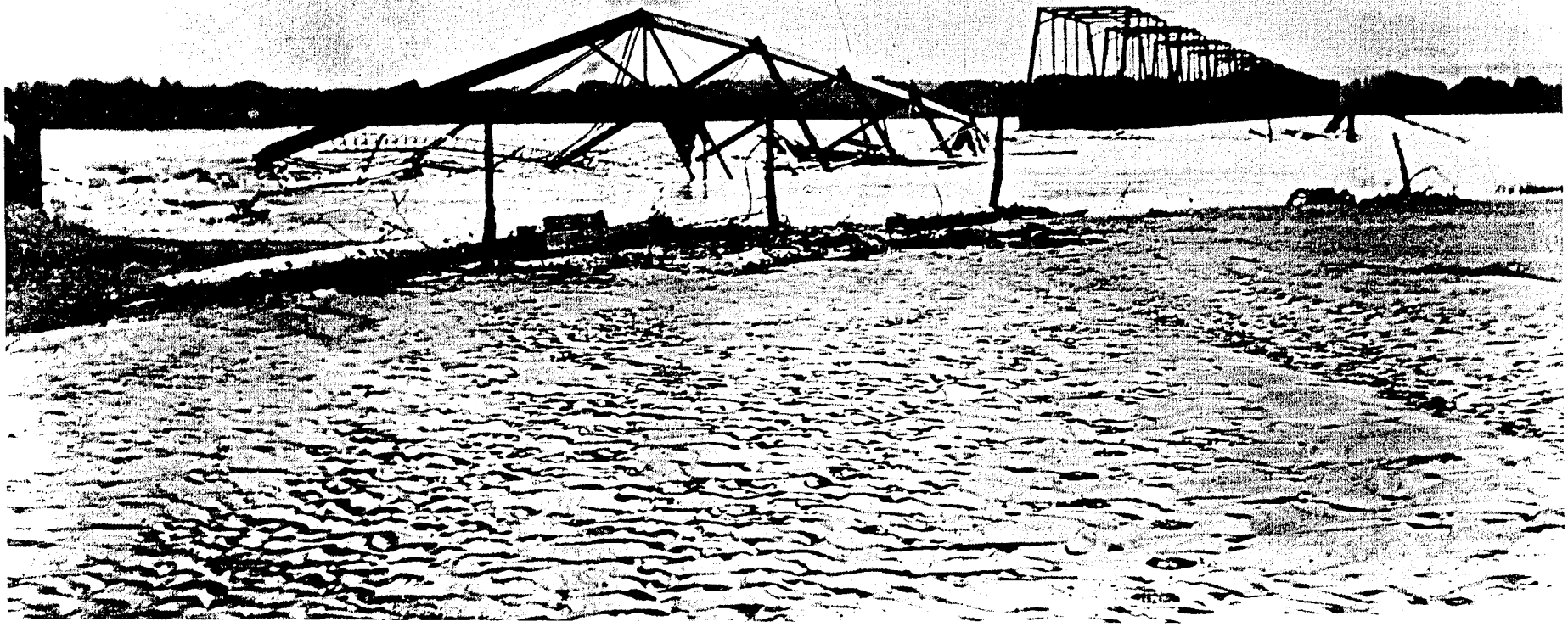

Figure 11. Iron Truss Bridge at Barelas, Partially Destroyed by the Flood of June 1912. Museum of Albuquerque Collections No. 1978.050.065

Figure 12. Barelas Bridge Showing the ca. 1898 Iron Truss Bridge North of the 1928 Highway Bridge. Museum of Albuquerque Collections No. 1992.005.107.

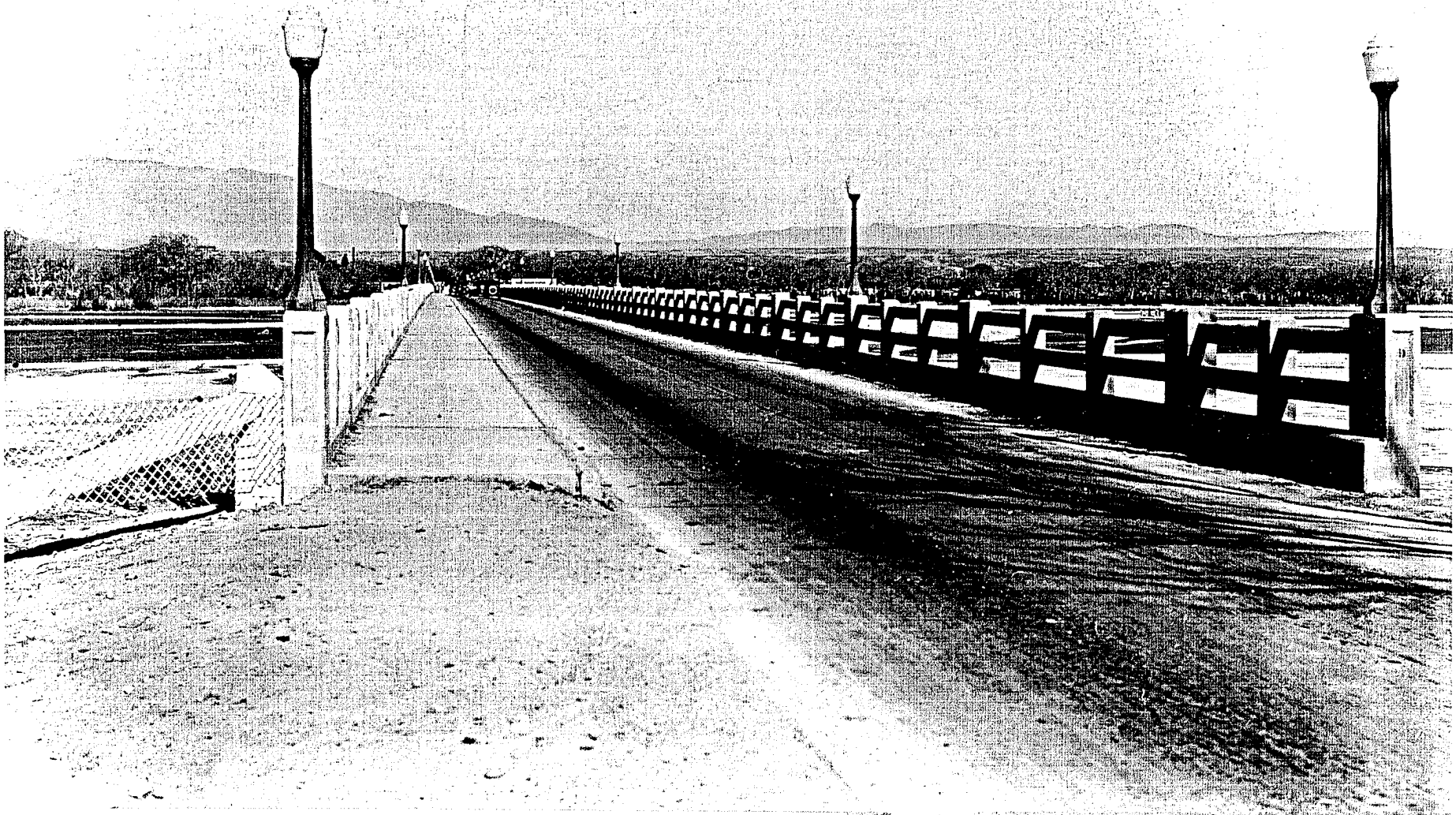

Figure 13. 1928 Barelas Bridge. Museum of Albuquerque Collections No. 1992.05.407.

Two modern highway bridges (NMSHTD Bridge Nos. 8417 and 8418) were built at the Barelas crossing in 1983 and replaced the 1929 structure (Bridge No. 9). A few timber pilings from Bridge No. 9 remain under the south bridge at Barelas and have been assigned a Museum of New Mexico site number (LA 138857).

Modern Central Avenue Bridges

There are no bridges illustrated in the Central Avenue or Old Town areas on the 1898 Willets map of Albuquerque. H.W.Yeo (1910) does not describe a bridge across the Rio Grande at Old Town. There is no bridge at the Central Avenue alignment on the 1915 City of Albuquerque map (MAGIC Map No. G4324 A4S1). An 1928 report by the Chief Engineer of the Middle Rio Grande Conservancy District reported 15 bridges between Cochiti and San Marcial. He refers to a bridge at Alameda and Barelas, but none at the Central Avenue alignment (Burkholder 1928:90).

The first modern Central Avenue Bridge (Bridge No. 1557) was constructed in 1930. A second adjacent bridge was built in 1952 (Bridge No. 5226) to accommodate increased traffic. The older 1930 bridge was westbound and the 1952 bridge was eastbound. These bridges were removed following the construction of a new double six-lane bridge in 1983 under NMSHTD Project No. BRM-4016(1). Both of the earlier bridges were in poor condition due to long use and deterioration (NMSHTD Bridge Records).

The present Central Avenue bridges were built in 1983. The eastbound Bridge No. 7898 (replaced the 1930 Bridge No. 1557), and westbound Bridge No. 7899 (replaced the 1952 Bridge No. 5226) are part of NMSHTD Project No. ST(M) 4016 (200). The last construction date was 1983. The bridges consist of 16 spans set on concrete piers, with a cast-in-place concrete deck. Each bridge has three lanes and a sidewalk. The structural widths are 50.25 feet and the lengths are 1203 feet (NMSHTD Bridge Records).

An excellent description of the 1930 West Central Avenue Bridge and its construction is provided in an article written in the New Mexico Highway Journal (Reynolds 1931). The article states that the bridge is important since "It gives the city a second and more direct outlet toward Gallup by way of State Road No. 6. It relieves Barelas Bridge of some of its traffic by serving the numerous farms and communities on the west side of the river, many of which are truck farms using Albuquerque as a marketing center. The road of which this bridge is the important link ties into State Road No. 6 close to the Western Air Express Airport, and makes a more direct route from the Airport to the City." (Reynolds 1931:16).

Levy Construction Company of Denver, Colorado built the 1930 West Central Avenue Bridge under the direction of J. H. Miner and Chas. O'Leary. It consisted of 54 twenty-five ft spans of steel and concrete superstructure resting on creosoted pile and timber bents and abutments. The bridge was 1,353 feet in length and 26 ft 6 inches in width. The bridge was similar to the Barelas structure built two years earlier, but of somewhat lighter construction. The bridge had a 20-ft wide roadbed and 6-ft wide sidewalk. The superstructure consisted of five lines of steel I-beam stringers that supported a concrete roadway slab and concrete handrail. The piles for the bridge were driven with an

overhanging driving rig that included a 60-ft steel derrick carrying a Vulcan-Warrington No. 3 steam hammer (Reynolds 1931:16).

The 1953 Central Avenue Bridge No. 5226 was an eastbound lane built to provide for the increased traffic that the adjacent 1930 bridge could not carry. The bridge had 18 cantilevered spans of 75 feet, and was 1,353 feet long and 35 feet in width. In was in very poor condition in 1983 when it was demolished and replaced.

Interstate Highway 40 Rio Grande Bridge

Two Interstate 40 highway bridges were constructed across the Rio Grande River in 1961 and 1963. They were rehabilitated in 1981, and in 1995 they were replaced by new structures. There were no earlier bridges at this location. The first bridges at I-40 included Bridge No. 6297, which carried the westbound traffic lanes and was located on the north. Bridge No. 6298 carried eastbound traffic lanes and was located on the south. "Both bridges in 1991 were 1,281 feet long and 40 feet, 6 inches in width. They were constructed with welded steel plate girders and steel form beams and stringers, concrete stub abutments and piers, and cast-in-place concrete deck with low slump overlay." In 1981, the steel railing was replaced with a concrete barrier, the vertical stiffening rods in the lateral draining system were replaced, and the low slump overlay was replaced with a concrete overlay (Marshall, Sandra 1991:2).

The I-40 bridges were rebuilt in 1995, and new bridge numbers were assigned to the structures. The eastbound bridge is Bridge No. 8830 (formerly Bridge No.6298), and the westbound bridge is Bridge No. 8831 (formerly Bridge No. 6297). Both of the bridges are five lanes in width and are 1,242 feet long and 66 feet, 2 inches wide. Each bridge has spans of 100 and 130 feet in length with 12 concrete girders per span. The bridges have a cast-in-place concrete deck (NMSHTD Bridge Records).

Existing Highway Bridges in the Project Area

There are six modern highway bridges in the project area. They include the two Interstate 40 bridges (Bridge Nos. 8830 and 8831) built in 1995, two bridges at Central Avenue (Bridge Nos. 7898 and 7899) built in 1983, and two bridges at the Barelas Bridge Street crossing (Bridge Nos.8417 and 8418), also built in 1983. None of the existing highway bridges are older than 20 years of age and none exhibit usual or architecturally significant characteristics. None of the bridges is listed in the New Mexico Historic Bridge Inventory (Rae et al. 1987). A photographic inventory of the bridges has been submitted with this report under separate cover for archival curation in the ARMS files at Santa Fe. None of these bridges has National Historic Register significance and none will be affected by the project improvements.

Modern Highways-Albuquerque and Rio Grande Bridge Crossings

The Territorial legislature of New Mexico in 1903 designated the first NM Highway 1 as the main north-south corridor following along the approximate route of the old Santa Fe Trail and Camino Real. Highway 1 entered Albuquerque from the north along North Fourth Street to Central Avenue and then continued south down Second Street to Bridge Street and the Barelas Bridge crossing. In 1924, south of Central Avenue, the route was

realigned along South Fourth Street. From the Barelas Bridge, the highway continued south on Isleta Boulevard to Isleta Pueblo and Los Lunas. The cutoff west from Los Lunas to Laguna Pueblo was originally known as Route 6 (Wilson 1996a:5). A new steel truss bridge was built at the Barelas crossing in 1910.

In 1926, a uniform system of national route numbers was adopted. New Mexico Route 1 became US 85, and was soon incorporated as part of the US Route 66 interstate system. NM Highway 1 also served as the first alignment of Route 66 between Romeroville and Los Lunas, a reminder of how the early federal highway system in the west often consisted of local roads spliced together to create the new federal road system. Thus, all east-west and north-south traffic was directed down Fourth Street and over the Barelas Bridge. By 1928, more than 3,500 vehicles a day were crossing at the bridge (Wilson 1996a). The US 66 traffic continued to flow down Fourth Street to the Barelas Bridge and Los Lunas cutoff until 1931, when the Santa Rosa cutoff brought US 66 traffic directly from the east through Tijeras Canyon (formerly Highway 10) and down Central Avenue to Fourth Street.

Highway traffic was extended west on Central Avenue in 1931 over the Rio Grande Bridge and followed a recently opened road to Laguna Pueblo, frequently referred to as the Laguna cutoff. This route was first designated as Highway 6. In 1937, the Laguna cutoff was formally completed and incorporated into the US 66 system. With the east-west realignment of US 66 down Central Avenue, the Fourth Street to Barelas Bridge corridor was by passed by US 66, but continued to be designated as US 85.

Following the passage of the Federal Interstate Highway Act in 1956, a system of major interstate highways was constructed throughout the country. In 1960, construction of the I-25 and I-40 interstate systems in Albuquerque was well underway. The Interstate 40 Bridge across the Rio Grande was completed in 1963. The interstate system was fully completed with the construction of the interchange between the two interstate highways in 1966. This carried the major east-west traffic away from the congested downtown area, and both the Barelas Bridge and West Central Avenue Bridge, as parts of the interstate system, were largely by-passed by 1966. However, Highway 66, at the West Central Avenue crossing, was not formerly decommissioned until 1985.

HISTORIC US HIGHWAY 66

Context

The historic Route 66 highway crossed the Rio Grande River in the bosque restoration project area along two alignments. Route 66 first crossed over the Barelas Bridge from 1926 to 1937, and was realigned across the West Central Avenue Bridge when the Laguna cutoff was opened in 1937. Route 66 was the major east-west highway until the construction of Interstate 40 in the 1960s. However, Route 66 continued to be officially recognized until it was finally decertified in 1985.

Prior to the designation of Route 66 as part of the U.S. Federal Highway system in 1926, the road across the Barelas Bridge was known as New Mexico Highway 1, El Camino Real, beginning in1904. Interstate traffic running north-south passed through Albuquerque over the Barelas Bridge and continued south of US 85 to Isleta, Los Lunas and points south. Interstate traffic running east-west followed the same route, but turned west on US 66 (prior to 1926 and after 1937, this was known as NM 6) towards Laguna and points west. The western interstate, prior to its designation as US 66, was variously known as "the Northern Arizona Route", "the Grand Canyon Route", or the "Western Extension of the Camino Real" (NM Board of Exposition Managers 1915:58-68).

The use of the Barelas Bridge as part of the US 66 system applies only to the early phases of the interstate highway. These early phases of US 66 have been identified by David Kammer (1993) as the Pioneer period (1926 to 1933), followed by the New Deal Depression Era (1934-1941). The use of the route during the early US 66 period saw the beginning of automobile tourism and the early Depression years. During the Depression, the highway was the corridor for a stream of displaced families, most from the Southern Plains, seeking work and new homes in California. However, during this period, considerable funds were devoted to highway construction as part of the New Deal's effort to revive the nation's economy and create jobs for the displaced.

Barelas Bridge was by-passed by Route 66 with the completion of the Laguna cutoff in 1937, and the highway was rerouted over the Central Avenue Bridge. The later history of US 66 saw the deployment of troops and equipment during World War II and a brief period of neglect during the post-war period. However, the West Central Bridge was used during the florescent or "Golden Age" of US 66 during the period from 1945 to 1956, when the road became an icon of popular American culture.

Integrity

Sections of the US 66 highway system in New Mexico are listed on the State and National registers. A multiple register nomination entitled "Historic and Architectural Resources of Route 66 through New Mexico" (HPD 1661) (David Kammer 1993) was listed on the State and National Register in 1993. It is a thematic nomination designed to incorporate eligible sections and associated properties of US 66 and may include individual properties or historic districts. Various sections of US 66 and associated properties are listed on the State and National Register, but none occur at the Rio Grande River bridge crossings

Historic road segments of US 66 may qualify for nomination to the National Register of Historic Places, if the road segments and associated properties maintain an integrity of historic structures utilized during the period from 1926 to 1956. "These segments vary in length, ranging from two to twenty miles, and contain a number of structural elements associated with road building during that period (1926-1956), including culverts, guard rails, curbing, bridges, grade separations, centerline markers, right-of-way and Federal Aid Project boundary markers, as well as the road's original cross-section template. Most segments are also flanked by associated properties, or their remains, including tourist courts, gas stations, and curio shops and trading posts. All of these road segments offer

ample evidence of how Route 66 appeared to early motorists as they crossed New Mexico" (Kammer 1993:F-80).

Registration requirements for properties of multiple nominations are defined as follows: "For a segment of former Route 66 to be eligible for listing on the National Register under Criterion A in the area of transportation and the rise of automobile tourism and Criterion C in the area of road engineering and construction it must retain a high degree of integrity of association (i.e., other cultural properties such as cafes, service stations, tourist courts etc.), design, material, workmanship, setting and feeling. While not all of these criteria apply equally to each of the road segment subtypes, all enter into determining the eligibility of each road segment" (Kammer 1993:F82-83).

While the Barelas Bridge and West Central Avenue Bridge crossings are important and interesting elements of the New Mexico US 66 system, they retain only minor remnants of the original bridges used during the period, and there are no visual indications that they were ever part of US 66. No associated properties such as cafes, tourist courts, gas stations, trading posts or curio shops remain standing in the project area that provide tangible evidence of US 66 use. Therefore, it is evident that the present river crossings at Barelas and West Central Avenue are not individually eligible for nomination to the National Register of Historic Places as part of the US 66 multiple register group.

IRRIGATION WORKS

Introduction

It is probable the irrigation from the Rio Grande was first developed by prehistoric Pueblo populations during the florescent Pueblo IV period (ca. 1300-1540), when a series of large adobe pueblos were built in the area. There are references to irrigation canals in the early Spanish records in the Piro Province to the south (Hammond and Rey 1966:220) during the Espejo Expedition of 1581 and in the Tewa area to the north during the Castaño de Sosa attempted colonization effort of 1591 (Hammond and Rey 1966:220). There has been some debate as to the extent and nature of these irrigation systems in the Rio Grande Valley, and some researchers believe they were confined to the floodplain and consisted of primitive diversion works and small canals (Wozniak 1987:15). No evidence of the prehistoric irrigation structures has been identified, to date, in the archaeological record.

Irrigation works of more extensive nature were certainly developed by the Spanish and Pueblos after the Spanish colonization in 1598. After the Pueblo Indian Revolt of 1680 to 1696, a rather extensive system of irrigation canals was built. Many of the pre-conservancy district canals in the Rio Grande Valley are believed to date to at least the early 18th century. The first detailed descriptions of irrigation facilities in the Rio Grande Valley and bosque project area were provided by Follett (1896) and Yeo (1910). A detailed map of the project area and irrigation facilities, that predates the Middle Rio Grande Conservancy District project, was compiled by the U.S. Reclamation Service in

1922 (Figure 14). A brief review of what is known about irrigation systems in the bosque project area is provided below.

Pre-MRGCD Irrigation Works in the Bosque Project Area

The earliest reference to irrigation canals in the Rio Grande bosque study area refers to four ditches—all of which were said to predate 1800. These canals included, from north to south, the Ranchos de Atrisco, the Upper Atrisco, Middle Atrisco and the Lower Atrisco (Follett 1896 and Ackerly et al. 1997:11).

H.W. Yeo in 1910 described five canals in the bosque project area. All five of the irrigation canal headings are on the west bank of the Rio Grande. These canals are oriented from north to south, and are described below.

The earliest survey, which shows these canals, was completed in 1917 (Figure 14) (U.S. Reclamation Service 1922). Most of these irrigation systems at the rivers edge have been removed by later MRGCD reconstructions, the construction of the Atrisco Riverside levee and drain, and by floods within the restricted channel-floodplain of the Rio Grande. A search for remnants of these early canals was made during the survey. Evidence of two adjacent canals was found, and both were recorded as LA 138859. A diversion work of pre-1910 affinity was also located (LA 138858).

In the inspection of the irrigation facilities made by H.W. Yeo in September of 1910, five irrigation canals are described that headed from the west bank of the Rio Grande in the Atrisco area. These canal headings began on the north near the limits of the high sand banks and extended south of what is now the Central Avenue Bridge. The canal intakes were located in this area because of an eastern bend of the river that threw the water channel against the west bank. In the same area on the east bank, there were no irrigation headings. The first detailed map of the area, based on a 1917 survey (Figure 14), shows four irrigation ditch headings on the west bank in the bosque project study area. There was also one canal discharge into the river on the east bank above Central Avenue. A similar pattern is illustrated on 1927 and 1932 MRGCD maps with two canal intakes above the Central Bridge and two below. In 1933, a MRGCD project replaced the headings of all these canals with the Atrisco diversion structure. This, in turn, was largely replaced by the Atrisco siphon in 1953.

Small Community Ditch

"The heading for this ditch is on the west side of the Rio Grande a short distance above that of the Acequia de Atrisco, and is close to the sand hills which are blown in from the west...The diversion works are temporary. On the day of examination September 16, 1910, it consisted of a long ditch excavated for over one-fourth of a mile, extending into the river bed, close under the high sand bluff. A great part of this was made by shovel...The area irrigated is about 335 acres" (Yeo 1910:69-70). Based on the description of this canal, it appears to have been located in the area of the later Atrisco header structure, and seems to have gathered water from the river by means of a ditch extending into the riverbed. This canal is not illustrated on the 1922 U.S. Reclamation map, and it may have been abandoned at the time of the 1917 survey.

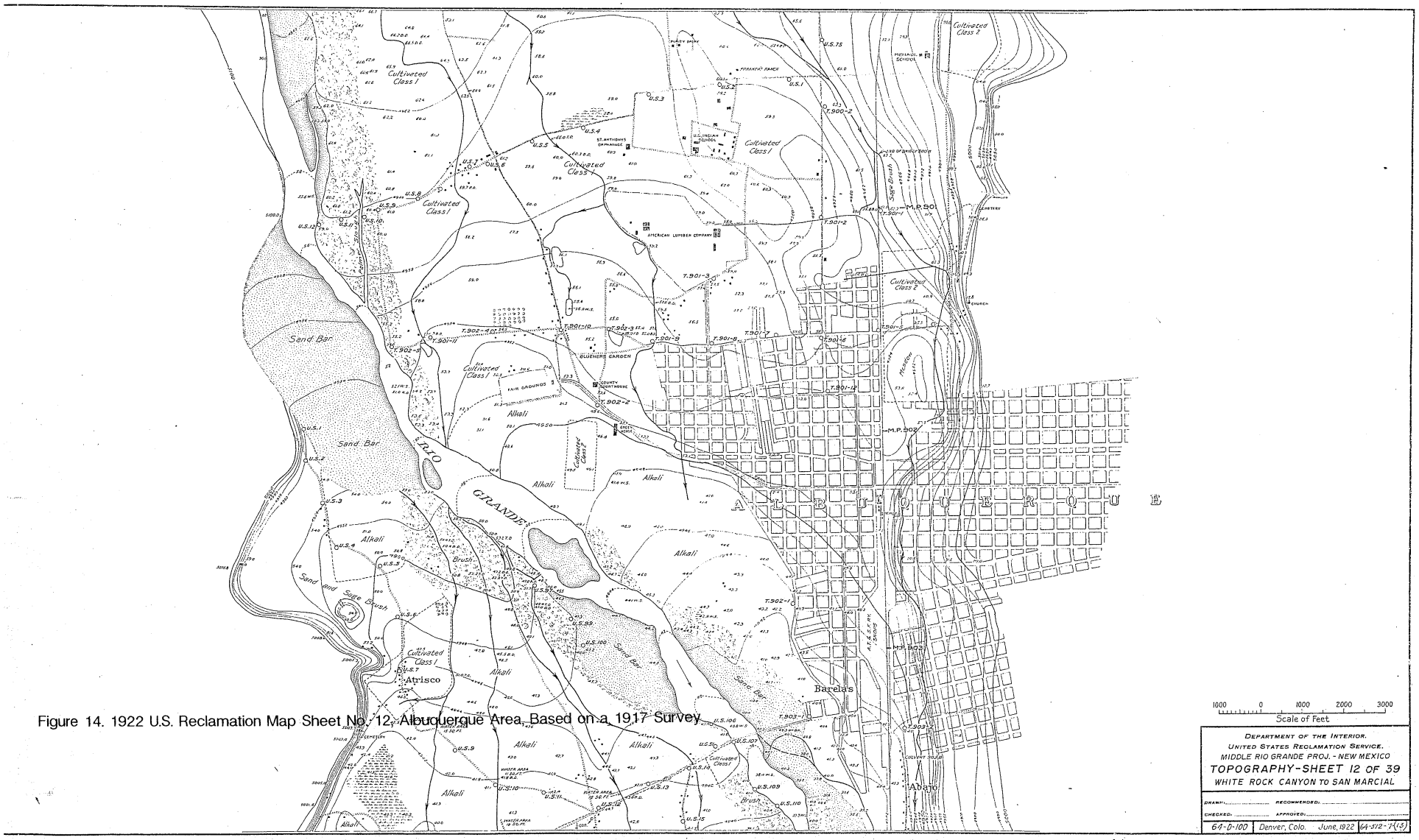

Figure 14. 1922 U.S. Reclamation Map Sheet No. 12, Albuquerque Area, Based on a 1917 Survey

Acequia de Atrisco
"The heading of the ditch is on the west side of the Rio Grande, almost due west of Old Albuquerque, and near the high sand cliffs on the west side of the river. The diversion works are temporary, consisting of a mud and brush wing dam... The area irrigated is 325 acres...The date of construction could not be learned" (Yeo 1910:68-69).

Acequia de Arenal
"The heading of this ditch is on the west side of the Rio Grande, southwest of Old Albuquerque, and about one-fourth a mile northwest of the heading of the Acequia Nueve de Atrisco. The diversion works are temporary, but were not examined. The area irrigated is 900 acres.... The date of construction was not learned" (Yeo 1910:68).

Acequia Nueve de Atrisco
"The heading of this ditch is on the west side of the Rio Grande, and about 100 yards further up the river than the Acequia Vieja. The diversion works consist of a wing dam made by driving poles in the river bed and placing sods, brush and mud thereabouts....The area irrigated was estimated at 1,200 acres...A dike has been built at varying distances back from the river to prevent destructive inundations. This ditch is not so old as the one lower down the valley" (Yeo 1910: 67-68).

Acequia Vieja de Atrisco
"The heading of this ditch is on the west side of the Rio Grande, and southwest from Old Albuquerque, and it is the first on the west side above the wagon bridge which crosses the river at Albuquerque (i.e. Barelas Bridge). The diversion works are temporary, being a mud and brush wing dam. The dam had been recently repaired and was diverting practically all the water in the river on the date of examination. The area irrigated was estimated at 450 acres. This is an old settlement and this ditch is probably very old....There is a dike along the river near the head of this ditch, but it was not ascertained how far down the river it extended" (Yeo 1910:67).

Middle Rio Grande Conservancy District Irrigation Works
The MRGCD was established in 1925 after many years of planning. Detailed plans for the project were submitted by the Chief Engineer, Joseph L. Burkholder in 1928 and the project was largely implemented during the 1930s. The project consisted of an extensive complex of flood control levees, diversion works, irrigation canals and drains. The project effaced many of the earlier irrigation and flood control works. However, many of the new irrigation canals followed the general route of the old ones. In the bosque project area, large riverside levees were built to protect the growing Albuquerque and Atrisco areas, and the old diversion works and canals were replaced by the Atrisco diversion built in 1933. Only remnants of the earlier pre-Conservancy District irrigation works have been identified in the project area (LA 138858 and LA 138859). A few notes regarding MRGCD construction in and adjacent to the project area are provided below.

Atrisco Riverside Drain
"According to MRGCD records a drain first appears on an 1898 map and again on the 1928 quadrangle map for the area. The Atrisco Riverside Drain was later rehabilitated in the early 1930s as part of a WPA project. The drain was again renovated in 1955 by the Bureau of Reclamation" (Kramer and Wells 1998:7). The present canal is an earth-banked structure, 8 meters across. The area east of the Atrisco Drain was widened in 1999 for use as a bike trail.

Atrisco Header and Diversion Works (LA 138860)
The diversion works were completed in 1933 as part of the MRGCD project (Ackerly et al. 1997:24). The function of the works was to provide a permanent header diversion for irrigation in the Atrisco area. Prior to 1933, there were four to five irrigation canals providing irrigation to the Atrisco area, four of which had temporary brush diversions and one a driven pole diversion. A photograph of the Atrisco header (Figure 15) is of interest since it shows the river channel running hard against the west side and the area entirely devoid of vegetation, where today, there is a rather extensive bosque. Additional information on the Atrisco diversion works is discussed in site LA 138860, and MRGCD construction maps that have been included under a separate package for inclusion with the site data records.

Atrisco Siphon
Brush division works were still in use as late as 1947 at the Atrisco Canal heading (Ackerly et al. 1997:29), since the Atrisco diversion was entirely dependent on the river channel flow remaining hard against the west bank. The early MRGDC project failed to provide any actual diversion works, except for a 50-ft skimmer wier, and simply relied on the river channel flow remaining at the west edge of the channel. This system was faulty, and during periods of low river flow did not provide adequate water into the Atrisco irrigation system. In order to rectify this problem, the MRGCD constructed the Atrisco siphon in 1955. This siphon brought irrigation water from the Atrisco feeder canal east side irrigation system under the riverbed and distributed irrigation waters into the Atrisco and Arenal canal systems. It was a great improvement, since it carried water to the Atrisco area from the Algodones diversion works and allowed for a consistent flow of water into Atrisco system. A similar situation at Corrales also required the construction of a sub-river siphon.

Detailed plans for the project were completed by the MRGCD on June 13, 1955. The siphon system included a wasteway structure from the east side Atrisco Feeder Canal to the river and the siphon under the river to the west side. The siphon is a 78-inch diameter concrete pipe crossing under the river for approximately 600 feet, where it links into the Arenal canal system.

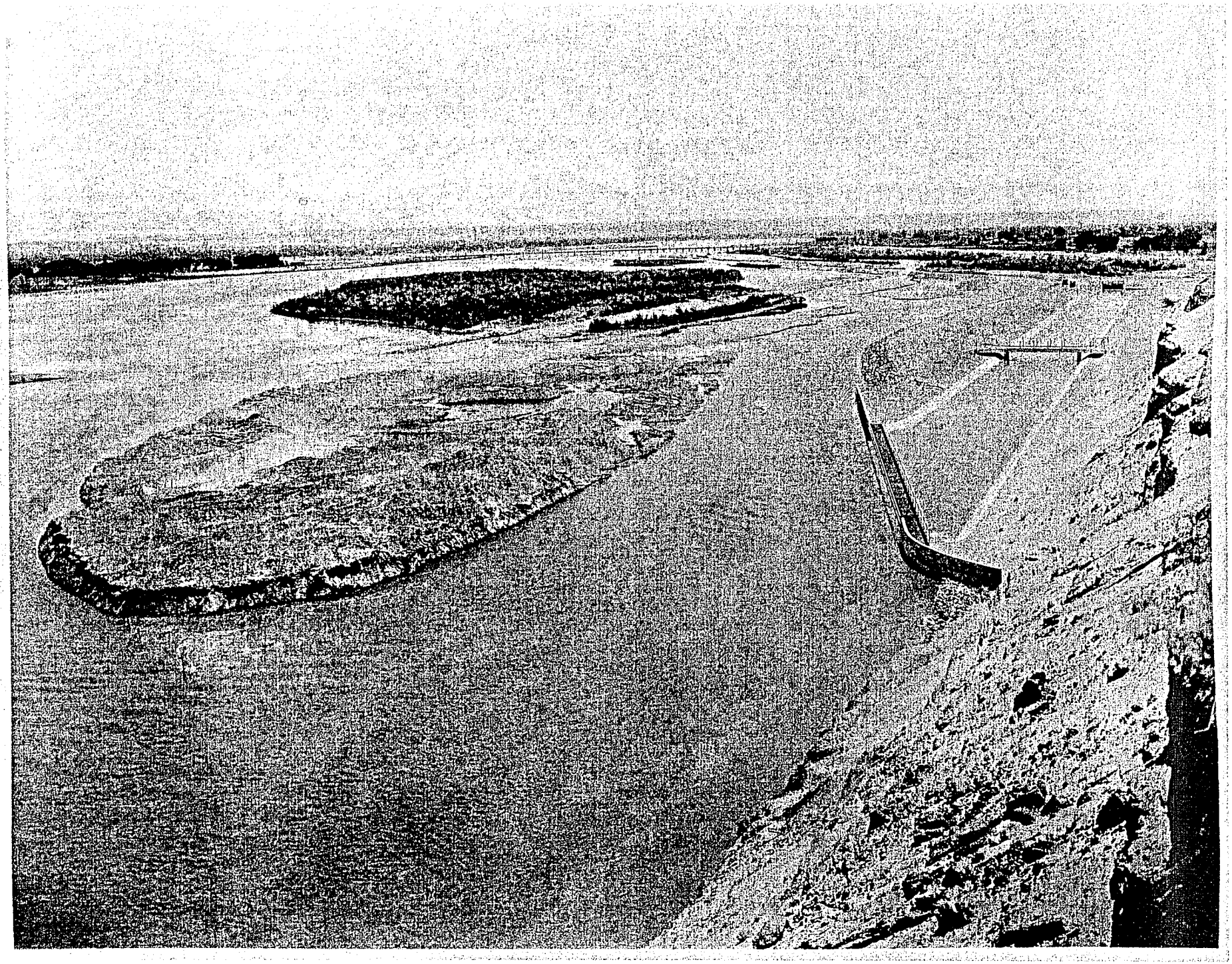

Figure 15. Historic Photograph of the Atrisco Header Structure, ca. 1933-1935. MRGCD Photo No. 494, Plate 10.

FLOOD CONTROL

The Albuquerque New Town site was founded in 1880 in a swampy area along the edge of the new railroad tracks and depot. It was soon realized that the New Town site faced a danger of flooding, due to its location within an old Rio Grande channel. This resulted in the formation of the first Bernalillo River Commission in 1883. Minor floods during the first two years of the New Town occupation demonstrated that the city was vulnerable to flood waters jumping the banks about two miles north of Alameda, and following the old river channel into the area of New Town. The construction of the railroad bank along the edge of the valley also funneled water into streets of New Town, part of which was a former swamp drained by the construction of a drainage canal (Marshall 2001:173-174).

In 1883 the Bernalillo River Commission constructed a dike across the opening of the old river channel north of Alameda. It was 5,000 feet long, and extended from the railroad embankment to the river edge, and was 4 feet high and 6 feet in width. It was faced with sod block terrones. This levee was constructed just in time to prevent major damage to the New Town area by the great flood of 1884 (Simmons 1982:298-299). The flood of 1884 demonstrated to the citizens of Albuquerque the great danger they faced with flooding, and over the next few year they completed the construction of various levees, installed rip-rap in areas most vulnerable to erosion, worked on some drainage structures, and reinforced bridge abutments. The important Alameda dike was reinforced in 1891.

Efforts to control flooding in the Albuquerque area, prior to the massive construction works following the formation of the Middle Rio Grande Conservancy District in 1925, were only partly successfully. Areas of Albuquerque continued to be flooded, even as late as 1941, when levees collapsed and floodwater flowed down First Street and into the city (Simmons 1982: 302). It was not until the major works by the U.S. Corps of Army Engineers in the 1950s, the construction of Jemez Dam in 1950 and Cochiti Dam in the late 1970s, that flooding of the Albuquerque area was controlled. However, given a great deluge like the estimated 100,000 cfs flood of 1884, the area could again be threatened by floodwaters.

Flood control dikes were located along the east and west sides of the river in the bosque restoration project area by H.W. Yeo in 1910. He refers to a dike on the west bank southwest of Albuquerque near the Acequia Nueve de Atrisco and to other flood control dikes along the east side of the river near Albuquerque (Yeo 1910:68 and 76). It is likely that these were low earth banks thrown up from adjacent soils and without sufficient compaction and surface protection to withstand major flooding, but they did prevent regular flooding during high water flows. Construction of the riverside drain and improvements to the levees at Albuquerque were completed in the early 1930s by the MRGCD.

In the Albuquerque area, the MRGCD constructed substantial earth bank levees for flood prevention. Along the east side of the river south of Central Avenue in the bosque project area, two parallel levees were under construction in 1930. During construction, it was recognized that the basin between the two levees could be developed as a swimming area

and park. The park was built by the MRGCD with encouragement from the City of Albuquerque's mayor, Clyde Tingley. On August 9, 1931, it was dedicated as a Conservancy Park and is now known as Tingley Beach (Polk, et al. 1999:8). Historic photographs of the riverside levees and Tingley Park while under construction are illustrated by Biebel (1986:63-64). This photograph is of interest, since it shows the major construction work on the riverside levees in the area of Conservancy Park and that of the adjacent riverbed. The photograph shows the area west of the levee entirely devoid of vegetation. The levees adjacent to Conservancy Park were further improved and widened in 1933 (Biebel 1986:30).

A flood control feature (LA 138855) was also identified in the survey that consisted of a vertical segment of iron railroad track set into the west river bank and stabilized with a wooden plank wall.

Flood Control "Retards" and Jetty Jacks

Various types of defensive retards were proposed by the MRGCD in order to control the channel of the Rio Grande during flood stage, and to prevent damage to levees along the riverside. The purpose of these retards and jetty jacks was to confine the river so that it would channelize and increase the flow, thereby reducing silt deposition and the elevation of the river floor. The retards not only helped to channelize the river, but acted as dams against which trees and brush would accumulate during high floods and keep the river in its channel and protect the earth levees along the riverside from direct and aggressive flow.

The levees and flood control works were built by the MRGCD in the 1930s, and by the 1950s had suffered from erosion, were in disrepair, and in some areas were inadequate. The U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation began a major improvement of the middle Rio Grande flood control system in the early 1950s, which continued into the early 1960s. Beginning in 1951, thousands of Kelner jetty jacks were installed along the Rio Grande riverside to protect the levees and contain the river channel. The levees were reconstructed and improved, and major channel modifications were made to improve the floodway. This was completed in conjunction with dam building in the Rio Chama and Jemez drainages (Ackerly et al. 1997:57-58; Scurlock 1998:282 and 354). In some areas of the jetty jack fields, deposition of 2 to 5 feet has occurred since their installation. Jetty jacks were installed in 1956-1957 in the floodplain adjacent to the Central Avenue Bridge and the Barelas Bridge (U.S. Army Corps of Engineers 2002).

SURVEY FINDINGS

The records search and archaeological survey for the proposed bosque restoration project identified 7 historical properties and 21 minor isolated occurrences (IOs) within the project area (Figure 2). The historic properties include the remnants of 3 bridges (LA 139208, LA 138856 and LA 138857), 2 adjacent pre-Conservancy irrigation canal segments (LA 138859), remnants of an old irrigation diversion work (LA 138858), a

flood control structure (LA 138855), and elements of the abandoned Atrisco header and diversion works (LA 138860). The IOs include trash and fill dumps, homeless camps, log shelters, and an earth bank of unknown origin. The cultural resources and isolated occurrences found in the project area are described below.

LA 138855 (Bosque Site 1)
Flood Control Structure

Site Type: Flood control structure
Cultural-Temporal Affinity: This site consists of a probable flood control and bank stabilization structure. It is undetermined if the structure is a pre-MRGCD construction or a defensive work for the Atrisco header and diversion works built in 1933.

References: None.

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. The north end of this flood control feature was found on the immediate west bank of the river channel, approximately 1.35 km north of the Central Avenue Bridge and 1.0 km south of the Interstate 40 Bridge. Timbers of the structure are visible on the edge of the river, and a few railroad track section supports are set into the riverbed. Evidence of the structure has been found along a southwest alignment for a distance of 300 meters. The site is in a cottonwood and Russian olive bosque, which has been recently burned.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: (North End). Zone 13, 345697 Easting by 3885113 Northing
Elevation: 4,965 feet
Land Ownership: Middle Rio Grande Conservancy District. This structure is located within the actual channel of the Rio Grande, and also probably comes under the jurisdiction of the U.S. Army Corps of Engineers.

Description (Figure 16): This consists of a wood plank wall or flood defensive work that was constructed along the west bank of the Rio Grande in the north Atrisco area. The structure is exposed in three locations, extending from the riverbank and channel on the north for at least 300 meters to the southwest. The structure was also unearthed in the bosque floor during a recent pond construction by the City of Albuquerque, and has been traced to the south where parts of the structure are exposed in the Atrisco Wasteway Canal.

The structure consists of vertical segments of iron railroad track driven into the riverbank and bosque, along what was previously the edge of the river channel. Attached to these vertical track segments by means of iron bolts are 2 by 12 inch wood planks. The planks are creosote treated, and the plank segments are offset and joined with iron bolts to make a frame 4 by 12 inches in size.

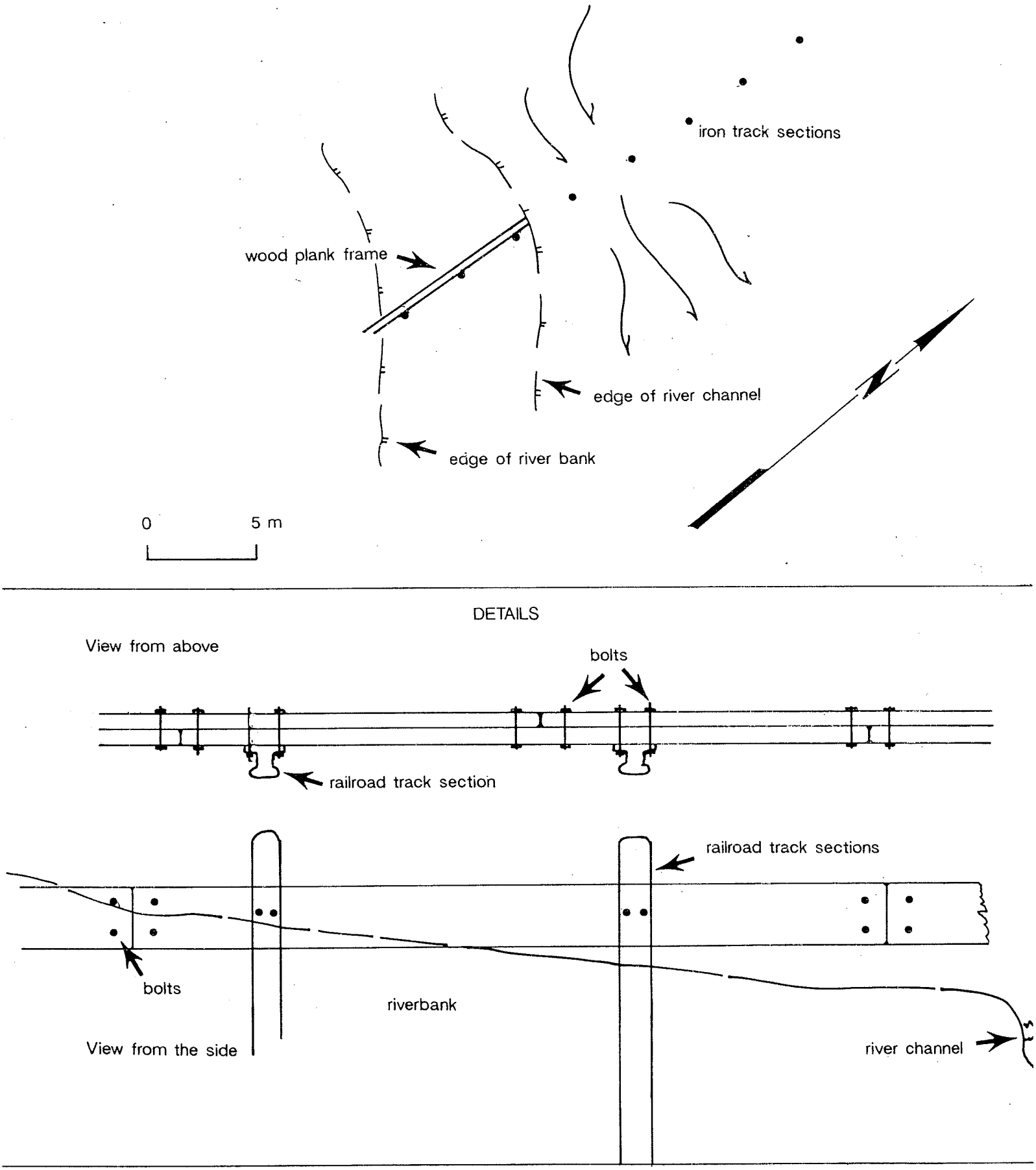

Figure 16. Site Map of the Flood Control Structure, LA 138855

Artifact Assemblage: There are no associated artifacts other than the bridge materials. These include iron railroad track segments, treated 2 by 12 planks, and large iron bolts and washers.

Research Value and Significance: This site is of historic interest since it is an earlier flood control feature designed to prevent river erosion and flooding along the west bank of the Rio Grande in the north Atrisco area. It is undetermined when the structure was built, but it is probably of late 19th or 20th century affinity.

Project Effect and Proposed Treatment: This flood control structure is located on the immediate west bank and within the channel of the Rio Grande. The structure is exposed in the river channel, and is buried about 50 cm below the silt in the west bosque floor. Iron track support posts are also visible in the Atrisco Wastewater Canal about 300 meters southwest from the river edge location. Most of this structure is either located within the river channel or is buried, and the site will be significantly affected by the proposed project. Avoidance of the exposed areas is recommended. Otherwise, no other treatment is needed.

LA 138856 (Bosque Site 2)
Remnants of the 1930 Central Avenue Bridge

Site Type: Highway bridge
Cultural-Temporal Affinity: American, 1930-1983

References: Reynolds 1931

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. It consists of the remnants of the 1930 Central Avenue Bridge, and is situated directly north of the present Central Avenue Bridge on the west side of the flowing river channel. The remnants of this bridge are within the active channel of the Rio Grande on the immediate west bank of the low water flow. Some of the piers are situated in the river. The area is a sand bank that supports growths of annual weeds and some willow.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Zone 13, 346738 Easting by 3884217 Northing
Elevation: 4,950 feet
Land Ownership: Middle Rio Grande Conservancy District. This structure is located within the active channel of the Rio Grande and also probably comes under the jurisdiction of the U.S. Army Corps of Engineers.

Description (Figure 17): This site consists of the remnants of the 1930 West Central Avenue highway bridge. Only two pier sets of the original bridge's 53 span sets remain. A search along the bridge alignments east and west of the river's edge failed to reveal any other evidence of the structure.

Two sets of piling remain; one on the immediate west edge of the low level channel and another within the riverbed. Each piling consisted of six log piers driven into the riverbed. One of the pilings still has the cross beams bolted to the piers.

The project engineer, Reynolds, described the structure in 1931 "The substructure of the West Central Avenue Bridge consists of 53 creosoted pile and timber bents and two creosoted pile and timber abutments. There are six 60-ft piles in each bend and eight 60-ft piles in each abutment. Caps are of 12" X 14" material, 30 ft long. The bents are braced in the usual manner with 3' X 10" sway braces and are further braced by means of 3" X 10" grits placed at the low water elevation, which for this river is the sand line. The abutment or bulkheads are lagged with 3 inch by 8 inch lagging and 8 inch by 12 inch buck braces 4 ft long are provided at each pile. All creosoted timber is dense Southern Yellow Pine, creosoted 12 lbs to the cubic foot."

Artifact Assemblage: None present.

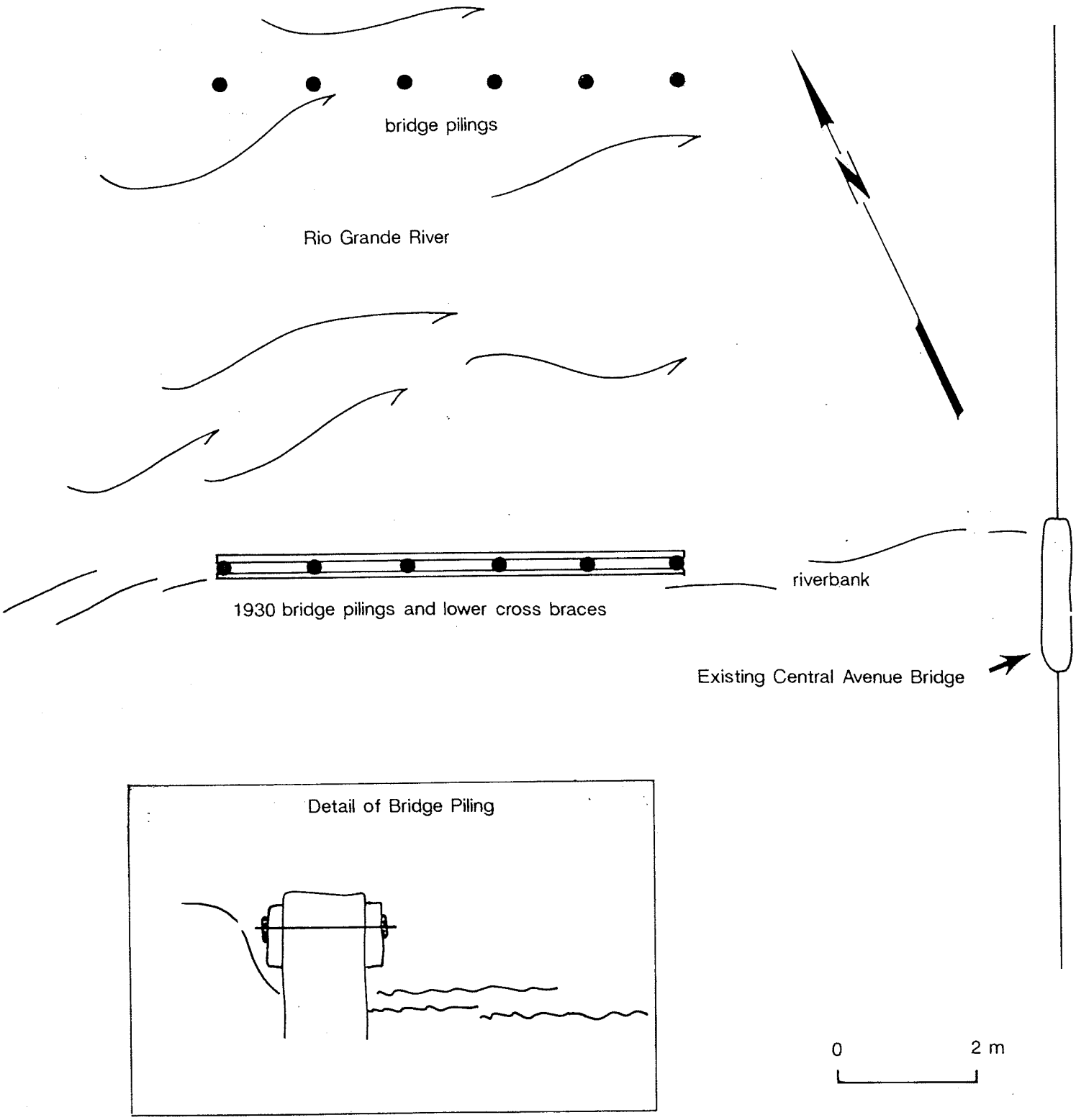

Figure 17. Site Map of the 1930 Central Avenue Bridge Remnant, LA 138856

Research Value and Significance: This site is of historic interest since it was the first modern highway bridge constructed on the West Central Avenue alignment, and was part of the US 66 highway system from 1930 to 1983. It was built by the New Mexico Highway Department by Levy Construction Company of Denver, Colorado under the direction of Chas. O'Leary. This bridge was incorporated as part of the US 66 highway system after the opening of the Laguna cutoff, and the realignment of US 66 down West Central Avenue in 1937. It continued to be used until 1983, when it was replaced by the present structure. This bridge was an important part of the transportation history of the Albuquerque area. However, only a small section of the structure remains intact, and it probably does not have the historic integrity for nomination to the National Register of Historic Places.

Project Effect and Proposed Treatment: This bridge remnant is located on the immediate west bank and within the channel of the Rio Grande. It is situated directly north of the present bridge, within and directly adjacent to the low level water channel. The bridge remnant will not be affected by the proposed bosque restoration undertaking since it is within the riverbed. No further treatment for this site is recommended.

LA 138857 (Bosque Site 3)
Remnants of the 1928 Barelas Bridge

Site Type: Highway bridge
Cultural-Temporal Affinity: American, 1928 construction date
References: Kammer 1996:11

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. The remnants of the 1928 bridge at the Barelas river crossing were identified under the south side of the present bridge on the east side of the river. The wooden piles for the 1928 bridge are within the river channel. No evidence of the structure was found elsewhere on the alignment.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Zone 13, 348743 Easting by 3882025 Northing
Elevation: 4,940 feet
Land Ownership: Middle Rio Grande Conservancy District. The remnants of this structure are located within the channel of the Rio Grande and probably also come under the jurisdiction of the U.S. Army Corps of Engineers.

Description: (No Map): The remnants of this bridge consist only of large timber pilings located under the south side of the present bridge and within the actual channel of the Rio Grande. These were large creosote treated timber pilings. They are within the active channel of the river and were not closely inspected.

Artifact Assemblage: None.

Research Value and Significance: This site is of historic interest since it was the third highway bridge constructed on the Barelas alignment, and was part of the US 66 highway system from its construction date in 1928 until the highway was realigned on the West Central alignment in 1937. It continued to be used until 1983 when it was replaced by the present structure. This bridge was an important part of the transportation history of the Albuquerque area. However, only a small section of the structure remains intact and it probably does not have the historic integrity for nomination to the National Register of Historic Places.

Project Effect and Proposed Treatment: The remnants of this bridge are within the channel of the Rio Grande. They are situated directly under the south side of the present bridge within the water channel. The bridge remnants will not be affected by the proposed bosque restoration undertaking, since it is within the riverbed. No further treatment for this site is recommended.

LA 138858 (Bosque Site 4)
Old Atrisco Irrigation Diversion Works

Site Type: Irrigation division dam
Cultural-Temporal Affinity: H.W. Yeo refers to an Atrisco area irrigation diversion near this location in 1910. If this is the site described by Yeo, it was probably built in the late 19th century.

References: None previous

Location: This site is within the City of Albuquerque, Bernalillo County, New Mexico. The diversion works are located within the Rio Grande, near the immediate west bank of the low water channel. All of the posts are within the actual river channel.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Zone 13, 346481 Easting by 3884313 Northing
Elevation: 4,950 feet
Land Ownership: U.S. Corp of Army Engineers

Description (Figure 18): This site consists of a group of large wooden posts or pilings set into the Rio Grande river channel near the west bank of the low water channel. The posts are all cylindrical and about 20 to 25 centimeters in diameter. They are visible in the river, and extend to about 26 meters from the edge of the present bank. The posts are water logged, and it cannot be determined if they were creosote treated. It is probable that other post stubs are present below the water level.

The posts resemble bridge pilings, but they are probably the remnants of the post frame diversion dam noted in the general area of H.W. Yeo in 1910. The structure is about 125 meters below the intake area for the old Atrisco and Ranchos de Atrisco irrigation canals and perhaps functioned as the diversion works for the canals.

Artifact Assemblage: None observed.

Research Value and Significance: This site is probably the remnants of an irrigation diversion work and is one of the few pre-MRCGD irrigation structures identified in the project area. Further investigation at lower water levels might reveal additional structural features. The site is of interest since it demonstrates the nature of early irrigation engineering in the area during the late 19th and early 20th centuries.

Project Effect and Recommended Treatment: This site is located within the active channel of the Rio Grande. The entire site is within the active flow of the riverbed. This area is outside the limits of the proposed bosque restoration project, and the site will not be affected by the proposed undertaking. This site justifies continued preservation, but no further treatment in regard to the bosque restoration project is recommended.

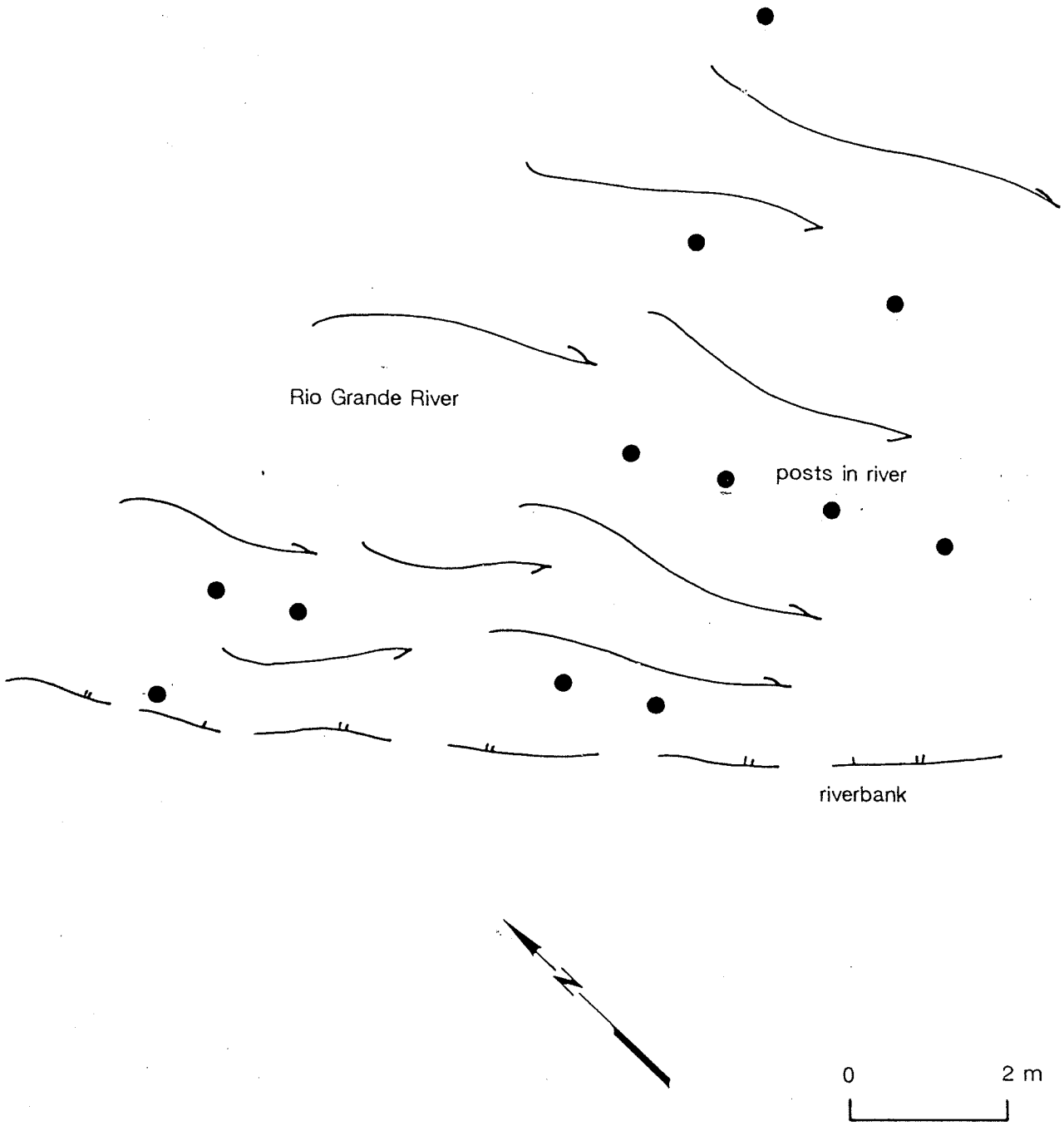

Figure 18. Site Map of the Old Atrisco Irrigation Diversion Structure, LA 138858

LA 138859 (Bosque Site 5)
Upper Canal Heading of the Atrisco and Rancho de Atrisco Irrigation Canals

Site Type: Irrigation canals
Cultural-Temporal Affinity: Hispanic. These canals were probably first opened in the 18th or 19th century, and were used until the development of the MRGCD project in the early 1930s.

References: These canals are shown on a 1922 U.S. Reclamation Service Map (Figure 14). These are also shown on a 1927 MRGCD Map No. F6-P101. The canals were described by H.W. Yeo in 1910, but the name differs from that identified on the MRGCD maps.

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. They are situated on the west side of the Rio Grande, 100 to 400 meters north of the Central Avenue Bridge. Each canal originates at the same intake on the riverbank—400 meters north of the bridge. The canals diverge as they continue south. Both of the canal headings and upper canal sections are in the Rio Grande bosque floor under a canopy of cottonwoods. The largest cottonwood trees in this section of the bosque are located along these old irrigation canals. It is probable that some of these trees were growing along these now abandoned irrigation canals when they were in use prior to 1930.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Zone 13. Both canals originate on the riverbank at GPS coordinate: 346450 Easting by 3884340 Northing. The Atrisco Ditch continues from this point southwest to GPS coordinate: 346405 Easting by 3884263 Northing. The Ranchos de Atrisco Ditch continues south from the intake to 346597 Easting to 3884167 Northing.
Elevation: 4,950 feet
Land Ownership: MRGCD

Description (Figure 19): This site consists of the intake area for the upper sections of the old Atrisco and Ranchos de Atrisco irrigation canals. Both canals originate at the same location on the west bank of the Rio Grande, about 400 meters north of the present Central Avenue Bridge. However, they quickly diverge. Flooding and re-deposition has reworked the actual intake area of the canals at the riverbank, and no structural features remain at the immediate riverside. However, the canals are well defined by linear depressions and adjacent embankments.

The Atrisco Ditch extends southwest from the intake area for a distance of about 200 meters, where it has been superimposed by the riverside levee. The canal was about 3 to 4 meters wide with earth embankments each about 5 meters wide. The earth banks are approximately 50 to 75 centimeters high.

CROSS-SECTION OF DITCHES

Atrisco Ditch

Rancho de Atrisco Ditch

Figure 19. Cross Sections of the Old Atrisco Irrigation Canals, LA 138859

The Ranchos de Atrisco Ditch extends in a southerly direction from the intake area for a distance of about 300 meters, where it has been obscured by the construction of the flood drain and leveling of the bosque floor. This canal was somewhat larger than the Atrisco Ditch. It is 6.0 meters in interior width, with 5.0-meter wide earth banks ranging in elevation from 50 centimeters to 1.0 meter high. The canal is well defined.

Artifact Assemblage: None observed.

Research Value and Significance: These canal segments are of historic interest since they represent segments of the old pre-Conservancy irrigation system. It is probable that no further information could be obtained from field examination. These canals were first constructed by Hispanic residents of the Atrisco area, and may date as early as the 18th century. They were in use until the 1930s. Examples of the pre-MRGCD irrigation systems are limited, and it is possible that these canal segments have potential National Historic Register significance.

Project Effect and Recommended Treatment: These canal segments are in an area of the bosque that has been recently cleared of underbrush, deadwood, and trees by the City of Albuquerque. This undertaking was completed with heavy equipment and has had a minor effect on the embankments of the canals. However, most of the structures remain intact. It is likely that no further work in the area will be needed and that the City project will have no further effect on the canals. Nonetheless, it should be recognized that these canal features are present and the area should not be graded or leveled. Since the area has been cleared by the City of Albuquerque, it is unlikely that there will be further work in the area as part of the U.S. Army Corps of Engineers project.

LA 138860 (Bosque Site 6)
MRGCD Atrisco Header and Diversion Works

Site Type: Irrigation header and diversion works
Cultural-Temporal Affinity: These diversion works were completed by the MRGCD in 1933. They were largely abandoned after the 1955 construction of the new Atrisco siphon. However, an attempt was made to use the diversion works as late as 1978 when the system filled with silt within a few days (personal communication with Subhas Shah, March 2003). They have been abandoned since that time.

References: Ackerly et al 1997:24 and 135; MRGCD plans for the Atrisco header, Plate I-E, Jan. 16, 1932 (Figure 20).

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. These diversion works are on the west bank of the Rio Grande in an area 1.5 km north of the Central Avenue Bridge in north Atrisco. The header is approximately 1.5 km north of Central and the actual diversion gates are 300 meters further south. The system also includes a waste canal that rejoins the river 700 meters north of the Central Avenue Bridge. The header is placed at the immediate south end of the high sand buffs on the west bank. The entire complex is now situated within the Rio Grande bosque, and is surrounded by willows and a canopy of cottonwoods.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Location of diversion heading at the Rio Grande channel is:
Zone 13, 345560 Easting by 3885200 Northing
Elevation: 4,960 feet
Land Status: Middle Rio Grande Conservancy District

Description (Figures 15 and 20): The Atrisco header and diversion works were constructed by the MRGCD in 1933 to provide water to the Atrisco-Arenal canal systems. This system replaced older diversion works in the Atrisco area (Yeo 1910: 67-68) as the flow of the channel against a western bend in the river had long been utilized to tap irrigation waters into the adjacent Atrisco farmlands.

The Atrisco header and upper diversion canal, as illustrated in the 1935 MRGCD photograph (Figure 15), was built adjacent to the active channel of the Rio Grande and required riprap defensive work around the intact gate and upper canal to prevent its erosion. Today, much of the former river channel is within the bosque and the river channel runs well to the east. The header is a simple gateway defended by erosion on its edges by concrete walls and is crossed by a metal frame and lumber-covered walkway. Details of the header and upper canal are provided in the January 1932 plans for the project (Figure 20), which were obtained from the MRGCD.

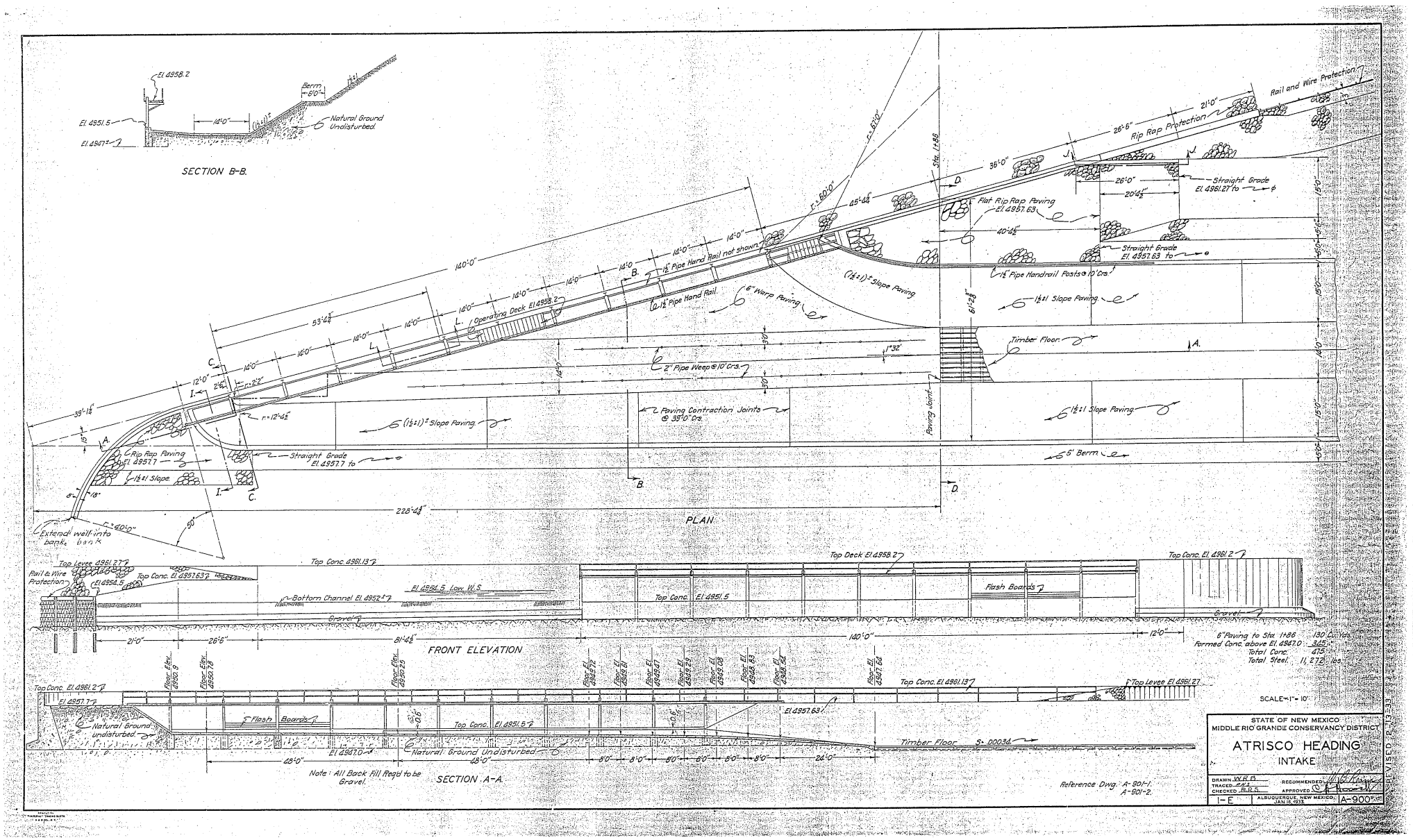

Figure 20. MRGCD Plans for the Atrisco Header, January 16, 1932

The canal, which is 45 ft in width, originally had a 14-ft wide floor. The header gate apparently operated as a skimmer wier that removed water from the top of the river channel.

The canal extended 300 meters to the south where the actual diversion works were constructed. This consisted of a large, concrete-framed gate and drop structure where the water was either diverted into the Main Arenal Canal, or was allowed to continue along the canal wasteway for 500 meters to the south and returned to the river. One of the problems with the system was the infill of silt from the river into the irrigation system. This accounts for the construction of the New Atrisco siphon in 1955 across the river from the Atrisco Feeder Canal. After 1955, irrigation water from the Algodones diversion works was carried through the Atrisco siphon into the Arenal and Atrisco irrigation ditches and the problem of infill silt into the system was resolved.

Artifact Assemblage: No associated artifacts are present.

Research Value and Significance: The Atrisco diversion works were constructed by the MRGCD in 1933-1934. Because of problems in the changing river channel and in-silting of the irrigation system, the system was replaced by the new Atrisco siphon in 1955. An attempt to use the diversion works was last made in 1978, and the system filled with silt in a few days. It has been abandoned since that time. Parts of the systems, especially the header, have deteriorated, but the overall system remains intact.

The system is one example of the engineering projects completed as part of the MRGCD project, and these works are probably eligible for nomination to the National Register of Historic Places.

Project Effect and Recommended Treatment: The proposed bosque restoration project involves the removal of non-native trees and fuel wood from the forest area. The project should have no direct effect on Atrisco header, diversion works or canals.

LA 139208 (Bosque Site 7)
The Old Town Perea Road Bridge

Site Type: Wagon and pedestrian bridge
Cultural-Temporal Affinity: The Albuquerque Bridge Company built this structure in 1881-1882. It was badly damaged in the flood of 1884, and was swept away by the flood of 1891.

References: Simmons 1982:278 and 300; Ross 1884; and Photograph 1978.50.098 (Albuquerque Museum, from the University of New Mexico Special Collections) (Figure 5).

Location: This site is located in the City of Albuquerque, Bernalillo County, New Mexico. Bridge remnants were found on the immediate west bank of the river channel, approximately 1.20 km north of the Central Avenue Bridge and 1.1 km south of the Interstate 40 Bridge. Timbers of the bridge frame are visible on the edge of the river. The site is in a cottonwood and Russian olive bosque, which has been recently burned.

USGS Quadrangle: Albuquerque West, N.M., 1990
Unplatted area
GPS Locus: Zone 13, 345815 Easting by 3885002 Northing
Elevation: 4,965 feet
Land Ownership: Middle Rio Grande Conservancy District. This structure is located within the actual channel of the Rio Grande and also probably comes under the jurisdiction of the U.S. Army Corps of Engineers.

Description (Figures 5 and 21): This site consists of a remnant of the Old Town-Mountain Road Bridge built in 1881-1882. One side of the bridge base, approximately 20 meters in length, is visible. It consists of vertical post pilings each about 25 cm in diameter. The posts extend above the present river channel about 25 to 50 cm. There are eight posts, each spaced about 2.0 meters apart. The posts extend from the present edge of the riverbank 20 meters into the river. No evidence of the structure was found in the bosque directly west of the remnants or on the opposite east bank of the Rio Grande.

Artifact Assemblage: There are no associated artifacts.

Research Value and Significance: This site is of historic interest since it is one of the earliest bridges to span the Rio Grande in the area of Old Town. It was built by the Albuquerque Bridge Company in 1881-1882 for a cost of $22,000.00, and was operated as a toll bridge. It was probably extensively damaged by the flood of 1884, but was apparently repaired and used until it was swept away by the flood of 1891. This bridge was an important part of the transportation history of the Albuquerque area. However, only a small section of the structure remains intact, and it probably does not have the historic integrity for nomination to the National Register of Historic Places.

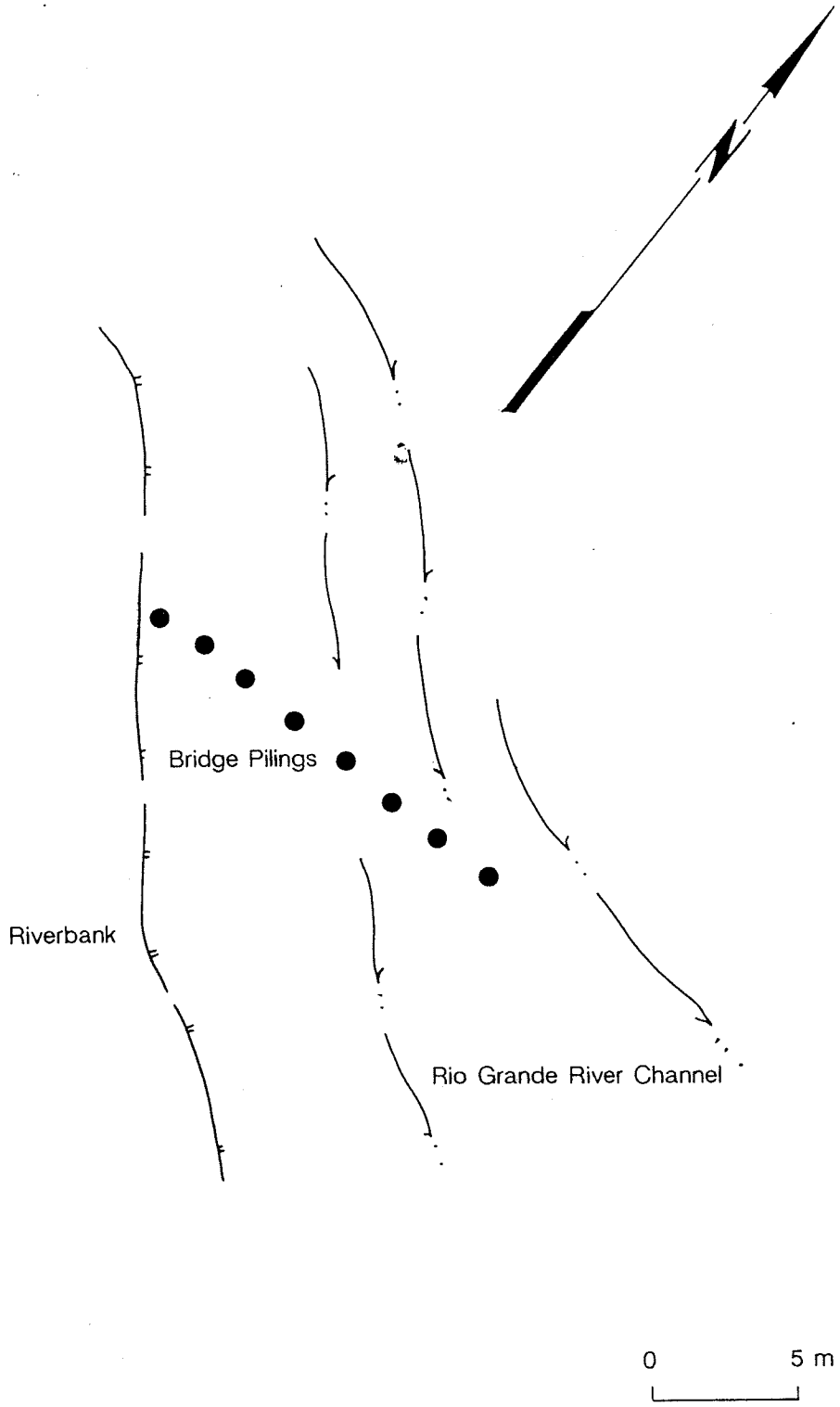

Figure 21. Site Map of the Perea Road Bridge Remnant, LA 139208

Project Effect and Proposed Treatment: This bridge remnant is located on the immediate west bank and within the channel of the Rio Grande. The bridge remnant should be recognized as an archaeological protection area and avoided. The bosque area adjacent to the bridge has been previously cleared after a major bosque fire, and it is unlikely that the present project will involve any work in the area. Nonetheless, it is recommended that site area be identified and flagged in the field prior to the project implementation and that the structure be avoided. Given this treatment, the project will have no effect on the structure.

Isolated Occurrences

IO #1, Trash and Debris Dump
East Bank, I-40 to Central Avenue Section
GPS Locus: Zone 13, 346268 Easting by 3884811 Northing

This is a large trash area on the east side of the Rio Grande, approximately 150 by 75 m in diameter, in which fragments of concrete debris have been dumped. There is also some other construction debris including terracotta tile building blocks and some household debris of ca. 1950 or later affinity.

IO #2, Trash Dump
East Bank, I-40 to Central Avenue Section
GPS Locus: Zone 13, 345752 Easting by 3885547 Northing

This is a trash dump on the immediate eastern edge of the Rio Grande river channel. It is about 10 m in diameter and contains household debris including clear bottle glass (8), green bottle glass (2), modern brown bottle glass (7), fiesta-ware (4), a narrow necked oil can, an iron strap and a porcelain electric insulator. This dump is of middle 20th century affinity.

IO #3, Trash Dump
East Bank, I-40 to Central Avenue Section
GPS Locus: Zone 13, 345732 Easting by 3885579 Northing

This trash dump is located on the eastern edge of the Rio Grande river channel. It consists of two dump areas about 10 m apart. One is 15 m in diameter and the other is 5 m in diameter. Artifacts include clear bottle glass (30), brown bottle glass (7), white ironstone (5), milk glass (1), green bottle glass (1), crockery (1), can fragments (2) and shoe leather (2). This dump is of middle 20th century affinity.

IO #4, Trash Dump
East Bank, I-40 to Central Avenue Section
GPS Locus: Zone 13, 345846 Easting by 3885708 Northing

This dump is on a low earth mound about 50 m west of the riverside dike on the east side of the Rio Grande. It is about 8.0 m in diameter. Artifacts include clear bottle glass (20), iron welding rods (2), round nails (2), plate glass (2) and crockery (3). This dump is of middle 20th century affinity.

IO # 5, Trash Dump
West Bank, I-40 to Central Avenue Section
GPS Locus: Zone 13, 345643 Easting by 3885113 Northing

This is a dump along the east bank of the old Arenal Canal. It occurs in a 10-meter area. The artifacts suggest a middle 20th century affinity and include: clear bottle glass (20), green bottle glass (10), brown bottle glass (10), plastic (2), crockery (3), and white ironstone (2).

IO # 6, Trash and Fill Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347046 Easting by 3884099 Northing

This dump is on the east side of the Rio Grande, and contains a group of old car bodies and concrete blocks that were discarded along the inside edge of the levee bank to stabilize the levee bank. The cars appear to be 1930s to 1940s models. There is a dead apple tree in the bosque floor nearby. This is one of the few fruit trees seen in the bosque.

IO # 7, Trash and Fill Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347266 Easting by 3883750 Northing

This dump is on the east side of the Rio Grande, along the inside edge of the east levee. Large concrete blocks have been discarded in this location for bank stabilization. Also present in the area is some construction debris such as bricks and terracotta block tiles. Dumping in this area was probably completed in the 1960s.

IO # 8, Trash and Fill Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347584 Easting by 3883472 Northing

This is a fill dump of large concrete blocks, which is part of a general area of trash and fill that has been dumped along the inside east levee. There is also some household debris such as old brown bottle glass and clear glass. Dumping in this area was probably completed in the 1960s.

IO # 9, Homeless Camp
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347800 Easting by 3883121

This is a homeless shelter built among a cluster of ailanthus trees near the east edge of the Rio Grande bosque. It consists of a small shelter covered with old rugs and plastic tarps. It was occupied at the time of the survey.

IO # 10, Log Shelter
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347799 Easting by 3882960 Northing
Photo No. 2-20 (on file ARMS):

This is a small log shelter located along the immediate eastern edge of the Rio Grande. The shelter is constructed of cottonwood logs and is a small rectangular enclosure with a log and branch roof and bench-like seat.

IO # 11, Trash Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347865 Easting by 3883224 Northing

A small trash dump was found near the inside of the east levee. Materials include clear bottle glass, brown bottle glass, blue bottle glass and a few fragments of amethyst bottle glass and terracotta clay building blocks. Dumping in this area probably occurred in the late 1950s and 1960s.

IO # 12, Trash and Fill Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348148 Easting by 3882888 Northing

This dump is on the east side of the Rio Grande. It is another fill dump of concrete block and occasional trash along the inside eastern edge of the levee. There is a large area of concrete slabs, large concrete pipes and manhole linings. There are a few areas of modern trash and one white chalcedony flake was found.

IO # 13, Trash and Fill Dump
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348451 Easting by 3882624 Northing

This fill and trash debris dump is on the east side of the Rio Grande. It was situated along the inside of the eastern levee for bank stabilization. There are numerous large fragments of concrete slabs and pipes. Other various debris includes: clear, brown, green and occasional amethyst bottle glass, as well as ironstone china, bricks, ceramic blocks, stucco fragments, cinder block and other construction debris. Dumping in this area probably occurred during the 1960s and 1970s.

IO # 14, Homeless Camp
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348300 Easting by 3882580 Northing

This is a homeless campsite on the east side of the Rio Grande. The shelter is made of rugs, tarps, boards and other materials. It is a rather elaborate shelter with two or more rooms. There are chairs and various other materials at the location. It appears to be in use.

IO # 15, Earth Bank
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348376 Easting by 3882497 Northing

This is a long linear bank of earth on the eastern floor of the Rio Grande bosque, about 50 m from the edge of the river. It extends about 200 m north-south and may be part of an older flood levee system or perhaps an embankment left during the construction of jetty jacks in the area during the late 1950s.

IO # 16, Homeless Camp
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348352 Easting by 3882477 Northing

This is a homeless campsite located along the immediate eastern edge of the Rio Grande. It is placed in a sheltered area in a thicket of tall grass. The camp has a sleeping tarp, buckets and other materials. It was not occupied at the time of the visit.

IO # 17, Log and Branch Shelter
East Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348712 Easting by 3882239 Northing

This is a dome-shaped structure of logs and branches, about 4 m in diameter. It is some type of shelter or children's construction. It is located along a major trail and has not been occupied or used for some time.

IO # 18, Homeless Camp
West Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347140 Easting by 3883500 Northing

This homeless camp is near the western edge of the Rio Grande. It was abandoned at the time of the survey. The camp contains a mattress and bedding material, tarps, rugs, and other clothing debris. There is a scatter of trash and a fire hearth.

IO # 19, Modern Dump
West Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 348135 Easting by 3882402 Northing

This small dump is located near the western edge of the river. The dump is about 5.0 m in diameter and contains green, clear and brown bottle glass, tin cans, shoe leather and china ironstone fragments. It is of post 1940 affinity.

IO # 20, Trash and Fill Dump
West Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347624 Easting by 3882748 Northing

This area of modern trash and construction dumps is located along the western edge of the Rio Grande bosque. The dumps extend over an area about 200 m north-south by 100 m east-west. Most of the material is construction debris such as concrete slab fragments, cinder blocks, bricks, and stucco. Cans, cobblestones, tile, and wire were also observed. All of this material is of post 1940s affinity.

IO # 21, Trash Dump
West Bank, Central Avenue to Barelas Bridge Section
GPS Locus: Zone 13, 347950 Easting by 3882514 Northing

This is small trash dump in a 5.0-meter area on the west floor of the Rio Grande bosque. Artifacts include clear glass, plastic fragments, tin cans, window glass, china ironstone and 1 Acoma Polychrome sherd. This dump is of ca. 1960 affinity.

CULTURAL RESOURCE MANAGEMENT RECOMMENDATIONS

A cultural resource records search and archaeological survey was completed for the 1135 Middle Rio Grande Bosque Ecosystem Restoration Project at Route 66 in February and March 2003. The project includes a 3.1-mile section of the Rio Grande bosque between Interstate 40 on the north to the Barelas Bridge on the south. The project area is confined to the bosque within the flood control levees and historic floodplain of the Rio Grande. The survey included the entire bosque from the inside edge of the levees to the edge of the active river channel.

The records search and archaeological investigations located three former bridge remnants (LA 139208, LA 138856 and LA 138857), a probable irrigation diversion work (LA 138858), two adjacent segments of abandoned irrigation canal (LA 138859), a flood control construction (LA 138855), and the abandoned MRGCD Atrisco diversion works (LA 138860).

A number of isolated occurrences were also identified in the project area that included fill and dump debris in the bosque and along the edges of the flood control levees, homeless camps, and temporary shelters. All of the bridge remnants and the possible diversion works were identified on the immediate west bank of the active river channel with extensions into the actual river. They all include posts driven into the riverbed for bridge supports and diversion works. These structures are within the river and on the immediate bank of the low water river channel and should not be affected by the removal of fuel wood or brush and trees in the bosque. However, it is recommended that each of the structures be identified in the field prior to the project to insure that they are not affected.

Two adjacent pre-Conservancy irrigation canal segments (LA 138859) and a pre-Conservancy diversion structure (LA 138858) are present in the bosque on the west side of the river, north of the Central Avenue Bridge. These canals are part of the old Atrisco irrigation system and might date as early as the late 18th century. They were used until the early 1930s when a MRGCD project reorganized irrigation works in the area. These canals are located in an area that has been recently cleared of vegetation by the City of Albuquerque and probably will not be affected by continued work. However, if work is continued here, the canal areas should avoided by heavy equipment, and no grading or leveling in the canal areas should be conducted.

It is recommended that all of the seven cultural resources identified in the project should be avoided during the project. The sites should be identified in the field and marked prior to implementation of the project. These locations should be recognized as archaeological protected areas and the field crews should be instructed to avoid the locations. Given this treatment, the bosque restoration project will have no effect on the cultural resources.

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FINAL REPORT
BOSQUE ECOSYSTEM RESTORATION AT ROUTE 66
ENVIRONMENTAL SITE ASSESMENT (ESA)
PHASE I HAZARDOUS WASTE SURVEY

INTRODUCTION

The purpose of this investigation is to support the National Environmental Policy Act (NEPA) compliance efforts for the U. S. Army Corps of Engineers (USACE) Bosque Ecosystem Restoration At Route 66 project. This project consists of various activities to enhance the bosque and related ecosystems and recreational potential within the bosque at Albuquerque, New Mexico between the I-40 Bridge and Bridge Boulevard. The report contains the results, findings and conclusions of completing an Environmental Site Assessment (ESA) Phase I Hazardous Waste Survey.

No ground disturbing work was authorized. No analytical samples collected from any environmental media. The assessment was completed using a review of readily available public records, site visits and interviews of local environmental agency personnel. The following documents were adhered to while completing the ESA: ASTM Standard E 1527 – 97 Standard Practice for Environmental Site Assessment: Phase I Environmental Site Assessment Process; CERCLA 120(h); U.S. Army Corps of Engineers Regulation Number 1165-2-132, Hazardous, Toxic and Radioactive Waste (HTRW) Guidance For Civil Works Projects and ASTM Standard E 1528 – 96 Standard Practice for Environmental Site Assessments: Transaction Screen Process.

SITE DESCRIPTION

The site is located entirely within the flood plain of the Rio Grande within Albuquerque, New Mexico, Bernalillo County. Specifically from the I-40 Bridge south to Barelas Avenue Bridge. The project area (area investigated) is illustrated within Figure 1. Topography of the project area is the floodplain of the Rio Grande between the levee structures on the west and east sides of the river. This area is primarily one of changing alluvial deposition of sands and silts, largely influenced by flood control of the river, and the diversion of water from the river for irrigation and other purposes. There are no permanent residential or commercial structures within the floodplain (area investigated), so no potable water supply or sewage disposal system is connected to the investigated area. Storm water drains across the area investigated at several locations as a result of storm events. Primary land use is as a park, or vacant land within the flood plain. The area is referred to as bosque, and is riparian in nature. Soils encountered within the area investigated are torrifluvents, which are frequently flooded, and the Vinton and Brazito soils, which are occasionally flooded. Ground water along side the river is normally shallow (less than 10 feet t depth) but does vary considerably.

The majority of landownership and management of this area are by the Middle Rio Grande Conservancy District (MRGCD) and the Open Space Division of the City of Albuquerque, respectively. The project area is considered riparian, and the land use is a

state park. There are no roads into or traversing the project area other than roads and trails on top of the levee roads. The project area (area investigated) is crossed by three bridges, I-40, Central Avenue and Barelas Avenue Bridge (see Figure 1.). Levee maintenance is the responsibility of the USACE or the U.S. Bureau of Reclamation (Reclamation).

Adjacent land use (adjacent to the levees) is primarily City and County parks and a golf course on the east side of the river, and residential/light commercial on the west side of the river. The area investigated by a site reconnaissance is inside the levees. There are several drains and acequias located directly east and west of the river. These are the property of the MRGCD, which has responsibility for maintenance and periodic cleaning of these facilities. The area between the levee and the river on the west side of the river from Central Bridge to the I-40 bridge is primarily private land or land that is in dispute. This land does contain some squatters that reside in the area on a periodic basis. There is no evidence of commercial or residential development. Aerial photographs showing the vegetation cover, wetted areas and some of the adjacent land use are provided within Appendix A. There are three Superfund sites in Bernalillo County; however, none are near the project area or would be likely to impact the Rio Grande (Appendix B).

RECORDS REVIEW

The following readily available and practically reviewable data bases were searched for information related to active and inactive hazardous waste reporting locations and locations that may be subject to remedial action by regulating agencies:

1) EPA Enviromapper
2) City of Albuquerque GIS
3) New Mexico Environment Department
4) EPA Superfund Site

Figure 2. shows the results of the City GIS search, while Figure 3. shows the results from EPA Enviromapper. There are no know hazardous waste sites or reporting locations within the floodplain, and most are located within residential and commercial areas as would be expected. There is a Leaking Underground Storage Tank (LUST) on Central, near the bridge on the west side of the river. This site is further considered within the interviews section. There are no landfills, active or inactive near (within ¼ mile) of the project area as defined in Figure 1.

INFORMATION FROM SITE RECONNAISSANCE AND INTERVIEWS

Site visits were conducted on two occasions, one on February 15, 2003 and a follow up visit on March 20, 2003. The project area was traversed in several parts, and the objective was to look for evidence normally associated with the production, storage or transportation of hazardous materials. In addition, the area was searched for physical

evidence of illegal dumping of solid waste or hazardous materials. Transects, going north and south, were used to walk through the area.

Interviews were conducted with the following individuals: Robert Miller, Environmental Scientist/Specialist, New Mexico Environment Department (NMED)/Petroleum Storage Tank Bureau; Bart Faris, Environmental Scientist, New Mexico Environment Department/Ground Water Quality Bureau; and Eileen L. Shannon, Environmental Compliance Coordinator, Albuquerque Environmental Health Department. Appendix C contains the results of interviews. The interviews were conducted in person on January 30, 2003.

As a result of the interviews, one LUST was identified near the project area (Figure 2). A case is being followed by the NMED at Central on the west side of the river. The case results from an investigation of a small kerosene/diesel fuel spill, which is being monitored by the NMED. It is low priority, and the NMED believes the site contamination will naturally attenuate. There were no other potential or actual concerns identified from the interviews.

As a result of the site reconnaissance visits, the following observations were noted:

1) Illegal dumping of solid waste, probably by individuals, occurs at several locations within the project area. The City and County may make attempts to remove this material. The Section 905(b) analysis report indicates that debris and any fill material will be removed to create a suitable substrate.
2) There were no permanent structures, such as storage sheds, or shops located within the outlined project area (Figure 1.).
3) There was no evidence of previous or current industrial property sites within the investigated area. There are some areas where concrete and asphalt has been dumped.
4) There were no industrial properties observed immediately adjacent to the investigated area.
5) There was no physical evidence of previous use of the area by gasoline stations, motor repair facilities, commercial printing operations, junkyards or landfills.
6) No industrial drums or sacks of chemicals were observed. Periodically, empty paint cans and cans of lubricants were observed at locations where illegal dumping had occurred. No evidence of soil discoloration, dead or stressed vegetation, or dead animals was noted at any of these locations.
7) No mounds of fill dirt were noted during the reconnaissance visits.
8) No pits, ponds or lagoons that might be associated with waste dumping were observed.
9) No above ground tanks were noted.
10) No vent pipe, fill pipes, or other small structures were seen.
11) No wastewater discharges, other than storm water from streets and bridges was indicated.
12) No transformers, capacitors or hydraulic equipment was found.
13) No automotive batteries were seen, although there may be some dumped illegally within the bosque.

14) There is an accumulation of solid waste near several culverts and similar areas of the drains within the bosqe.

FINDINGS AND CONCLUSIONS

I have performed a Phase I Environmental Site Assessment in conformance with the scope and limitations of ASTM Practice E 1527 of the Rio Grande floodplain between I-40 Bridge and the Barelas (Bridge Avenue) Bridge. This assessment has revealed no evidence of recognized environmental conditions in connection with the assessed area. Neighboring or near by conditions are described or located within the report.

There are no recorded HTRW facilities or material directly within the investigated area. There are several small sites within the investigated area that show evidence of illegal dumping, largely consisting of solid waste, and some paint and lubricant cans. These areas could be easily cleaned, and the solid waste removed when encountered. There was no evidence (structural remains, flooring, vent pipes) of any buildings within the floodplain. Nearby water wells are located on Figure 4.

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SIGNATURES AND QUALIFICATIONS

Rick M. Billings, Senior Environmental Scientist of Parsons, completed the site assessment. He has been an environmental consultant for twenty two years, and has completed similar site assessments in the Albuquerque area.

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APPENDICES

Appendix A – Land Use and Vegetation
Appendix B – Superfund Sites and Solid Waste
Appendix C - Interviews

BOSQUE REVITILIZATION @ ROUTE 66

Designed By: Bohannan Huston 505 823-1000
Estimated By: Balis & Company 505 883-7990

Prepared By: JB, ARB

Preparation Date: 10/06/05
Effective Date of Pricing: 10/06/05

Sales Tax: 0.00%

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CC_06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
CC. CONSTRUCTION COST											
CC_06. FISH AND WILDLIFE FACILITIES											
CC_06:03. WILDLIFE FACILITIES/ SANCTUARIES											
CC_06:03.73. HABAITAT AND FEEDING FACILITIES											
CC_06:03.73.02. SITEWORK											
CC_06:03.73.02.0201. SHRUB THICKET AND BOSQUE PATCH											
M USR GC <02947 0021 > Shrub Thicket					0.00	0.00	0.00	0.00	11428	11428.00	
	37.99	ACR		0.00	0	0	0	0	434,150	434,150	11428.00
USR GC <02947 0022 > Bosque Patch					0.00	0.00	0.00	0.00	16175	16175.00	
	62.99	ACR		0.00	0	0	0	0	1018863	1,018,863	16175.00
CC_06:03.73.02.0204. MOIST SOIL DEPRESSIONS											
USR GC <02110 1071 > Root Plowing					18.22	293.02	627.15	0.00	0.00	920.17	
	13.00	ACR	COMCB88	0.38	237	3,809	8,153	0	0	11,962	920.17
USR GC <02215 1201 > Backfill and Compaction					0.05	0.80	0.72	0.00	0.00	1.52	
	7898.00	CY	CODTB10L	28.41	417	6,318	5,694	0	0	12,012	1.52
USR GC <02224 4212 > Unclassified Excavation - Upstream Plug					0.06	0.98	2.08	0.00	0.00	3.06	
	78980	CY	CODTB10B	23.19	5,110	77,400	164223	0	0	241,624	3.06
USR GC <02234 4001 > Excess Soil Removal & Disposal Disperse in Area					0.05	0.76	1.93	0.00	0.00	2.69	
	71082	CY	CODEB30	58.32	3,654	54,022	137366	0	0	191,388	2.69
M USR GC <02947 0021 > Revegetation					0.00	0.00	0.00	0.00	51.18	51.18	
	7800.00	LF		0.00	0	0	0	0	399,204	399,204	51.18
CC_06:03.73.02.0205. STORM WATER / IRRIGATION RETURN OUTFALL WETLANDS, SUNSET IRRIGATION RETURN											
USR GC < > Ported Risef for Debris Removal At Existing Plunge Pool					0.00	2060.00	0.00	3105.00	0.00	5165.00	
	1.00	LS		0.00	0	2,060	0	3,105	0	5,165	5165.00
USR GC < > Lowflow Wetland Diversion Struct					0.00	9090.00	0.00	11008	0.00	20098.00	
	1.00	LS		0.00	0	9,090	0	11,008	0	20,098	20098.00
USR GC < > 6" PVC Piping					0.00	2.90	0.00	3.20	0.00	6.10	
	200.00	LF		0.00	0	580	0	640	0	1,220	6.10
USR GC <02110 1071 > Root Plowing					18.65	299.97	642.02	0.00	0.00	942.00	
	0.96	ACR	COMCB88	0.38	18	288	616	0	0	904	942.00
M USR GC <02140 1701 > Dewatering					0.04	0.59	0.16	0.88	0.00	1.63	
	600.00	LF	CODLB6	68.31	26	354	99	528	0	981	1.63

CC_06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
USR GC <02215 1201 > Backfill and Compaction					0.06	0.90	0.81	0.00	0.00	1.71	
	1305.00	CY	CODTB10L	25.26	78	1,175	1,058	0	0	2,233	1.71
USR GC <02224 4212 > Unclassified Excavation -					0.07	1.10	2.33	0.00	0.00	3.43	
Upstream Plug	730.00	CY	CODTB10B	20.66	53	803	1,704	0	0	2,507	3.43
M USR GC <02240 0021 > Import, Backfill - Low					0.03	0.50	1.16	4.69	0.00	6.35	
Permeability Material	180.00	CY	CODTB15	100.54	6	90	209	844	0	1,144	6.35
M USR GC <02250 2131 > Filter Fabric					0.01	0.15	0.05	0.45	0.00	0.65	
	1550.00	SF	ULABA2	246.75	19	233	81	698	0	1,011	0.65
M USR GC <02270 1001 > Rip-rap Type VL					2.28	30.00	20.50	96.00	0.00	146.50	
	103.00	CY	CODEB3A	2.19	235	3,090	2,111	9,888	0	15,089	146.50
M USR GC <02947 0021 > Revegetation					0.00	0.00	0.00	0.00	28.00	28.00	
	1200.00	LF		0.00	0	0	0	0	33,600	33,600	28.00
TOTAL HABAITAT AND FEEDING FACILITIES					9,853	159,312	321315	26,711	1885817	2,393,155	
CC_06:03.99. ASSOCIATED GENERAL ITEMS											
CC_06:03.99.02. SITEWORK											
CC_06:03.99.02.0201. REMOVALS											
L MIL GC <02045 0000 > Jetty Jack Removal					6.79	94.99	102.36	0.00	0.00	197.35	
	1087.00	EA	CLADB38	0.74	7,377	103,258	111261	0	0	214,519	197.35
USR GC <02045 0000 > Debris Removal					0.10	1.40	1.51	0.00	0.00	2.91	
	94902	CY	CLADB38	49.99	9,490	132,863	143160	0	0	276,022	2.91
USR GC <02110 1071 > Vegetation Removal					23.62	379.95	813.20	0.00	0.00	1193.15	
	77.12	ACR	COMCB88	0.30	1,822	29,302	62,714	0	0	92,016	1193.15
TOTAL ASSOCIATED GENERAL ITEMS					18690	265,423	317134	0	0	582,558	
TOTAL WILDLIFE FACILITIES/ SANCTUARIES					28542	424,736	638449	26,711	1885817	2,975,713	
TOTAL FISH AND WILDLIFE FACILITIES					28542	424,736	638449	26,711	1885817	2,975,713	

CC_09. CHANNELS AND CANALS	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
CC_09. CHANNELS AND CANALS											
CC_09:01. CHANNELS											
CC_09:01.30. BANK STABILIZATION, DIKES AND JETTIES											
CC_09:01.30.02. SITEWORK Conveyance High Flow Channels											
M USR GC <02140 1701 > Dewatering					0.04	0.59	0.16	0.88	0.00	1.63	
	8150.00	LF	CODLB6	68.37	358	4,804	1,343	7,172	0	13,320	1.63
USR GC <02224 4212 > Unclassified Excavation -					0.07	1.10	2.33	0.00	0.00	3.43	
Upstream Plug	775.00	CY	CODTB10B	20.66	56	853	1,809	0	0	2,661	3.43
USR GC <02224 4222 > Unclassified Excavation -					0.07	1.10	2.33	0.00	0.00	3.43	
Channel	18250	CY	CODTB10B	20.66	1,325	20,075	42,596	0	0	62,671	3.43
USR GC <02234 4001 > Excess Soil Removal & Disposal					0.03	0.50	1.27	0.00	0.00	1.77	
Disperse in Area	19025	CY	CODEB30	88.65	643	9,513	24,186	0	0	33,699	1.77
M USR GC <02240 0021 > Import, Backfill - Low					0.03	0.50	1.16	3.90	0.00	5.56	
Permeability Material	8400.00	CY	CODTB15	100.54	292	4,200	9,771	32,760	0	46,731	5.56
M USR GC <02947 0021 > Revegetation					0.00	0.00	0.00	0.00	37.00	37.00	
	8150.00	LF		0.00	0	0	0	0	301,550	301,550	37.00
TOTAL BANK STABILIZATION, DIKES AND					2,674	39,444	79,705	39,932	301,550	460,631	
CC_09:01.99. ASSOCIATED GENERAL ITEMS											
CC_09:01.99.02. SITEWORK											
USR GC < > Upstream Inlet Structure					0.00	4584.00	0.00	7275.00	0.00	11859.00	
	3.00	LS		0.00	0	13,752	0	21,825	0	35,577	11859.00
USR GC < > Flume/Piping Across Osage SD and					0.00	11610	0.00	17920	0.00	29530.00	
Wetland Outfall	1.00	LS		0.00	0	11,610	0	17,920	0	29,530	29530.00
TOTAL ASSOCIATED GENERAL ITEMS					0	25,362	0	39,745	0	65,107	
TOTAL CHANNELS					2,674	64,806	79,705	79,677	301,550	525,738	
TOTAL CHANNELS AND CANALS					2,674	64,806	79,705	79,677	301,550	525,738	

CC_14. RECREATION FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
CC_14. RECREATION FACILITIES											
CC_14:72. DAY USE AREAS											
CC_14:72.02. SITEWORK											
M USR GC <02244 0051 > Stabilized CF Trail (H)					0.02	0.25	0.49	0.30	0.00	1.04	
	50000	LF	COFGB36C	308.04	810	12,500	24,625	15,000	0	52,125	1.04
M USR GC <02842 0591 > Signage					16.05	191.01	0.00	673.00	0.00	864.01	
	50.00	EA	ALABCLAB1	0.06	803	9,551	0	33,650	0	43,201	864.01
TOTAL SITEWORK					1,613	22,051	24,625	48,650	0	95,326	
CC_14:72.06. WOOD AND PLASTIC											
M USR GC <06103 2621 > Boardwalk and Bridge					1538	24240	0.00	37875	0.00	62115.00	
	4.00	LS	ACARCARP2	0.00	6,154	96,960	0	151,500	0	248,460	62115.00
M USR GC <06103 2622 > Benches					33.96	535.01	0.00	710.00	0.00	1245.01	
	20.00	LS	ACARCARP2	0.06	679	10,700	0	14,200	0	24,900	1245.01
M USR GC <06103 2623 > Wildlife Blinds					588	9268.24	0.00	14650	0.00	23918.24	
	2.00	LS	ACARCARP2	0.00	1,176	18,536	0	29,300	0	47,836	23918.24
TOTAL WOOD AND PLASTIC					8,009	126,197	0	195,000	0	321,197	
TOTAL DAY USE AREAS					9,622	148,247	24,625	243,650	0	416,522	
TOTAL RECREATION FACILITIES					9,622	148,247	24,625	243,650	0	416,522	
TOTAL CONSTRUCTION COST					40839	637,789	742779	350,038	2187367	3,917,973	

PC_01. LANDS AND DAMAGES	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
PC. PROJECT COST											
PC_01. LANDS AND DAMAGES											
PC_01:17. LERRD CREDITING											
PC_01:17.01. LAND PAYMENTS											
USR < > LERRD					0.00	0.00	0.00	0.00	55000	55000.00	
	1.00	LS		0.00	0	0	0	0	55,000	55,000	55000.00
TOTAL LAND PAYMENTS					0	0	0	0	55,000	55,000	
TOTAL LERRD CREDITING					0	0	0	0	55,000	55,000	
TOTAL LANDS AND DAMAGES					0	0	0	0	55,000	55,000	

PC_30. PLANNING, ENGINEERING AND DESIGN	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
PC_30. PLANNING, ENGINEERING AND DESIGN											
PC_30:04. CONSTRUCTION CONTRACT PLANNING, ENGINEERING & DESIGN											
PC_30:04.01. PLANS AND SPECIFICATIONS (P&S)											
PC_30:04.01.02. PLANS AND SPECIFICATIONS											
USR < > Plans and Specifications					0.00	0.00	0.00	0.00	500000	500000.00	
	1.00	LS		0.00	0	0	0	0	500,000	500,000	500000.00
TOTAL PLANS AND SPECIFICATIONS (P&S)					0	0	0	0	500,000	500,000	
PC_30:04.02. ENVIRONMENTAL STUDIES DOCUMENTS (EA, EIS, SEIS)											
PC_30:04.02.09. ALL OTHER ENVIRONMENTAL DOCS											
USR < > Detailed Project Report/ Environmental Assessment					0.00	0.00	0.00	0.00	660000	660000.00	
	1.00	LS		0.00	0	0	0	0	660,000	660,000	660000.00
TOTAL ENVIRONMENTAL STUDIES DOCUMENTS					0	0	0	0	660,000	660,000	
TOTAL CONSTRUCTION CONTRACT PLANNING,					0	0	0	0	1160000	1,160,000	
TOTAL PLANNING, ENGINEERING AND DESIGN					0	0	0	0	1160000	1,160,000	

PC_31. CONSTRUCTION MANAGEMENT	QUANTY	UOM	CREW ID	OUTPUT	MnHrs	Labor	Equip	Matrl	Misc/Su	TOTAL COST	UNIT COST
PC_31. CONSTRUCTION MANAGEMENT											
PC_31:01. SUPERVISION AND ADMINISTRATION											
PC_31:01.01. PROJECT OFFICE S&A											
PC_31:01.01.01. PROJECT OFFICE OPERATIONS											
USR < > Construction Management					0.00	0.00	0.00	0.00	216000	216000.00	
	1.00	LS		0.00	0	0	0	0	216,000	216,000	216000.00
TOTAL PROJECT OFFICE S&A					0	0	0	0	216,000	216,000	
TOTAL SUPERVISION AND ADMINISTRATION					0	0	0	0	216,000	216,000	
TOTAL CONSTRUCTION MANAGEMENT					0	0	0	0	216,000	216,000	
TOTAL PROJECT COST					0	0	0	0	1431000	1,431,000	
TOTAL BOSQUE REVITILIZATION @ ROUTE 66	1.00	EA			40839	637,789	742779	350,038	3618367	5,348,973	5348973

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT COST
CC CONSTRUCTION COST						
CC_06 FISH AND WILDLIFE FACILITIES			3,895,435	779,087	4,674,523	
CC_09 CHANNELS AND CANALS			688,232	137,646	825,878	
CC_14 RECREATION FACILITIES			545,259	109,052	654,311	
TOTAL CONSTRUCTION COST			5,128,926	1025785	6,154,712	
PC PROJECT COST						
PC_01 LANDS AND DAMAGES			55,000	11,000	66,000	
PC_30 PLANNING, ENGINEERING AND DESIGN			1,160,000	232,000	1,392,000	
PC_31 CONSTRUCTION MANAGEMENT			216,000	43,200	259,200	
TOTAL PROJECT COST			1,431,000	286,200	1,717,200	
TOTAL BOSQUE REVITILIZATION @ ROUTE 66	1.00	EA	6,559,926	1311985	7,871,912	7871912

	QUANTITY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT COST
CC CONSTRUCTION COST					
CC_06 FISH AND WILDLIFE FACILITIES					
CC_06:03 WILDLIFE FACILITIES/ SANCTUARIES					
CC_06:03.73 HABAITAT AND FEEDING FACILITIES					
CC_06:03.73.02 SITEWORK					
CC_06:03.73.02.0201 SHRUB THICKET AND BOSQUE PATCH		1,902,105	380,421	2,282,526	
CC_06:03.73.02.0204 MOIST SOIL DEPRESSIONS		1,120,818	224,164	1,344,982	
CC_06:03.73.02.0205 STORM WATER / IRRIGATION RETURN		109,900	21,980	131,880	
TOTAL SITEWORK		3,132,823	626,565	3,759,388	
TOTAL HABAITAT AND FEEDING FACILITIES		3,132,823	626,565	3,759,388	
CC_06:03.99 ASSOCIATED GENERAL ITEMS					
CC_06:03.99.02 SITEWORK					
CC_06:03.99.02.0201 REMOVALS		762,612	152,522	915,135	
TOTAL SITEWORK		762,612	152,522	915,135	
TOTAL ASSOCIATED GENERAL ITEMS		762,612	152,522	915,135	
TOTAL WILDLIFE FACILITIES/ SANCTUARIES		3,895,435	779,087	4,674,523	
TOTAL FISH AND WILDLIFE FACILITIES		3,895,435	779,087	4,674,523	
CC_09 CHANNELS AND CANALS					
CC_09:01 CHANNELS					
CC_09:01.30 BANK STABILIZATION, DIKES AND					
CC_09:01.30.02 SITEWORK		603,002	120,600	723,602	
TOTAL BANK STABILIZATION, DIKES AND		603,002	120,600	723,602	
CC_09:01.99 ASSOCIATED GENERAL ITEMS					
CC_09:01.99.02 SITEWORK		85,230	17,046	102,276	

	QUANTITY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT COST
TOTAL ASSOCIATED GENERAL ITEMS		85,230	17,046	102,276	
TOTAL CHANNELS		688,232	137,646	825,878	
TOTAL CHANNELS AND CANALS		688,232	137,646	825,878	
CC_14 RECREATION FACILITIES					
CC_14:72 DAY USE AREAS					
CC_14:72.02 SITEWORK		124,788	24,958	149,746	
CC_14:72.06 WOOD AND PLASTIC		420,471	84,094	504,565	
TOTAL DAY USE AREAS		545,259	109,052	654,311	
TOTAL RECREATION FACILITIES		545,259	109,052	654,311	
TOTAL CONSTRUCTION COST		5,128,926	1025785	6,154,712	
PC PROJECT COST					
PC_01 LANDS AND DAMAGES					
PC_01:17 LERRD CREDITING					
PC_01:17.01 LAND PAYMENTS		55,000	11,000	66,000	
TOTAL LERRD CREDITING		55,000	11,000	66,000	
TOTAL LANDS AND DAMAGES		55,000	11,000	66,000	
PC_30 PLANNING, ENGINEERING AND DESIGN					
PC_30:04 CONSTRUCTION CONTRACT PLANNING,					
PC_30:04.01 PLANS AND SPECIFICATIONS (P&S)					
PC_30:04.01.02 PLANS AND SPECIFICATIONS		500,000	100,000	600,000	
TOTAL PLANS AND SPECIFICATIONS (P&S)		500,000	100,000	600,000	
PC_30:04.02 ENVIRONMENTAL STUDIES DOCUMENTS					
PC_30:04.02.09 ALL OTHER ENVIRONMENTAL DOCS		660,000	132,000	792,000	
TOTAL ENVIRONMENTAL STUDIES DOCUMENTS		660,000	132,000	792,000	

	QUANTITY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT COST
TOTAL CONSTRUCTION CONTRACT PLANNING,			1,160,000	232,000	1,392,000	
TOTAL PLANNING, ENGINEERING AND DESIGN			1,160,000	232,000	1,392,000	
PC_31 CONSTRUCTION MANAGEMENT						
PC_31:01 SUPERVISION AND ADMINISTRATION						
PC_31:01.01 PROJECT OFFICE S&A						
PC_31:01.01.01 PROJECT OFFICE OPERATIONS			216,000	43,200	259,200	
TOTAL PROJECT OFFICE S&A			216,000	43,200	259,200	
TOTAL SUPERVISION AND ADMINISTRATION			216,000	43,200	259,200	
TOTAL CONSTRUCTION MANAGEMENT			216,000	43,200	259,200	
TOTAL PROJECT COST			1,431,000	286,200	1,717,200	
TOTAL BOSQUE REVITILIZATION @ ROUTE 66	1.00	EA	6,559,926	1311985	7,871,912	7871912

R2029: BOSQUE REVITILIZATION @ No Unit Price Database - No Division Summary, Reprice, or UPB Titles

* * * END OF ERROR REPORT * * *

A. Process

Eleven potential Solution Areas were developed to carry out environmental restoration in the Study Area. Each Solution Area as described above consists of a combination of removal feature and restoration features targeted to one of eleven specific sub-areas within the Study Area. The possible removal feature includes removal of jetty jacks, non-native vegetation, and debris. The possible restoration features include bosque patches, shrub thickets, and water-related habitat features such as high-flow channels, moist soil depressions and outfall channels. An environmental output measure – the average annual habitat acreage created –- and a cost measure - the average annual dollar cost of the restoration activities - were developed for each management measure as the input variables for the analysis. The management measures are summarized in **Table Appendix E.1: Management Measures** on the following page. IWR-PLAN combined these management measures in different ways to obtain the various environmental restoration plans. The output of IWR Plan is shown the following pages.

B. Assumptions

IWR-PLAN model had the following assumptions built into it:

- A maximum total project cost cap of $7 million was used to limit the analysis to plans that fall within the project budget range.
- 25 year project implementation life for the project, based on characterization of the resource in spring 2004 using in a modified vegetation classification from 1996.
- Only net change in habitat units were accounted for in the model, i.e. it was assumed that no new habitat units would result under the no action scenario.
- Habitat units ("HU") equal acres of proposed restoration measures, except where there were overlapping features, i.e. one acre of restored habitat equals 1 HU.
- High flow channels were accounted for in the entirety in the solution area where any part of it was found, because a partially completed high flow channel would not function. Therefore, if two adjacent Solution Areas were selected which shared a high flow channel, the habitat units and costs would be counted only once.
- If two adjacent solution areas were selected a 5% reduction in the total cost was implemented to reflect the sharing of mobilization costs.
- Recreational and interpretive features were set at 10% of total project cost based on input from the Sponsor, and therefore were not included in the ICA. A separate economic analysis (NED) was conducted to determine cost-effectiveness of those features.

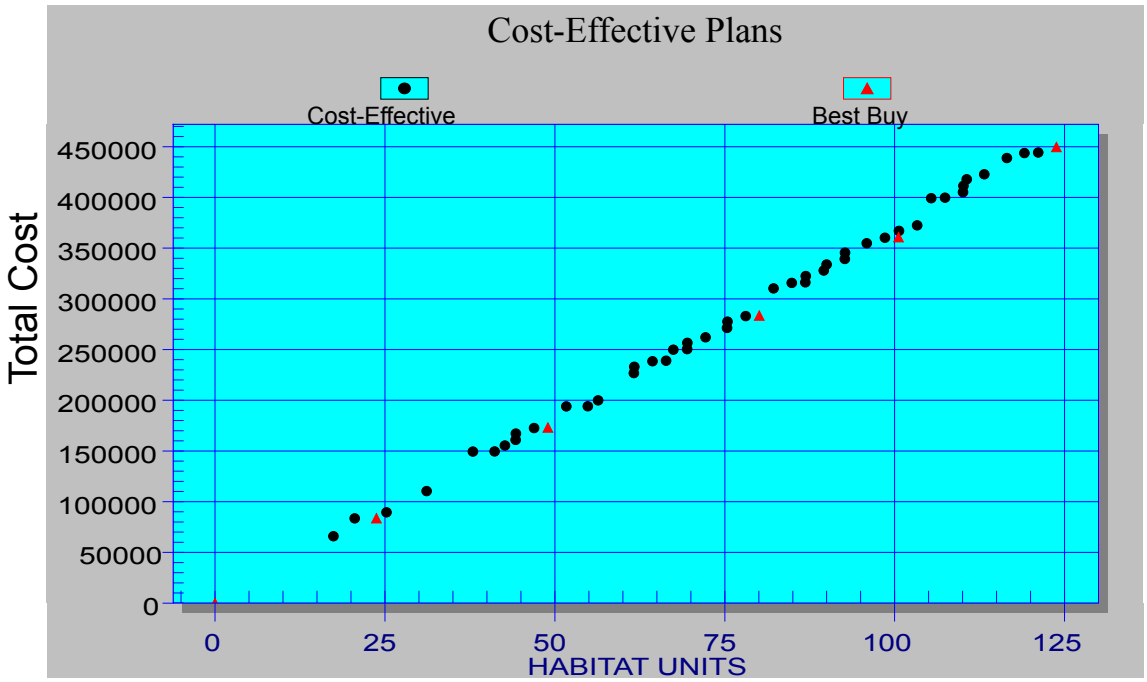
Table Appendix E.1 Summary of Restoration Features by Solution Areas

Solution Area	Removal Features		Restoration Features		Net Habitat Created	Average Annual Cost
A	Jetty jacks: Non-native vegetation:	192 9.3 ac	High-Flow Channel: Swale: Shrub thicket:	2.3 ac 5.0 ac 22.5 ac	23.2 HUs	$88,881
B	Jetty jacks: Non-native vegetation: Dump:	308 7 ac 46,864 cy	Outfall Channel: High-Flow Channel: Swale: Bosque patch: Shrub thicket:	2.1 ac 3.7 ac 5.5 ac 8.2 ac 17.3 ac	25.7 HUs	$137,629
C	Jetty jacks: Dump: Non-native vegetation:	153 109,151 cy 3 ac	Outfall Channel: Swale: Bosque patch: Shrub thicket:	0.3 ac 2.5 ac 16.8 ac 3.5 ac	20.0 HUs	$103,935
D	Jetty jacks: Dump:	87 27,906 cy	High-Flow Channel: Bosque patch:	0.9 ac 17.8 ac	18.3 HUs	$67,764
E	Jetty jacks: Dump:	278 23,477 cy	High-Flow Channel: Swale: Bosque patch: Shrub thicket:	1.6 ac 4.0 ac 17.9 ac 6.6 ac	30.1 HUs	$89,448
F	Jetty jacks: Non-native vegetation:	287 25 ac	High-Flow Channel: Swale: Bosque patch: Shrub thicket:	0.9 ac 2.5 ac 9.0 ac 9.3 ac	21.3 HUs	$65,866
G	Jetty jacks: Non-native vegetation: Dump:	254 24.8 ac 153,902 cy	High-Flow Channel: Swale: Bosque patch: Shrub thicket:	0.9 ac 2.0 ac 18.7 ac 3.0 ac	13.7 HUs	$91,018
H	Jetty jacks: Non-native vegetation: Dump:	80 25.0 ac 7,964 cy	High-Flow Channel: Swale: Outfall Channel: Bosque patch: Shrub thicket:	2.6 ac 1.5 ac 1.0 ac 18.3 ac 3.3 ac	24.1 HUs	$83,659
I	Non-native vegetation: Dump:	33 ac 86,273 cy	Outfall Channel: High-Flow Channel: Swale: Bosque patch: Shrub thicket:	1.8 ac 0.9 ac 1.0 ac 18.3 ac 2.7 ac	9.4 HUs	$98,207
J	Jetty jacks: Non-native vegetation: Dump:	355 27.3 ac 35,555 cy	High-Flow Channel: Swale: Shrub thicket:	2.6 ac 5.5 ac 19.8 ac	26.9 HUs	$108,196
K	Jetty jacks: Non-native vegetation: Dump:	286 26.9 ac 81,633 cy	Outfall Channel: Swale: Bosque patch: Shrub thicket:	0.4 ac 1.5 ac 24.9 ac 18.8 ac	20.5 HUs	$83,493

C. Results

The cost-effectiveness analysis identified 51 cost-effective plans (**Figure Appendix E.1**) within the project budget from among 807 possible combinations of management measures. Again, these plans represent the least-cost way to achieve various levels of environmental output.

Figure Appendix E.1 Cost-Effective Plans

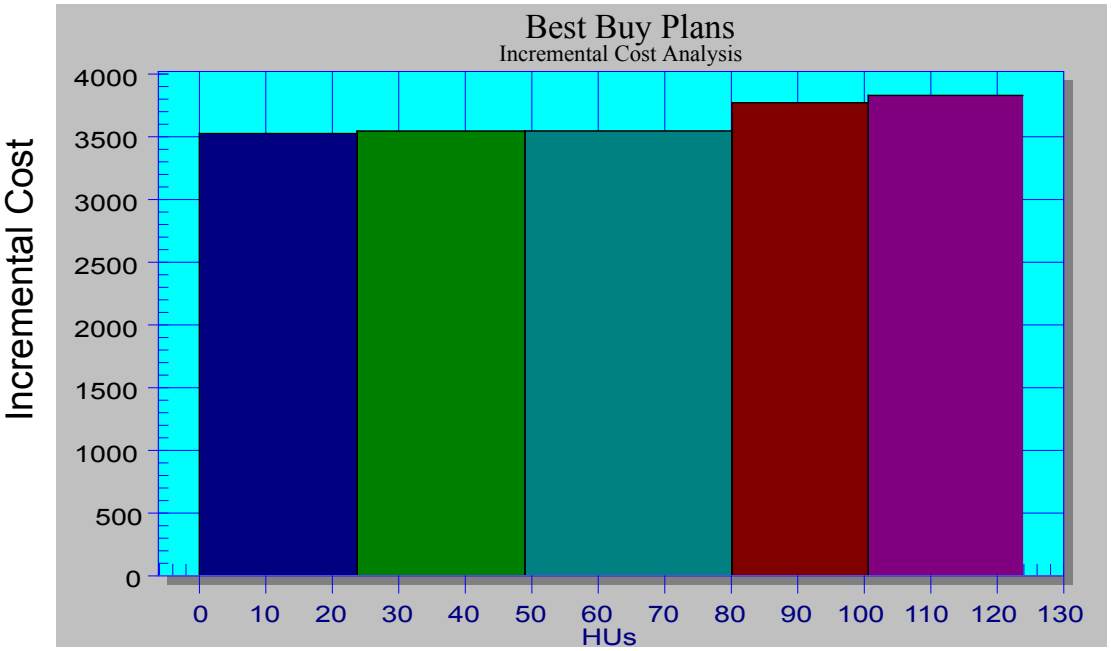


Three Solution Areas did not appear in any of the cost-effective plans – measures B, G, and I. These Solution Areas have the highest cost per acre of habitat created. In the case of measures G and I, the targeted areas also have a comparatively large amount of pre-existing habitat, so the net increase in habitat due to the management measures is reduced.

The incremental cost analysis identified six "best-buy" plans from among the 51 cost-effective plans. (Included in this group is the "No Action Alternative" option.) These plans are the most efficient in generating environmental outputs – they have the lowest incremental costs per unit of environmental output.

Figure Appendix E.2 shows the incremental cost analysis for the six best-buy plans including the "No-Action Alternative." The incremental cost per habitat unit remains consistent for each of the plans, indicating that there is no obvious point of diminishing returns across the range of these plans.

Figure Appendix E.2 Best Buy Plans Incremental Cost Analysis Graph



In all of the Best Buy alternatives, a suite of wetland and bosque upland patches would be created in addition to removal features relevant to the particular Solution Areas. Solution Area H includes outfall wetlands, high-flow channels, moist soil depressions and bosque patches. Solution areas H and E together would provide even more of these types of features and would also include shrub thickets. The addition of Solution Areas D, F and ultimately J add additional features of the same type. The overall number of habitat units (HUs) would also increase significantly with each successive Solution Area added. Total net HUs created would range from 22.3 to 125.6. Water feature HUs would range from 5.0 HUs to 30.3 HUs. Bosque patch HUs would range from 18.3 HUs to 63.0 HUs and shrub thickets would range from 3.3 HUs to 60.58 HUs. Total Restoration costs vary from approximately $1.04 million to $5.6 million.

This technical appendix contains backup information related to hydrology /hydraulics calculations for the High-Flow Channels. The calculations, were performed by the Albuquerque District to determine if connectivity of the High-Flow Channels is likely in route flow scenarios.

The analysis was performed using the Hydrologic Engineering Center - River Analysis System (HEC-RAS). HEC-RAS is a widely used and accepted one dimensional hydraulic model. HEC-RAS was developed by the US Army Corps of Engineers Hydrologic Engineering Center to predict water surface elevations through a river reach given certain input parameters such as cross sections, Manning's roughness coefficients, bridges, etc.

This HEC-RAs model was developed for the Rio Grande Bosque Feasibility Study and these particular cross sections were taken from a survey by the US Bureau of Reclamation performed in 2002 for their Rio Grande Aggradation - Degradation Study. The sections show that possible opportunities exist to provide a hydraulic connection between the active river channel and the Rio Grande Bosque (and High-Flow Channel components) between the levees at this flow rate (3,000 cfs). The over-bank bosque locations that show up as cross hatched areas are not currently connected to the active river channel at the flow rates indicated but are at an elevation such that, if a connection improvement could be made, there would be a high probability that they would flood. This flooding would provide additional water habitat.

The attached cross sections represent flow calculations at various locations in the subject area. The perspective view is shown to assist the reader in understanding the location the given cross sections.

Depletions Analysis

A detailed study done for the *Rio Grande Habitat Restoration Project, Los Lunas, New Mexico*, showed that there was no net depletion of water within the reach as a result of the project. In fact, the study showed that there would likely be a net increase in the water availability within the reach. While this project is further south from the current project location, the analysis performed is valid as the treatments are very similar.

It is estimated that the average annual water loss due to evapotranspiration (ET) in the Middle Rio Grande riparian corridor accounts for 20-50 percent of that reach's total water depletion (Dahm et al. 2002). Bosque ET appears to be higher in dense stands of salt cedar and in mature stands of cottonwood containing extensive understories of salt cedar and Russian olive than it is in less dense salt cedar stands and mature cottonwood stands with few understory trees (Dahm et al. 2002). Thus reduction of tree densities, especially those of invasive species occurring either in mono specific stands or in the subcanopies of mature cottonwood stands, is a major component to reducing the amount of water lost to ET.

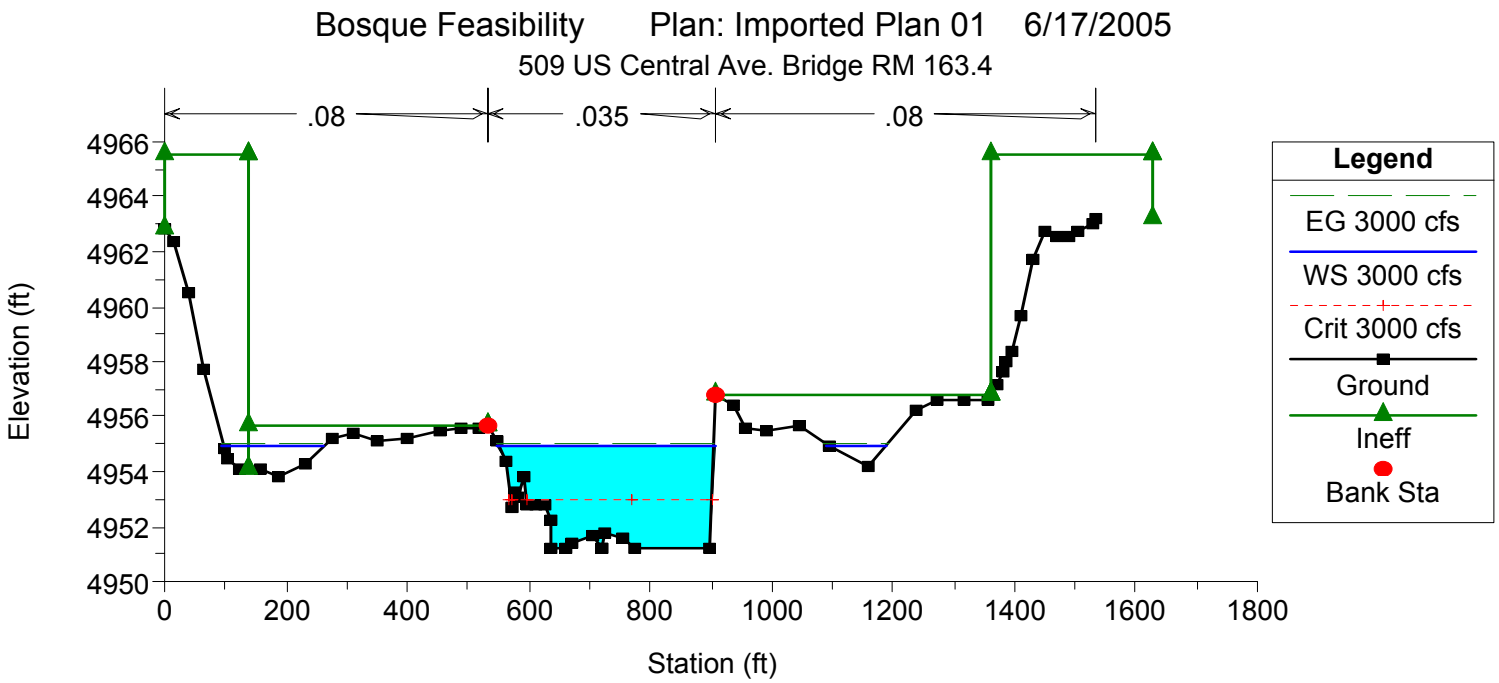
Table Appendix F.1 portrays a simple depletion analysis performed for the area encompassed by the Preferred Alternative. As shown in this table, there are no net depletions, thus no negative impacts are anticipated. Using the changes in various vegetation classes expected as a result of implementing the Preferred Alternative, and some previously published and accepted ET data, the analysis shows there will be a net gain of approximately 0.5 acre-feet of ET per year as a result of this project.

Table Appendix F.1 Approximate Depletions Utilizing Previous ET Data and Restoration Areas

Structure	Vegetation Classification	Acres Before	ET In Ft/yr*	Ac-ft Total ET	Acres After	ET In Ft/yr**	Ac-ft Total ET	Acres Change	ET Change
I	Forest/Woodland	256.3	4.50	1153.5	72.3	3.90	282.0	-184.02	-871.46
II	Forest/Woodland	0.0	4.50	0.0	142.9	3.90	557.4	142.93	557.43
III	Forest/Woodland	7.4	4.50	33.3	6.4	3.90	24.8	-1.05	-8.54
IV	Forest/Woodland	0.5	4.50	2.2	32.7	3.90	127.7	32.24	125.45
V	Shrub Thicket	49.3	4.20	207.0	59.8	4.20	251.3	10.56	44.33
VI	Grassland	184.2	1.00	184.2	164.0	1.00	164.0	-20.24	-20.24
VI(a) (Wetland)	Wetland	13.2	4.65	61.4	32.8	4.65	152.5	19.60	91.14
	River & Drain Channel	no change	-	-	no change	-	-	0.02	0.00
	Totals	**510.9**		**1641.5**	**510.9**		**1559.7**		**-81.88**

* Based on mean of high and low estimates from Los Lunas Habitat Restoration Project. Assumes that pre-restoration forest/woodland is primarily non-native.

** Based on mean of high and low estimates from Los Lunas Habitat Restoration Project. Assumes that post-restoration forest/woodland is primarily native cottonwood.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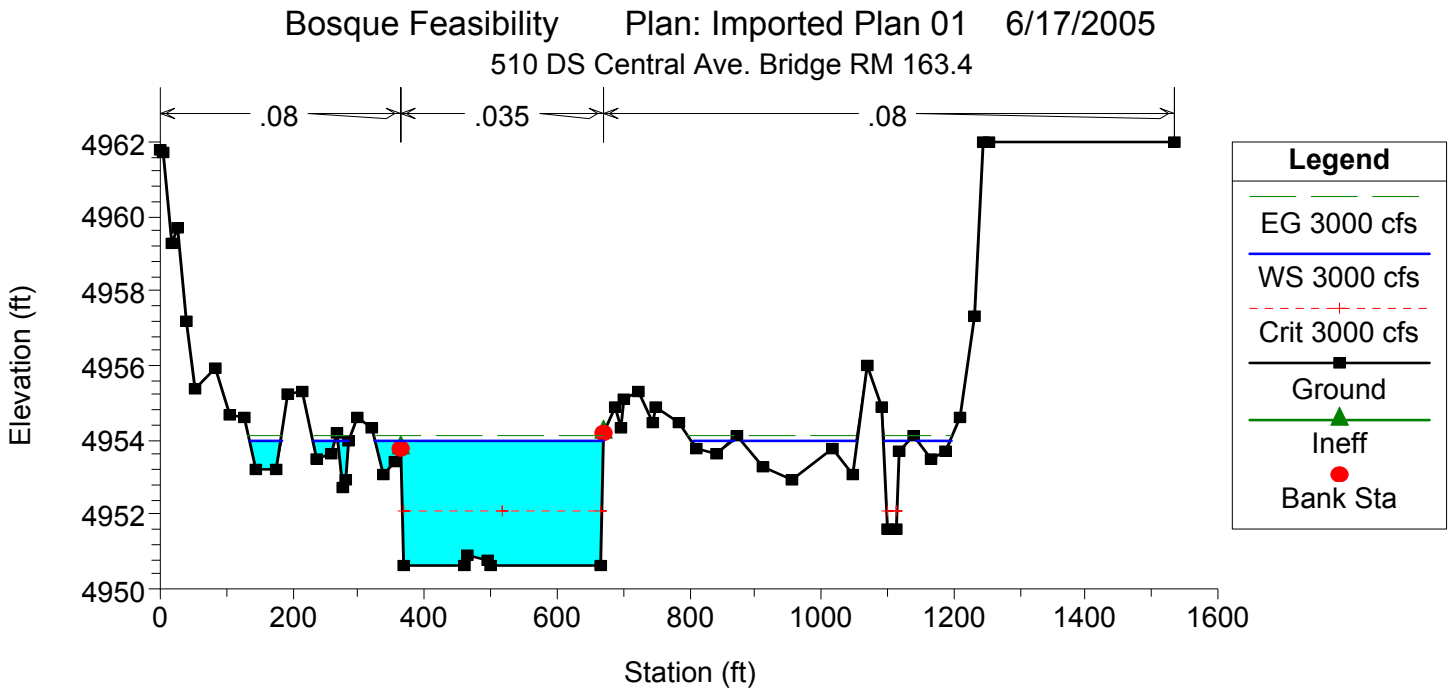
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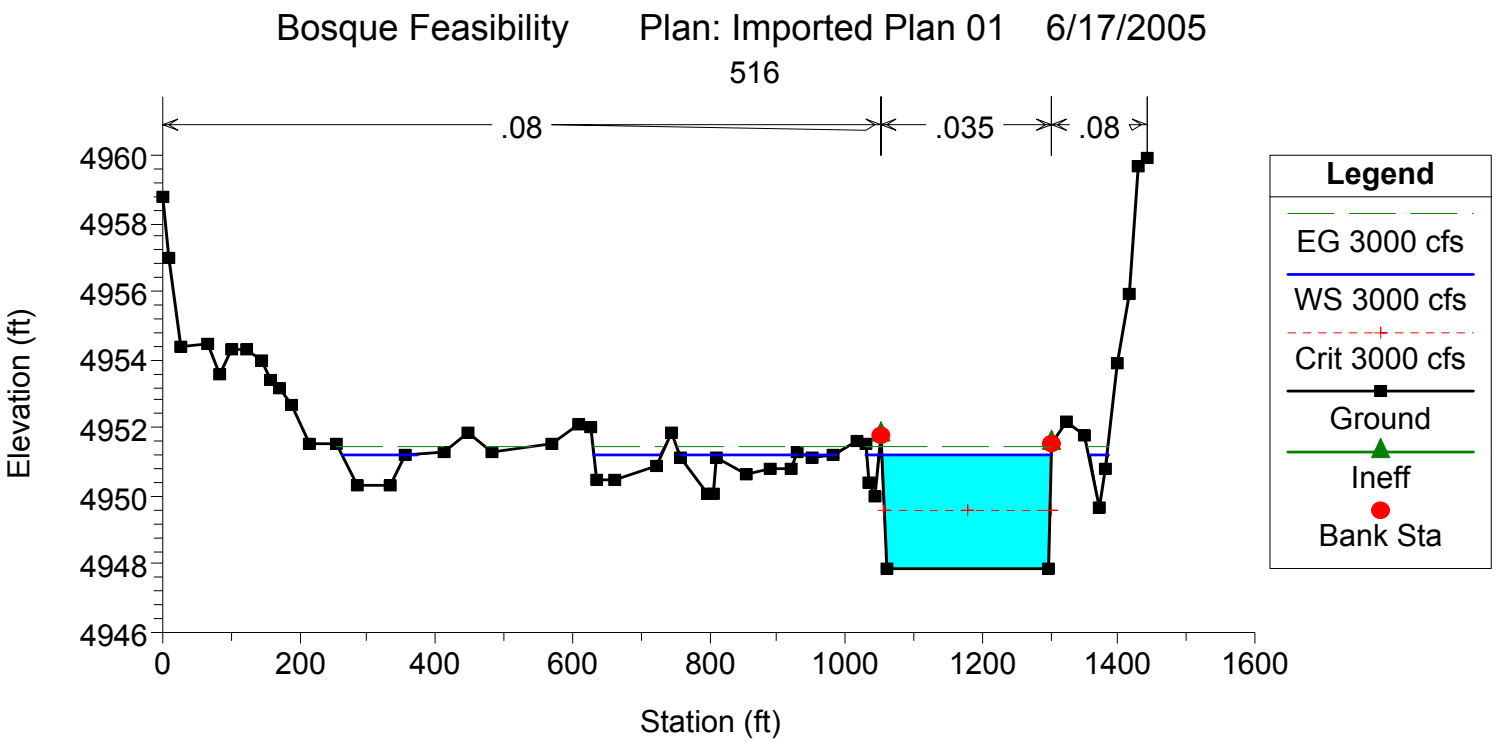
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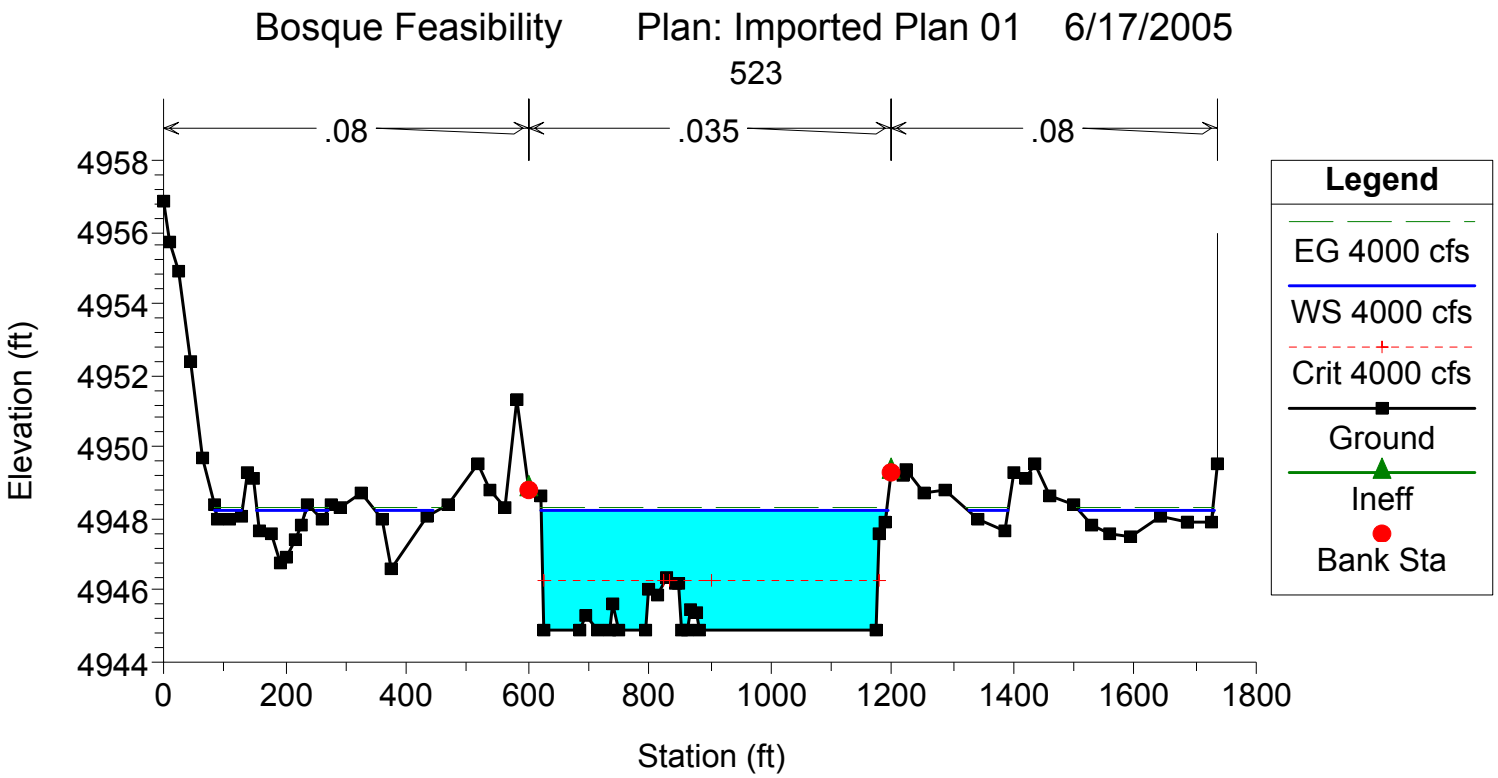
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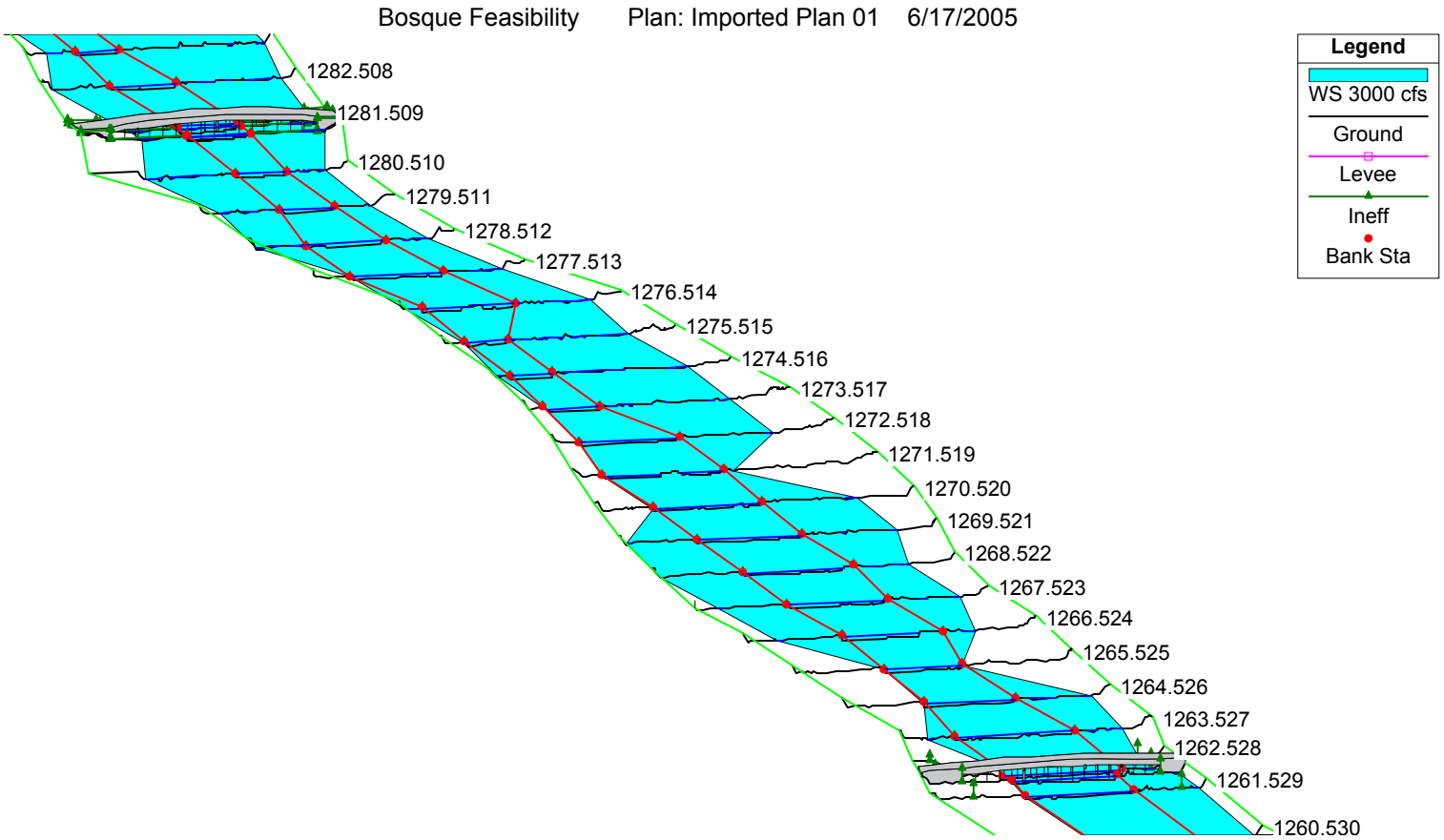
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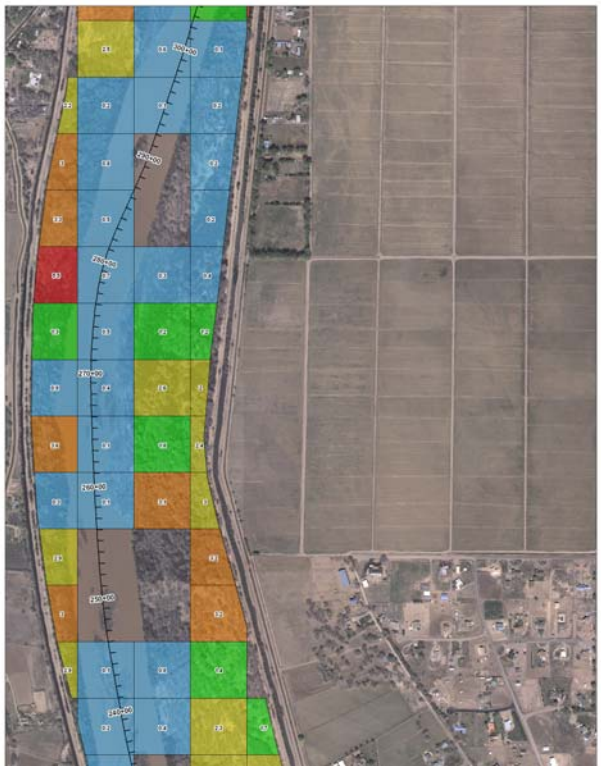
FLO-2D Model Development, Albuquerque Reach, Rio Grande, NM



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Albuquerque District
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Fort Collins, Colorado 80525
MEI Project 05-03

January 24, 2006

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1. INTRODUCTION

Mussetter Engineering, Inc. (MEI) was retained by the U.S. Army Corps of Engineers (Corps) (Contract DACW47-02-D-005, Delivery Order 0006) to perform FLO-2D modeling to support a planning study of the Albuquerque Reach of the Rio Grande, which extends from the southern boundary of the Pueblo of Sandia to the northern boundary of the Pueblo of Isleta (**Figure 1.1**). *The objective of the planning study is to increase river channel Bosque overbank connectivity, produce enhanced cover and aquatic habitat diversity, restore healthy riparian function to enhance natural riverine processes and improve terrestrial wildlife habitat, protect existing structural features such as pipelines, bridges and levees with a preference toward using bank biostabilization techniques when structures are found to be at risk from natural geomorphic processes* (USACE, 2004). The FLO-2D modeling is intended to provide assessment of overbank flows and storage, as well as hydraulic data to facilitate an analysis of sediment-transport conditions and geomorphic processes along the reach, results from which will be used to evaluate various 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.

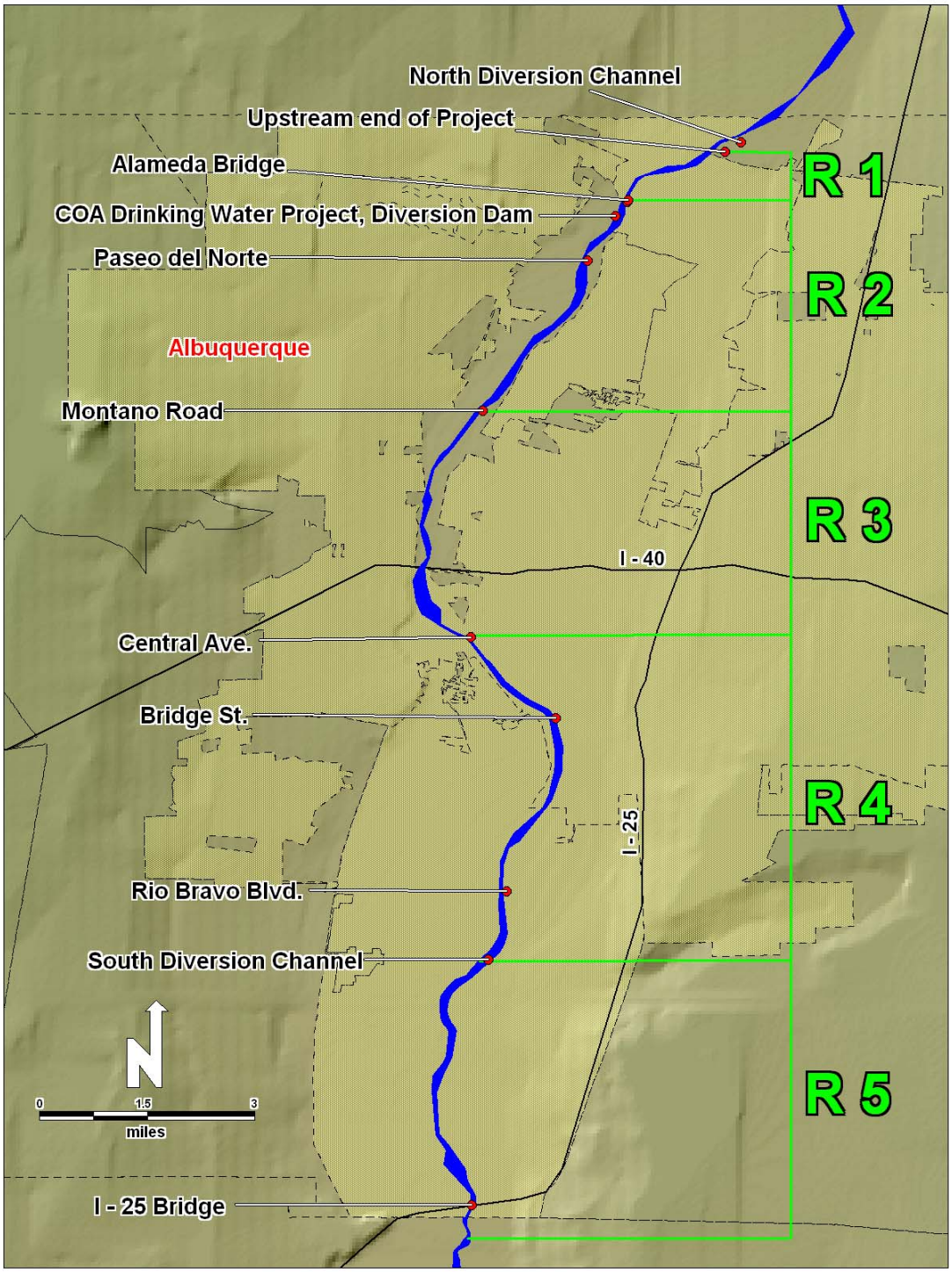

Figure 1.1. Location map showing the project reach and subreach boundaries used in the channel-stability analysis.

2. REVIEW OF EXISTING STUDIES AND BACKGROUND MATERIAL

In performing this study, MEI reviewed available historic reports and information that were provided by the Corps or that were obtained directly by MEI. Information from previous studies by MEI within the reach was also considered. Specific, relevant documents included the following:

1. The FLO-2D model that extends from Cochiti Dam to Elephant Butte Reservoir that was previously developed by the Corps to support the Upper Rio Grande Water Operations Planning Study (URGWOPS) (Tetra Tech, 2004)
2. An existing HEC-RAS model of the project reach being refined by the Corps.
3. Data from a high flow monitoring project that was conducted by the Corps and Tetra Tech in May 2005, when peak discharges in the study area reached approximately 6,300cfs. These data included water-surface elevations and field mapping of overbank inundation on May 24 and 25, 2005, near the peak flow.
4. High-water marks surveyed in June and July 2005 by Steve Boberg (Corps) at Old Alameda Boulevard, Central Avenue, Bridge Boulevard, and Rio Bravo Boulevard Bridges.
5. Aerial photography and satellite imagery of the project reach that shows the extent of the June 2003 wildfires.
6. Bosque Wildfires plans that detail the burn restoration and fuel reduction areas (Corps, March 2005).
7. Existing geomorphic, sedimentologic and sediment continuity reports written by MEI (Mussetter and Harvey, 1993; MEI, 2002, 2003, 2004).

3. HYDROLOGY

The scope of work for this project specifies that the following four hydrologic events are to be modeled in evaluating baseline conditions and other project scenarios that will be developed as the project progresses:

1. The active channel-full flow of ±5,000 cfs,
2. A representative post-Cochiti annual spring runoff hydrograph (peak flow ±3,000 cfs),
3. A 10,000-cfs post-Cochiti flow hydrograph, and
4. The 100-year post-Cochiti flood-flow hydrograph.

The specific flow hydrographs for the first three scenarios were developed in consultation with the Corps from an analysis of the flow records at the Rio Grande at Albuquerque gage (USGS Gage No. 08330000) for the post-Cochiti Dam period [Water Year (WY) 1974 to WY 2002]. The Corps will provide the 100-year hydrograph for Hydrology Scenario 4 to MEI after completion of an ongoing reanalysis of the Rio Grande flood hydrology.

The Rio Grande at Albuquerque gage (USGS Gage No. 08330000) is located immediately upstream of the Central Avenue bridge and 48.6 miles downstream from Cochiti Dam, and it has a contributing drainage area of 14,500 mi^2 (drainage area is 17,440 mi^2). The Rio Grande below Cochiti Dam gage (USGS Gage No. 08317400) has a drainage area of 14,900 mi^2; thus, the contributing drainage area between Cochiti Dam and the Albuquerque gage is 400 mi^2.

To place the various flow scenarios into the context of the existing and historic hydrology of the project reach, MEI performed a general analysis of flow records at the Albuquerque gage. Upstream reservoirs and water diversion projects have significantly altered the hydrology of the project reach compared to the pre-Cochiti Dam hydrology. Peak flows at the Albuquerque gage regularly exceeded 10,000 cfs prior to construction of Cochiti Dam in 1974, but they have not exceeded that level since its completion. In spite of the effects on the peak flow regime, the annual runoff increased substantially between the two periods, from an average of about 714,000 ac-ft during the period from 1943 through 1974 to about 1,011,000 ac-ft between 1975 and 2002 (MEI, 2002). The median flow during the post-Cochiti period was about 850 cfs, and flows exceeded 320 cfs about 90 percent of the time and 3,350 cfs about 10 percent of the time (**Figure 3.1**). A Log-Pearson Type III flood-frequency analysis of the post-Cochiti peak flows (1974-2004) at the Albuquerque gage that was performed using the Corps HEC-FFA computer program (USACE, 1992) indicates that the magnitude of the 2-, 5-, and 100-year floods are 5,630, 7,520, and 13,300 cfs, respectively (**Figure 3.2**). The magnitudes of other recurrence interval peak discharges are also summarized in Figure 3.2.

Based on field observations during the 2005 runoff season, the active channel-full flow in this reach is actually closer 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

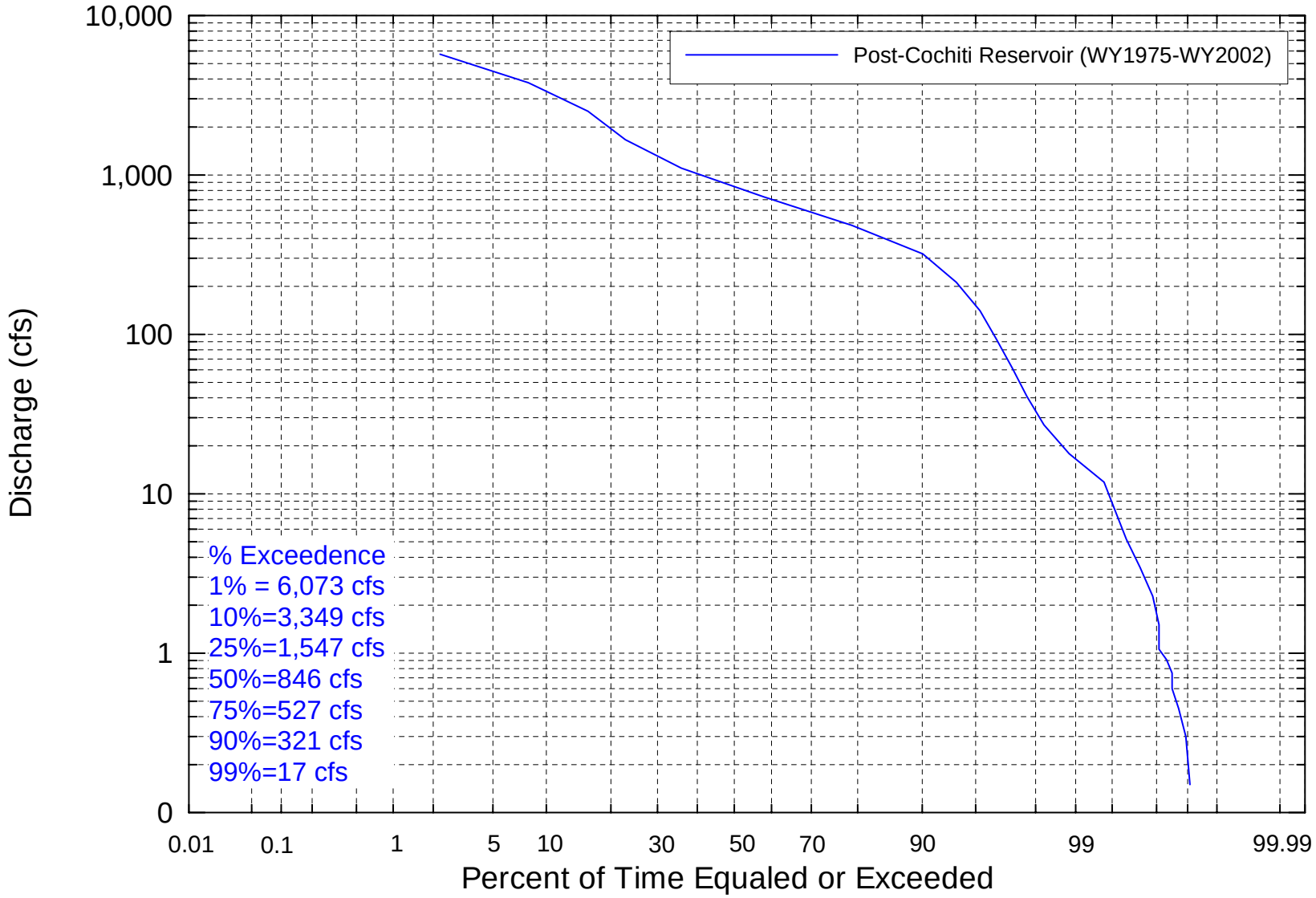

Figure 3.1. Post-Cochiti Reservoir (1974-2002) mean-daily flow-duration curve for the Rio Grande at Albuquerque.

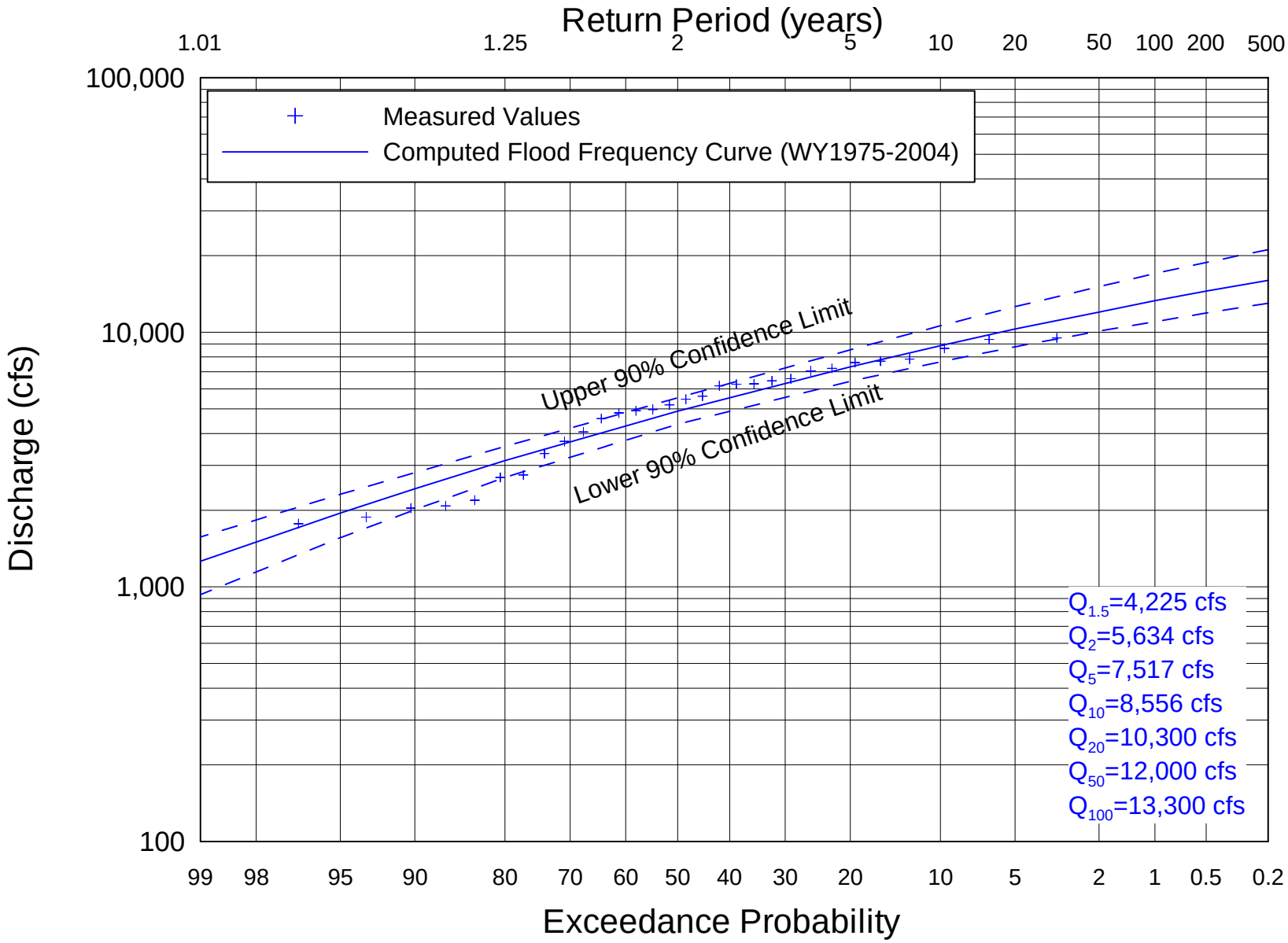

Figure 3.2. Post-Cochiti Reservoir (1974-2004) recorded peak flows and computed flood-frequency curves for Rio Grande at Albuquerque.

sustained discharge at this level. This discharge has a peak flow recurrence interval (RI) 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 with a maximum mean-daily flow of 3,770 cfs was developed for evaluating the various wetland restoration alternatives. To develop the hydrograph, the mean daily flow values for each of the 29 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 corresponds to a recurrence interval of about 1.4 years and the mean daily flow exceedence probability of 8.1 percent [i.e., occurs 30 days per year, on average]).

Although hydrographs were translated to match as closely as possible, the resulting hydrograph still appeared to overestimate the volume of flow due to individual shape and duration characteristics of each hydrograph. To account for this issue, and to obtain a hydrograph with a shape that is representative of the individual yearly hydrographs, a 15-point moving average was applied to smooth out irregularities, and the duration of the hydrograph was scaled in order to maintain a target run-off volume estimate. The target volume for the hydrograph was determined from a regression relationship between the maximum mean daily flow and the hydrograph volume during the runoff period (**Figure 3.3)**, which typically occurs sometime between the 120th and 340th day of the water year (January 28 through September 5). Based on Figure 3.3, the typical hydrograph with a maximum mean daily discharge of 3,770 cfs would have a volume of about 590,190 ac-ft. The remaining ordinates of the hydrograph were computed by adjusting the duration and shape until the target volume was achieved while still maintaining a peak discharge of 3,770 cfs. Comparison of the resulting hydrograph with five measured hydrographs that had similar peak discharges indicates that the shape, including the slope of the rising and falling limbs, approximates that of the measured hydrographs reasonably well (**Figure 3.4**).

The 10,000-cfs hydrograph (Hydrology Scenario 3) was developed by scaling the ordinates of the 10-percent exceedence hydrograph (**Figure 3.5**) to provide a peak discharge of 10,000 cfs, and then adjusting the duration to achieve the target volume of 1,467,000 ac-ft that was determined by extrapolating the best-fit curve in Figure 3.3 to 10,000 cfs. In the development of the 50-percent exceedence hydrograph, the peak discharge was contained within the range of discharges and no scaling of the peak discharge was required. However, since the peak discharge of 10,000 cfs has not occurred during the post-dam period, the 10-percent exceedence hydrograph was scaled, rather than the 50-percent hydrograph, because it provides a more realistic shape of the largest hydrographs.

The resulting hydrograph is shown in **Figure 3.6**, along with the five largest recorded hydrographs. Although the maximum flows exceed all of the recorded flows, the overall hydrograph duration and slope of the rising and falling limbs are reasonably representative of the recorded high-flow hydrographs.

At the time of this report, the Corps has not completed its reanalysis of the Rio Grande flood hydrology; thus, the 100-year hydrograph was not available. Interim results from the Corps study, however, indicate that the 100-year peak discharge may change from the 13,000 cfs

presented in this report and a discussion of the effect of the revised frequency analysis will be presented in the final report.

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.

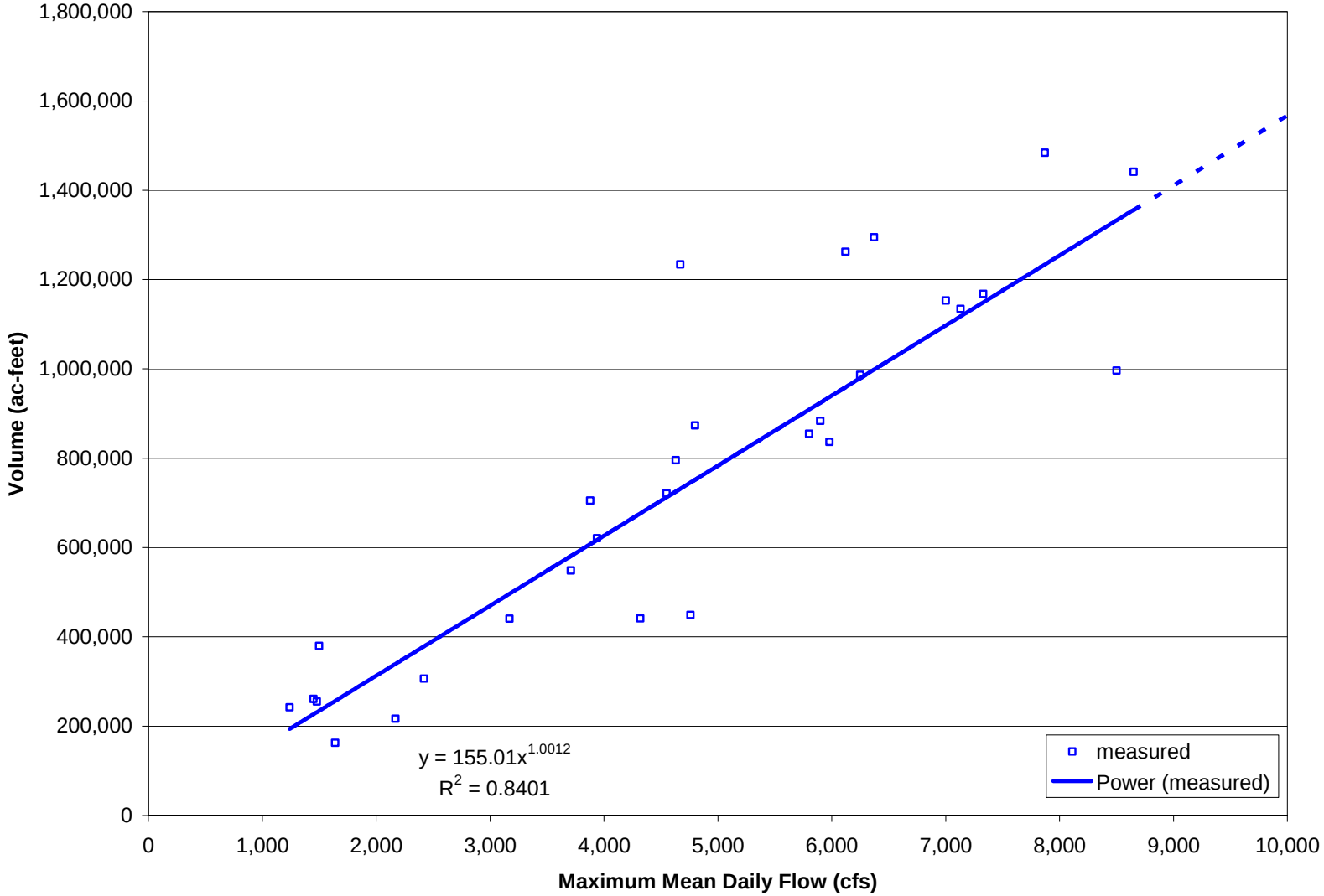

Figure 3.3. Comparison of maximum annual mean daily flow values versus computed volumes during the runoff period for WY 1974 to WY 2002. The curve is extrapolated to 10,000 cfs using a power function.

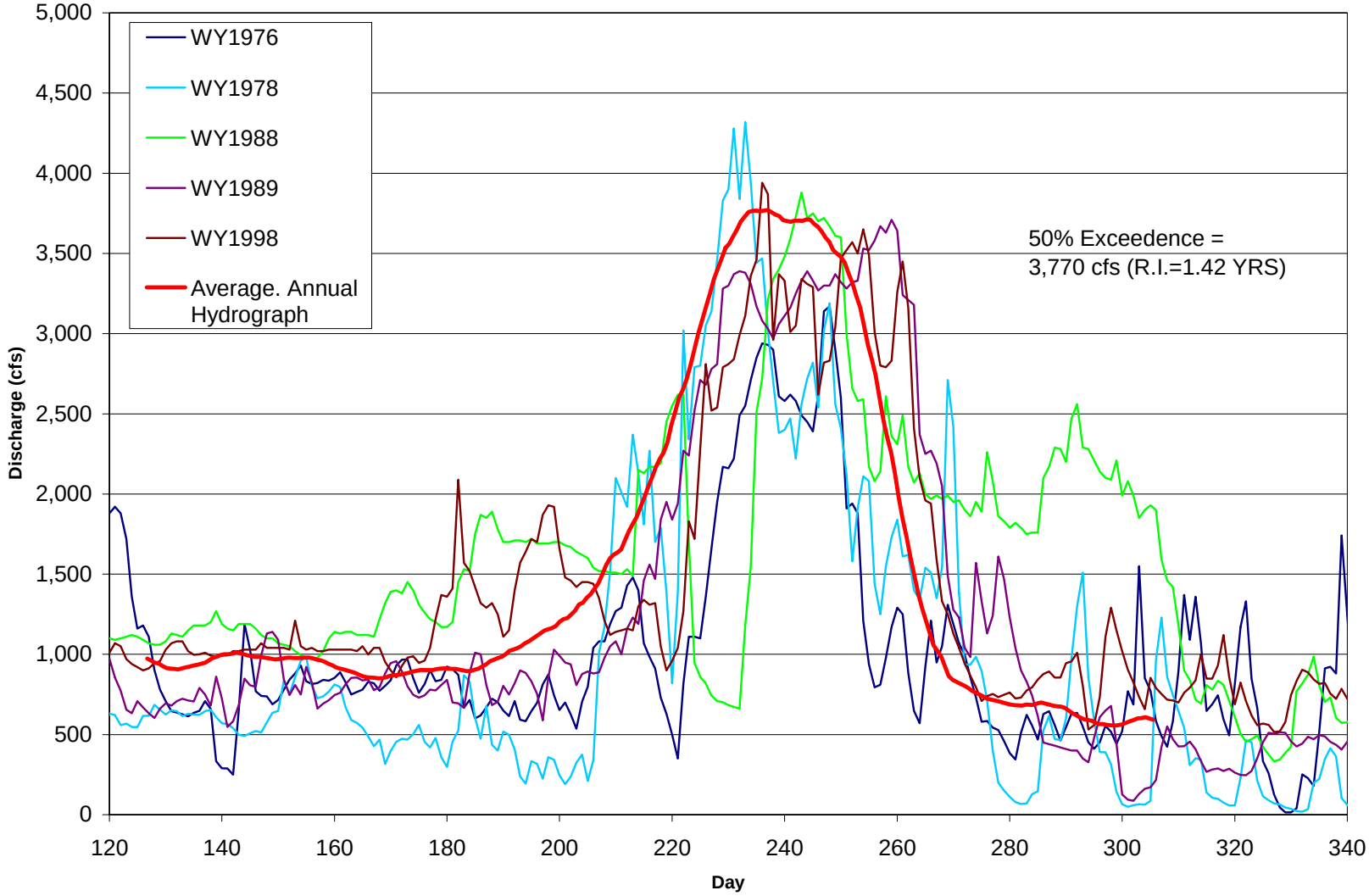

Figure 3.4. The representative 50-percent exceedence hydrograph and a comparison with five natural hydrographs with similar peak discharges.

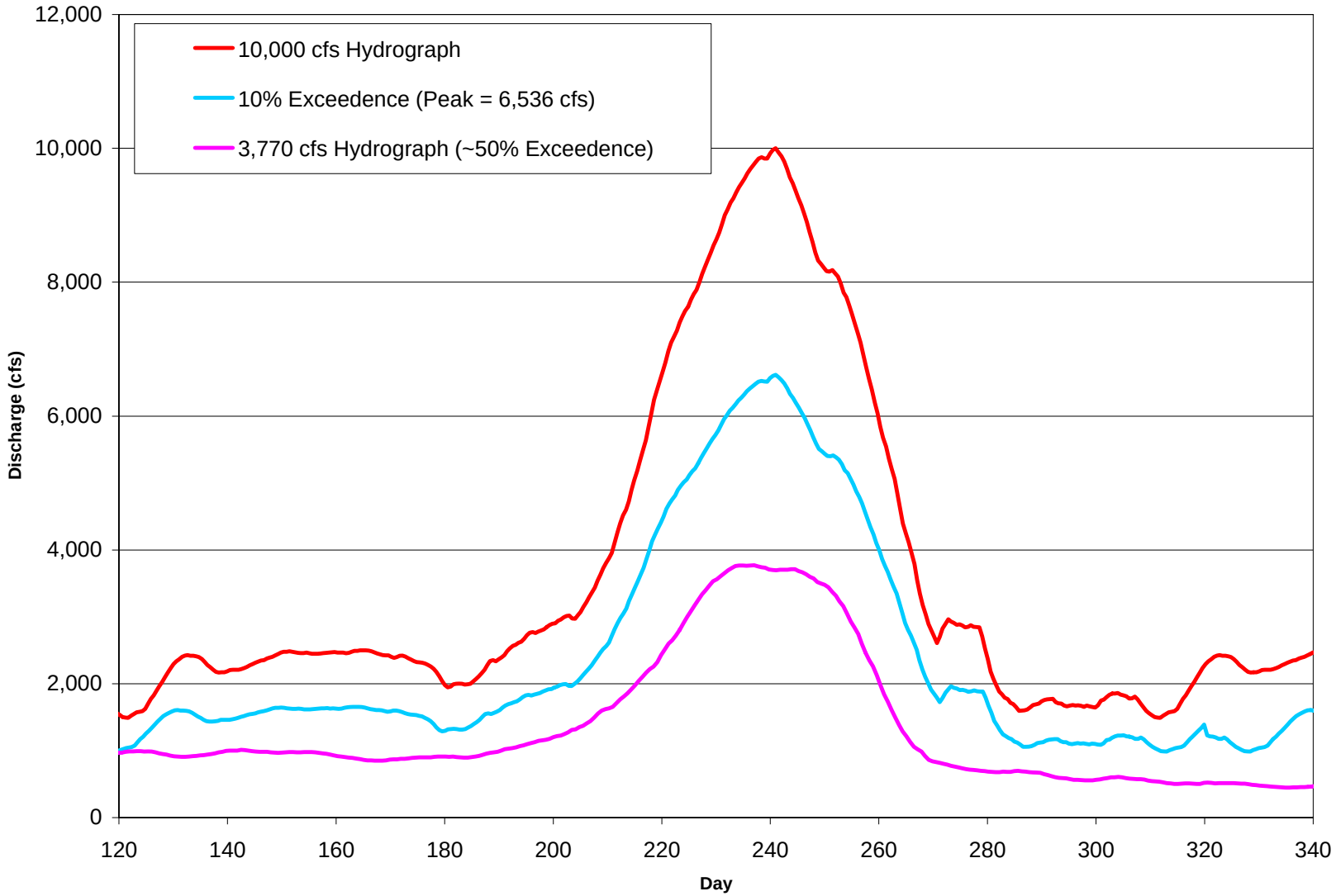

Figure 3.5. Comparison of the 10,000-cfs hydrograph with the 10- and 50-percent exceedence hydrographs.

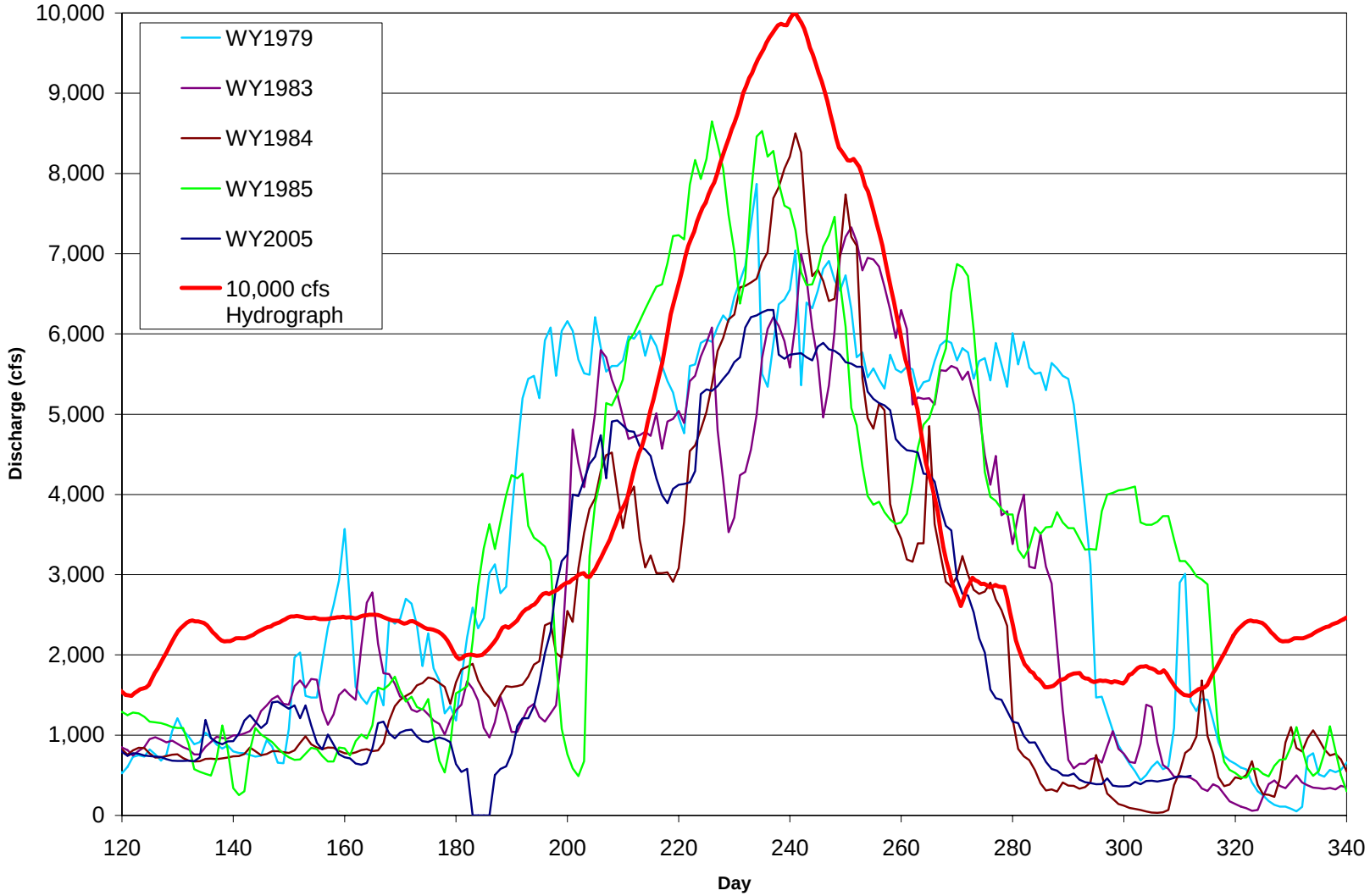

Figure 3.6. Comparison of the 10,000-cfs hydrograph with five largest recorded hydrographs for the post-Cochiti Dam period.

4. MODEL DEVELOPMENT

The existing conditions FLO-2D model was developed by updating the FLO-2D model that was originally developed for the Upper Rio Grande Water Operations (URGWOPS) project. The original model that was developed by Tetra Tech, Inc. (2004) extends from Cochiti Dam to Elephant Butte Reservoir. This model has a grid resolution of 500 feet, and it contains over 36,000 grid elements. Tetra Tech used the Grid Developer System, which is part of the FLO-2D program, to assign elevations to the FLO-2D grid using a series of digital terrain models (DTMs) that were developed from aerial photogrammetry and LIDAR data collected during the 1990s and early 2000s by the Albuquerque District. All horizontal coordinates in the model were specified using the New Mexico Central State Plane (NAD83) coordinate system, and elevations were specified in the North American Vertical Datum (NAVD) of 1988. Cross sections assigned to the main channel grid elements were developed from rangeline cross sections surveyed by the Bureau of Reclamation (BOR) between 1989 and 2002. At channel grids where no surveyed cross sections are available, the cross sections were interpolated between surveyed cross sections using the PROFILES program included in FLO-2D.

To facilitate development of the model, interpretation of the model results, and to assign locations of other GIS data, MEI developed a station line that represents the distance along the approximate centroid of the flow, with the downstream end (Sta 0) located at the Isleta Diversion Dam. Along this station line, the downstream end of the modeled reach for this project is located at Sta 16,050 and the upstream end of the reach is located at Sta 129,060. **Table 4.1** lists points of interest along the station line and the River Mile stationing developed by the U.S. Bureau of Reclamation (BOR, 2003).

Table 4.1. Stationing of points of interest along the project reach.

River Mile*	Station (ft)	Station (mi)	Description
169.3	0	0	Isleta Diversion
172.5	16,050	3.04	Downstream end of project reach
172.6	17,170	3.25	I-25 Bridge
177.0	41,110	7.79	South Diversion Channel
173.4	47,770	9.05	Rio Bravo Blvd. Bridge
181.6	64,370	12.19	Bridge Street
183.4	74,060	14.03	Central Avenue Bridge
185.0	82,510	15.63	I-40 Bridge
188.0	97,910	18.54	Montano Road Bridge
191.0	113,730	21.54	Paseo del Norte Bridge
191.9	118,280	22.40	COA Drinking Water Project, Diversion Dam
192.2	119,810	22.69	New Alameda Boulevard. Bridge
192.3	119,960	22.72	Old Alameda Bridge
194.0	129,060	24.44	Upstream end of Project
194.3	131,100	24.83	North Diversion Channel
232.0			Cochiti Dam

*BOR (2003) River Mile stationing

A review of the URGWOPS FLO-2D model indicated that modifications to the overbank *n*-values were required due to the 2003 wildfires and non-native vegetation removal, and more recent surveyed cross sections were available to update the cross-section geometry. Also, two locations in the URGWOPS FLO-2D model where identified and corrected where the channel elements were not continuous.

Overbank *n*-values used in the original URGWOPS FLO-2D model ranged from 0.1 to 0.125. Application of the Arcement and Schneider (1989) method for areas that were not affected by the 2003 wildfires or the fuel reduction and non-native vegetation removal program that is being conducted by the Corps indicates that overbank roughness is in the range of 0.12 (**Table 4.2**). This result agrees well with the original model values; thus, the original overbank *n*-values were retained for all grid elements that were not affected by fire or clearing. The Arcement and Schneider (1989) method also indicates that the *n*-value for the burned and cleared areas should be in the range of 0.065 (Table 4.2). The model grid elements that were affected by the wildfires and clearing program were identified from satellite imagery, aerial photography, and available maps (USACE, 2004), and the *n*-value for these 224 elements was, therefore, changed to 0.065.

Table 4.2. Overbank Manning's *n*-values (Arcement and Schneider, 1989).

$n=(n_b+n_1+n_2+n_3+n_4)m$

	Bosque	Cleared	Description
n_b	0.04	0.04	Base value of *n* for the floodplains bare surface
n_1	0.01	0.01	Correction factor for the effect of surface irregularities on the floodplain
n_2	0	0	Value for variations in shape and size of the floodplain cross section, assumed 0.0
n_3	0.02	0.005	Value for obstructions on the floodplain
n_4	0.05	0.011	Value for vegetation on the floodplain
m	1	1	Correction factor for sinuosity of the floodplain, equal to 1.0
n	0.12	0.065	Final overbank *n*-value

Computed water-surface elevations from the URGWOPS FLO-2D model at 6,300 cfs are lower than water-surface elevations that were measured by the Corps during the 2005 spring runoff at discharges in this range. Comparison of the thalweg profile from the original model with more recent data from surveys that were conducted by MEI in 2004 and 2005 between the South Diversion Channel (SDC) and Rio Bravo Boulevard and in the vicinity of Central Avenue and the North Diversion Channel (NDC) outlet, and by Bohannon-Huston in 2003 between I-40 and Montano indicates that the model thalweg is about 1.2 feet low, on average (**Figure 4.1**). A specific gage analysis based on USGS data at the Albuquerque gage shows that the gage rating curve lowered by about 2.5 feet between the mid-1970s and the mid-1980s in the low to intermediate ranges of flows, which indicates bed lowering during this period (**Figures 4.2 and 4.3**). The water-surface elevations in this range of flows remained relatively stable from 1982 to the late 1990s, and since the late 1990s, the channel has shown a slight aggradational trend, which may explain the difference in thalweg elevations between the URGWOPS FLO-2D sections and the MEI-surveyed sections. This trend is corroborated by data collected at Rangeline CO-36, which is located just downstream of the Central Avenue Bridge (**Figure 4.4**). The most recent survey by MEI (2004) shows the thalweg 3.1 feet higher than the 2001 BOR survey and 2.1 feet higher than the 2000 BOR survey. It is also interesting to note that the channel width from the BOR photo-interpreted rangeline (Agg/Deg Line 510) and the MEI (2004) survey at this location is about 100 feet less than indicated by the 2001 CO-36 rangeline

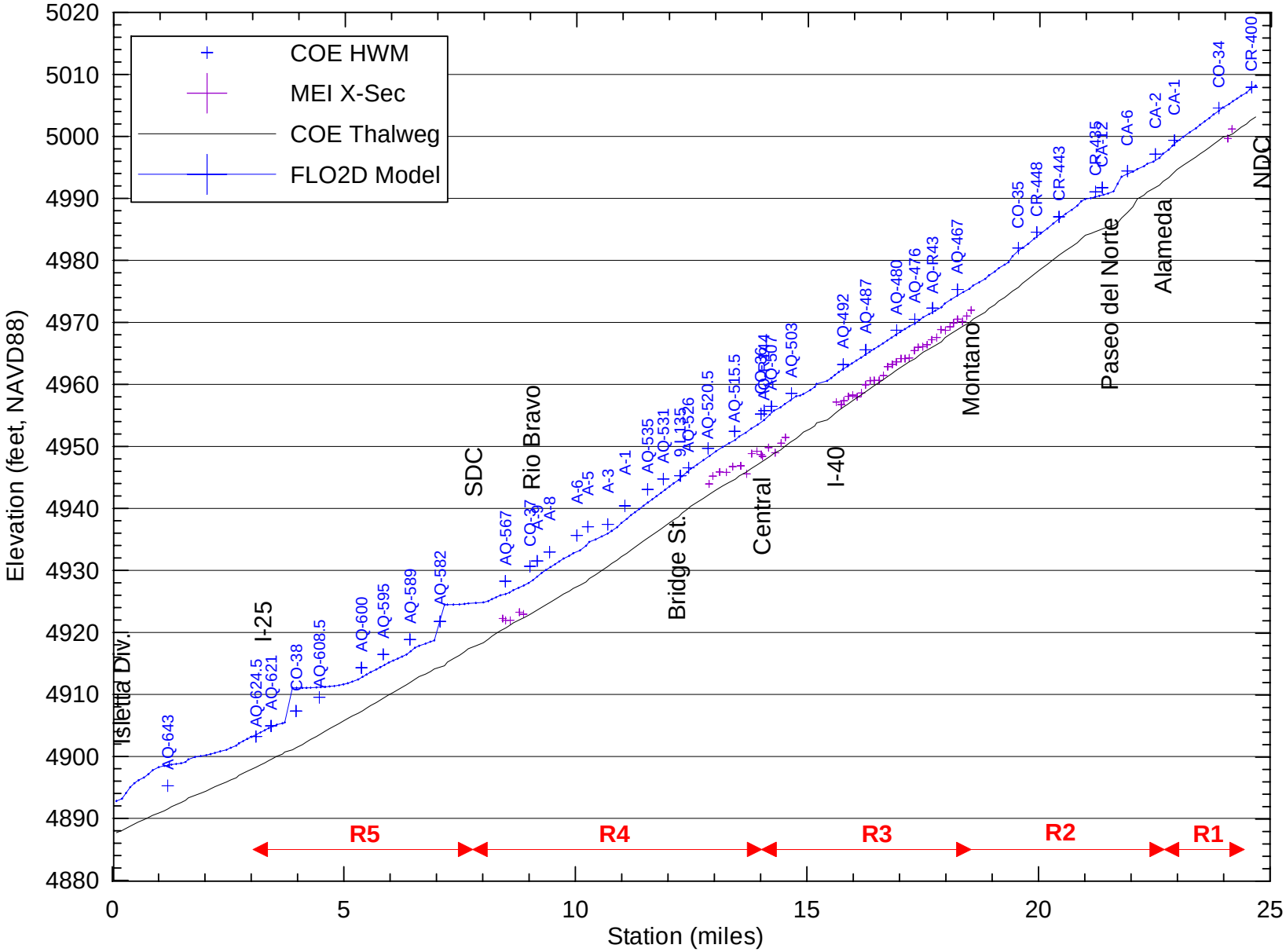

Figure 4.1. Comparison of computed water-surface and Thalweg profile from URGWOM FLO-2D model to measured high-water marks at 6,300 cfs and thalweg elevations from surveyed cross sections.

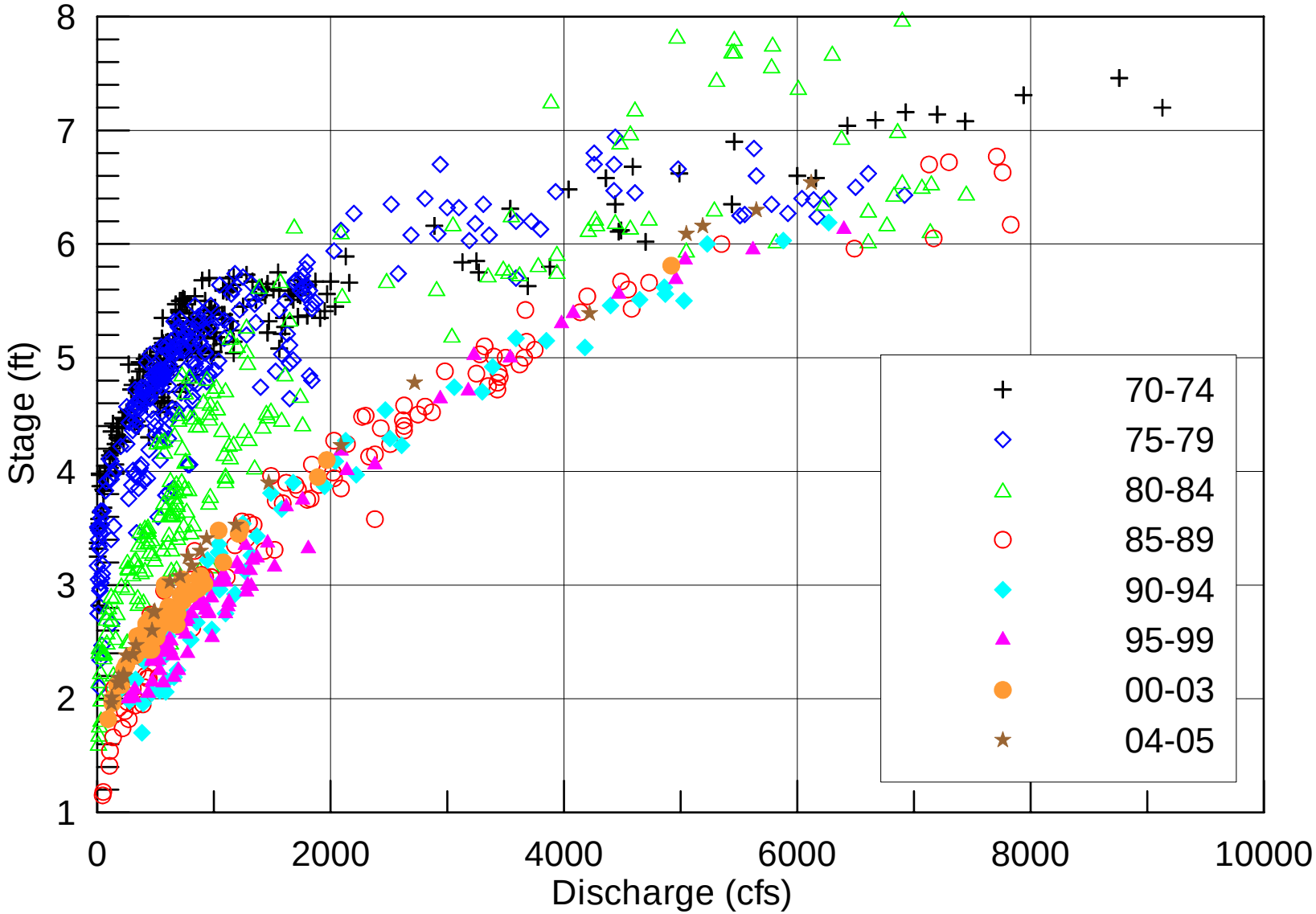

Figure 4.2. Measured stage-discharge data for the Albuquerque gage. Data collected during different time periods are shown with different symbols.

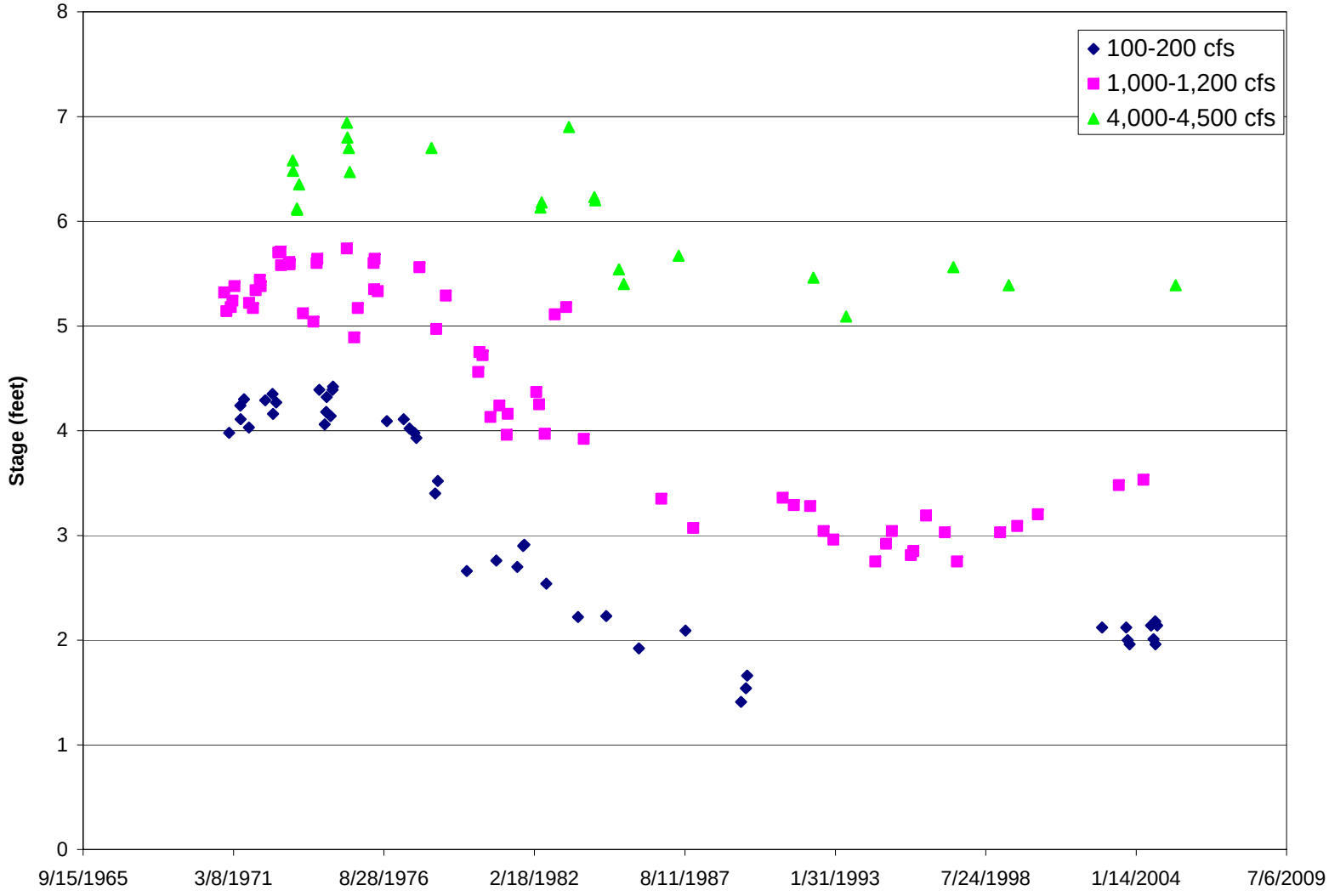

Figure 4.3. Specific gage plot showing changes in stage over time for three ranges of discharges (100 to 200 cfs, 1,000 to 2,000 cfs, and 4,000 to 5,000 cfs).

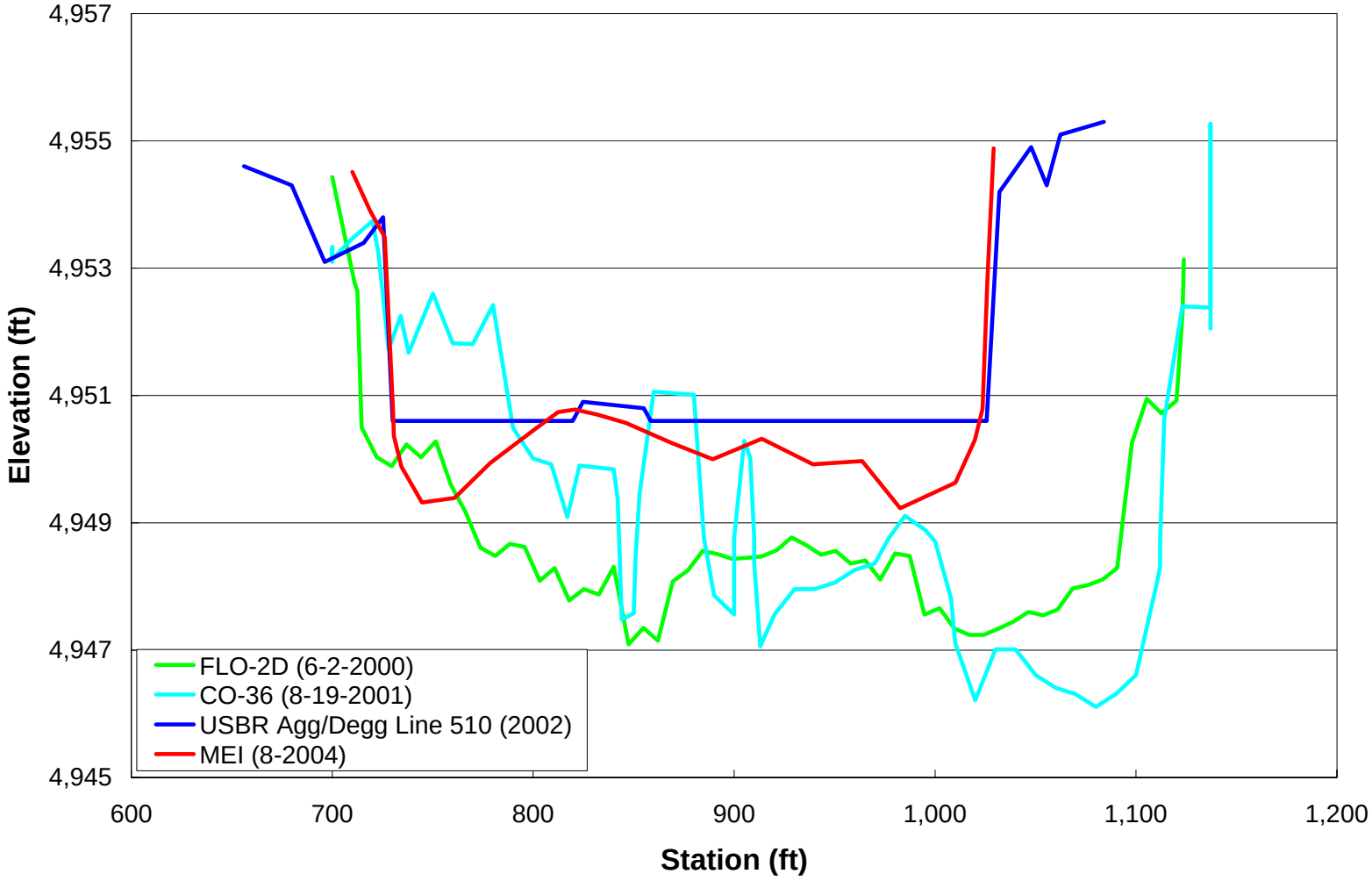

Figure 4.4. Cross-section comparison at Rangeline CO-36, located just below Central Avenue Bridge.

survey and 2000 cross section that were used in the FLO-2D model, even though all sections appear to have been surveyed in very close proximity to each other. This difference is believed to be the result from attachment of a small island located under the bridge to the left bank.

To improve calibration of the model to the recent high-flow data, cross sections in applicable portions of the project reach were updated with the more recently surveyed sections (**Table 4.3**). In other areas, the model cross sections were updated using data from an HEC-RAS model that is being developed by the Corps using BOR agg/deg lines that were developed from 2002 aerial photography.

Table 4.3. Summary of surveyed cross sections used to update the FLO-2D model.

Number of Cross Sections	Location Description	Station (miles)	Year of Survey
2	Approximately 3,500 feet downstream of North Diversion Channel	24.1 – 24.2	2005
29	Central Avenue to Montano	15.6 – 18.5	2003
14	Up- and downstream of Central Avenue	12.9 – 14.5	2004
3	Rio Bravo to South Diversion Channel	8.4 – 8.5	2005

It is important to note that the cross sections from the agg/deg lines do not include subaqueous data, and therefore, the minimum bed elevations are the same as the water-surface elevation at the time of the aerial photography (The discharge was about 300 cfs at the time of the aerial survey). To account for the subaqueous portion of the channel, the BOR lowered the bed elevations using a prism adjustment method, the details of which are not specifically known. On average, the difference in thalweg elevation between the prism-adjusted and unadjusted cross sections is about 1.0 feet throughout the project reach. As a result, the Corps initially evaluated whether using the unadjusted or adjusted data in their HEC-RAS model would produce better results. Corps efforts to calibrate the models indicated that the unadjusted cross sections produce results that are more consistent with the measured water-surface elevation data. Based on this result, cross sections in the FLO-2D model for locations where more recent surveyed cross sections were not available were updated using the unadjusted agg/deg line data. Of the 234 FLO-2D channel elements within the project reach, 49 were updated with surveyed cross sections and 185 were updated with unadjusted agg/deg line data.

In the original URGWOPS FLO-2D model, main channel Manning's *n*-values varied from 0.025 to 0.047 (**Figure 4.5**). Manning's *n*-values used in the Corps unadjusted HEC-RAS model ranged from 0.025 to 0.034, and there was less variability with distance along the reach. MEI made further adjustments to the Manning's *n*-values in the unadjusted HEC-RAS model which produced results that are more consistent with the 2005 observed high-water profile. The revised Manning's *n*-values used in the HEC-RAS model were applied to the updated FLO-2D model (Figure 4.5).

The FLO-2D model does not have the capability to model losses through bridges or other in-line hydraulic structures, such as the City of Albuquerque's inflatable raw-water diversion dam that is located Sta 118,280. The recommended method of accounting for the effects of these structures is to develop rating curves using other techniques that can be applied in the appropriate place in the model. As a result, MEI updated the Corps HEC-RAS model that uses the unadjusted agg/deg data with the newer surveyed cross sections, as appropriate, and applied the updated model to evaluate the effects of the bridges and diversion dam. Results of the analysis indicate that the bridges and the diversion dam (in its deflated position) have very

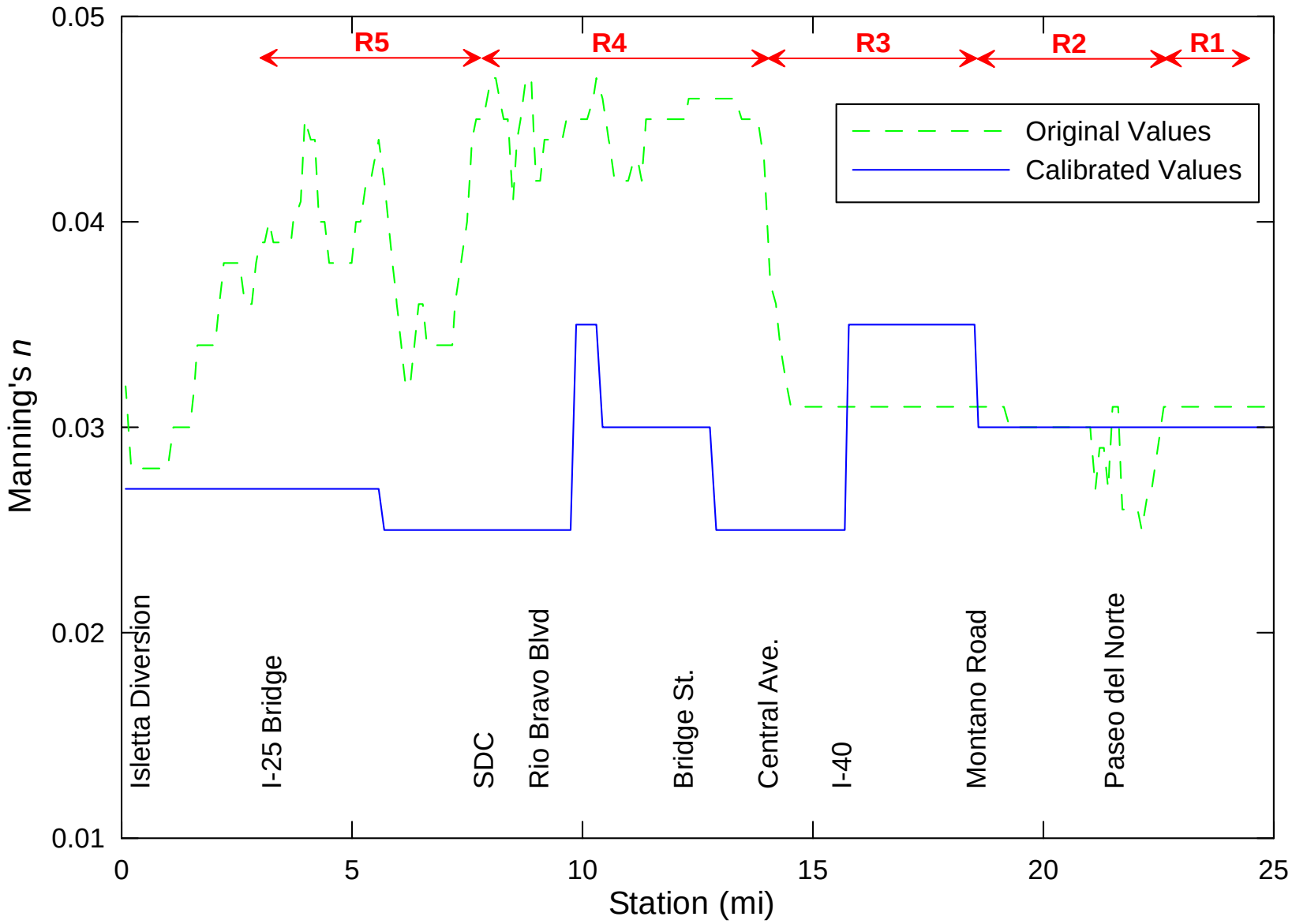

Figure 4.5. Manning's *n*-values used in the updated HEC-RAS and FLO-2D models compared to the original URGWOMS FLO-2D model.

little hydraulic effect and, therefore, it was concluded that rating curves at these locations are not required in the FLO-2D model. The rating curve from the original URGWOPS FLO-2D model at the Isleta Diversion Dam was used as the downstream boundary conditions in the model.

4.1. Model Validation

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 (**Figure 4.6**). To evaluate the performance of the model over a broader range of flows, a stepped hydrograph was modeled from 500 to 15,000 cfs with the discharge increasing (by 500 cfs up to 3,000 cfs and by 1,000 cfs from 3,000 to 15,000 cfs) every 72 hours to allow the model to reach steady-state conditions during each discharge period. The results at the end of each period were then used to develop rating curves at four bridges where measured water-surface elevations were available (**Figures 4.7 through 4.10**). The bank elevations and water-surface elevations for 4,000, 6,000, and 8000 cfs are shown in **Appendix A**. Appendix A.3 details the bank, thalweg and water-surface elevations from 1,000 to 10,000 cfs.

The Old Alameda Bridge is located at the corner of two FLO-2D grid elements. The rating curves predicted by the model for these two grid elements bound the water-surface elevations at this location that were measured at discharge between 1,000 and 4,200 cfs, and the predicted rating curves are also consistent with results from the HEC-RAS model (Figure 4.7). Similar agreement is obtained at the Central Avenue, Bridge Street, and Rio Bravo bridges (Figures 4.8 through 4.10).

Field mapping indicated that very little overbank inundation occurred during the 2005 peak flows. The validated FLO-2D model that predicts that inundation occurs in only two locations: (1) just upstream of the Central Avenue Bridge on the left bank, and (2) midway between Bridge Street and Rio Bravo Boulevard on the right bank, consistent with the field-mapped inundation.

Based on the above-described results, the updated FLO-2D model appears to be reasonably well validated.

4.2. 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 (**Appendices A and B**). In the FLO-2D model, an average elevation is assigned to each grid cells; thus, the depth and duration of overbank inundation maps represent the average for the cell. As a result, the local depth or duration at any point within the cell may vary from the average due to variation in the ground elevation. The ground elevations on which these depths were based were, however, developed using the grid developer system that is available with FLO-2D, and they are therefore believed to be representative of the overall condition within the cell. A more detailed depiction of the variation in depth could be developed based on the difference between the water-surface elevation in each grid cell and the detailed ground surface model (DTM). Development of this surface model is beyond the scope of this effort.

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. At 6,000 cfs, which corresponds to the steady-state discharge for Hydrology Scenario 1, the water-surface elevation is above the

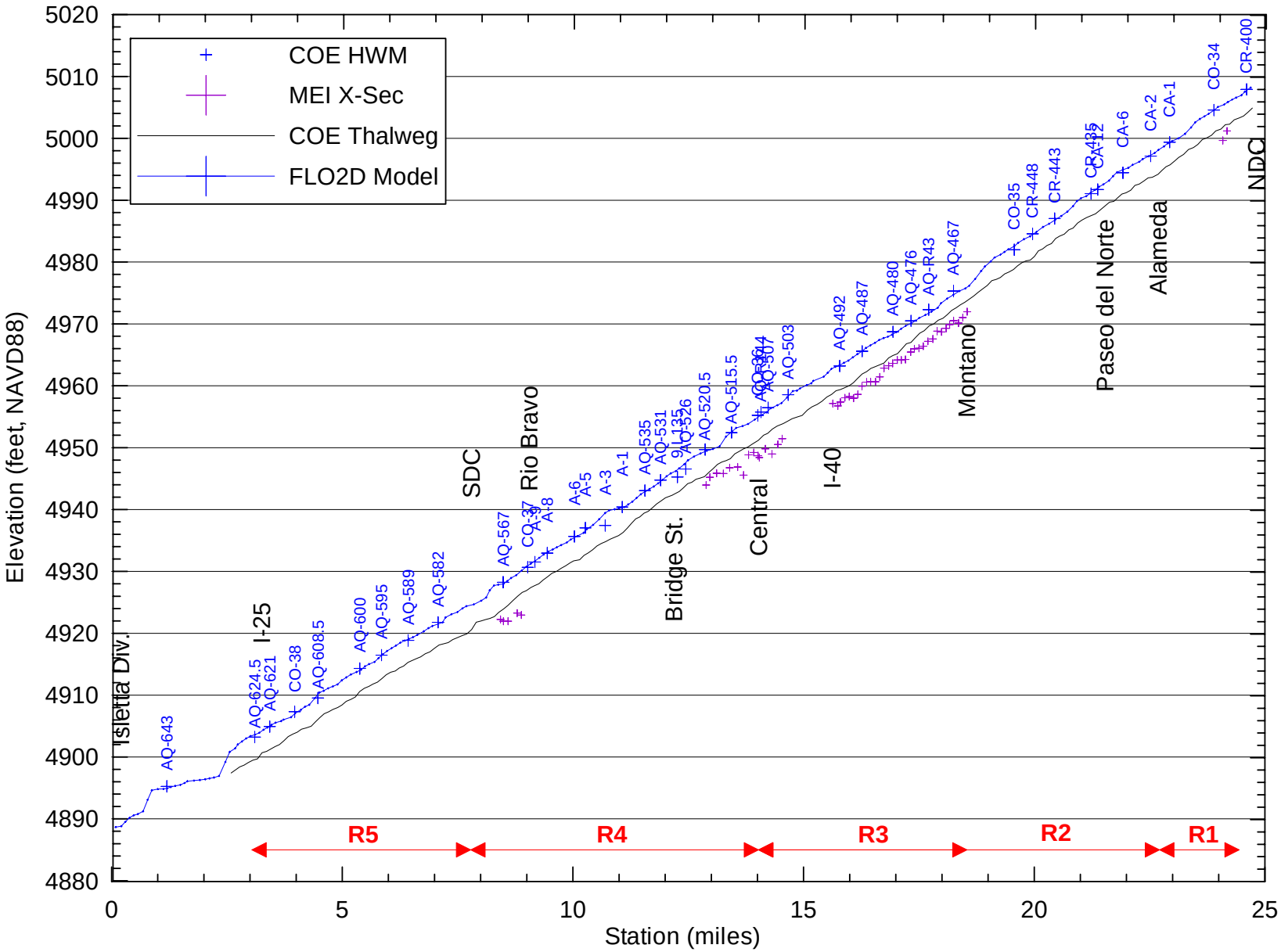

Figure 4.6. Comparison of computed water-surface elevation from the MEI FLO-2D model and the thalweg profile from URGWOM FLO-2D model to measured high-water marks at 6,300 cfs and thalweg from surveyed cross sections.

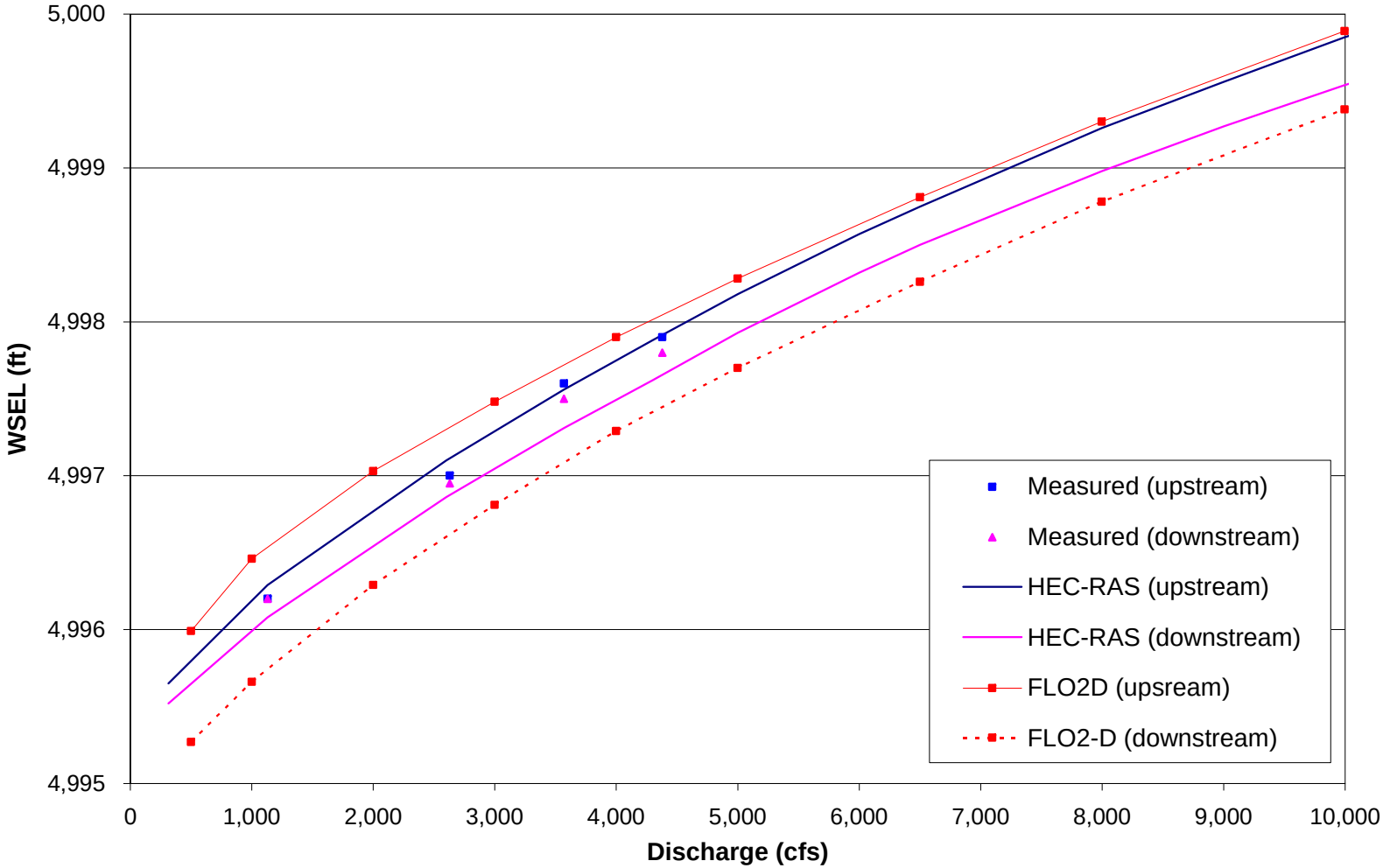

Figure 4.7. Comparison of computed rating curves from the FLO-2D model and HEC-RAS with measured values up- and downstream of the Old Alameda Bridge.

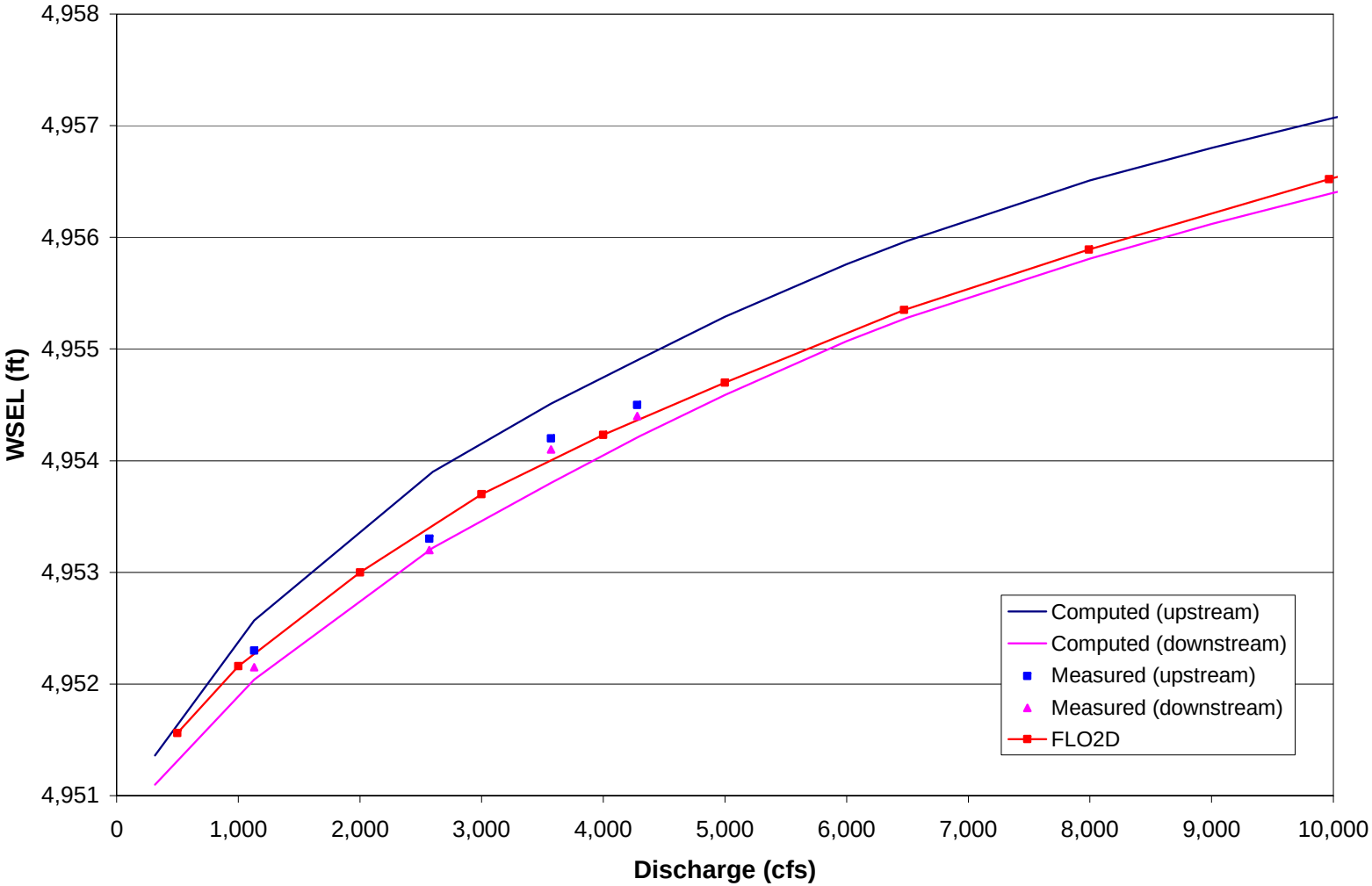

Figure 4.8. Comparison of computed rating curves from the FLO-2D model and HEC-RAS with measured values up- and downstream of the Central Avenue Bridge.

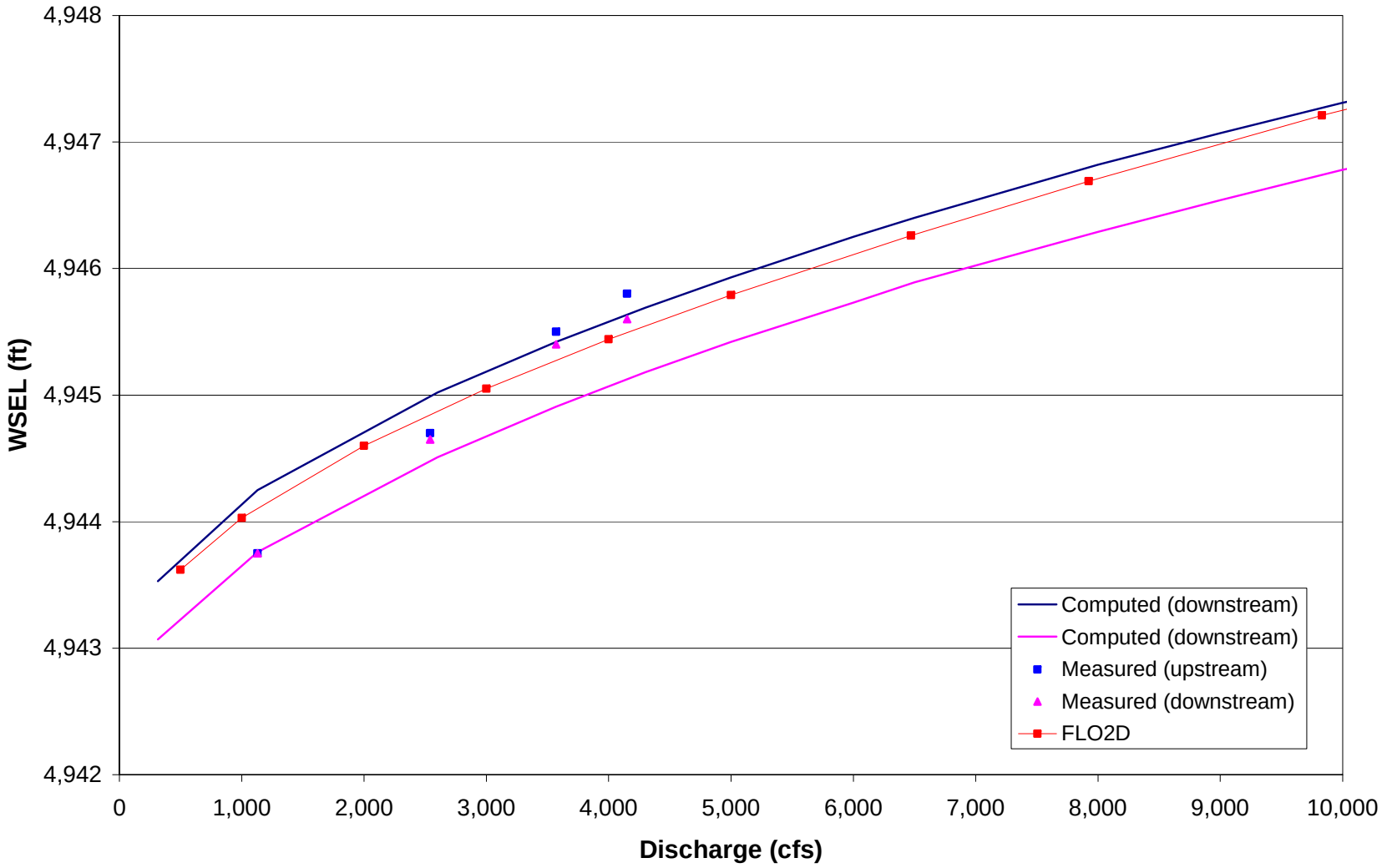

Figure 4.9. Comparison of computed rating curves from the FLO-2D model and HEC-RAS with measured values up- and downstream of Bridge Street.

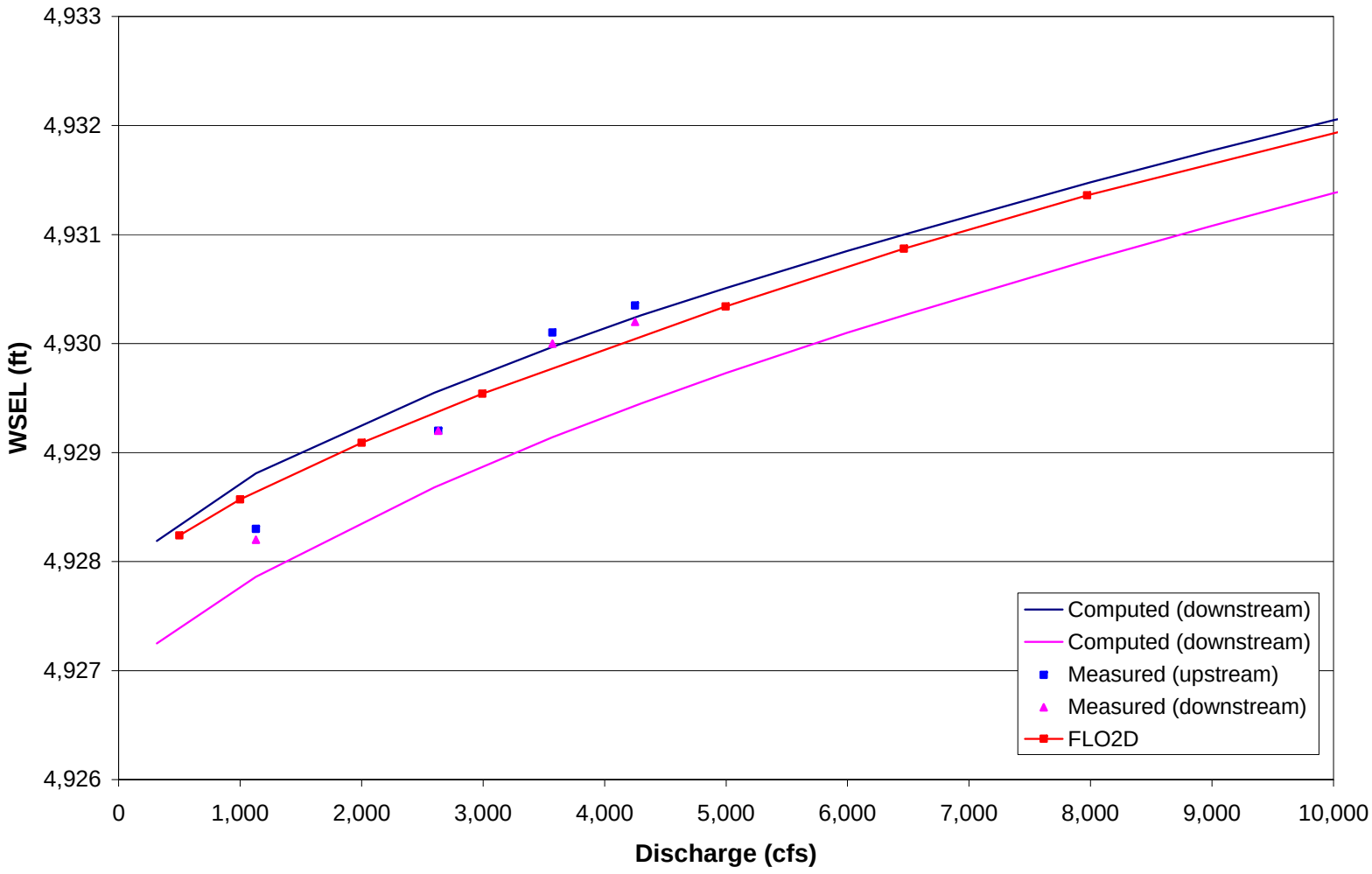

Figure 4.10. Comparison of computed rating curves from the FLO-2D model and HEC-RAS with measured values up- and downstream of the Rio Bravo Bridge.

top-of-bank at only two locations: (1) left bank just upstream from Central Avenue, and (2) between Bridge Street and Rio Bravo Boulevard. At 8,000 cfs, the top-of-bank elevation is exceeded at several locations, including:

1. right bank, approximately 8,000 feet upstream of Alameda,
2. left bank approximately 1,300 feet upstream Paseo del Norte,
3. left and right banks upstream of I-40, and
4. extensively between Central Avenue and the downstream end of the project reach.

Inundation results from Hydrology Scenario 1 are very similar to the 6,300 cfs validation run that was described in the previous section, 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 Street and Rio Bravo Boulevard (depth of 0.2 to 3.2 feet) (**Appendices B.1 and B.2**). 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.

Under Hydrology Scenario 3 (10,000-cfs peak discharge hydrograph), approximately 1,800 acres of the 2,760 acres of available floodplain (about 65 percent) is inundated at the peak of the hydrograph. The extent, maximum depth and duration of inundation for this scenario is shown in **Appendices B.3 to B.17 and C.1 to C.15** respectively, using different colors to show durations in 5-day increments up to the maximum of 65 days, and the depths in one foot increments up to the maximum of 5 feet. Model elements with the longest durations of inundation are scattered from just upstream of the I-40 Bridge to the downstream end of the project reach. The areas that experience the most inundation, in terms of depth and/or duration, are among the locations that are most likely to provide the best opportunity for habitat improvement under the Bosque restoration plan, and they include the following:

1. Left overbank approximately 2,500 feet upstream from the I-40 Bridge in the area identified as “Suitable WIFI Habitat” on the Corps 2005 inundation mapping. This area is inundated for approximately 60 days during the 10,000-cfs hydrograph (Appendix C.6).
2. The low elevation area in the left bank approximately 1,000 feet upstream from the Central Avenue Bridge. This area was inundated during the 2005 runoff, and is inundated for approximately 61 days during the 10,000-cfs hydrograph (Appendix C.7).
3. Left overbank approximately 2,500 feet downstream from the Central Avenue Bridge. This area has recently been cleared of vegetation and some bank scalloping has been conducted by the Interstate Stream Commission. This area is inundated for approximately 63 days during the 10,000-cfs hydrograph (Appendix C.8).
4. Left overbank immediately upstream from Bridge Street. This area was inundated during the 2005 runoff, and is inundated for approximately 60 days during the 10,000-cfs hydrograph (Appendix C.9).

The model indicates that some elements that are located away from the channel have unusually long periods of inundation under this scenario due to ponding (i.e., model elements shown in Appendix C that are disconnected from the channel or to other elements that are connected to the channel). These elements are inundated on rising limb of the hydrograph, and due to lack of a hydraulic connection to the main channel, they apparently do not drain on the receding limb of the hydrograph. Since the hydrograph is below 6,000 cfs for 22 days on the receding limb of the hydrograph, there may be sufficient time for the ponded water to evaporate or infiltrate, two mechanisms that were not applied in the FLO-2D models.

4.3. Reach-averaged and Main-channel Hydraulic Results

The one-dimensional hydraulic results for the main channel (e.g., flow velocity, depth, topwidth, and energy slope) were taken from the model output for the stepped hydrograph run that was described in the validation section for use in the sediment-transport and channel stability analysis. These results indicate that main channel velocities vary from approximately 0.9 to 3.4 fps at 1,000 cfs and from 1.7 to 7 fps at 6,000 cfs (**Figure 4.11**). Higher velocities typically occur at contractions created by islands, bank-attached bars, bridges and at tributary confluences; whereas the lower velocity areas occur at locally wide sections. Channel topwidths vary from 160 to 1,060 feet at 1,000 cfs and 200 to 1,060 feet at 6,000 cfs (**Figure 4.12**).

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 (Steve Boberg, Corps, personal communication, August 2005) (Figure 1.1, **Table 4.4**). 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 subreach (**Table 4.5**).

Table 4.4. Summary of subreaches defined for the channel-stability analyses.

Subreach	Subreach Length (ft)	Main Channel Topwidth (ft)[1]	Limits
1	10,760	710	Southern boundary of the Pueblo of Sandia to Alameda Bridge
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

[1]at the active channel-full flow of 6,000 cfs

Table 4.5. Reach-averaged hydraulic conditions in the project reach.							
Subreach	Discharge (cfs)						
	500	1,000	2,000	4,000	6,000	8,000	10,000
Velocity (ft/s)							
1	1.23	1.60	2.02	2.59	3.01	3.34	3.59
2	1.20	1.66	2.11	2.69	3.11	3.45	3.74
3	1.11	1.69	2.19	2.83	3.30	3.64	3.92
4	1.00	1.69	2.21	2.86	3.32	3.66	3.95
5	0.91	1.77	2.36	3.05	3.50	3.82	4.12
Hydraulic Depth (ft)							
1	0.75	1.07	1.53	2.21	2.79	3.29	3.73
2	0.82	1.16	1.67	2.42	2.97	3.45	3.88
3	0.88	1.22	1.83	2.75	3.52	4.17	4.75
4	0.91	1.19	1.75	2.58	3.22	3.77	4.26
5	0.82	1.12	1.70	2.49	3.08	3.55	4.00
Top Width Channel (ft)							
1	520	580	645	698	713	727	743
2	468	509	562	611	647	671	686
3	415	456	478	494	499	509	515
4	407	476	507	535	556	570	573
5	437	472	488	516	549	576	583
Energy Slope (ft/ft)							
1	0.00090	0.00095	0.00094	0.00094	0.00094	0.00092	0.00090
2	0.00076	0.00092	0.00091	0.00090	0.00092	0.00093	0.00093
3	0.00066	0.00098	0.00096	0.00094	0.00091	0.00088	0.00087
4	0.00040	0.00080	0.00081	0.00082	0.00082	0.00080	0.00080
5	0.00033	0.00083	0.00084	0.00084	0.00084	0.00083	0.00082

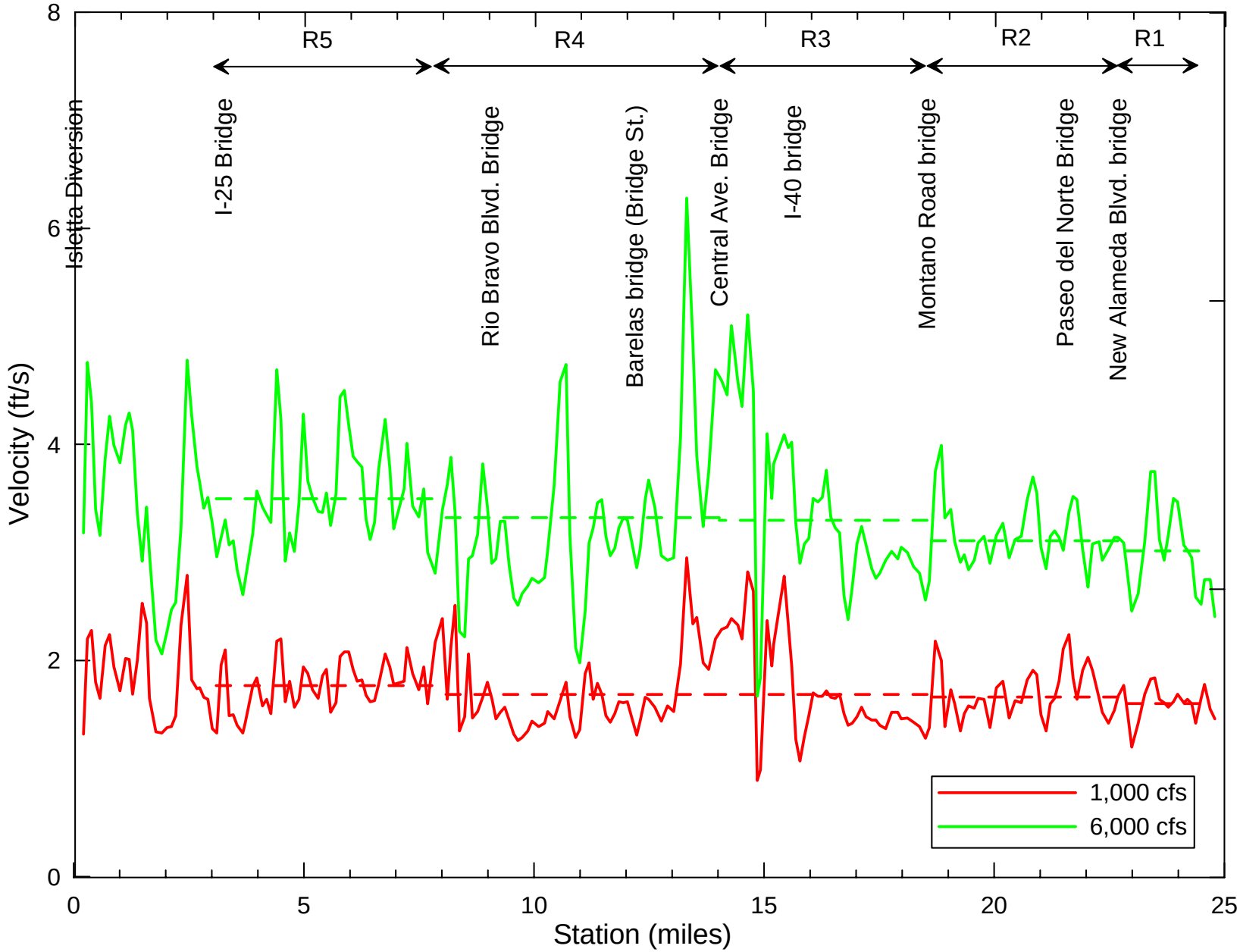

Figure 4.11. Channel velocities and reach-averaged velocities at 1,000 and 6,000 cfs.

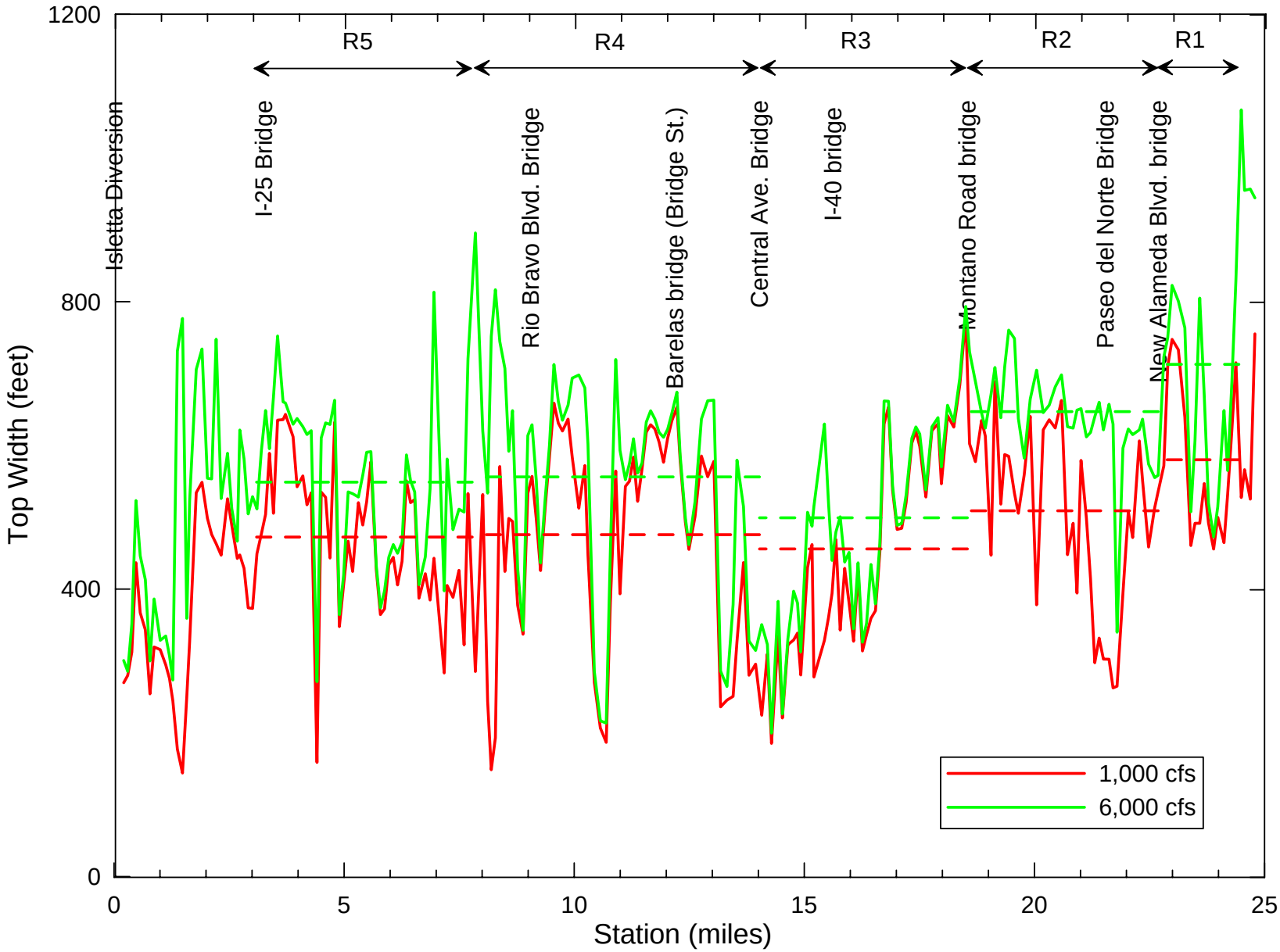

Figure 4.12. Channel topwidth and reach-averaged topwidth at 1,000 and 6,000 cfs.

5. SEDIMENT-CONTINUITY ANALYSIS

A baseline sediment continuity analysis was performed to evaluate the potential for aggradation or degradation in response to both individual short-term hydrographs 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. For this analysis, Hydrology Scenarios 2 and 3 (mean annual runoff and 10,000-cfs hydrographs, respectively) were used for the individual hydrographs, 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. As previously discussed, although the updated flood hydrology has not been completed at the time of this report, preliminary results indicate that the 100-year peak discharge may change from the 13,000 cfs presented in this report and a discussion of the effect of the revised frequency analysis will be presented in the final report.

The continuity analysis was performed by developing bed-material transport capacity rating curves for each subreach using Yang's (Sand) sediment-transport equation (Yang, 1973), integrating the rating curves over the individual hydrographs or the flow-duration curve to obtain a transported volume, and comparing the volumes with the estimated upstream and tributary supply from reach to reach. Where the transport capacity of a particular subreach exceeds the supply, the channel will respond by either degrading (i.e., channel downcutting) or coarsening its bed material, and where the supply exceeds the capacity, the channel will respond by aggrading or fining its bed material. It should be noted, however, that significant amounts of downcutting or aggradation can also lead to lateral instability. The upstream supply reach used for this study extends from the upstream limit of the project reach to Arroyo de la Baranca (located approximately 2 miles downstream of Bernalillo), a distance of approximately 29,000 feet.

In a previous study for the URGWOPS EIS, MEI (2004) evaluated a range of possible transport equations that were developed for conditions similar to those in the project reach, and determined that the Yang (Sand) equation (Yang, 1973) produced results that were the most consistent with the available measured data at the Rio Grande gages downstream from Cochiti Dam among the available equations. The bed-material transport capacity rating curves for each subreach were, therefore, developed using this equation with the reach-averaged hydraulics that were presented in the previous section and a representative bed-material gradation.

The representative bed-material gradations used in the analysis were taken from MEI (2004), with the gradation for URGWOPS Subreach 12a (Bernalillo to Rio Rancho Wastewater Treatment Plant) representing the supply reach and Subreach 12b (Rio Rancho to Isleta Diversion Dam) representing the primary study reach for this project (**Figure 5.1**).

These gradations were developed using data collected by the BOR and USGS after 1990 and by MEI for various studies in 2002 and 2003. Observations by the BOR indicate that fine material that is not characteristic of the typical bed material that controls the form of the channel tends to accumulate as a veneer over the primary bed material during the non-runoff season but is removed during the runoff season. To avoid biasing the results to this finer material, the data sets were restricted to samples that were collected between May 1 and August 31 because this is the period of highest flows when the fine material is not likely present.

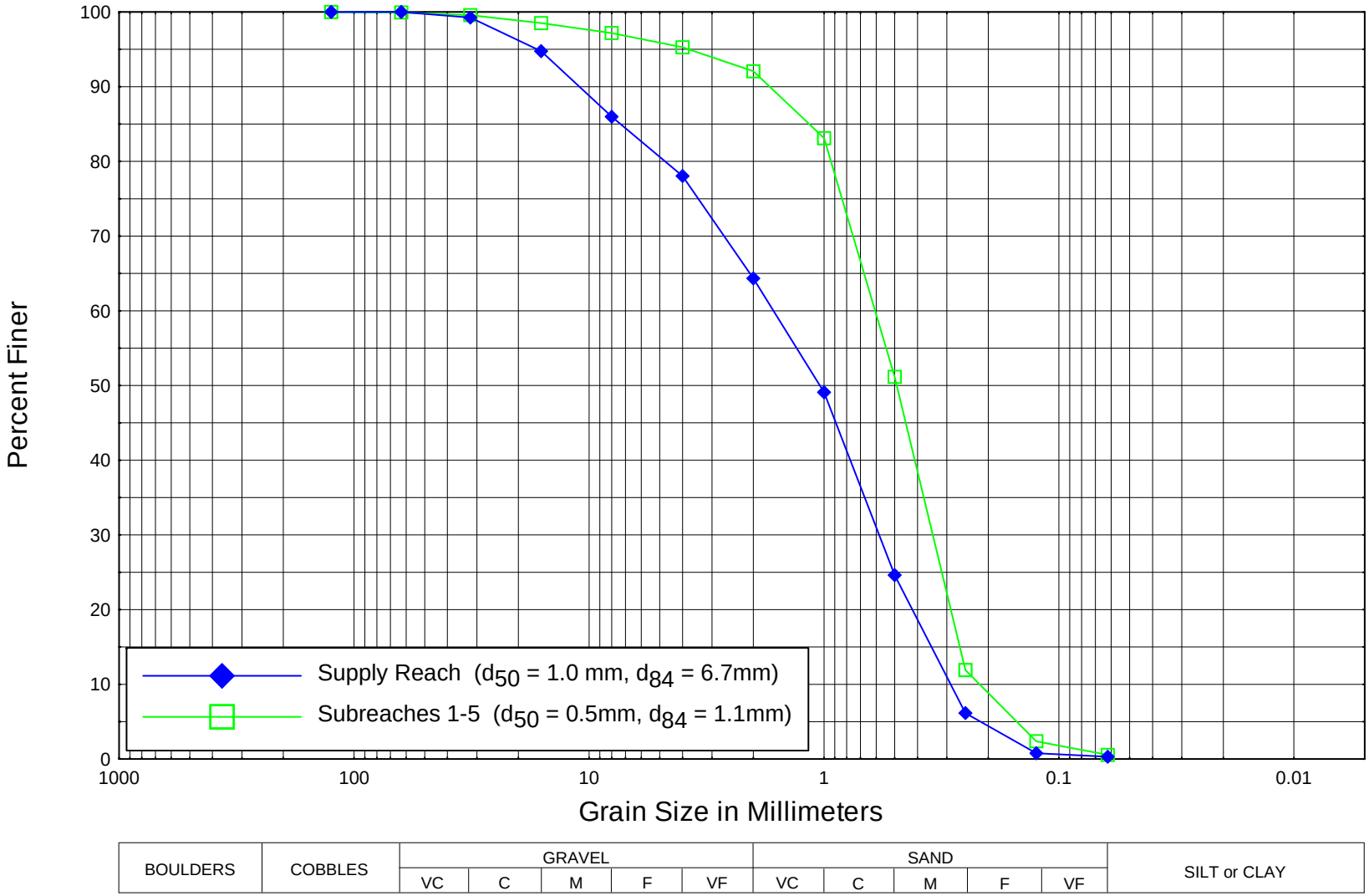

Figure 5.1. Representative bed-material gradation curve for the project reach that was used in the sediment-continuity analysis.

The bed-material gradations for the supply reach were based on a previous analysis of bed-material data collected at BOR Rangelines BB340 and BB345 in May 2001 (MEI, 2004). These data were used to develop a representative bed material gradation for Subreach 12a that is located between Bernalillo and Rio Rancho (**Figure 5.2**). The data set for the primary project reach consisted of 17 bed-material samples collected by the USGS at the Albuquerque gage between 1990 and 1996, and 16 samples collected by the BOR at Rangelines CA-1 to CA-13, A-1, A-4, A-6, and CR355, CR378 and CR443 between 1998 and 2001. The BOR data typically included several surface bed-material measurements along each range line. As a result, the samples collected at each range line were averaged to represent a single measurement location. The USGS samples also include several surface bed-material measurements collected along the cross section where their discharge measurements were collected. Similar to the BOR data, the samples collected along the cross section were averaged to represent a single measurement location. The project reach data set also included three bulk samples collected by MEI in July 2003 from exposed channel bars between Interstate 40 and Montano Boulevard that are representative of the surface bed material in this reach (MEI, 2003).

The supply reach gradation has a median size of about 1 mm (coarse sand), contains material up to about 128 mm, and about 42 percent of the material is in the gravel- and cobble-size range (Figure 5.1). The gradation for the primary project reach has a median size of 0.5 mm (medium and coarse sand), contains material up to about 32 mm, and about 92 percent of the material is sand.

To validate the general approach for estimating the transport capacity rating curves, a bed-material rating curve was developed using hydraulic results from the FLO-2D model for the main channel at Central Avenue gage and compared to measured values at the gage (**Figure 5.3**). The resulting rating curve aligns reasonably well with the measured data, indicating that the approach is appropriate. Rating curves based on the reach-averaged hydraulics for each of the subreaches are shown in **Figure 5.4**.

5.1. Tributary Bed-material Contributions

Three tributaries (Calabacillas Arroyo, North Diversion Channel, and South Diversion Channel) were identified along the study reach that have the capability to deliver significant quantities of sediment to the Rio Grande (**Table 5.1**). Sediment loads from the North Diversion Channel (NDC) were obtained from a study performed by the Corps Waterways Experiment Station (WES) to evaluate sedimentation conditions in the NDC (Copeland, 1995). The basic sediment supply information used by Copeland (1995) was developed from a study of the arroyos draining to the NDC that was performed by Mussetter and Harvey (1993). Due to the lack of available data for Calabacillas Arroyo and the South Diversion Channel (SDC), annual bed-material loads were estimated by assuming a unit bed-material supply of 0.1 ac-ft/mi^2, which is generally consistent with the range of unit yields from the tributaries for which information is available. Calabacillas Arroyo, the NDC and the SDC are ephemeral channels that flow in response to rainfall events. Historically, significant floods from Calabacillas Arroyo have formed a large fan at the confluence with the Rio Grande that have fully or partially blocked the river at various times. Large magnitude events in the arroyo, such as the 1941 and 1988 floods, caused the Calabacillas Arroyo fan to prograde into the Rio Grande. Development of the watershed, channelization of Calabacillas Arroyo and construction of Swinburne Dam (completed in 1991) has likely reduced the sediment load to the Rio Grande.

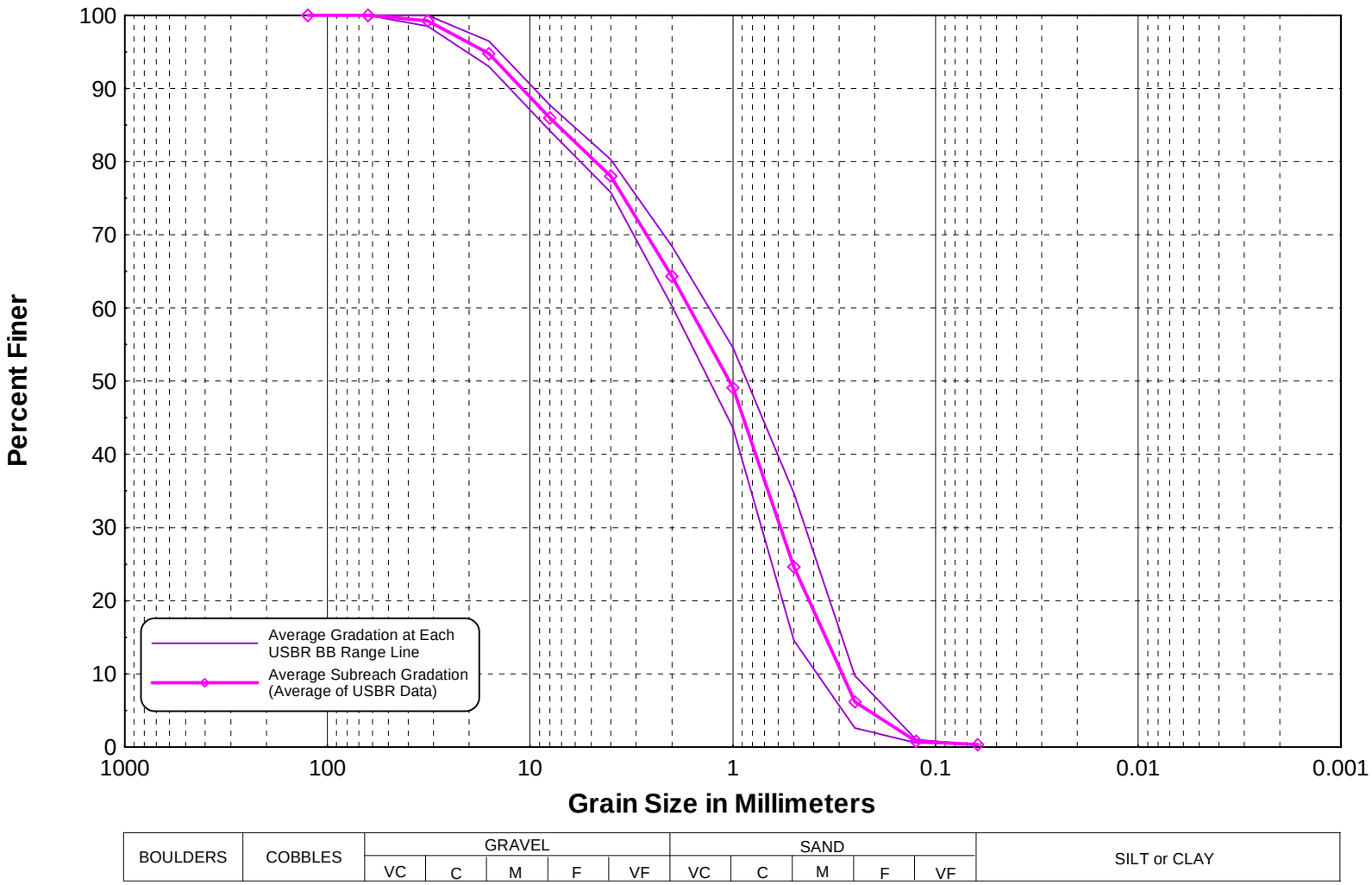

Figure 5.2. Representative bed-material gradation curve for the supply reach that was used in the sediment-continuity analysis.

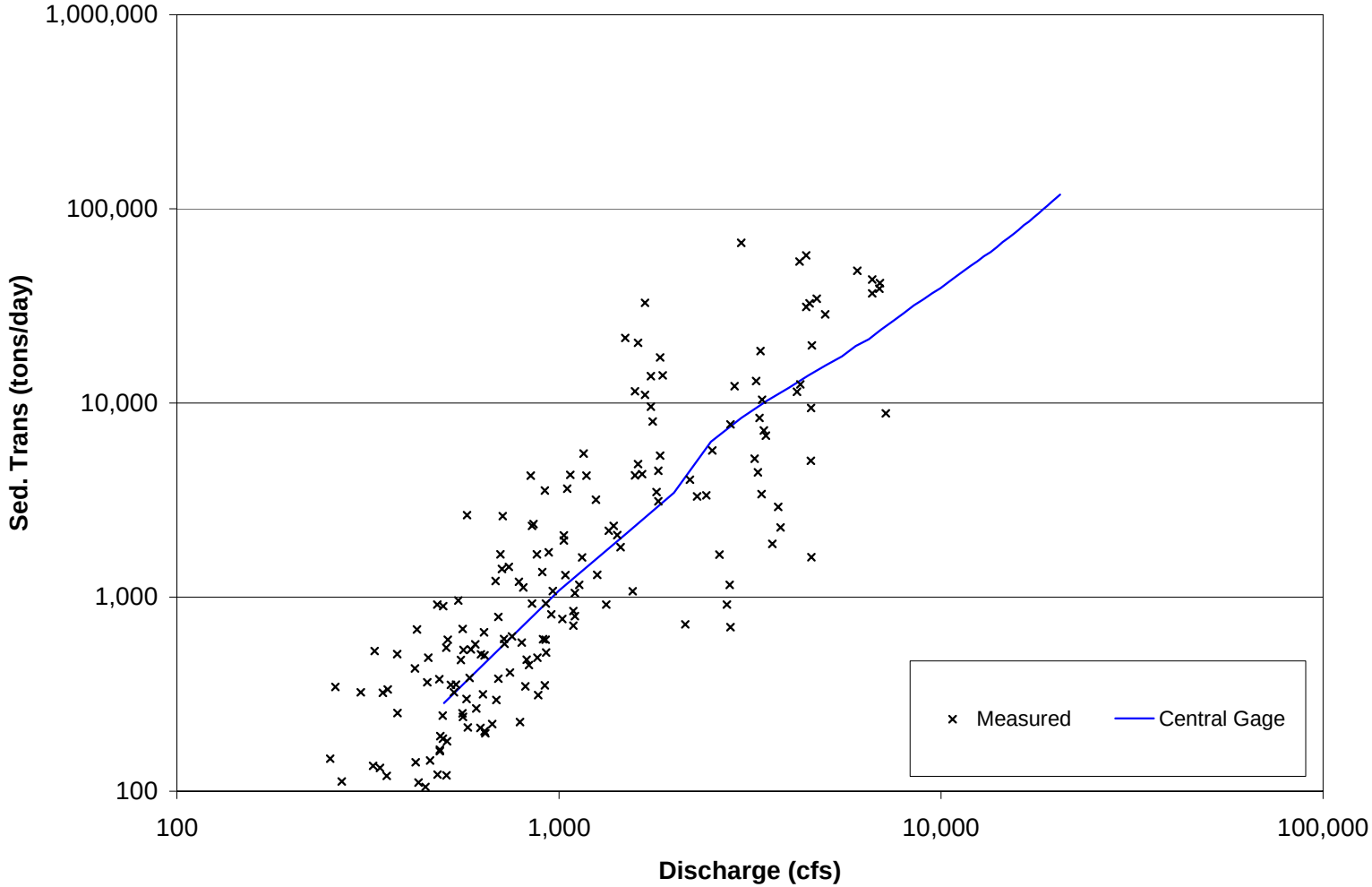

Figure 5.3. Bed-material rating curve at the Albuquerque gage developed using the Yang (Sand) (1973) relationship and measured bed-material loads at the Albuquerque gage.

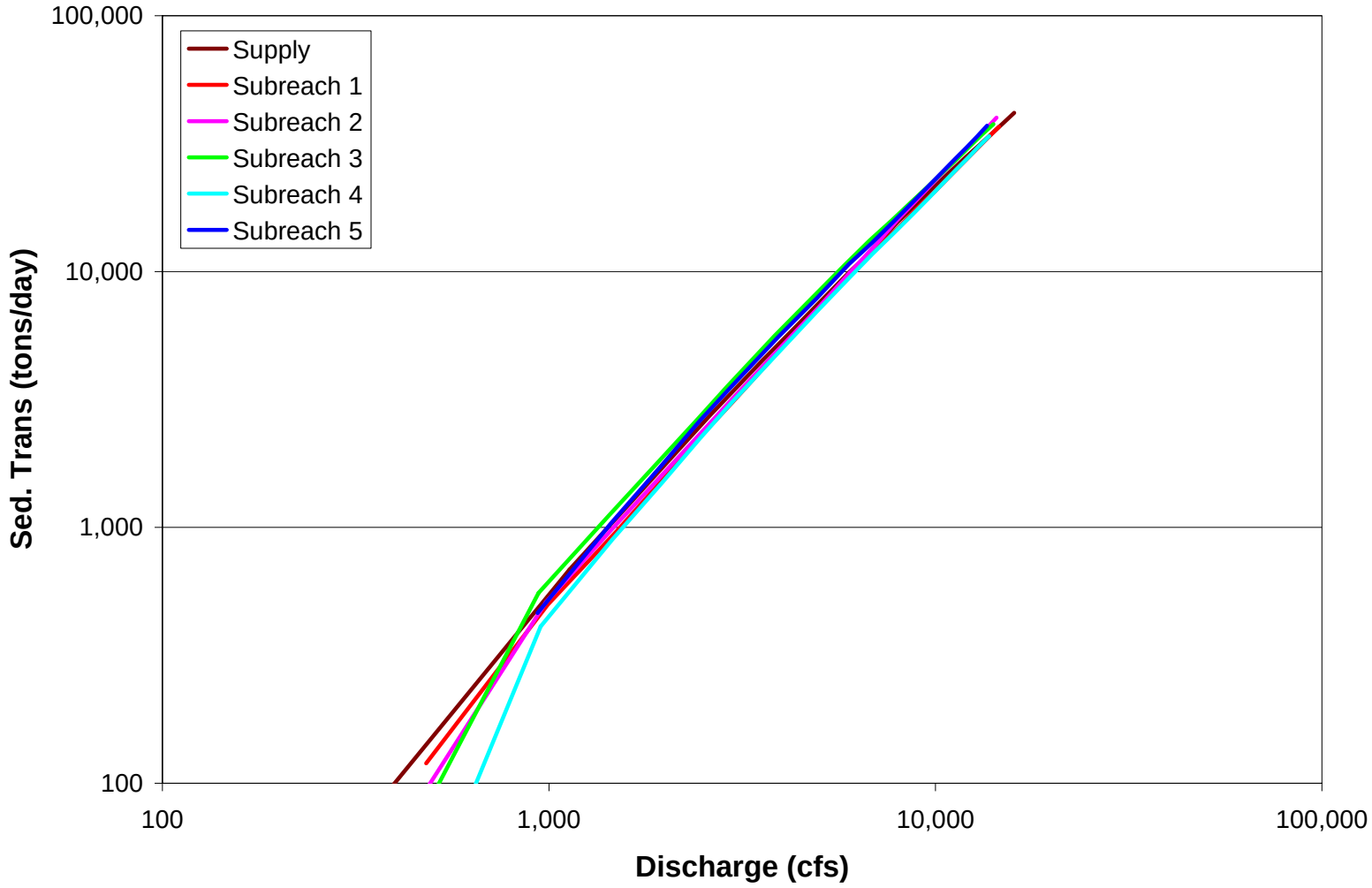

Figure 5.4. Bed-material rating curves for each of the subreaches in the sediment-continuity analysis.

Table 5.1. Summary of tributaries included in the sediment-continuity analysis, and the average annual bed-material contribution from each of the tributaries (modified from MEI (2004).				
Tributary Name	Drainage Area (mi^2)	Average Annual Sediment Volume (ac-ft)	Unit Volume (ac/mi^2)	Source
Calabacillas Arroyo	100.8	10.1	0.10	Assumed 0.1 $ac\text{-}ft/mi^2$
North Diversion Channel	102	8.3	0.08	Copeland (1995)
South Diversion Channel	133	13.3	0.10	Assumed 0.1 $ac\text{-}ft/mi^2$

5.2. Sediment-continuity Analysis Results

Integration of the hydrographs for Hydrology Scenarios 2 and 3 indicates that an average of about 100 ac-ft of sediment would be transported through the study reach during the mean annual hydrograph, and this increases to an average of about 450 ac-ft for the 10,000-cfs hydrograph (**Figures 5.5 and 5.6**). Based on integration of the annual flow-duration curve, the long-term, average annual bed-material load through the study reach is about 240 ac-ft (**Figure 5.7**). (This value is higher than obtained for the mean annual hydrograph because the flow-duration curve includes flows that exceed the mean annual flood peak.) The results shown in Figures 5.5 through 5.7 also indicate that the bed-material transport capacity is relatively consistent from subreach to subreach. For the average annual hydrograph, there is a net deficit of material to the study reach compared to the transport capacity, in the absence of tributary input (76 ac-ft supply versus 90 ac-ft capacity at the downstream end, Figure 5.5). For the 10,000-cfs hydrograph, there is also a net degradation tendency (404 ac-ft of supply versus 468 ac-ft capacity at the downstream end, Figure 5.6). (Note that tributary inputs were not considered for the mean annual and 10,000-cfs hydrographs because storms in the tributaries will most likely occur during the monsoon season in late-summer and early-fall, while the large runoff hydrographs in the river typically occur during the runoff period.) On a long-term average annual basis there is also a net degradational tendency (209 ac-ft supply versus 246 ac-ft capacity at the downstream end, Figure 5.7). Over time, Subreaches 1, 2 and 3 will probably respond to the deficit by coarsening of the bed material as these subreaches approach a balance between supply and capacity. This coarsening will decrease the supply to Subreach 4 which will create better balance between supply and capacity for Subreach 4, reducing the aggradation potential.

The approximate change in bed elevation (i.e., aggradation/degradation potential) associated with these differences in volume were estimated by dividing the difference between bed material supply and capacity of the subreach by the surface area of the channel, based on the product of the subreach length and channel topwidth (Table 4.4). In evaluating this information, it is important to note that the actual changes will not occur uniformly throughout the reach or across the channel at any given location, nor will they continue progressively for a long period of time because the bed material, channel geometry and gradient will adjust to compensate for imbalances between the sediment supply and transport capacity. In spite of this limitation, the analysis provides a reasonable basis for comparing results from the sediment-continuity analysis.

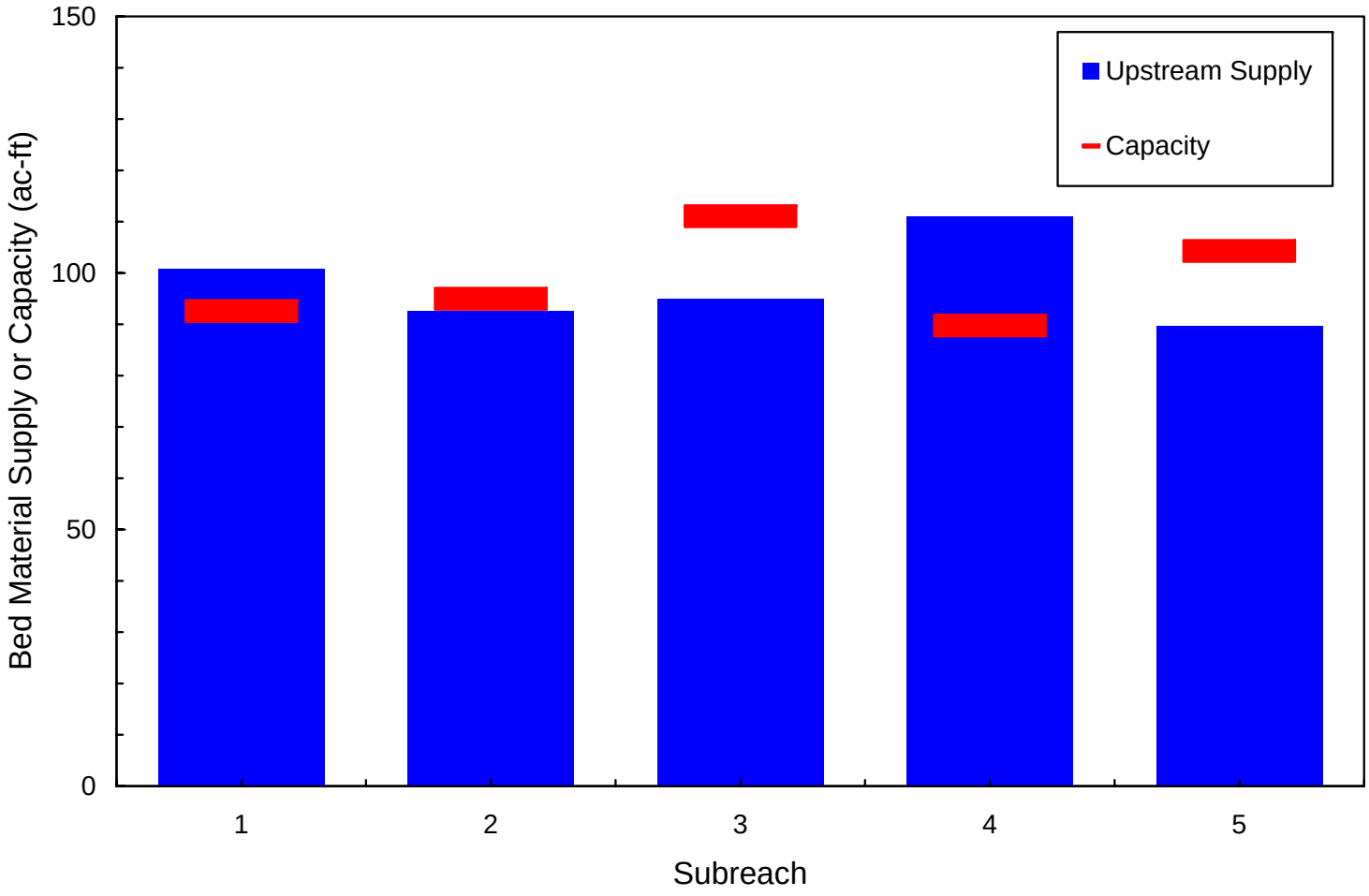

Figure 5.5. Comparison of average annual supply and bed-material transport capacity for each subreach.

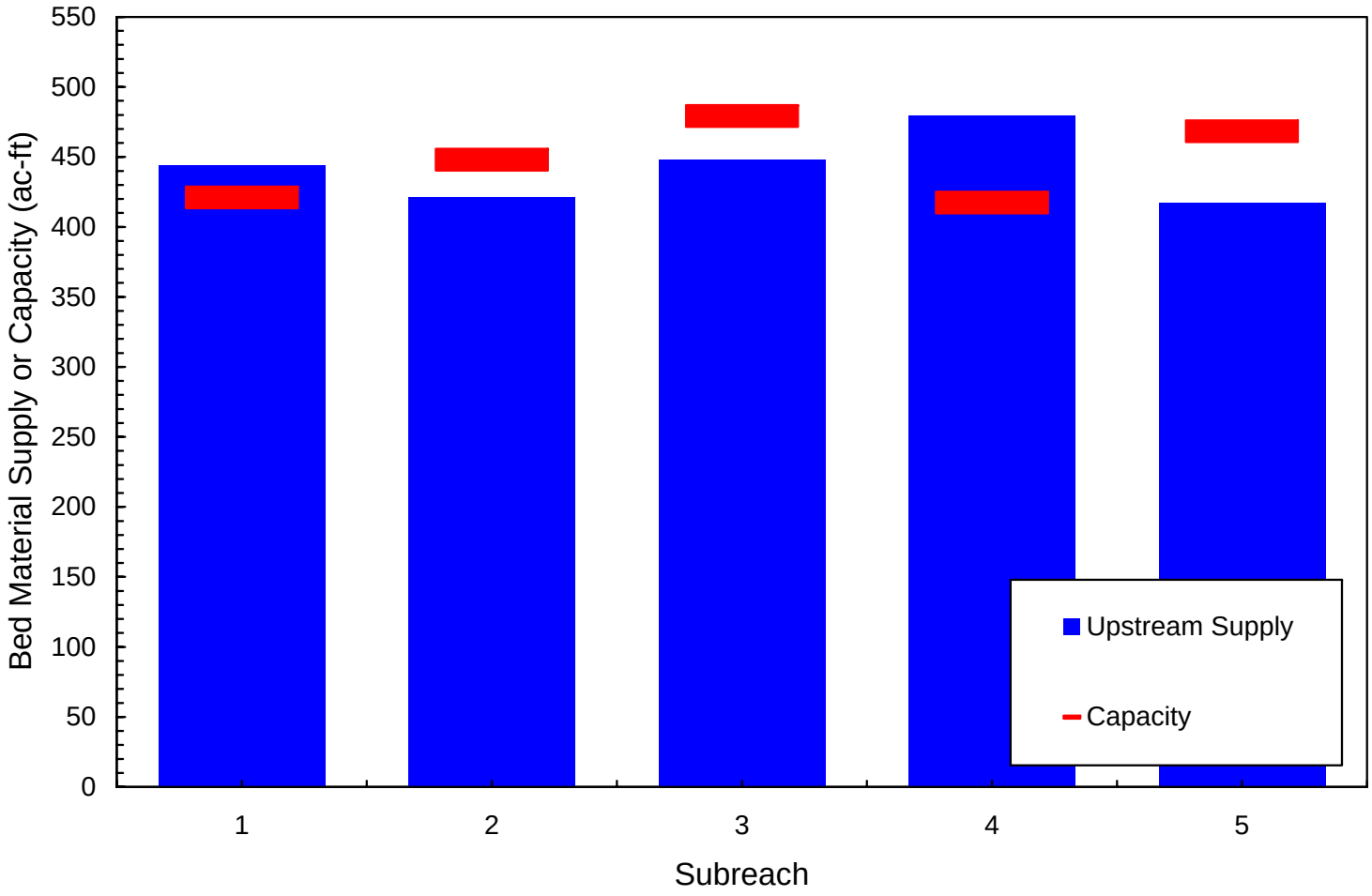

Figure 5.6. Comparison of supply and bed-material transport capacity for each subreach for the 10,000-cfs hydrograph.

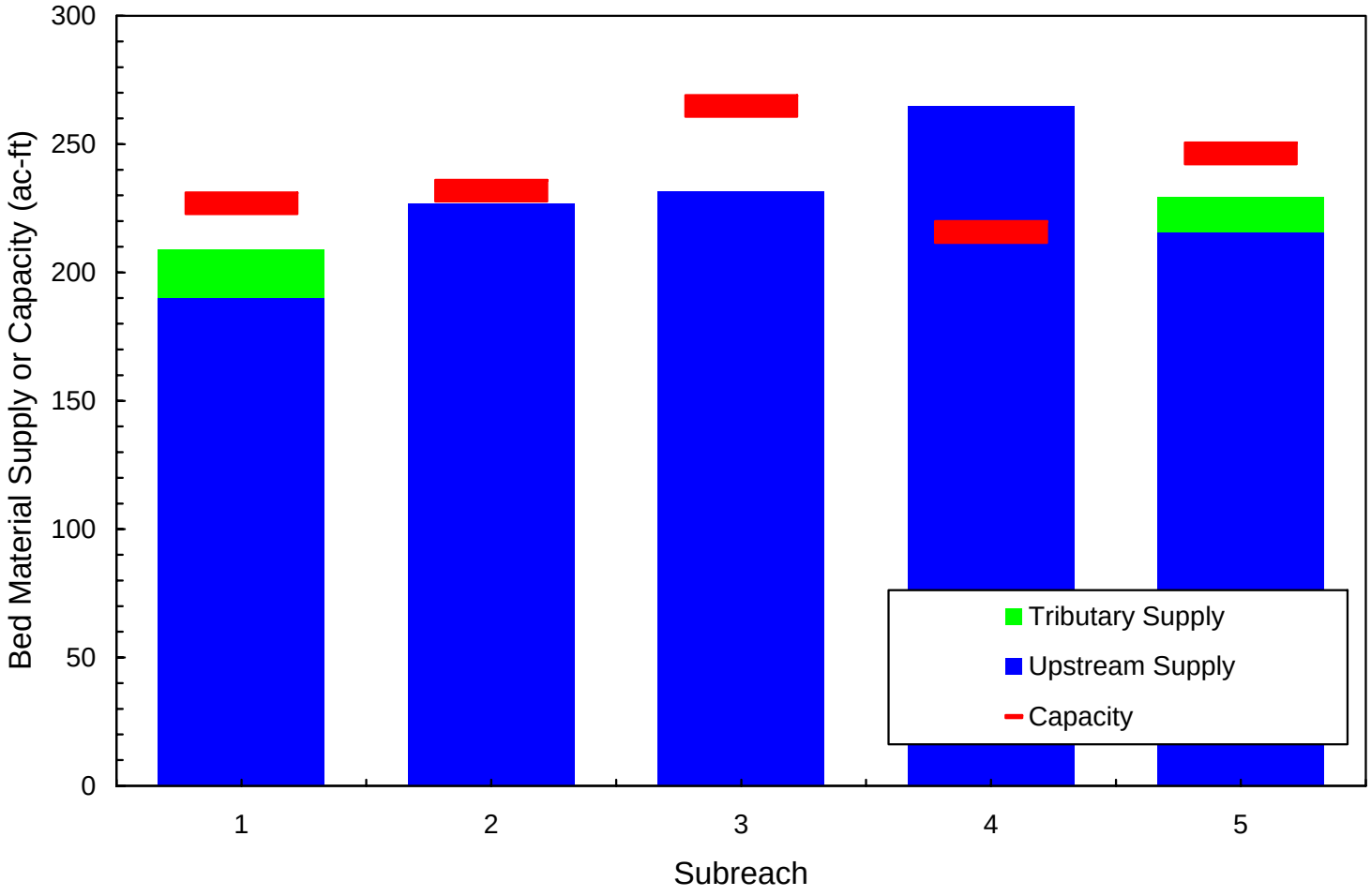

Figure 5.7. Comparison of supply and bed-material transport capacity for each subreach for the flow-duration curve.

For the average annual hydrograph, Subreaches 1, 2 and 5 are approximately in balance with the upstream supply (0.01, -0.01, and 0.00 feet, respectively) with no tributary inputs (**Figure 5.8**). The results for this hydrograph also indicate that Subreach 3 is net degradational (average depth of -0.06 feet) and Subreach 4 is net aggradational (average depth of about 0.05 feet). For the 10,000-cfs hydrograph, Subreaches 1, 2, 3 and 5 are net degradational (average of -0.1, -0.07, -0.11, and -0.15 feet, respectively), and Subreach 4 is net aggradational (average of about 0.13 feet) in the absence of tributary inputs (**Figure 5.9**). On a long-term, average annual basis, Subreaches 1, 3 and 5 are net degradational (average of -0.11, -0.11, 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 0.13 feet) with tributary inputs (**Figure 5.10**).

This indicates 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. As previously discussed however, the channel will also respond to the sediment imbalance by alterations in the bed-material gradation, and potentially width. As a result these estimates represent an upper limit, and the actual amount of aggradation/degradation will likely be much smaller.

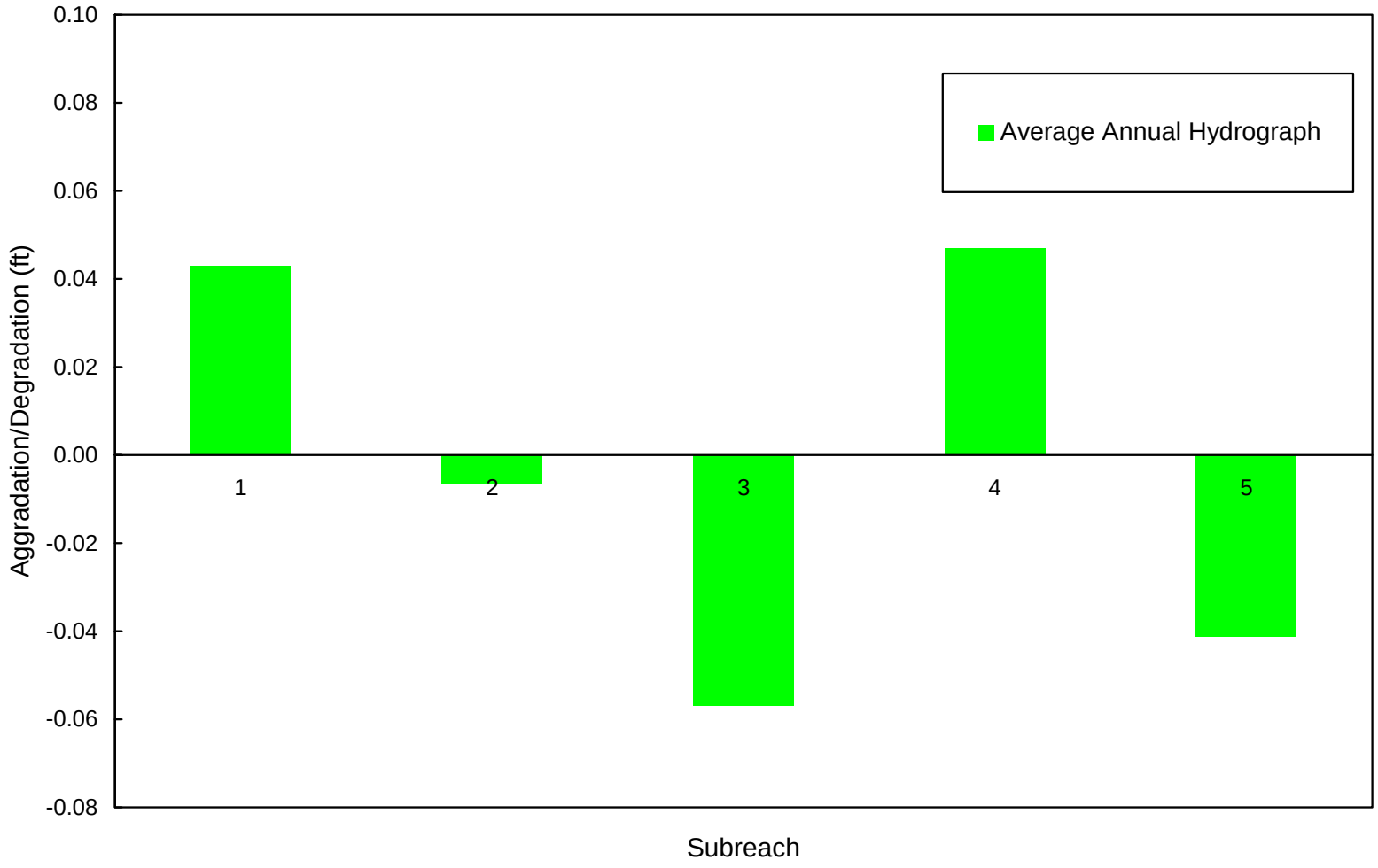

Figure 5.8. Computed average annual aggradation/degradation depths for each subreach.

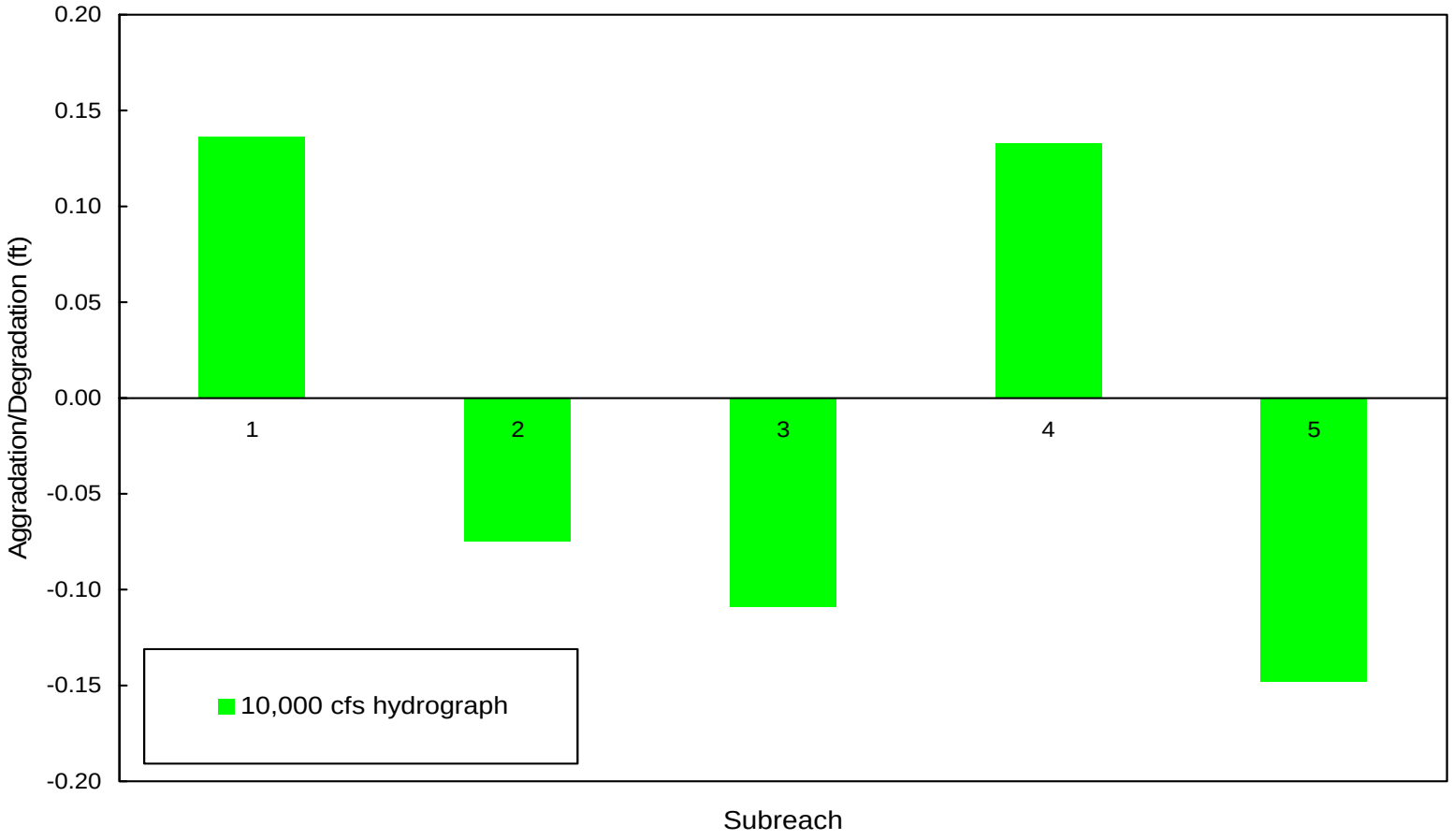

Figure 5.9. Computed aggradation/degradation depths for each subreach for the 10,000-cfs hydrograph.

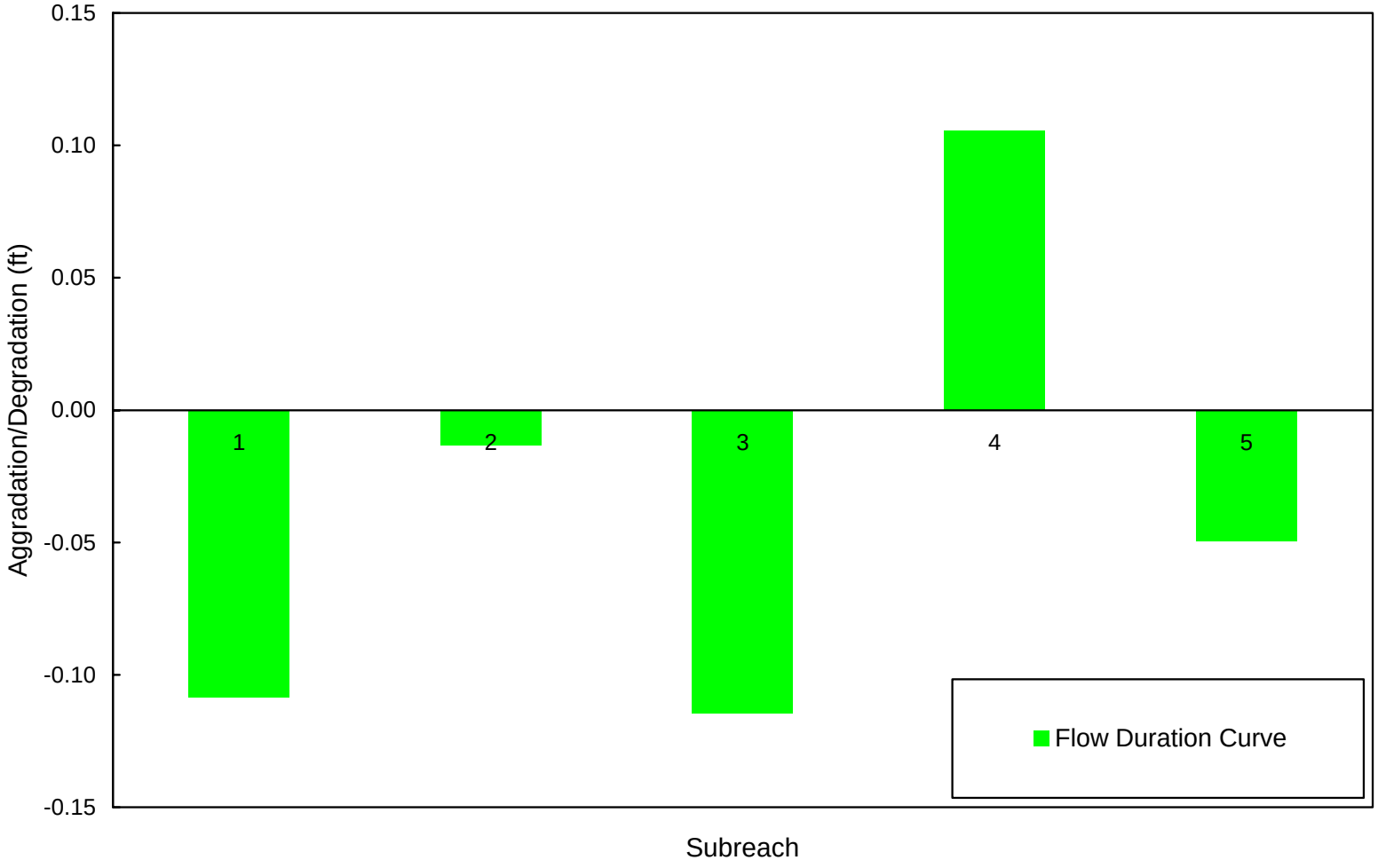

Figure 5.10. Computed aggradation/degradation depths for each subreach for the flow-duration curve.

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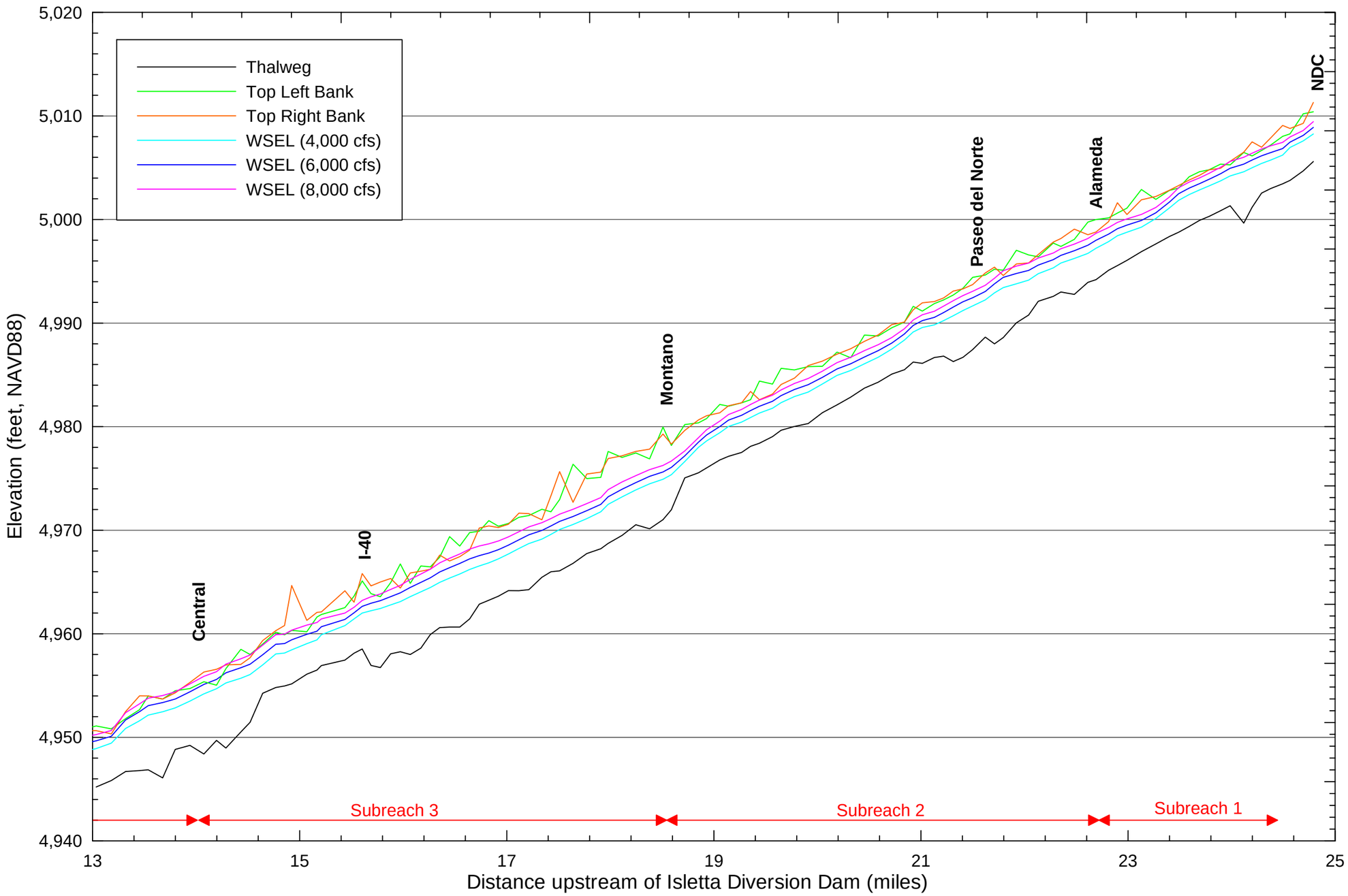
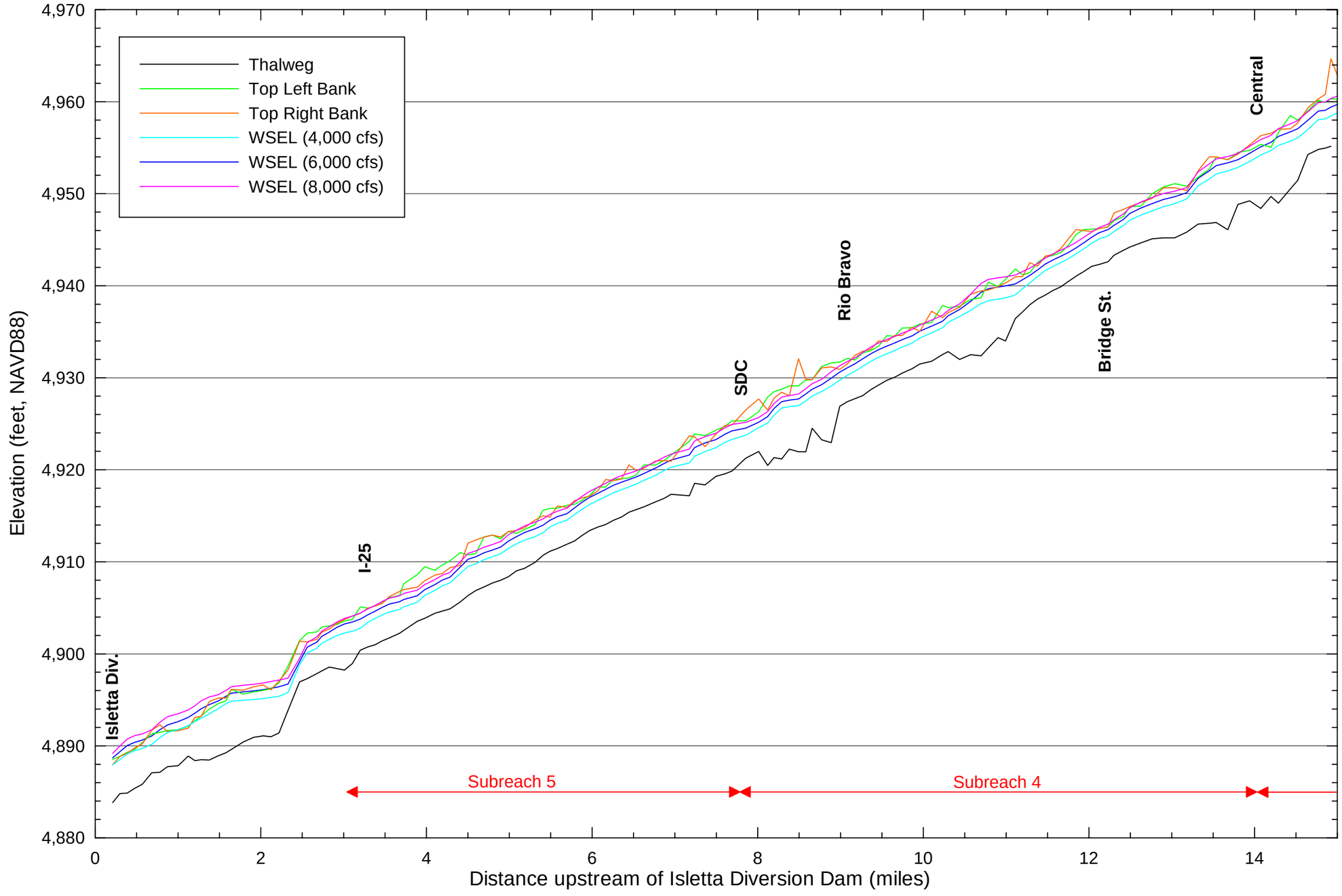
APPENDIX A

Thalweg, Top-of-bank, and Water-surface Profiles



Appendix A.1. Bed, top of bank and water-surface elevation profiles at 4,000, 6,000, and 8,000 cfs.



Appendix A.2. Bed, top of bank and water-surface elevation profiles at 4,000, 6,000, and 8,000 cfs.

Appendix A.3. Summary of bank, thalweg and water-surface elevations from 1,000 to 10,000 cfs.														
Element	Station (ft)	Thalweg Elevation (ft)	Bank Elevation (ft)		Water-surface elevation (ft)									
			Left	Right	1,000 cfs	2,000 cfs	3,000 cfs	4,000 cfs	5,000 cfs	6,000 cfs	7,000 cfs	8,000 cfs	9,000 cfs	10,000 cfs
2076	129,325	5003.45	5008.03	5009.08	5004.85	5005.42	5005.84	5006.22	5006.55	5006.85	5007.15	5007.45	5007.73	5008.00
2105	128,719	5003.00	5007.20	5007.90	5004.25	5004.84	5005.32	5005.75	5006.12	5006.47	5006.80	5007.12	5007.42	5007.71
2104	128,246	5002.55	5006.67	5006.98	5003.87	5004.50	5004.99	5005.41	5005.80	5006.15	5006.49	5006.81	5007.11	5007.40
2103	127,764	5001.18	5006.14	5007.50	5003.40	5004.09	5004.58	5005.00	5005.39	5005.75	5006.08	5006.40	5006.70	5006.98
2102	127,340	4999.65	5006.48	5006.50	5002.98	5003.67	5004.17	5004.61	5005.00	5005.35	5005.69	5006.01	5006.31	5006.59
2130	126,645	5001.33	5005.27	5005.62	5002.58	5003.25	5003.77	5004.21	5004.60	5004.95	5005.29	5005.61	5005.91	5006.18
2129	126,156	5000.85	5005.35	5004.95	5002.11	5002.80	5003.29	5003.73	5004.09	5004.42	5004.74	5005.04	5005.33	5005.59
2156	125,568	5000.30	5004.80	5004.80	5001.70	5002.37	5002.83	5003.25	5003.59	5003.89	5004.18	5004.46	5004.73	5004.97
2155	125,082	4999.92	5004.62	5004.27	5001.28	5001.96	5002.42	5002.86	5003.17	5003.46	5003.75	5004.02	5004.27	5004.50
2154	124,557	4999.33	5004.13	5003.81	5000.86	5001.52	5001.98	5002.41	5002.73	5003.03	5003.33	5003.61	5003.86	5004.10
2153	124,015	4998.77	5003.04	5003.28	5000.44	5001.06	5001.48	5001.85	5002.18	5002.49	5002.79	5003.07	5003.32	5003.57
2152	123,546	4998.36	5002.81	5002.82	4999.83	5000.37	5000.76	5001.11	5001.41	5001.68	5001.93	5002.17	5002.41	5002.66
2179	122,855	4997.64	5001.94	5002.23	4998.97	4999.42	4999.77	5000.10	5000.38	5000.65	5000.91	5001.16	5001.41	5001.66
2205	122,120	4996.90	5002.90	5001.90	4997.99	4998.50	4998.90	4999.26	4999.60	4999.91	5000.20	5000.49	5000.77	5001.04
2233	121,382	4996.06	5001.10	5000.48	4997.37	4997.95	4998.39	4998.77	4999.13	4999.46	4999.77	5000.06	5000.35	5000.63
2262	120,898	4995.55	5000.62	5001.62	4997.05	4997.61	4998.05	4998.43	4998.78	4999.11	4999.42	4999.72	5000.02	5000.30
2291	120,445	4995.10	5000.16	4999.80	4996.45	4997.02	4997.47	4997.87	4998.25	4998.59	4998.92	4999.23	4999.54	4999.83
2320	119,810	4994.20	5000.00	4998.80	4995.65	4996.28	4996.78	4997.23	4997.64	4998.00	4998.35	4998.67	4998.99	4999.28
2350	119,392	4993.93	4999.75	4998.53	4995.04	4995.73	4996.26	4996.73	4997.16	4997.52	4997.85	4998.17	4998.49	4998.77
2380	118,701	4992.77	4998.08	4999.07	4994.61	4995.27	4995.79	4996.24	4996.65	4996.99	4997.32	4997.63	4997.96	4998.23
2409	118,014	4993.00	4997.40	4998.17	4994.29	4994.89	4995.37	4995.80	4996.19	4996.54	4996.87	4997.18	4997.49	4997.76
2439	117,620	4992.58	4997.73	4997.82	4993.81	4994.41	4994.89	4995.33	4995.76	4996.12	4996.45	4996.76	4997.07	4997.33
2469	116,865	4992.11	4996.40	4996.62	4993.25	4993.84	4994.32	4994.77	4995.22	4995.60	4995.96	4996.28	4996.58	4996.85
2501	116,369	4990.78	4996.58	4995.81	4992.39	4993.07	4993.61	4994.15	4994.66	4995.09	4995.46	4995.79	4996.11	4996.39
2533	115,741	4990.02	4997.03	4995.71	4991.43	4992.43	4993.13	4993.79	4994.36	4994.79	4995.17	4995.50	4995.80	4996.08
2565	115,077	4988.60	4995.10	4994.60	4990.91	4991.97	4992.73	4993.43	4993.99	4994.41	4994.76	4995.05	4995.33	4995.58
2597	114,626	4988.00	4995.20	4995.40	4990.69	4991.66	4992.32	4992.92	4993.39	4993.79	4994.08	4994.33	4994.57	4994.80
2630	114,158	4988.64	4994.64	4994.84	4990.36	4991.26	4991.77	4992.24	4992.66	4993.05	4993.38	4993.65	4993.90	4994.14
2665	113,513	4987.44	4994.41	4993.72	4989.69	4990.60	4991.15	4991.66	4992.10	4992.45	4992.79	4993.07	4993.33	4993.59
2700	113,020	4986.69	4993.36	4993.30	4989.11	4990.04	4990.66	4991.21	4991.71	4992.06	4992.38	4992.65	4992.92	4993.19
2735	112,525	4986.29	4992.71	4993.09	4988.79	4989.62	4990.21	4990.71	4991.20	4991.55	4991.88	4992.16	4992.42	4992.69
2770	112,034	4986.81	4992.24	4992.43	4988.50	4989.22	4989.79	4990.24	4990.66	4991.02	4991.36	4991.64	4991.90	4992.15
2806	111,559	4986.68	4991.88	4992.08	4988.12	4988.84	4989.40	4989.83	4990.21	4990.55	4990.87	4991.14	4991.41	4991.66
2841	110,948	4986.11	4991.16	4991.96	4987.88	4988.60	4989.15	4989.57	4989.94	4990.24	4990.54	4990.80	4991.06	4991.31
2877	110,486	4986.24	4991.62	4991.28	4987.56	4988.23	4988.76	4989.14	4989.49	4989.77	4990.05	4990.30	4990.56	4990.80
2912	110,034	4985.50	4990.10	4990.10	4986.92	4987.53	4988.00	4988.36	4988.67	4988.95	4989.21	4989.46	4989.71	4989.95
2946	109,390	4985.07	4989.55	4989.86	4986.20	4986.73	4987.16	4987.49	4987.79	4988.07	4988.34	4988.60	4988.84	4989.07
2979	108,701	4984.29	4988.75	4988.86	4985.44	4985.94	4986.35	4986.70	4987.03	4987.34	4987.63	4987.91	4988.16	4988.41
3012	107,998	4983.72	4988.84	4988.24	4984.75	4985.26	4985.69	4986.07	4986.42	4986.73	4987.05	4987.34	4987.59	4987.84
3045	107,297	4982.85	4986.65	4987.52	4983.96	4984.53	4985.01	4985.42	4985.76	4986.07	4986.40	4986.70	4986.95	4987.21
3079	106,600	4982.10	4987.20	4987.00	4983.43	4984.02	4984.53	4984.95	4985.27	4985.57	4985.90	4986.18	4986.42	4986.67
3113	105,855	4981.35	4985.83	4986.33	4982.59	4983.20	4983.70	4984.12	4984.45	4984.76	4985.08	4985.36	4985.62	4985.88
3146	105,128	4980.30	4985.80	4985.90	4981.83	4982.46	4982.94	4983.34	4983.72	4984.05	4984.36	4984.65	4984.93	4985.21
3180	104,427	4980.02	4985.48	4984.68	4981.42	4982.06	4982.51	4982.91	4983.27	4983.59	4983.88	4984.17	4984.44	4984.69
3214	103,748	4979.65	4985.63	4984.07	4980.82	4981.47	4981.92	4982.32	4982.70	4983.00	4983.28	4983.55	4983.82	4984.05
3249	103,308	4979.04	4984.11	4983.15	4980.31	4980.93	4981.39	4981.78	4982.15	4982.45	4982.75	4983.04	4983.29	4983.52
3284	102,642	4978.40	4984.40	4982.60	4979.85	4980.46	4980.93	4981.31	4981.65	4981.97	4982.27	4982.57	4982.83	4983.07
3319	102,188	4978.10	4982.60	4983.40	4979.35	4979.99	4980.48	4980.88	4981.24	4981.55	4981.85	4982.14	4982.40	4982.64
3355	101,735	4977.51	4982.30	4982.30	4978.95	4979.59	4980.05	4980.44	4980.79	4981.10	4981.39	4981.66	4981.91	4982.15

Appendix A.3. Summary of bank, thalweg and water-surface elevations from 1,000 to 10,000 cfs (continued).														
Element	Station (ft)	Thalweg Elevation (ft)	Bank Elevation (ft)		Water-surface elevation (ft)									
			Left	Right	1,000 cfs	2,000 cfs	3,000 cfs	4,000 cfs	5,000 cfs	6,000 cfs	7,000 cfs	8,000 cfs	9,000 cfs	10,000 cfs
3390	101,071	4977.14	4981.98	4982.02	4978.59	4979.22	4979.66	4980.02	4980.34	4980.63	4980.91	4981.17	4981.41	4981.64
3427	100,619	4976.78	4982.14	4981.34	4978.01	4978.62	4979.05	4979.41	4979.72	4980.01	4980.27	4980.53	4980.76	4980.99
3463	99,952	4976.02	4980.78	4981.06	4977.31	4977.86	4978.28	4978.62	4978.93	4979.20	4979.46	4979.70	4979.92	4980.14
3501	99,531	4975.54	4980.37	4980.65	4976.89	4977.35	4977.72	4978.00	4978.26	4978.50	4978.72	4978.93	4979.13	4979.32
3538	98,838	4975.05	4980.20	4979.64	4975.65	4976.00	4976.34	4976.63	4976.90	4977.18	4977.43	4977.65	4977.85	4978.06
3575	98,151	4971.97	4978.18	4978.32	4974.00	4974.54	4974.97	4975.36	4975.71	4976.07	4976.39	4976.68	4976.94	4977.20
3613	97,727	4971.02	4979.96	4979.29	4973.51	4974.08	4974.53	4974.92	4975.28	4975.63	4975.95	4976.26	4976.55	4976.82
3650	97,043	4970.14	4976.89	4977.83	4973.04	4973.61	4974.08	4974.48	4974.85	4975.20	4975.53	4975.85	4976.14	4976.41
3687	96,341	4970.53	4977.46	4977.61	4972.44	4973.02	4973.49	4973.89	4974.26	4974.60	4974.94	4975.27	4975.55	4975.82
3724	95,635	4969.50	4977.03	4977.19	4971.75	4972.34	4972.82	4973.22	4973.60	4973.96	4974.31	4974.66	4974.94	4975.21
3761	94,932	4968.73	4977.60	4976.92	4971.03	4971.63	4972.10	4972.50	4972.88	4973.23	4973.58	4973.92	4974.20	4974.48
3799	94,552	4968.21	4975.10	4975.61	4970.36	4970.91	4971.37	4971.78	4972.15	4972.50	4972.83	4973.15	4973.46	4973.76
3836	93,839	4967.75	4974.99	4975.43	4969.60	4970.20	4970.70	4971.12	4971.52	4971.89	4972.24	4972.57	4972.89	4973.21
3873	93,137	4966.80	4976.37	4972.70	4968.96	4969.61	4970.12	4970.55	4970.95	4971.33	4971.68	4972.02	4972.35	4972.67
3912	92,454	4966.08	4972.96	4975.66	4968.53	4969.14	4969.64	4970.07	4970.47	4970.85	4971.20	4971.55	4971.88	4972.21
3950	92,010	4965.99	4971.78	4973.33	4968.04	4968.65	4969.16	4969.60	4970.02	4970.41	4970.77	4971.13	4971.48	4971.81
3987	91,550	4965.46	4972.02	4971.01	4967.49	4968.14	4968.68	4969.14	4969.58	4969.98	4970.36	4970.73	4971.08	4971.42
4023	90,883	4964.26	4971.42	4971.60	4967.00	4967.68	4968.24	4968.71	4969.15	4969.56	4969.95	4970.32	4970.67	4971.02
4059	90,376	4964.16	4971.25	4971.65	4966.56	4967.23	4967.78	4968.24	4968.67	4969.08	4969.48	4969.86	4970.21	4970.56
4095	89,846	4964.17	4970.65	4970.58	4966.06	4966.72	4967.25	4967.71	4968.15	4968.56	4968.97	4969.36	4969.72	4970.08
4131	89,330	4963.63	4970.39	4970.26	4965.63	4966.25	4966.76	4967.23	4967.69	4968.12	4968.55	4968.96	4969.33	4969.69
4167	88,847	4963.24	4970.93	4970.41	4965.15	4965.78	4966.34	4966.85	4967.34	4967.80	4968.25	4968.69	4969.07	4969.44
4203	88,355	4962.86	4969.91	4970.21	4964.64	4965.37	4966.00	4966.55	4967.06	4967.55	4968.02	4968.48	4968.87	4969.24
4239	87,862	4961.44	4969.77	4968.08	4964.12	4964.96	4965.63	4966.21	4966.74	4967.23	4967.71	4968.18	4968.57	4968.95
4275	87,364	4960.65	4968.47	4967.45	4963.61	4964.50	4965.19	4965.77	4966.30	4966.79	4967.25	4967.71	4968.10	4968.47
4309	86,843	4960.65	4969.38	4967.03	4963.20	4964.11	4964.81	4965.38	4965.91	4966.39	4966.85	4967.29	4967.69	4968.06
4343	86,339	4960.60	4967.40	4967.60	4962.81	4963.70	4964.40	4964.97	4965.50	4965.97	4966.42	4966.85	4967.24	4967.61
4377	85,862	4959.93	4966.46	4966.23	4962.41	4963.26	4963.93	4964.47	4964.96	4965.41	4965.83	4966.24	4966.61	4966.95
4410	85,377	4958.62	4966.55	4966.05	4961.98	4962.85	4963.51	4964.05	4964.53	4964.97	4965.39	4965.77	4966.14	4966.47
4443	84,839	4958.00	4964.87	4965.87	4961.52	4962.42	4963.07	4963.59	4964.06	4964.48	4964.87	4965.26	4965.60	4965.93
4477	84,333	4958.27	4966.74	4964.42	4961.07	4961.95	4962.61	4963.11	4963.55	4963.95	4964.32	4964.68	4965.01	4965.33
4511	83,842	4958.07	4964.94	4965.34	4960.74	4961.64	4962.30	4962.79	4963.21	4963.59	4963.94	4964.29	4964.61	4964.92
4543	83,311	4956.74	4963.58	4965.00	4960.56	4961.39	4961.98	4962.44	4962.84	4963.20	4963.53	4963.85	4964.15	4964.45
4576	82,836	4956.95	4963.88	4964.63	4960.48	4961.27	4961.81	4962.23	4962.61	4962.95	4963.27	4963.57	4963.86	4964.14
4609	82,390	4958.53	4965.11	4965.81	4960.35	4961.12	4961.61	4962.00	4962.34	4962.65	4962.94	4963.22	4963.50	4963.77
4642	81,972	4958.13	4963.64	4963.05	4959.91	4960.66	4961.10	4961.44	4961.74	4962.03	4962.29	4962.56	4962.83	4963.10
4676	81,506	4957.46	4962.53	4964.15	4959.25	4960.02	4960.46	4960.79	4961.09	4961.39	4961.69	4962.00	4962.31	4962.60
4710	80,305	4956.93	4961.86	4962.11	4958.29	4959.00	4959.51	4959.91	4960.30	4960.68	4961.06	4961.44	4961.81	4962.12
4743	80,084	4956.50	4961.62	4962.07	4957.82	4958.46	4958.97	4959.41	4959.84	4960.25	4960.67	4961.09	4961.48	4961.78
4777	79,564	4956.10	4960.20	4961.30	4957.35	4958.04	4958.58	4959.05	4959.51	4959.95	4960.40	4960.84	4961.24	4961.54
4812	78,791	4955.16	4960.33	4964.66	4956.63	4957.35	4957.94	4958.45	4958.95	4959.42	4959.88	4960.35	4960.77	4961.08
4846	78,430	4954.96	4959.90	4960.80	4956.44	4957.11	4957.65	4958.14	4958.61	4959.06	4959.51	4959.97	4960.38	4960.69
4847	77,983	4954.81	4960.15	4960.30	4956.35	4957.01	4957.56	4958.05	4958.54	4958.99	4959.45	4959.91	4960.33	4960.63
4883	77,316	4954.26	4959.01	4959.35	4955.14	4955.85	4956.46	4957.00	4957.51	4957.98	4958.45	4958.91	4959.32	4959.62
4920	76,672	4951.45	4958.00	4957.69	4953.98	4954.85	4955.52	4956.07	4956.59	4957.06	4957.54	4957.95	4958.31	4958.60
4956	76,199	4950.52	4958.50	4957.05	4953.56	4954.45	4955.15	4955.71	4956.25	4956.72	4957.20	4957.59	4957.94	4958.24
4994	75,437	4948.97	4956.63	4957.00	4953.09	4953.98	4954.70	4955.25	4955.77	4956.23	4956.69	4957.07	4957.41	4957.71
4995	74,963	4949.71	4955.04	4956.57	4952.62	4953.49	4954.21	4954.70	4955.17	4955.59	4956.00	4956.34	4956.65	4956.94
5032	74,317	4948.40	4955.37	4956.31	4952.12	4952.98	4953.69	4954.20	4954.68	4955.11	4955.53	4955.89	4956.20	4956.51
5069	73,602	4949.23	4954.71	4955.30	4951.56	4952.37	4952.98	4953.50	4953.98	4954.40	4954.80	4955.16	4955.45	4955.73
5105	72,855	4948.84	4954.50	4954.30	4951.01	4951.80	4952.36	4952.85	4953.29	4953.70	4954.07	4954.39	4954.66	4954.91
5139	72,213	4946.09	4953.70	4953.70	4950.58	4951.39	4951.95	4952.47	4952.94	4953.36	4953.72	4954.04	4954.33	4954.59

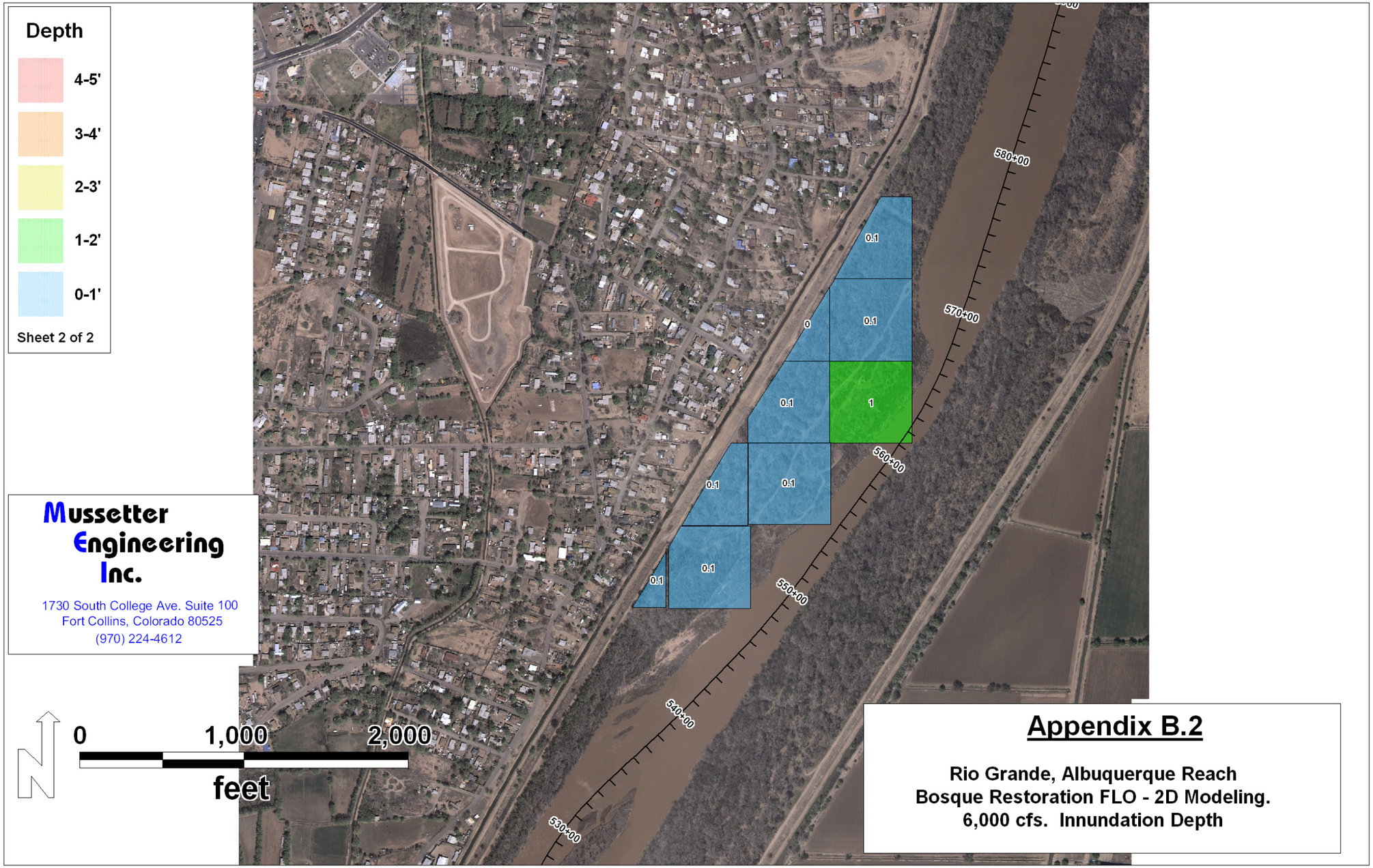
Appendix A.3. Summary of bank, thalweg and water-surface elevations from 1,000 to 10,000 cfs (continued).														
Element	Station (ft)	Thalweg Elevation (ft)	Bank Elevation (ft)		Water-surface elevation (ft)									
			Left	Right	1,000 cfs	2,000 cfs	3,000 cfs	4,000 cfs	5,000 cfs	6,000 cfs	7,000 cfs	8,000 cfs	9,000 cfs	10,000 cfs
5172	71,473	4946.87	4954.00	4954.00	4950.10	4950.94	4951.59	4952.15	4952.63	4953.06	4953.44	4953.78	4954.08	4954.36
5203	71,030	4946.79	4952.67	4954.01	4949.49	4950.34	4951.02	4951.60	4952.06	4952.48	4952.89	4953.24	4953.55	4953.84
5236	70,323	4946.70	4951.81	4952.49	4949.06	4949.81	4950.38	4950.86	4951.29	4951.68	4952.06	4952.38	4952.67	4952.93
5268	69,595	4945.83	4950.82	4950.34	4947.98	4948.59	4949.05	4949.44	4949.80	4950.11	4950.40	4950.66	4950.89	4951.12
5298	68,827	4945.21	4951.10	4950.65	4947.43	4948.03	4948.50	4948.92	4949.31	4949.67	4949.98	4950.27	4950.53	4950.78
5328	68,105	4945.21	4950.73	4950.65	4947.04	4947.66	4948.16	4948.59	4948.99	4949.38	4949.72	4950.02	4950.30	4950.56
5358	67,395	4945.10	4950.00	4949.50	4946.49	4947.17	4947.70	4948.14	4948.55	4948.93	4949.29	4949.60	4949.89	4950.14
5389	66,668	4944.65	4948.65	4949.05	4946.03	4946.72	4947.25	4947.68	4948.08	4948.45	4948.80	4949.10	4949.39	4949.64
5421	65,962	4944.20	4948.60	4948.60	4945.57	4946.21	4946.71	4947.12	4947.50	4947.85	4948.17	4948.47	4948.74	4948.99
5422	65,560	4943.85	4947.52	4948.30	4945.11	4945.70	4946.16	4946.54	4946.89	4947.22	4947.53	4947.82	4948.08	4948.31
5455	64,955	4943.32	4947.08	4947.91	4944.48	4945.05	4945.51	4945.89	4946.24	4946.57	4946.88	4947.16	4947.42	4947.66
5486	64,577	4942.61	4946.40	4946.40	4943.99	4944.59	4945.04	4945.42	4945.77	4946.10	4946.41	4946.70	4946.97	4947.21
5519	63,988	4942.30	4946.20	4946.20	4943.68	4944.25	4944.70	4945.07	4945.42	4945.74	4946.04	4946.32	4946.60	4946.84
5552	63,524	4942.11	4946.15	4945.89	4943.25	4943.81	4944.24	4944.61	4944.95	4945.26	4945.55	4945.84	4946.12	4946.36
5586	63,041	4941.56	4946.10	4945.99	4942.70	4943.24	4943.67	4944.04	4944.37	4944.69	4944.99	4945.28	4945.56	4945.81
5620	62,550	4941.05	4945.60	4946.11	4942.14	4942.67	4943.10	4943.47	4943.81	4944.13	4944.43	4944.73	4945.01	4945.26
5654	62,054	4940.48	4944.41	4945.10	4941.55	4942.11	4942.56	4942.94	4943.29	4943.62	4943.94	4944.25	4944.53	4944.78
5688	61,556	4939.88	4943.60	4944.05	4941.08	4941.66	4942.13	4942.51	4942.87	4943.20	4943.53	4943.85	4944.13	4944.39
5723	61,062	4939.49	4943.30	4943.40	4940.69	4941.27	4941.73	4942.11	4942.47	4942.81	4943.14	4943.46	4943.76	4944.02
5758	60,571	4938.98	4943.08	4943.22	4940.27	4940.84	4941.28	4941.65	4942.01	4942.35	4942.68	4943.00	4943.30	4943.57
5794	60,083	4938.56	4942.54	4942.12	4939.70	4940.23	4940.65	4941.01	4941.37	4941.73	4942.09	4942.42	4942.73	4943.01
5830	59,591	4937.94	4941.42	4942.50	4938.97	4939.51	4939.93	4940.30	4940.70	4941.12	4941.55	4941.92	4942.25	4942.55
5866	59,128	4937.16	4941.18	4941.01	4938.40	4938.87	4939.28	4939.70	4940.16	4940.66	4941.14	4941.55	4941.90	4942.21
5904	58,666	4936.44	4941.83	4940.96	4937.22	4937.82	4938.42	4939.01	4939.60	4940.20	4940.73	4941.17	4941.54	4941.86
5941	58,043	4934.00	4940.70	4940.30	4936.19	4937.17	4937.99	4938.68	4939.34	4939.98	4940.52	4940.97	4941.34	4941.65
5979	57,565	4934.36	4939.90	4939.90	4935.84	4936.94	4937.82	4938.54	4939.21	4939.86	4940.40	4940.86	4941.22	4941.54
6017	56,937	4933.24	4940.40	4939.53	4935.57	4936.75	4937.66	4938.38	4939.05	4939.68	4940.23	4940.69	4941.05	4941.37
6056	56,483	4932.39	4938.70	4939.44	4935.33	4936.48	4937.36	4938.06	4938.69	4939.28	4939.82	4940.26	4940.60	4940.89
6094	55,807	4932.52	4938.50	4939.06	4935.02	4936.00	4936.75	4937.32	4937.83	4938.30	4938.75	4939.07	4939.34	4939.59
6133	55,108	4931.99	4937.76	4937.64	4934.72	4935.54	4936.20	4936.66	4937.06	4937.42	4937.75	4938.03	4938.25	4938.45
6172	54,386	4932.84	4937.62	4937.09	4934.38	4935.07	4935.63	4936.04	4936.40	4936.73	4937.02	4937.33	4937.56	4937.76
6212	54,029	4932.53	4937.86	4936.53	4933.81	4934.53	4935.03	4935.44	4935.81	4936.15	4936.46	4936.80	4937.06	4937.28
6252	53,325	4931.79	4936.00	4937.23	4933.30	4934.00	4934.48	4934.88	4935.26	4935.61	4935.93	4936.27	4936.53	4936.77
6292	52,571	4931.49	4935.84	4935.03	4932.80	4933.41	4933.89	4934.31	4934.70	4935.06	4935.40	4935.72	4936.00	4936.24
6333	52,086	4931.00	4935.44	4935.49	4932.22	4932.84	4933.35	4933.78	4934.18	4934.56	4934.92	4935.25	4935.54	4935.79
6372	51,450	4930.50	4935.40	4934.60	4931.74	4932.38	4932.90	4933.34	4933.75	4934.14	4934.51	4934.84	4935.13	4935.38
6412	50,967	4930.05	4934.49	4934.60	4931.33	4931.98	4932.51	4932.95	4933.37	4933.77	4934.15	4934.48	4934.77	4935.03
6453	50,469	4929.73	4934.58	4933.94	4930.95	4931.61	4932.15	4932.60	4933.03	4933.44	4933.82	4934.16	4934.46	4934.72
6495	49,957	4929.22	4933.45	4934.01	4930.53	4931.22	4931.77	4932.23	4932.67	4933.06	4933.45	4933.80	4934.10	4934.37
6537	49,445	4928.70	4932.94	4933.10	4930.04	4930.76	4931.32	4931.78	4932.22	4932.61	4932.98	4933.34	4933.64	4933.91
6578	48,942	4928.06	4932.71	4932.89	4929.54	4930.26	4930.80	4931.25	4931.68	4932.06	4932.40	4932.75	4933.04	4933.30
6619	48,444	4927.73	4931.94	4932.45	4929.10	4929.77	4930.29	4930.73	4931.15	4931.52	4931.86	4932.18	4932.47	4932.74
6662	47,958	4927.40	4932.10	4931.50	4928.65	4929.26	4929.79	4930.25	4930.70	4931.09	4931.44	4931.76	4932.05	4932.33
6712	47,469	4926.90	4931.70	4930.90	4927.93	4928.66	4929.24	4929.73	4930.20	4930.61	4930.98	4931.31	4931.62	4931.91
6748	46,925	4922.95	4931.60	4931.18	4927.21	4928.04	4928.63	4929.12	4929.56	4929.96	4930.32	4930.65	4930.94	4931.23
6791	46,321	4923.26	4931.24	4931.08	4926.77	4927.53	4928.08	4928.51	4928.90	4929.25	4929.56	4929.84	4930.10	4930.34
6834	45,714	4924.52	4929.79	4929.80	4926.34	4927.03	4927.56	4928.00	4928.41	4928.76	4929.06	4929.35	4929.60	4929.84
6876	45,299	4921.95	4929.76	4929.83	4925.89	4926.49	4927.02	4927.49	4927.90	4928.24	4928.54	4928.81	4929.06	4929.29
6917	44,840	4921.96	4929.13	4932.07	4924.63	4925.81	4926.46	4926.97	4927.38	4927.70	4927.97	4928.23	4928.47	4928.68
6953	44,250	4922.24	4929.12	4928.05	4924.31	4925.67	4926.34	4926.86	4927.26	4927.56	4927.82	4928.07	4928.31	4928.51
6989	43,763	4921.18	4928.75	4928.42	4924.19	4925.55	4926.22	4926.72	4927.11	4927.40	4927.65	4927.89	4928.11	4928.31
7025	43,286	4921.33	4928.50	4927.80	4923.75	4924.88	4925.51	4925.95	4926.35	4926.68	4926.96	4927.21	4927.44	4927.65

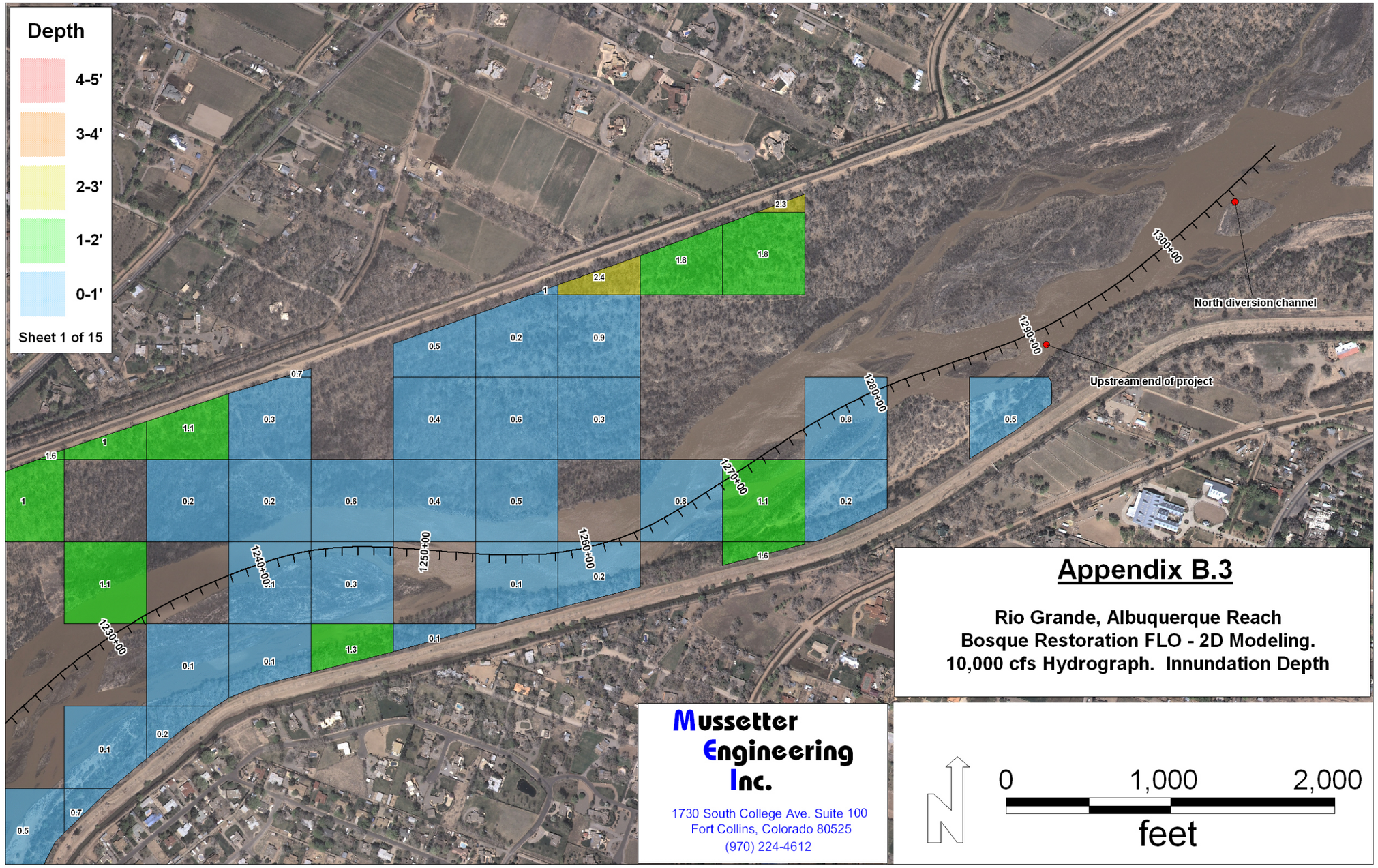
Appendix A.3. Summary of bank, thalweg and water-surface elevations from 1,000 to 10,000 cfs (continued).														
Element	Station (ft)	Thalweg Elevation (ft)	Bank Elevation (ft)		Water-surface elevation (ft)									
			Left	Right	1,000 cfs	2,000 cfs	3,000 cfs	4,000 cfs	5,000 cfs	6,000 cfs	7,000 cfs	8,000 cfs	9,000 cfs	10,000 cfs
7060	42,871	4920.48	4927.91	4926.49	4923.49	4924.24	4924.71	4925.08	4925.44	4925.78	4926.08	4926.33	4926.58	4926.79
7094	42,299	4922.00	4926.30	4927.70	4923.20	4923.82	4924.26	4924.57	4924.89	4925.17	4925.43	4925.67	4925.92	4926.13
7129	41,465	4921.25	4925.32	4926.50	4922.08	4922.76	4923.33	4923.75	4924.16	4924.53	4924.86	4925.16	4925.46	4925.69
7164	40,613	4919.87	4925.33	4924.88	4921.39	4922.14	4922.81	4923.31	4923.80	4924.23	4924.60	4924.93	4925.23	4925.48
7199	40,155	4919.57	4924.71	4924.82	4921.11	4921.85	4922.50	4922.98	4923.45	4923.88	4924.25	4924.57	4924.87	4925.11
7233	39,578	4919.30	4924.30	4923.90	4920.56	4921.29	4921.91	4922.41	4922.85	4923.29	4923.66	4923.98	4924.27	4924.50
7267	38,883	4918.36	4923.72	4922.51	4920.17	4920.90	4921.49	4921.99	4922.46	4922.92	4923.30	4923.61	4923.89	4924.11
7300	38,213	4918.53	4923.90	4923.57	4919.65	4920.41	4920.98	4921.47	4921.96	4922.42	4922.80	4923.13	4923.41	4923.62
7333	37,887	4917.18	4923.10	4923.70	4919.00	4919.81	4920.32	4920.75	4921.18	4921.61	4921.95	4922.25	4922.51	4922.73
7368	36,717	4917.34	4921.60	4920.93	4918.64	4919.40	4919.88	4920.28	4920.67	4921.06	4921.41	4921.70	4921.97	4922.20
7404	36,270	4916.89	4921.02	4920.99	4918.29	4918.99	4919.49	4919.91	4920.31	4920.68	4921.06	4921.37	4921.65	4921.89
7440	35,724	4916.52	4920.52	4920.96	4917.85	4918.49	4918.99	4919.41	4919.81	4920.18	4920.56	4920.87	4921.13	4921.36
7476	34,985	4915.98	4920.53	4920.20	4917.33	4917.96	4918.44	4918.85	4919.24	4919.60	4919.97	4920.27	4920.52	4920.73
7512	34,499	4915.68	4919.45	4919.93	4916.95	4917.56	4918.05	4918.46	4918.85	4919.23	4919.60	4919.89	4920.13	4920.34
7547	34,028	4915.39	4919.12	4920.53	4916.58	4917.21	4917.71	4918.14	4918.54	4918.94	4919.33	4919.62	4919.87	4920.07
7582	33,548	4914.86	4919.03	4918.99	4916.22	4916.88	4917.41	4917.85	4918.26	4918.66	4919.07	4919.36	4919.60	4919.81
7617	33,047	4914.51	4918.97	4918.82	4915.87	4916.55	4917.08	4917.52	4917.94	4918.33	4918.73	4919.02	4919.27	4919.47
7652	32,541	4914.05	4918.12	4918.93	4915.49	4916.14	4916.66	4917.09	4917.49	4917.87	4918.24	4918.52	4918.76	4918.97
7687	32,037	4913.77	4918.13	4917.71	4915.12	4915.75	4916.25	4916.68	4917.07	4917.44	4917.80	4918.09	4918.33	4918.53
7722	31,536	4913.41	4917.22	4917.15	4914.66	4915.30	4915.81	4916.24	4916.64	4917.01	4917.37	4917.66	4917.91	4918.12
7757	31,041	4912.86	4916.69	4916.94	4914.10	4914.77	4915.29	4915.71	4916.11	4916.47	4916.83	4917.13	4917.39	4917.61
7791	30,561	4912.27	4916.23	4916.64	4913.61	4914.25	4914.74	4915.14	4915.51	4915.85	4916.18	4916.49	4916.76	4917.00
7826	30,088	4911.92	4916.14	4915.93	4913.09	4913.70	4914.16	4914.55	4914.92	4915.25	4915.57	4915.84	4916.12	4916.34
7860	29,462	4911.44	4915.83	4916.05	4912.74	4913.34	4913.79	4914.18	4914.56	4914.91	4915.24	4915.51	4915.79	4916.03
7895	28,993	4911.15	4915.80	4914.87	4912.39	4912.94	4913.39	4913.78	4914.17	4914.52	4914.87	4915.16	4915.45	4915.69
7930	28,545	4910.70	4915.58	4915.00	4911.70	4912.28	4912.76	4913.17	4913.57	4913.97	4914.36	4914.66	4914.98	4915.22
7966	28,041	4909.95	4914.04	4914.54	4911.10	4911.76	4912.29	4912.73	4913.14	4913.59	4914.01	4914.31	4914.62	4914.86
8001	27,369	4909.30	4913.50	4913.70	4910.73	4911.40	4911.92	4912.36	4912.77	4913.19	4913.59	4913.90	4914.22	4914.46
8036	26,858	4909.01	4913.10	4913.40	4910.33	4910.99	4911.50	4911.94	4912.35	4912.73	4913.10	4913.42	4913.77	4914.01
8070	26,354	4908.40	4913.30	4913.30	4909.80	4910.50	4911.03	4911.48	4911.88	4912.26	4912.63	4912.95	4913.31	4913.53
8104	25,853	4908.00	4912.50	4912.70	4909.34	4909.96	4910.46	4910.88	4911.26	4911.60	4911.92	4912.21	4912.49	4912.71
8139	25,315	4907.70	4912.90	4912.90	4908.98	4909.60	4910.11	4910.56	4910.94	4911.28	4911.59	4911.87	4912.13	4912.35
8173	24,785	4907.27	4912.70	4912.67	4908.61	4909.23	4909.76	4910.23	4910.63	4910.98	4911.30	4911.59	4911.85	4912.08
8207	24,271	4906.89	4910.89	4912.38	4908.07	4908.72	4909.29	4909.79	4910.19	4910.56	4910.90	4911.20	4911.46	4911.68
8240	23,772	4906.34	4910.77	4912.03	4907.68	4908.39	4909.00	4909.50	4909.91	4910.28	4910.62	4910.92	4911.18	4911.40
8273	23,274	4905.64	4910.99	4909.61	4906.96	4907.66	4908.26	4908.73	4909.10	4909.43	4909.73	4910.00	4910.23	4910.43
8306	22,626	4904.90	4910.13	4909.37	4906.28	4906.90	4907.35	4907.72	4908.04	4908.34	4908.60	4908.85	4909.08	4909.29
8338	22,139	4904.65	4909.66	4908.73	4905.98	4906.59	4907.03	4907.39	4907.72	4908.02	4908.30	4908.55	4908.80	4909.02
8368	21,663	4904.41	4909.08	4908.56	4905.54	4906.11	4906.55	4906.90	4907.23	4907.53	4907.81	4908.07	4908.32	4908.54
8399	21,003	4903.86	4909.46	4907.93	4905.12	4905.62	4906.02	4906.36	4906.67	4906.97	4907.26	4907.52	4907.78	4908.01
8428	20,538	4903.55	4908.62	4907.25	4904.36	4904.84	4905.25	4905.60	4905.97	4906.31	4906.64	4906.93	4907.21	4907.44
8458	19,671	4902.54	4907.62	4906.99	4903.64	4904.23	4904.71	4905.11	4905.52	4905.91	4906.27	4906.56	4906.84	4907.07
8487	19,412	4902.24	4906.35	4906.79	4903.29	4903.92	4904.42	4904.83	4905.26	4905.66	4906.03	4906.31	4906.58	4906.81
8517	18,760	4901.73	4906.11	4906.23	4903.00	4903.65	4904.14	4904.56	4905.00	4905.41	4905.79	4906.06	4906.32	4906.55
8546	18,301	4901.41	4905.54	4905.48	4902.72	4903.34	4903.82	4904.23	4904.65	4905.05	4905.42	4905.69	4905.96	4906.19
8574	17,837	4900.98	4905.20	4905.20	4902.37	4902.97	4903.43	4903.85	4904.27	4904.63	4904.98	4905.26	4905.53	4905.76
8602	17,388	4900.76	4904.96	4904.96	4902.03	4902.55	4903.00	4903.43	4903.87	4904.26	4904.62	4904.90	4905.16	4905.39
8629	16,900	4900.40	4905.10	4904.40	4901.09	4901.73	4902.29	4902.79	4903.33	4903.77	4904.15	4904.43	4904.71	4904.95
8655	16,395	4898.95	4903.75	4904.11	4900.45	4901.28	4901.91	4902.45	4903.02	4903.46	4903.84	4904.10	4904.37	4904.60
8680	15,893	4898.24	4903.56	4903.73	4900.33	4901.13	4901.74	4902.26	4902.81	4903.24	4903.60	4903.85	4904.10	4904.33

APPENDIX B
Depth of Inundation Mapping

Appendix B.1

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
6,000 cfs. Innundation Depth


Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 2 of 2
580+00
570+00
560+00
550+00
540+00
530+00
0.1
0
0.1
0.1
1
0.1
0.1
0.1
0.1
Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
N
0
1,000
2,000
feet
Appendix B.2
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
6,000 cfs. Innundation Depth



Appendix B.3

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

Appendix B.4

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

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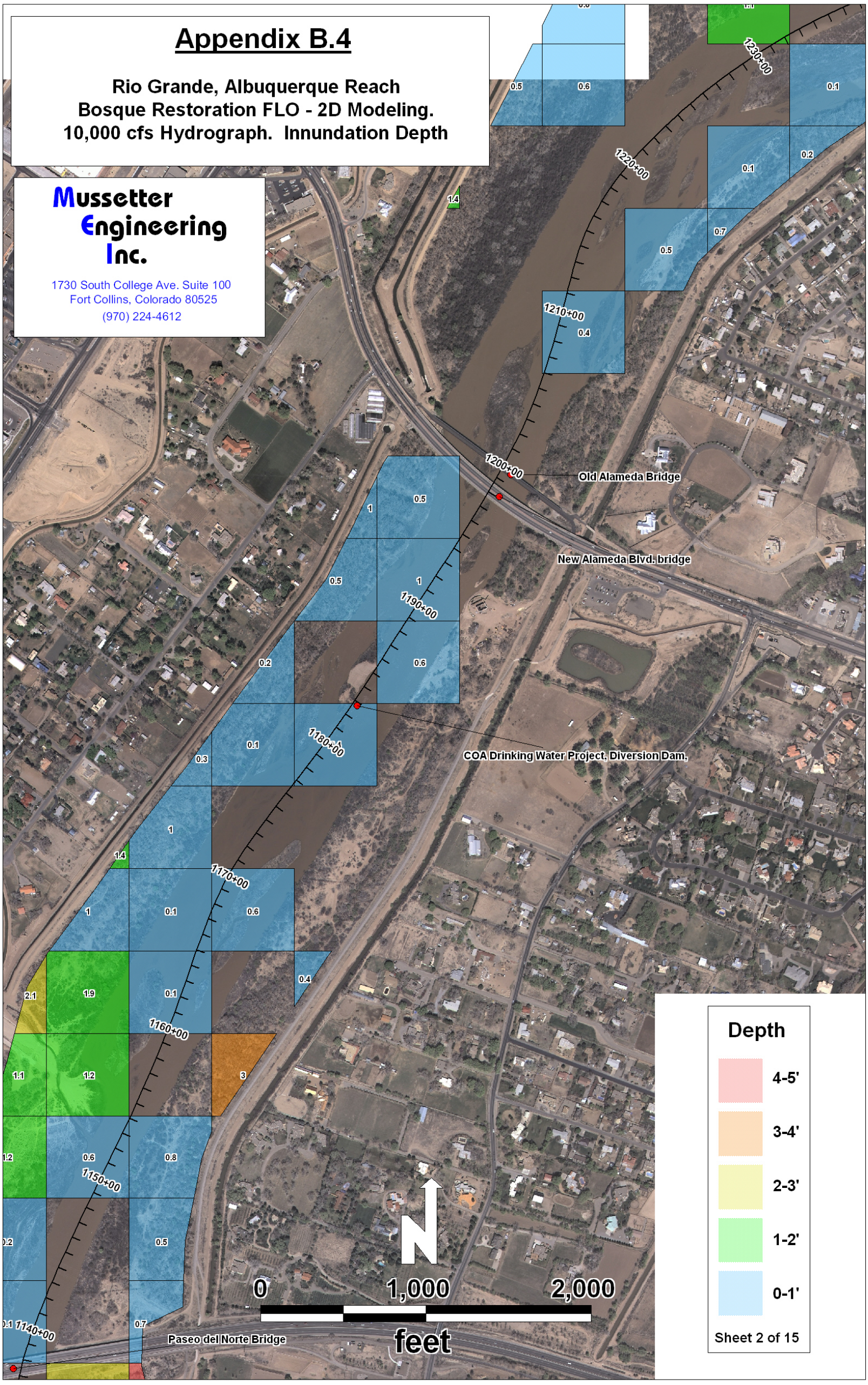

Appendix B.5

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

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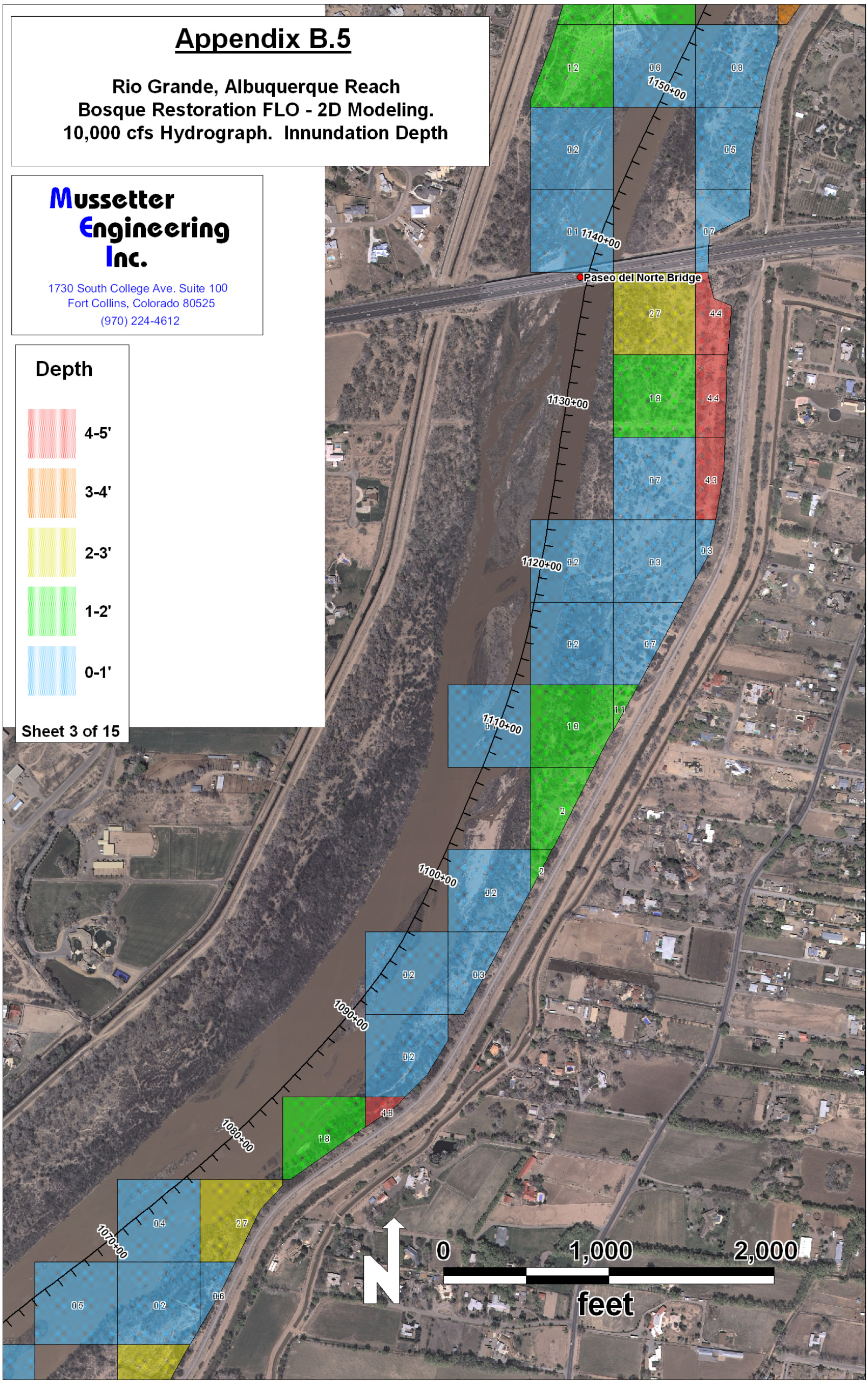

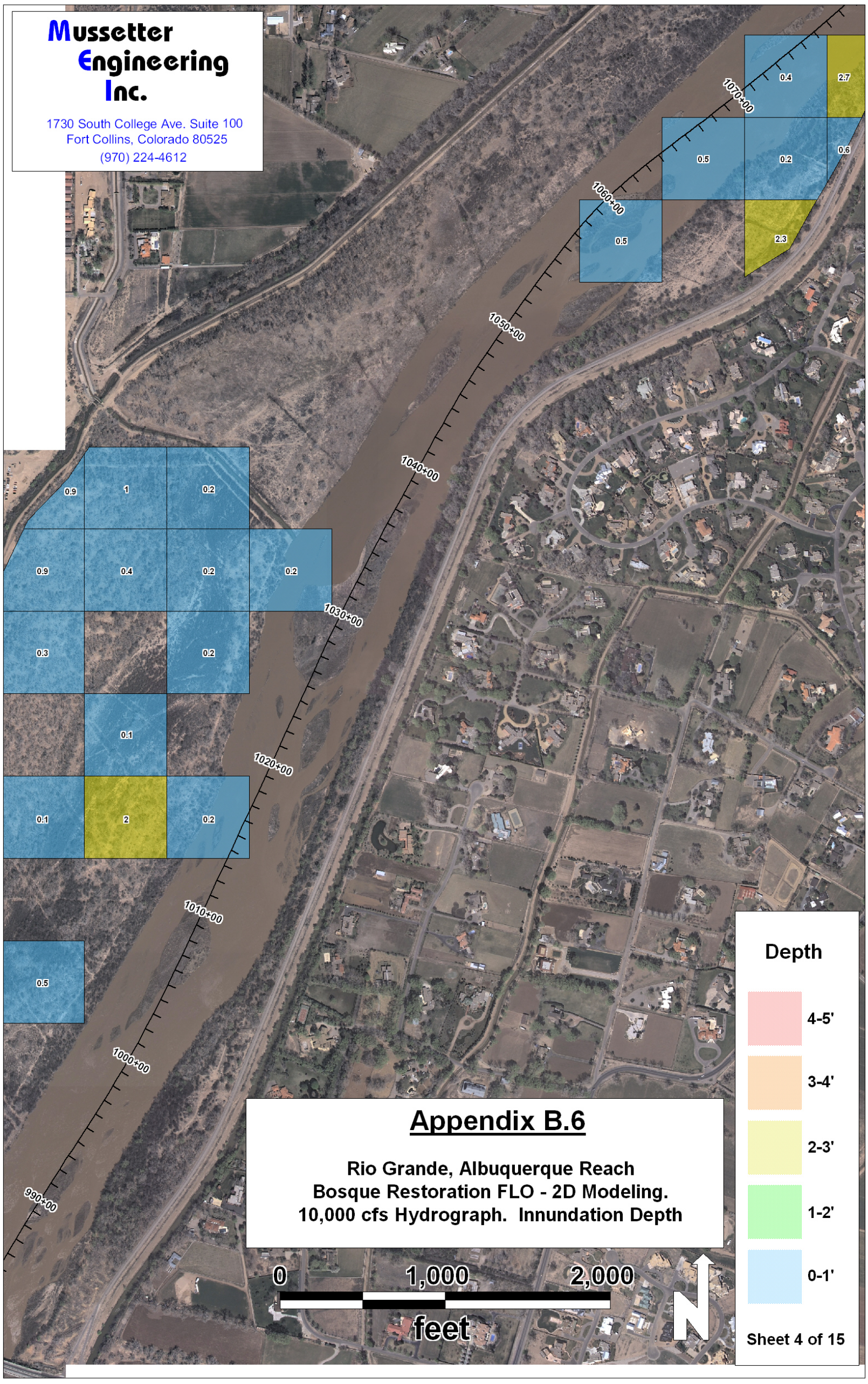
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Appendix B.6
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 4 of 15
0
1,000
2,000
feet
N
990+00
1000+00
1010+00
1020+00
1030+00
1040+00
1050+00
1060+00
1070+00

Appendix B.7

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

Mussetter Engineering Inc.
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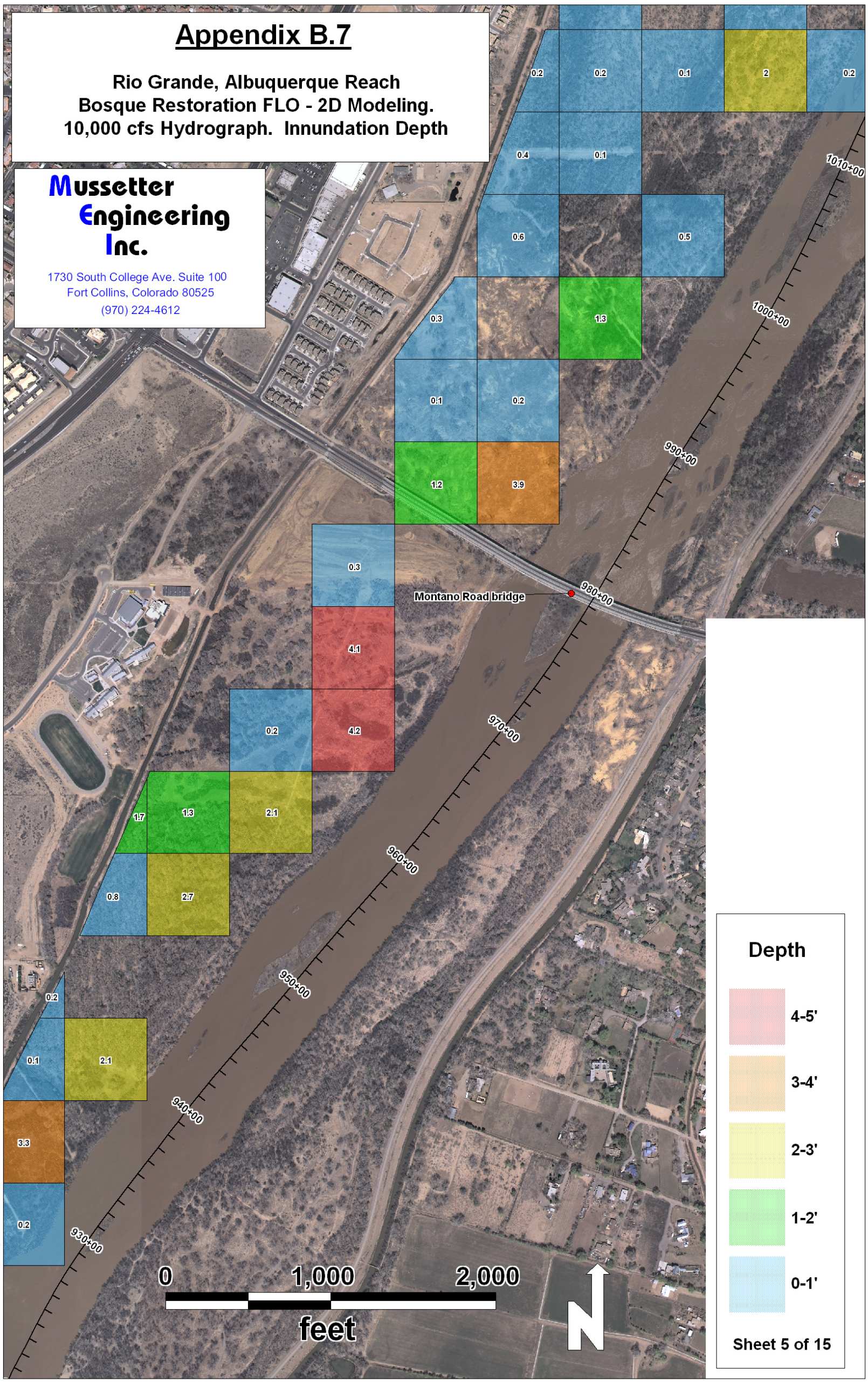
(970) 224-4612



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Engineering
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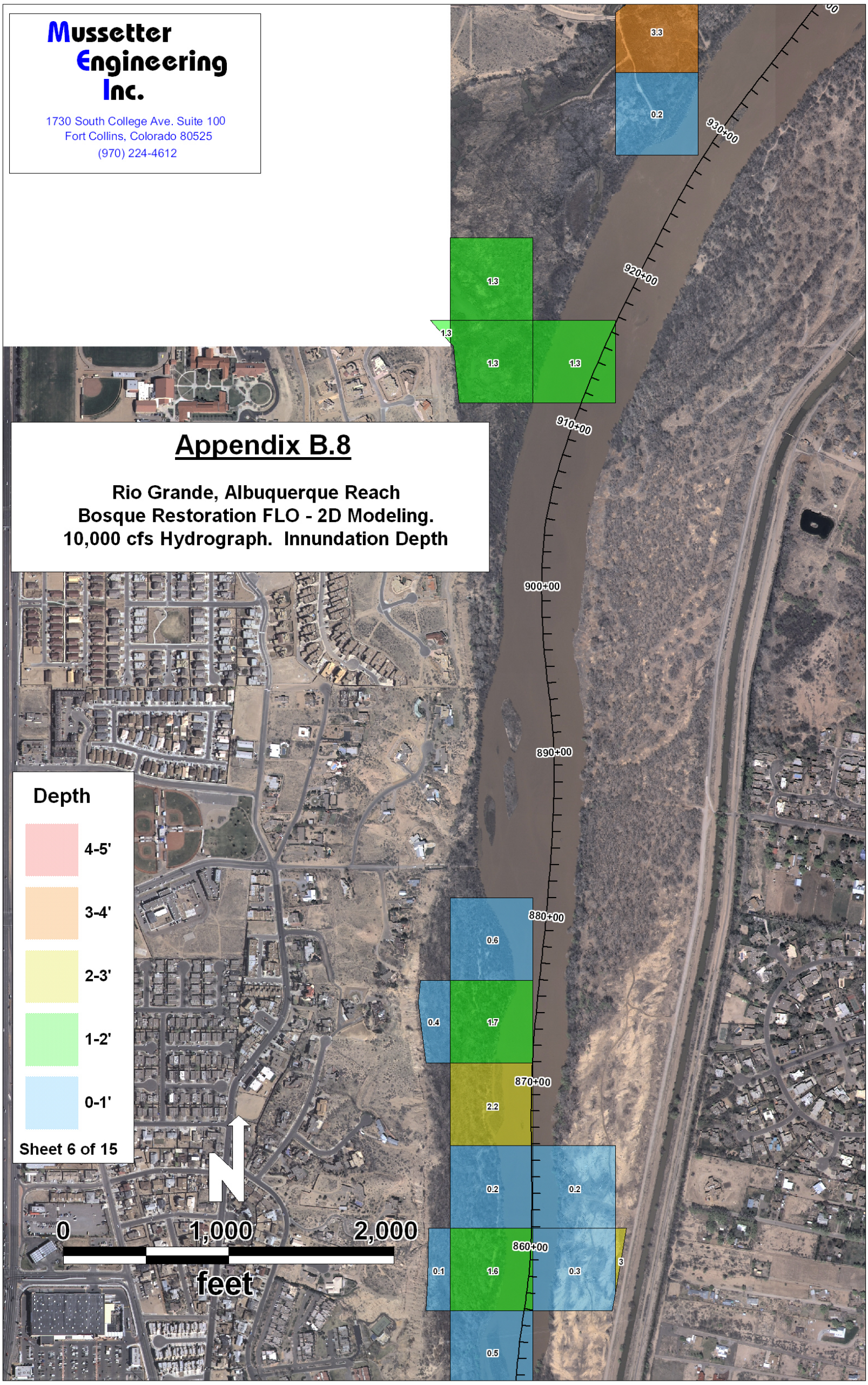

Appendix B.8

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

Appendix B.9

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

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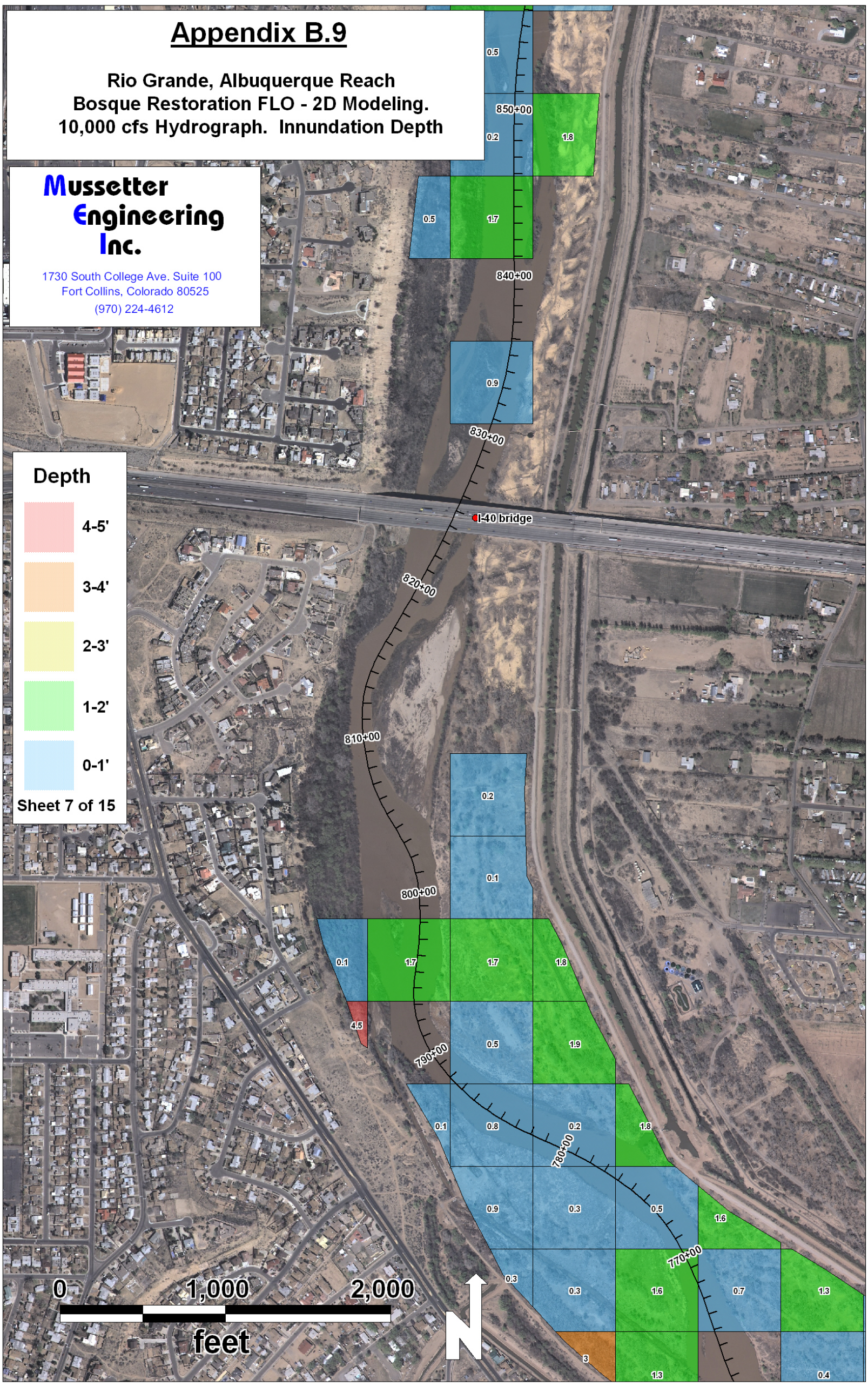

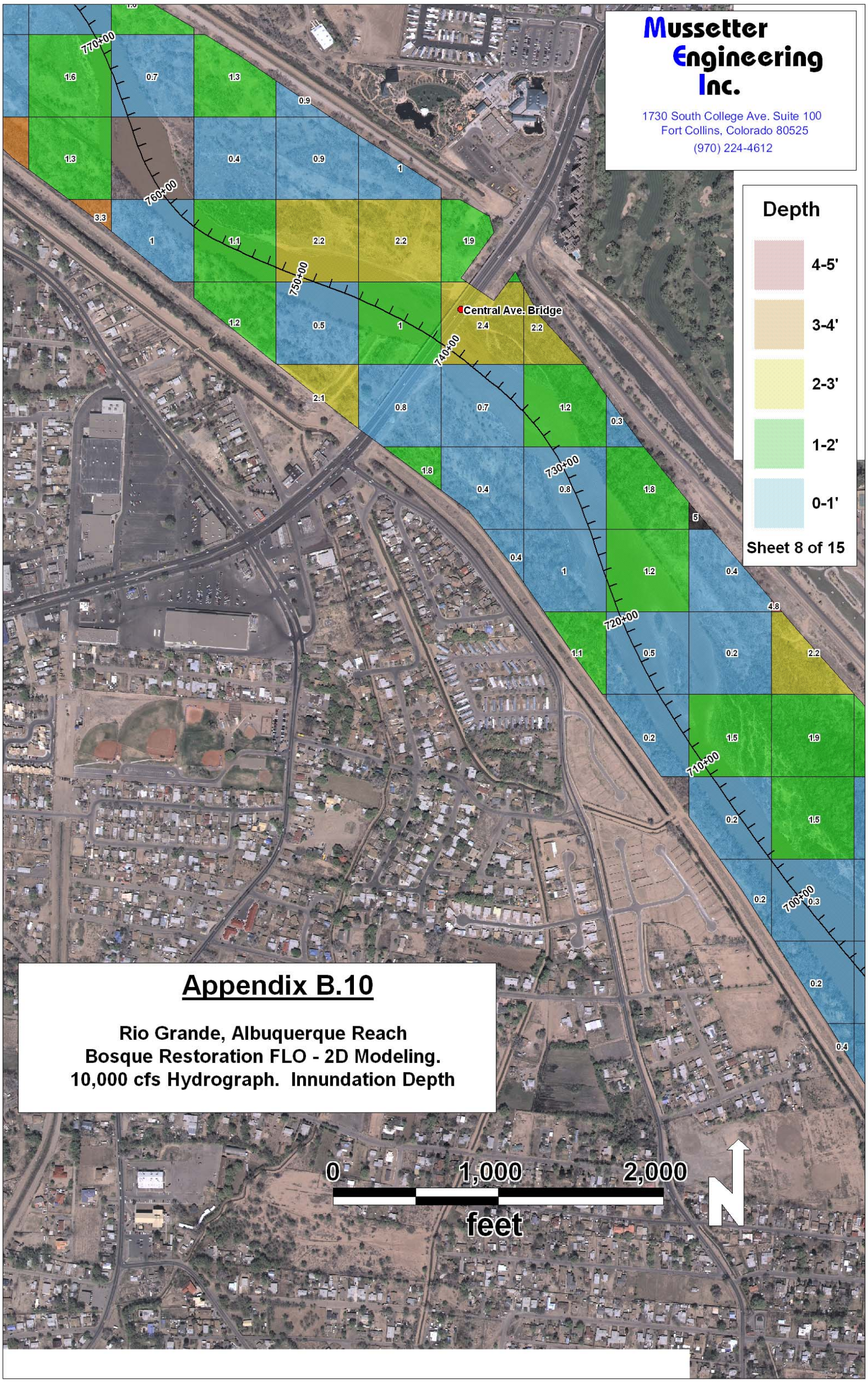
Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 8 of 15
Central Ave. Bridge
770+00
760+00
750+00
740+00
730+00
720+00
710+00
700+00
Appendix B.10
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
0
1,000
2,000
feet
N

Appendix B.11

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

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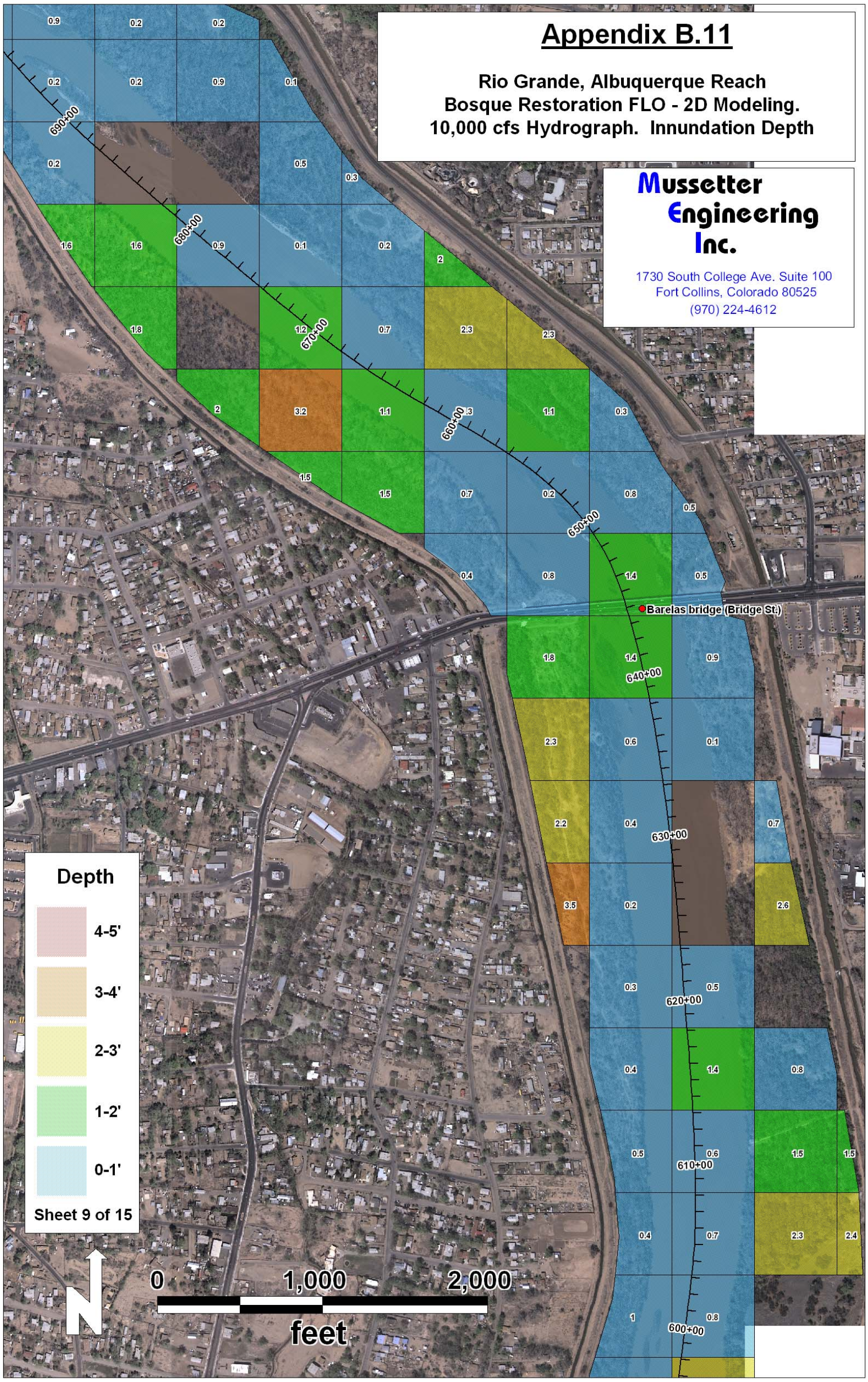

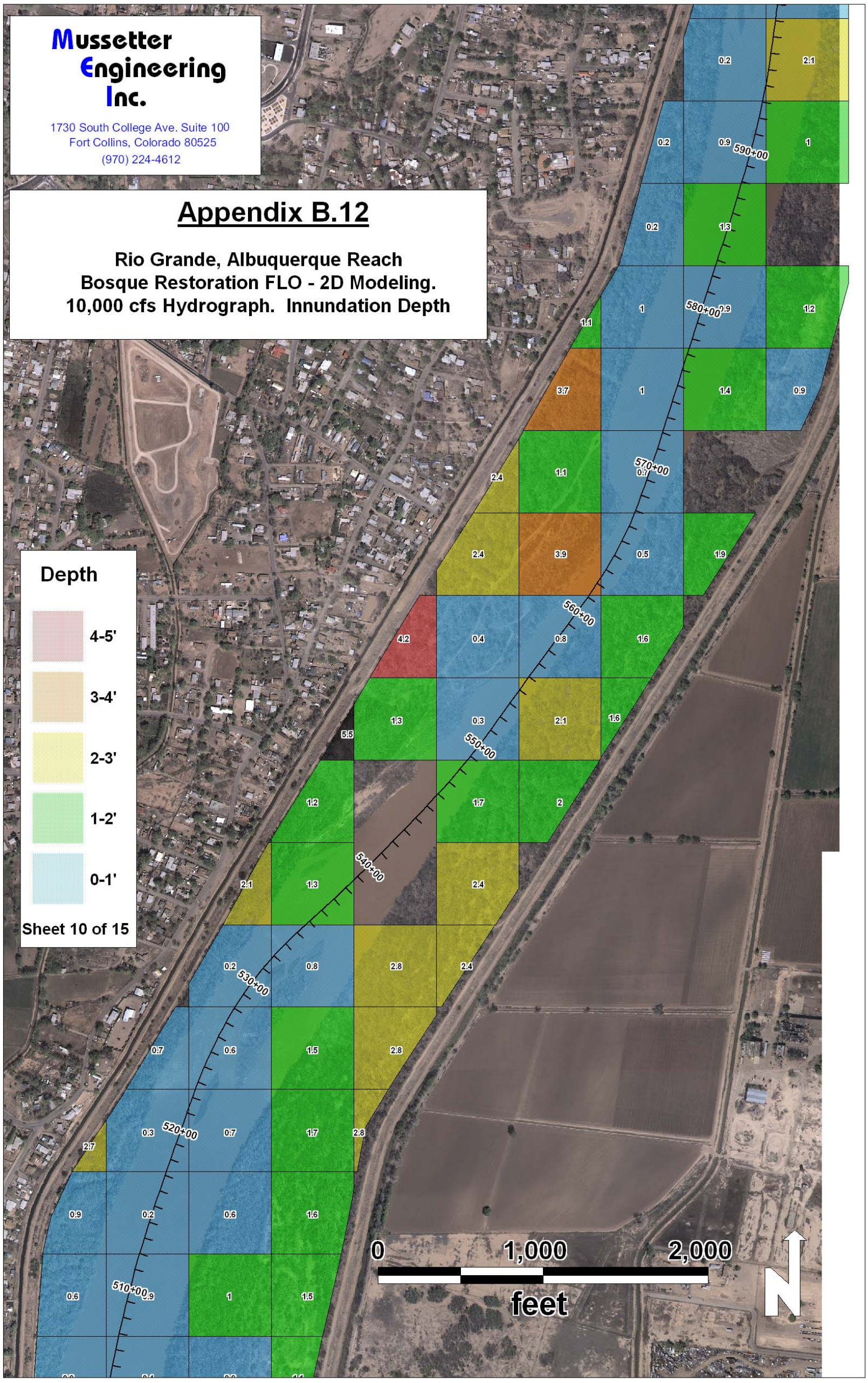
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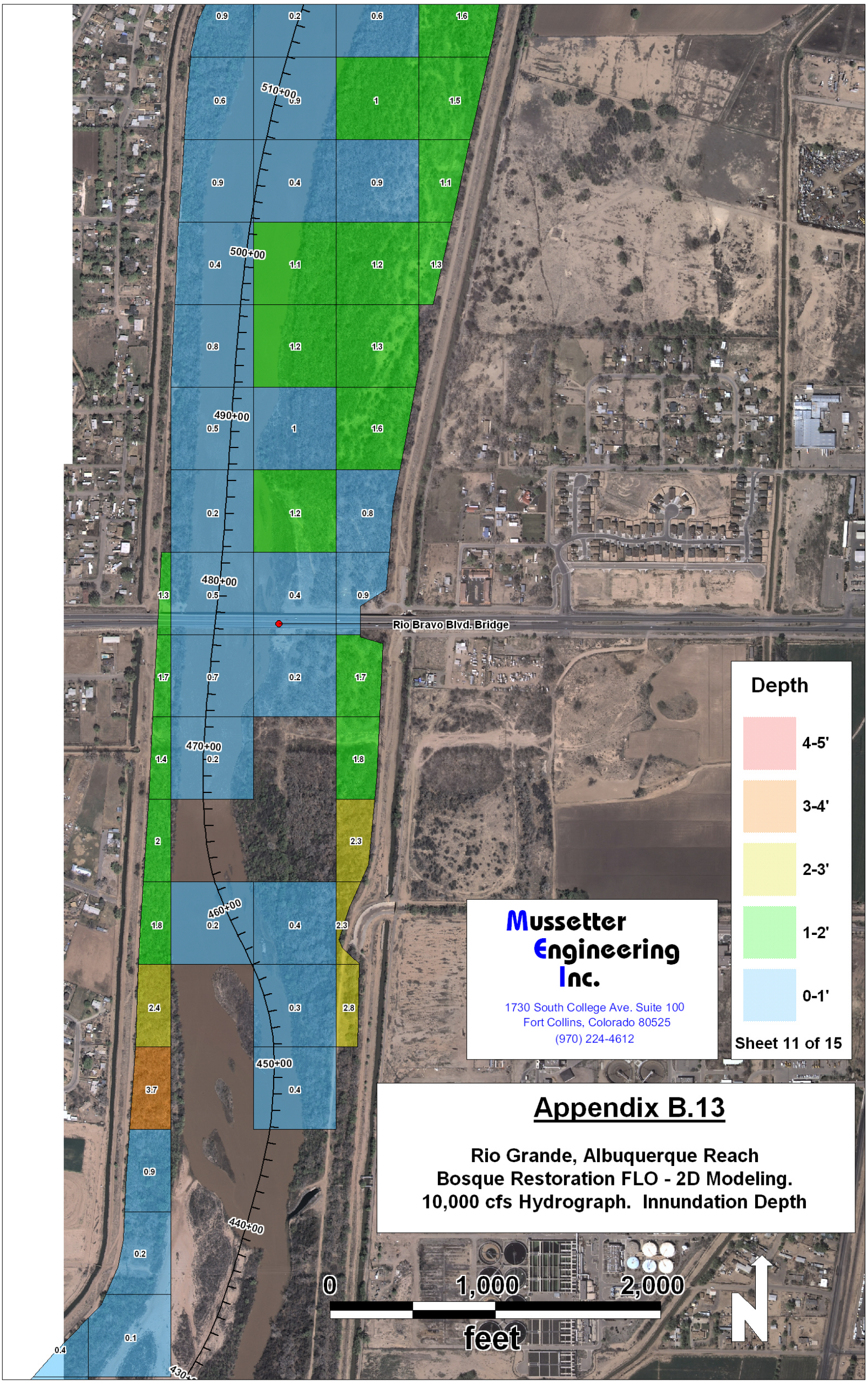
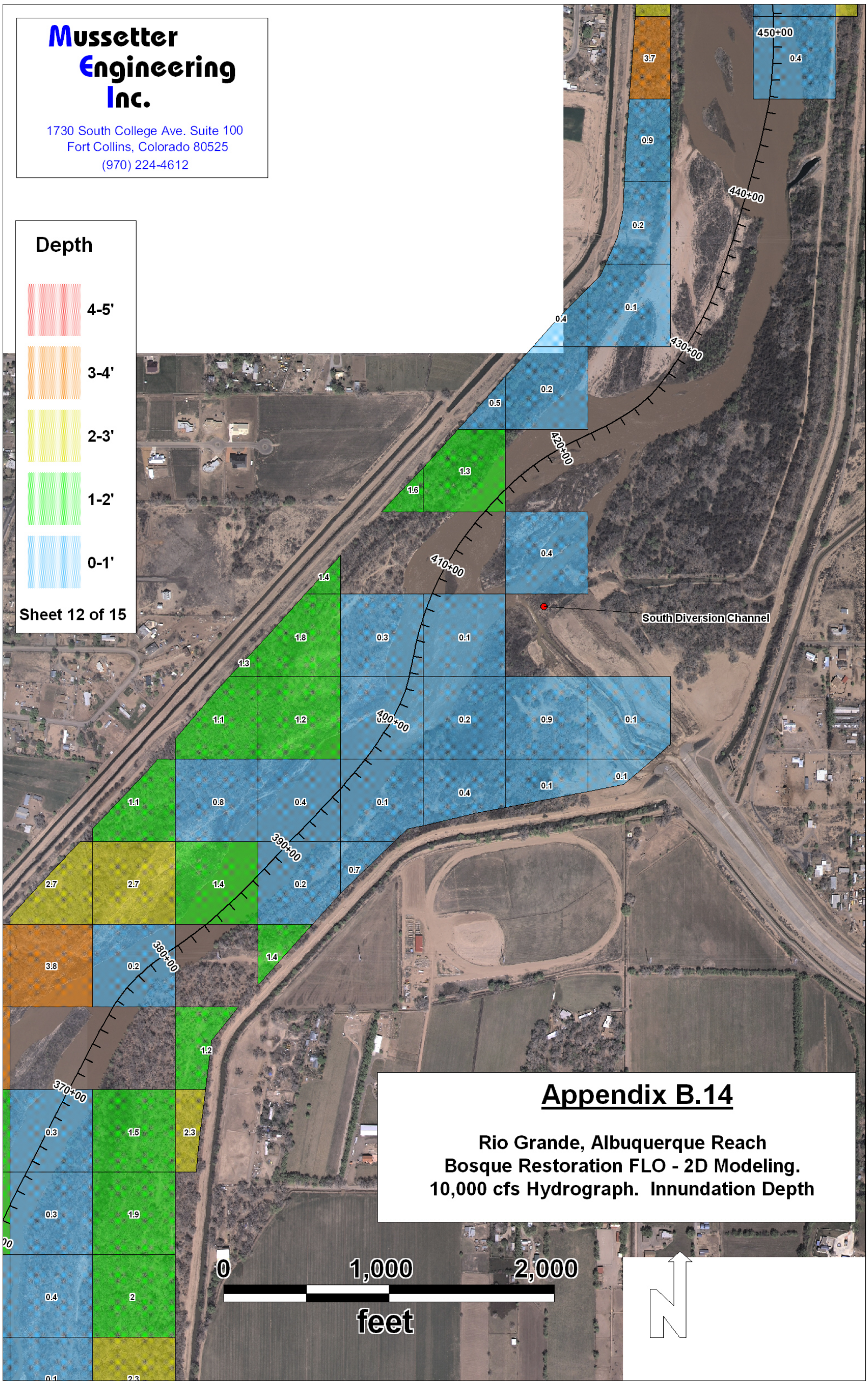
Appendix B.12
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 10 of 15
590+00
580+00
570+00
560+00
550+00
540+00
530+00
520+00
510+00
0
1,000
2,000
feet
N



Appendix B.13

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth


Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 12 of 15
South Diversion Channel
450+00
440+00
430+00
420+00
410+00
400+00
390+00
380+00
370+00
Appendix B.14
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
0
1,000
2,000
feet
N

Appendix B.15

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth

Mussetter Engineering Inc.
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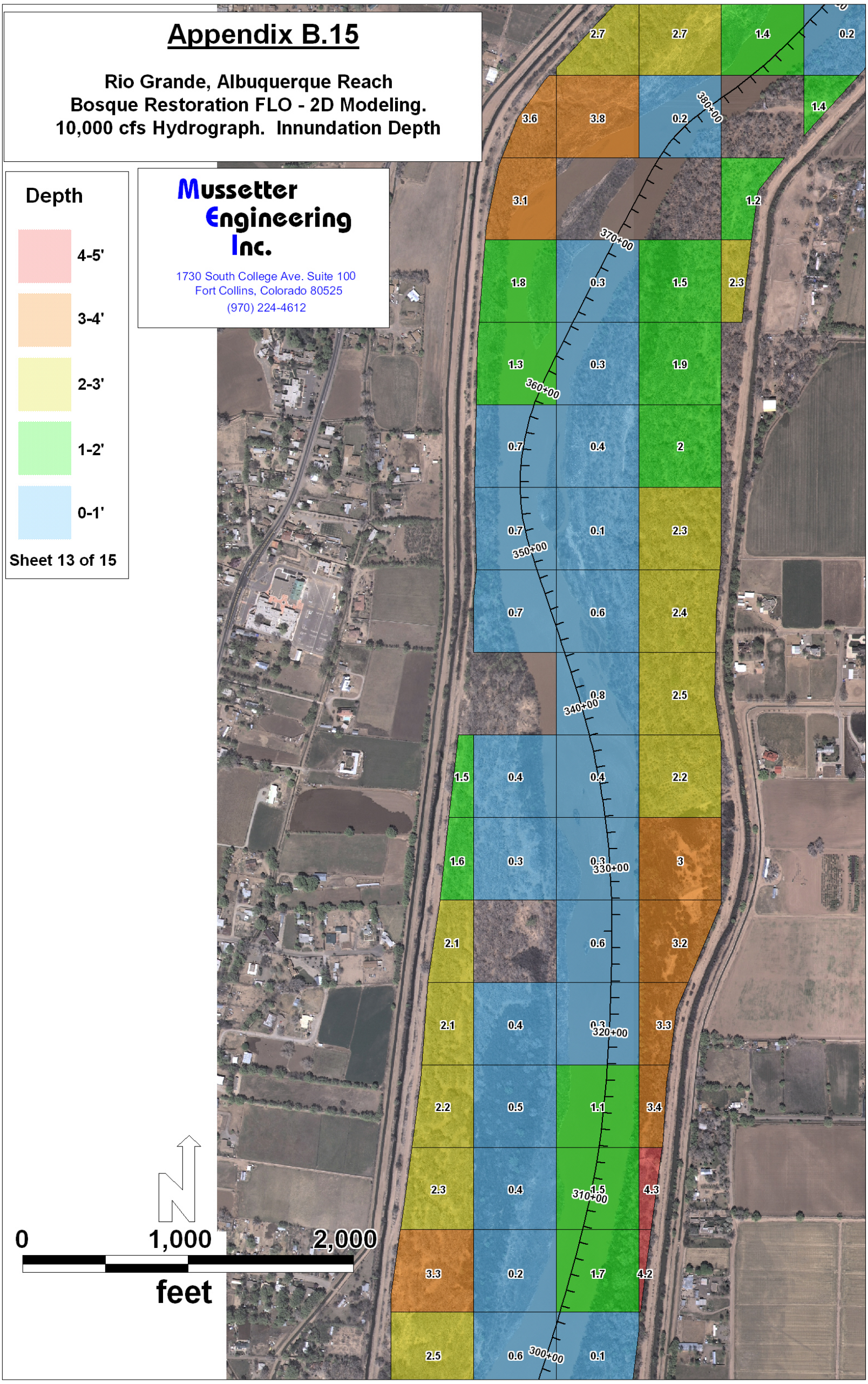

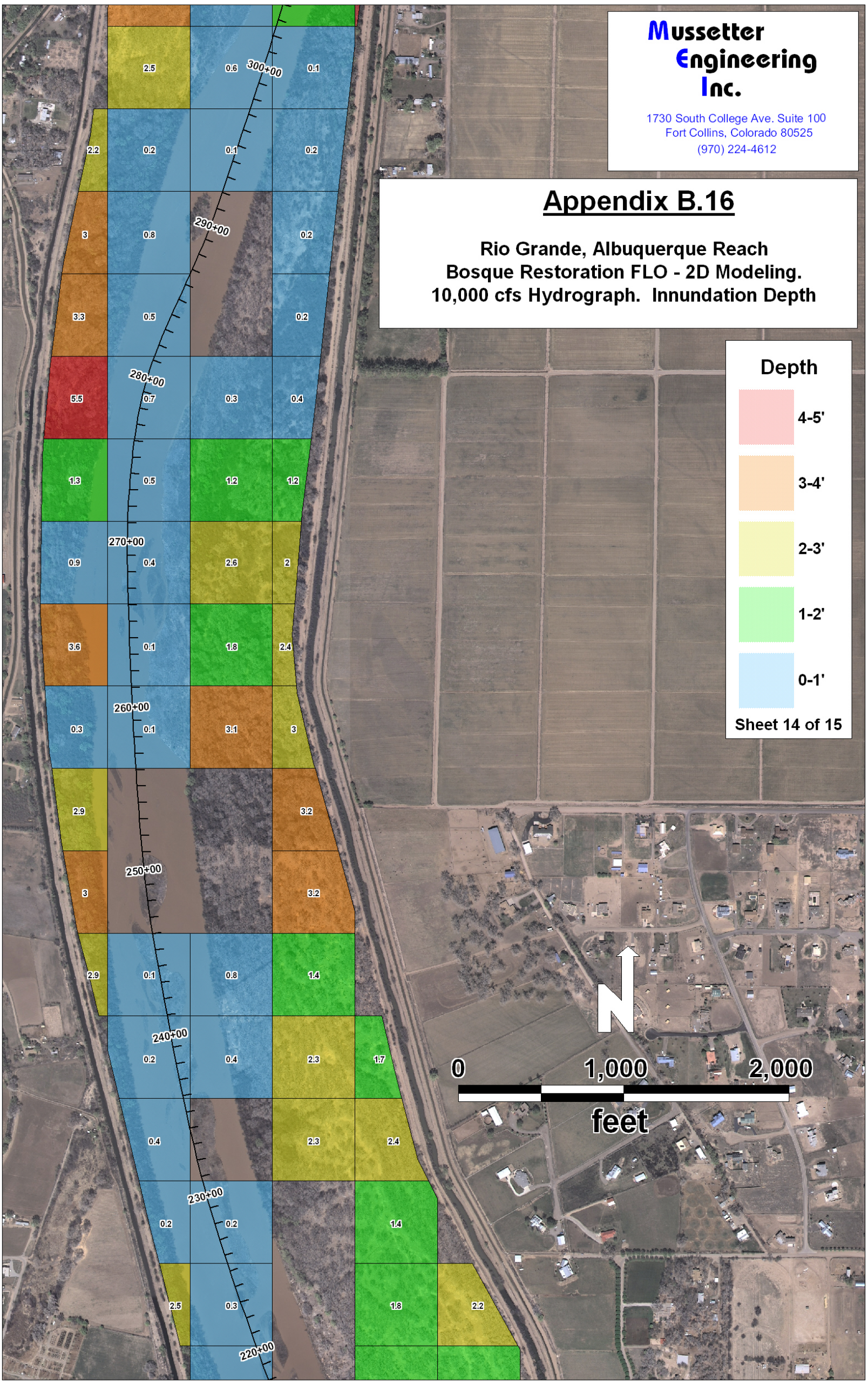
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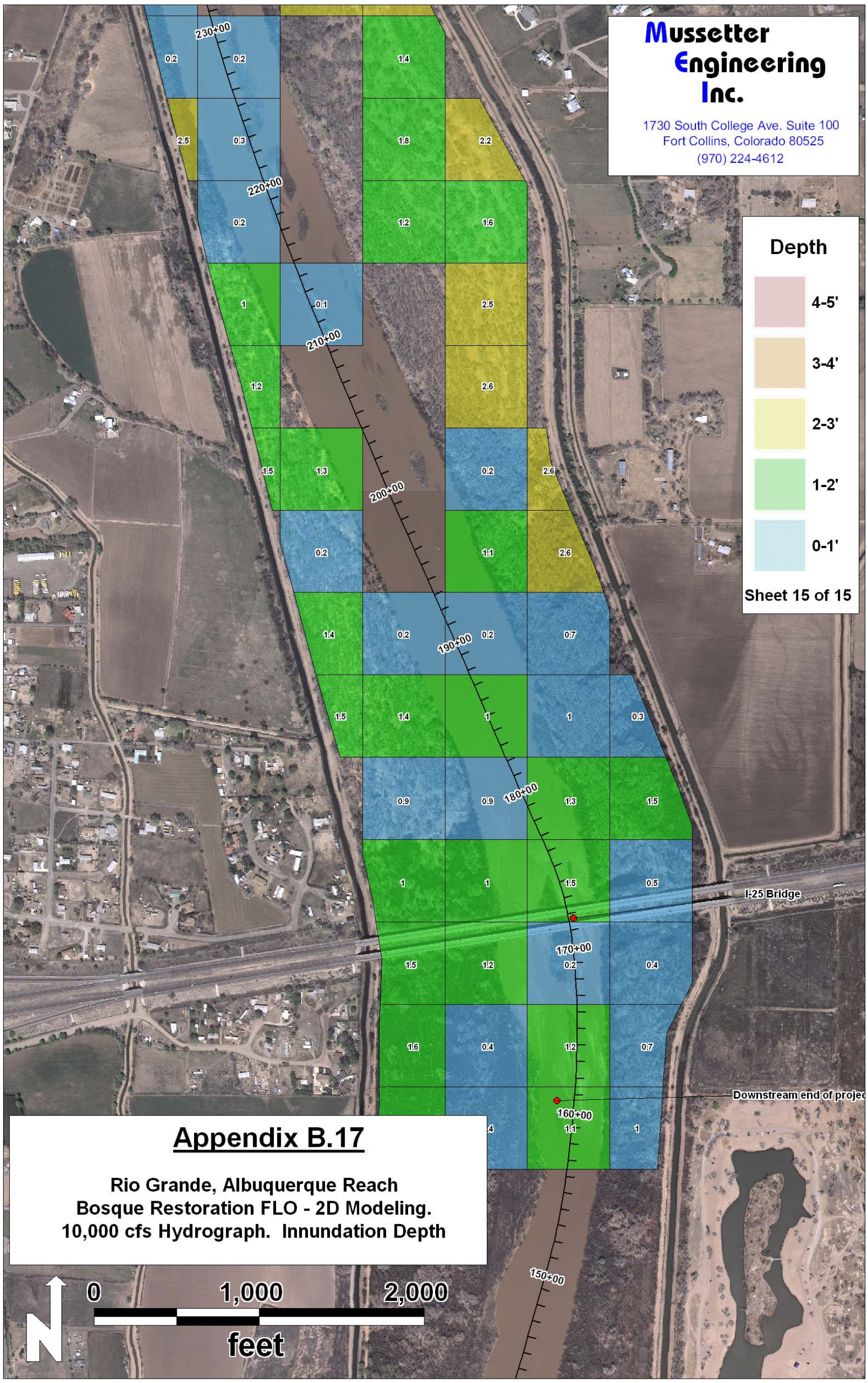
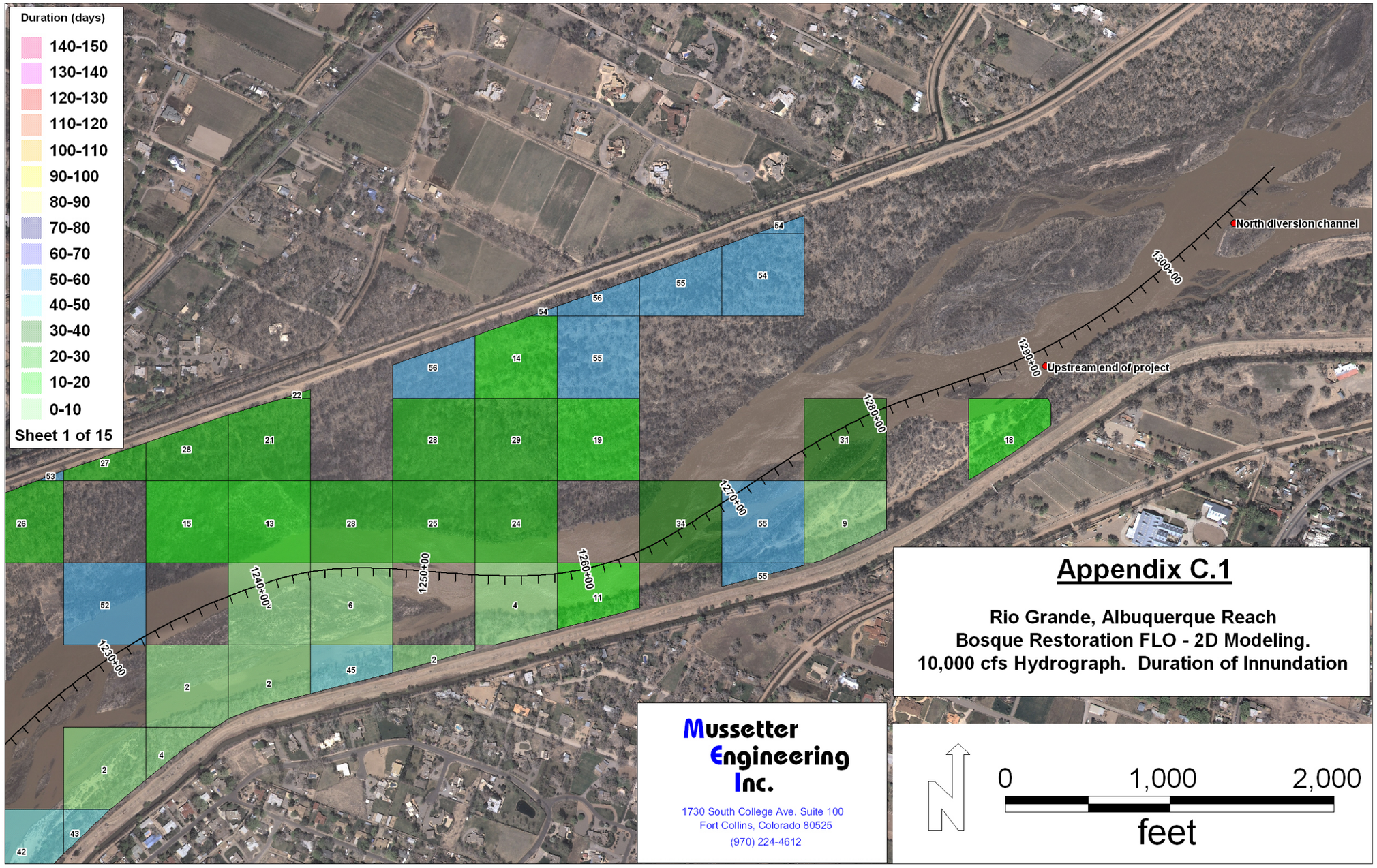
Appendix B.16
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 14 of 15
300+00
290+00
280+00
270+00
260+00
250+00
240+00
230+00
220+00
0
1,000
2,000
feet
N


Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
Depth
4-5'
3-4'
2-3'
1-2'
0-1'
Sheet 15 of 15
230+00
220+00
210+00
200+00
190+00
180+00
170+00
160+00
150+00
I-25 Bridge
Downstream end of projec
Appendix B.17
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Innundation Depth
0
1,000
2,000
feet
N

APPENDIX C
Duration of Inundation Mapping



Appendix C.1

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation

Mussetter Engineering Inc.

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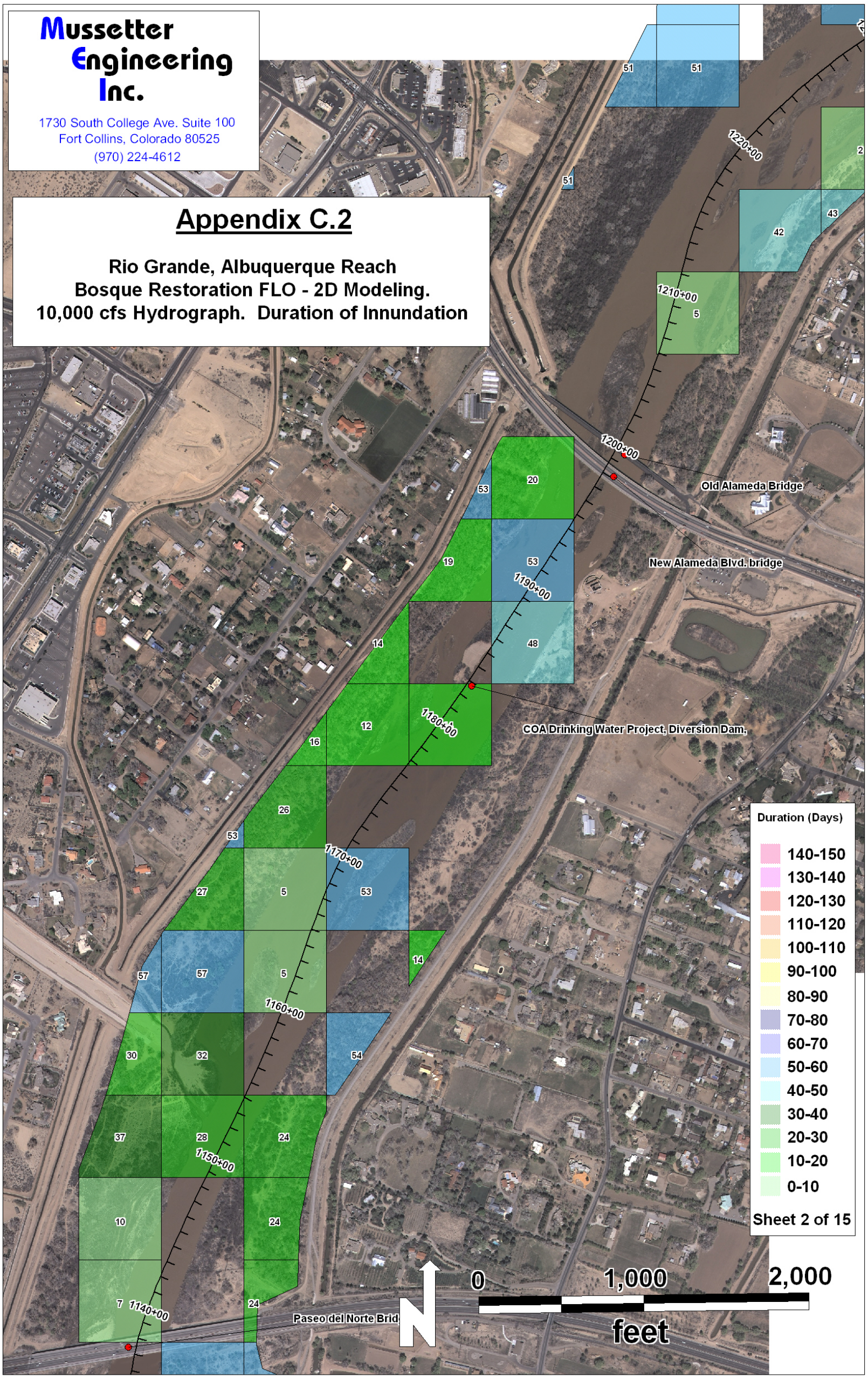
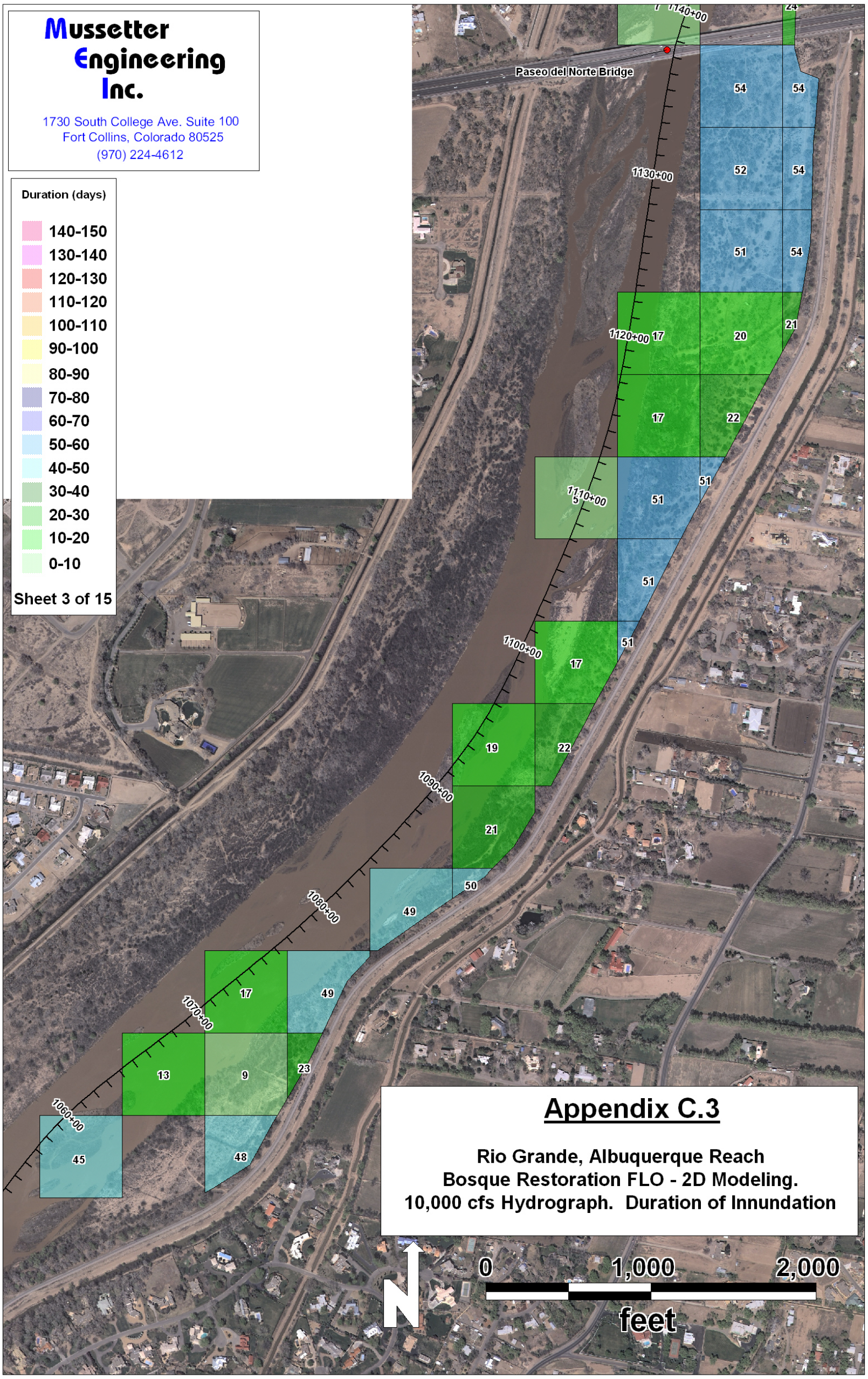
Appendix C.2

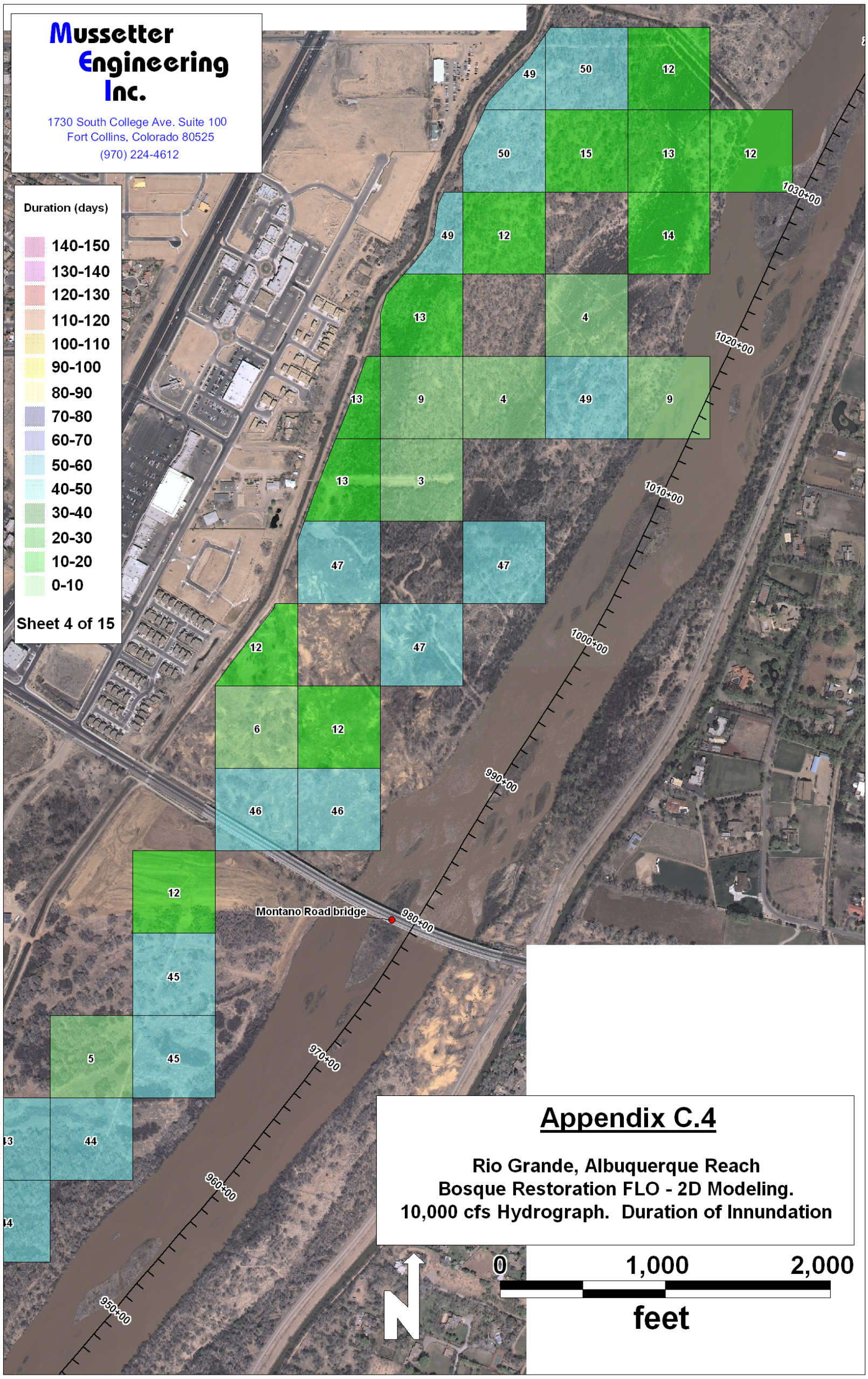
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation





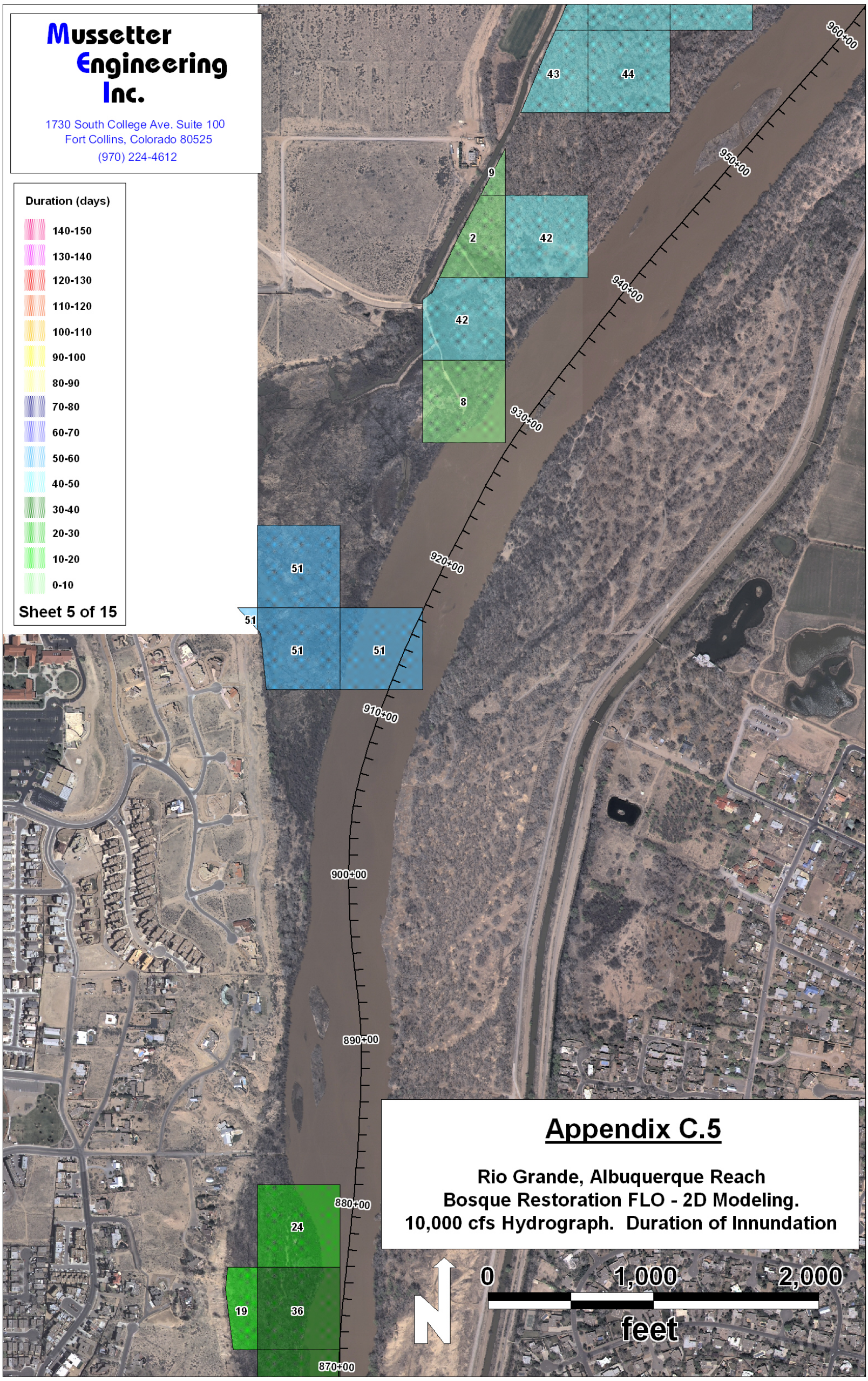
Appendix C.3

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation



Appendix C.4

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation


Mussetter Engineering Inc.
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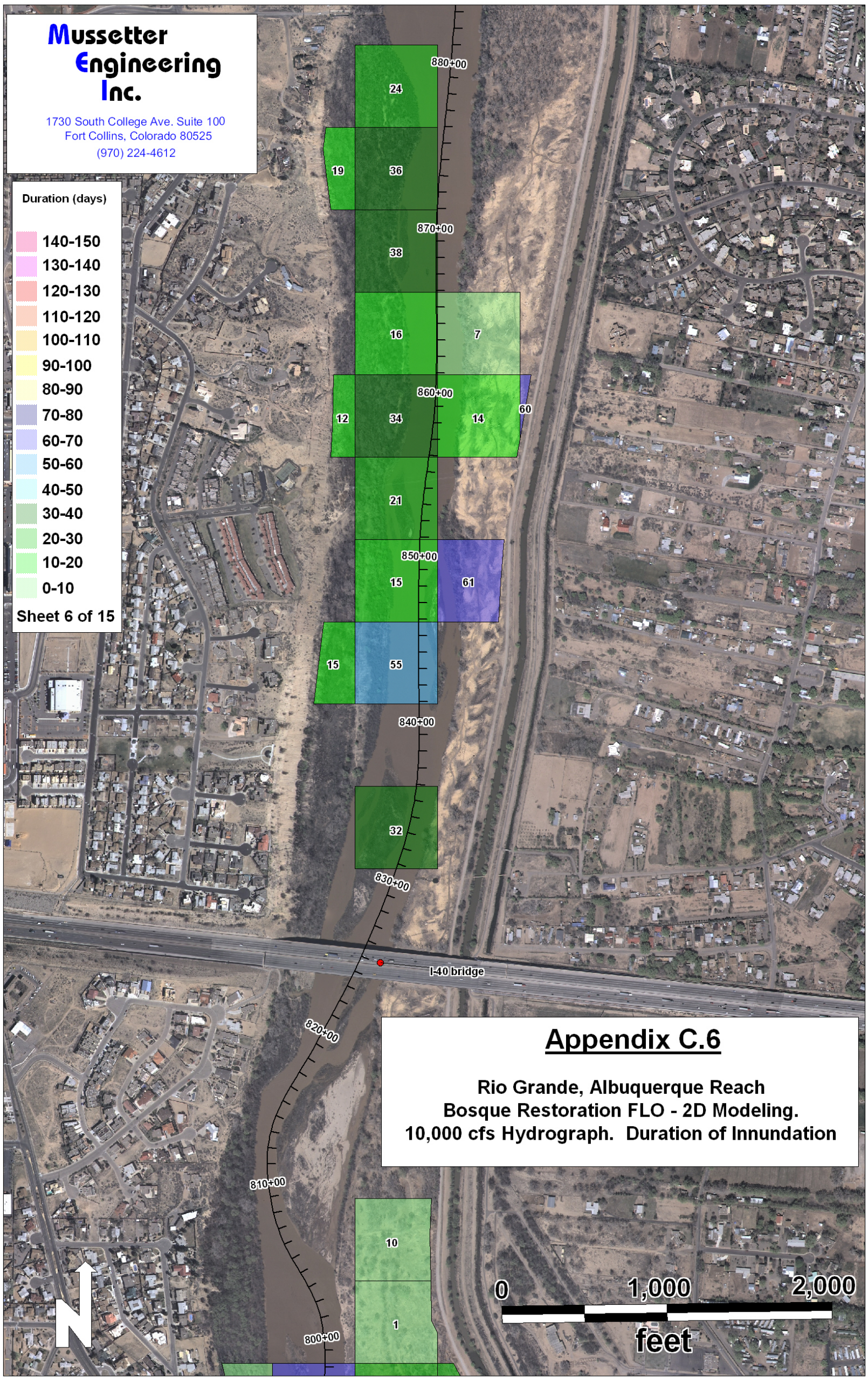
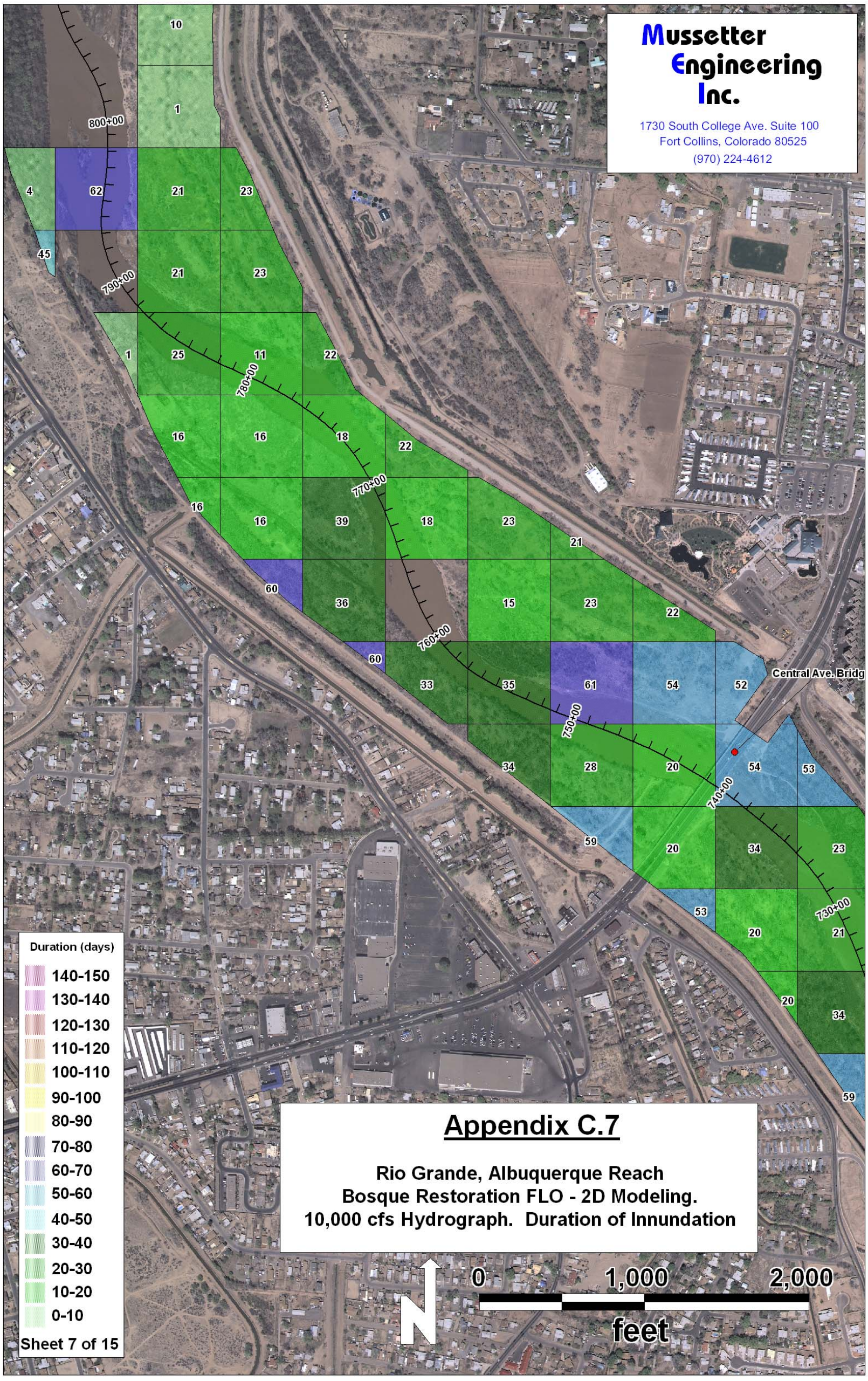
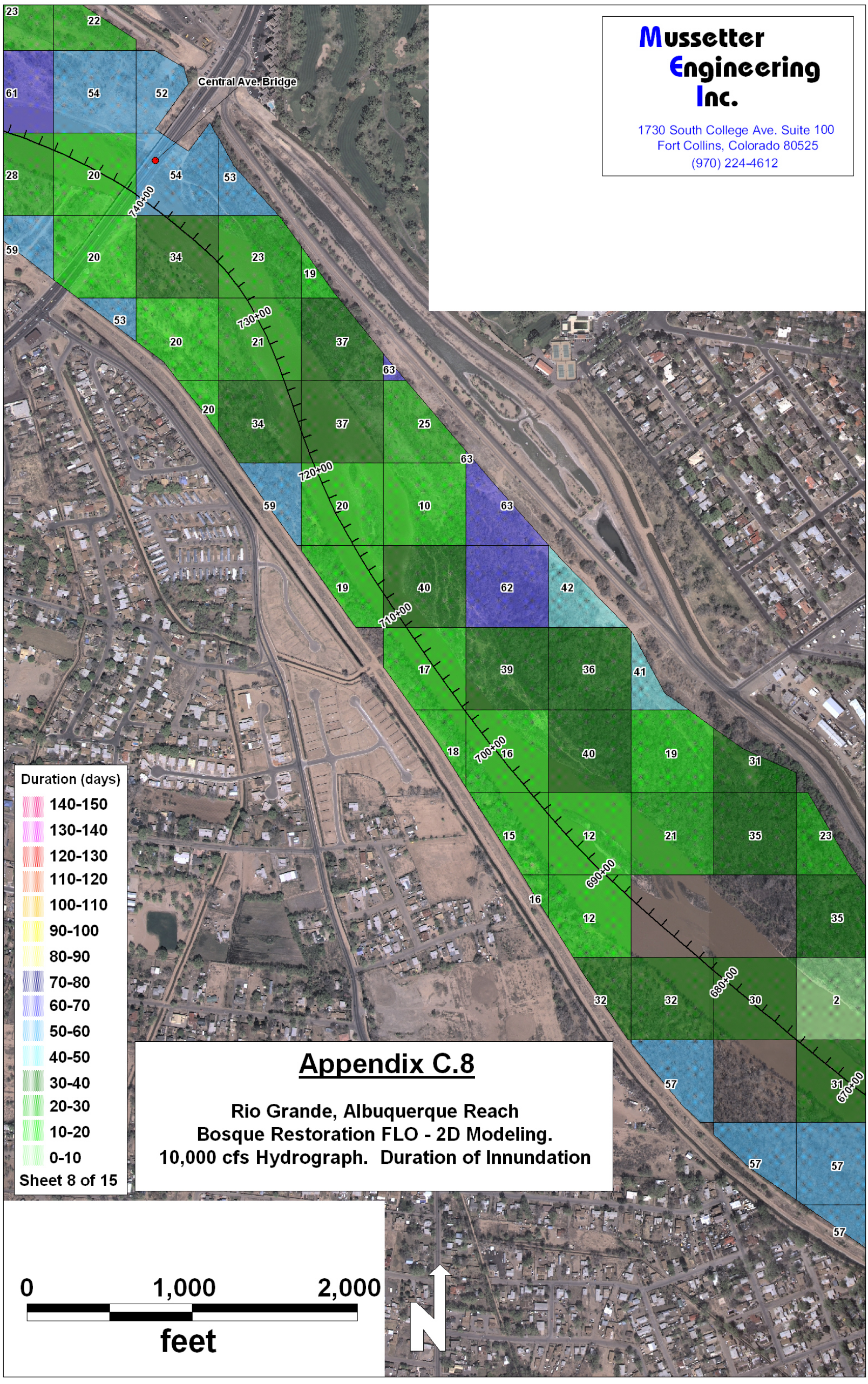
Fort Collins, Colorado 80525
(970) 224-4612
Duration (days)
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 5 of 15
Appendix C.5
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation
0
1,000
2,000
feet
N
960+00
950+00
940+00
930+00
920+00
910+00
900+00
890+00
880+00
870+00
43
44
9
2
42
42
8
51
51
51
51
24
19
36



Appendix C.6

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation


Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
Central Ave. Bridg
800+00
790+00
780+00
770+00
760+00
750+00
740+00
730+00
Duration (days)
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 7 of 15
Appendix C.7
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation
N
0
1,000
2,000
feet



Appendix C.8

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation

Appendix C.9

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation

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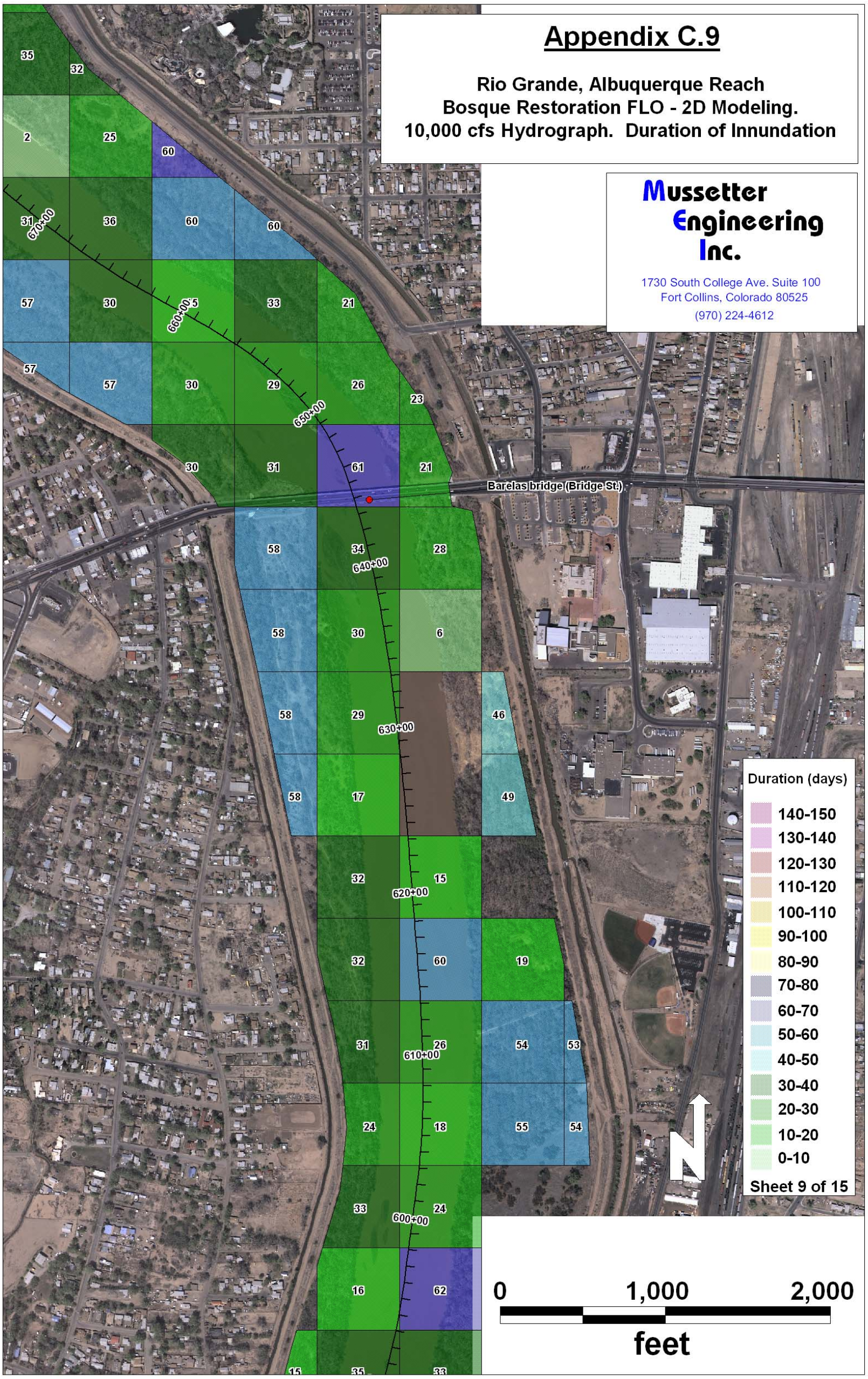

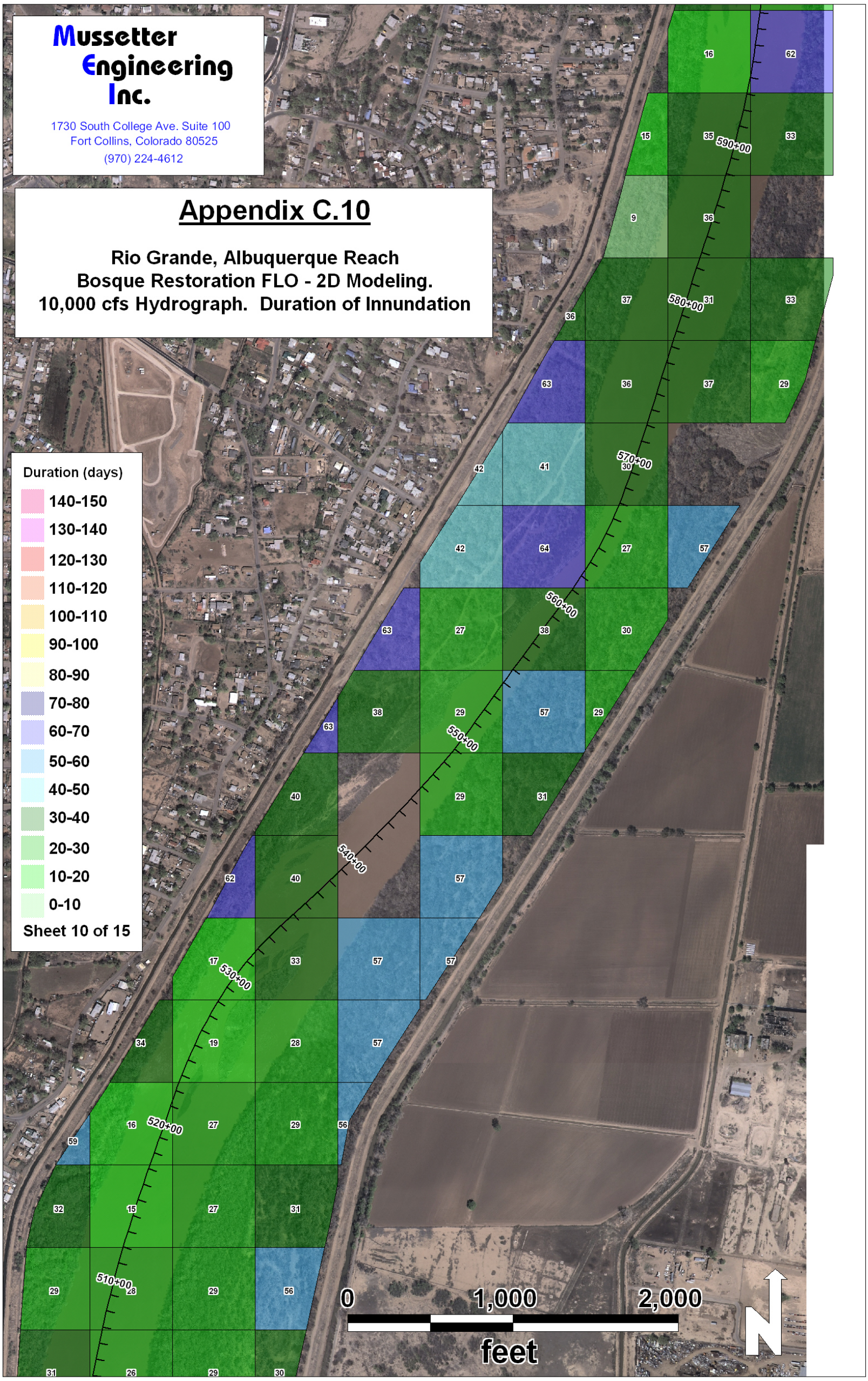
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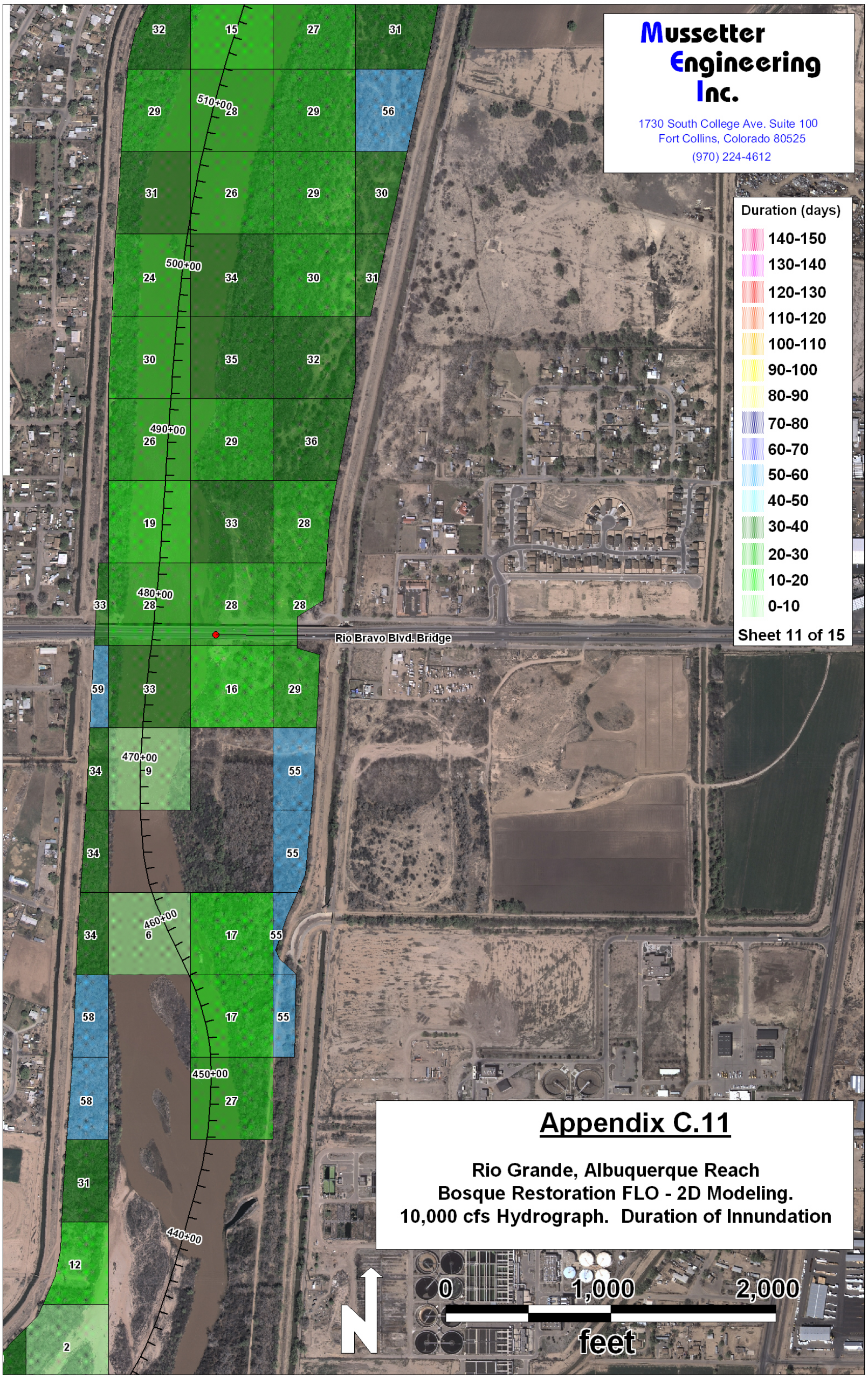
Appendix C.10
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation
Duration (days)
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 10 of 15
590+00
580+00
570+00
560+00
550+00
540+00
530+00
520+00
510+00
0
1,000
2,000
feet
N


Mussetter Engineering Inc.
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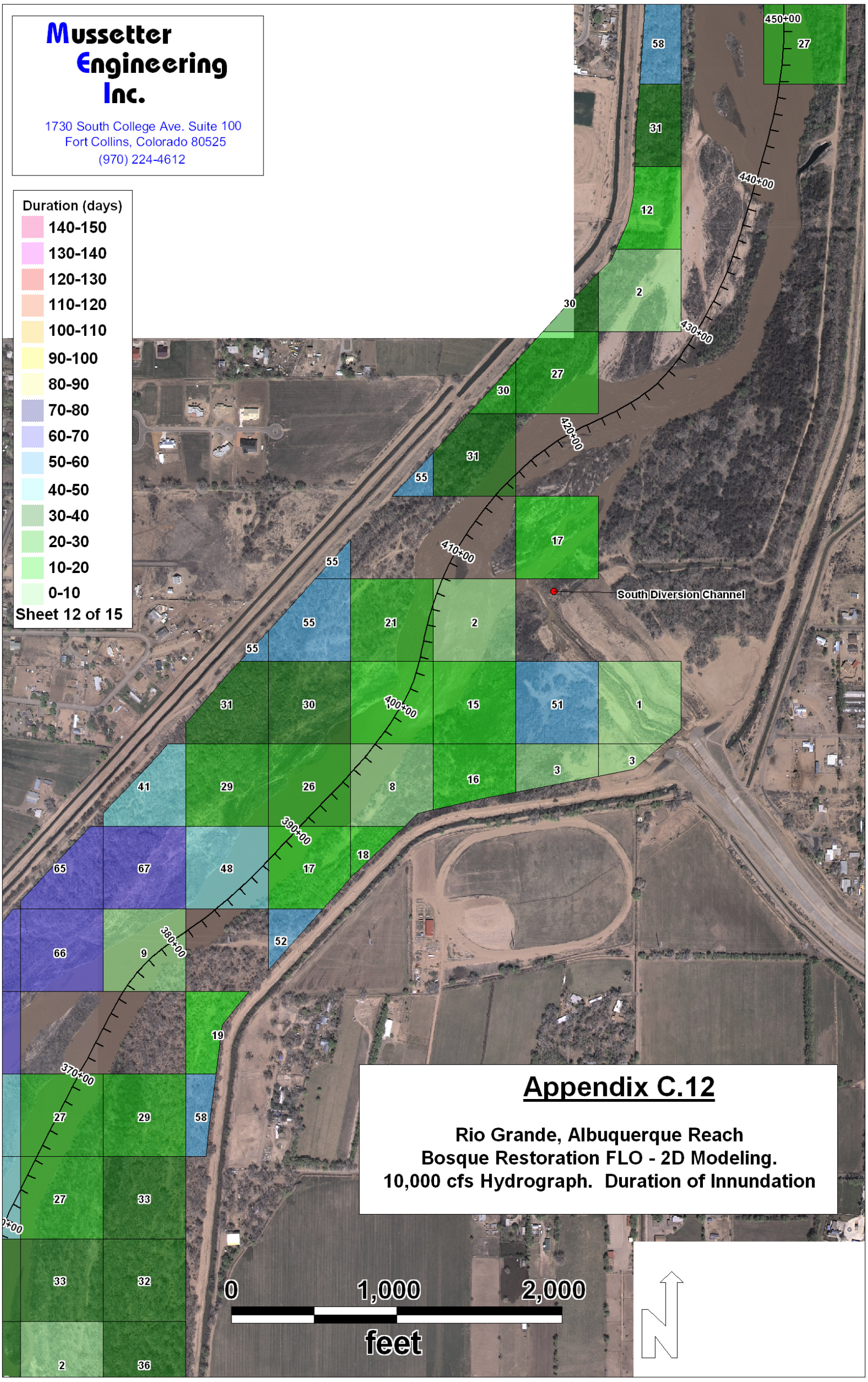
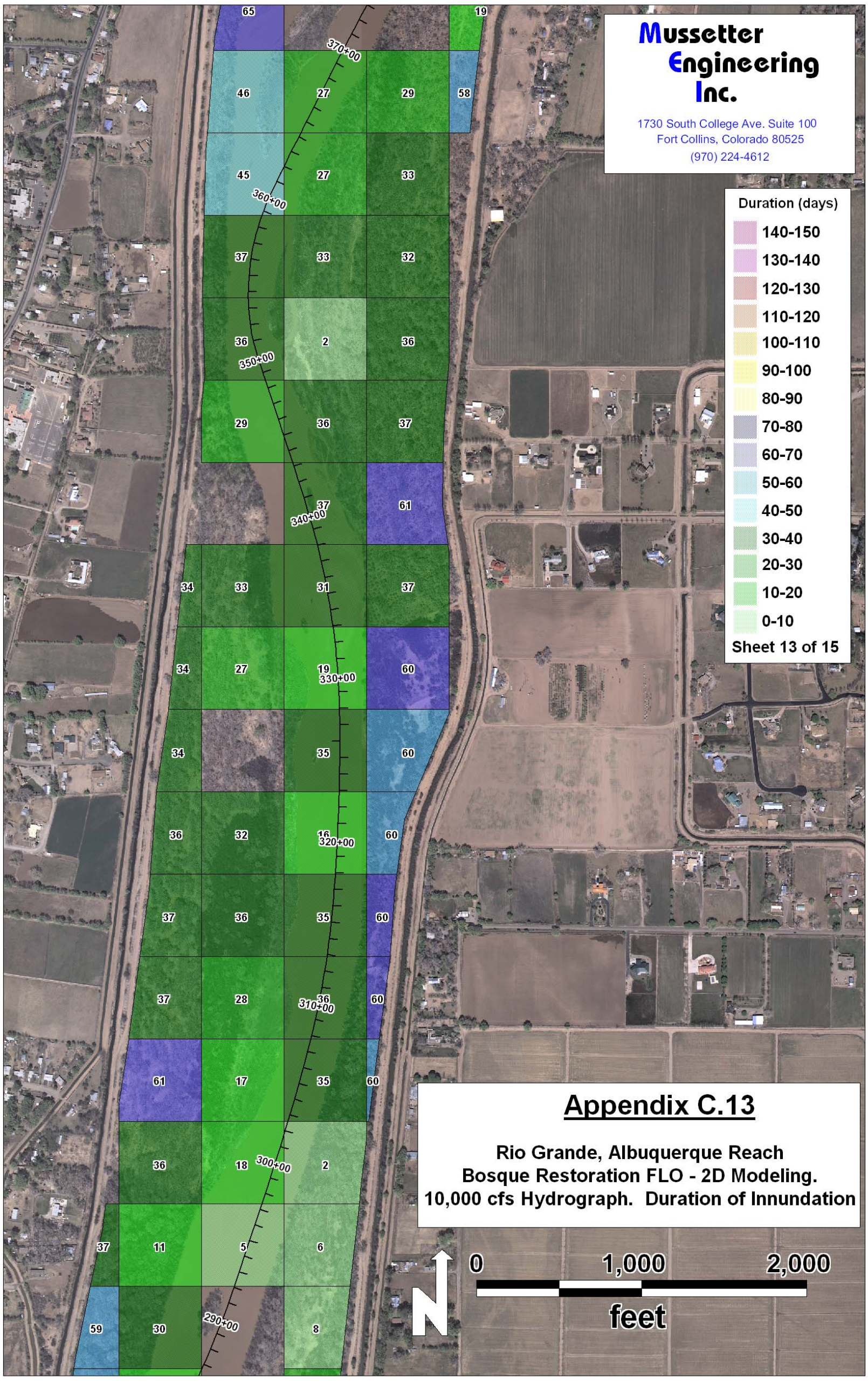
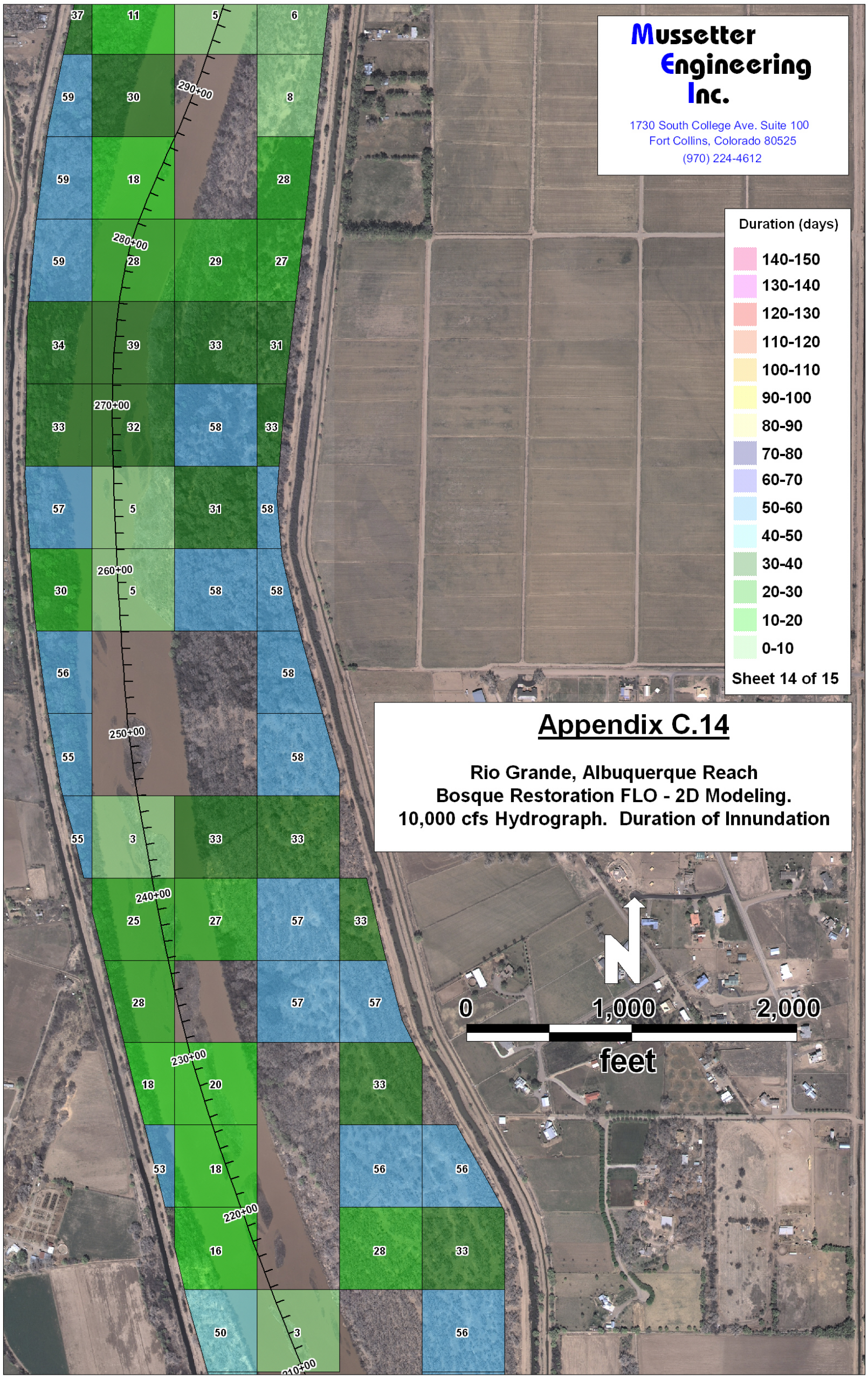
Fort Collins, Colorado 80525
(970) 224-4612
Duration (days)
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 11 of 15
Rio Bravo Blvd. Bridge
510+00
500+00
490+00
480+00
470+00
460+00
450+00
440+00
32
15
27
31
29
28
29
56
31
26
29
30
24
34
30
31
30
35
32
26
29
36
19
33
28
33
28
28
28
59
33
16
29
34
9
55
34
55
34
6
17
55
58
17
55
58
27
31
12
2
0
1,000
2,000
feet
N
Appendix C.11
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation



Appendix C.12

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation


Mussetter Engineering Inc.
1730 South College Ave. Suite 100
Fort Collins, Colorado 80525
(970) 224-4612
Duration (days)
140-150
130-140
120-130
110-120
100-110
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 13 of 15
Appendix C.13
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation
0
1,000
2,000
feet
N
370+00
360+00
350+00
340+00
330+00
320+00
310+00
300+00
290+00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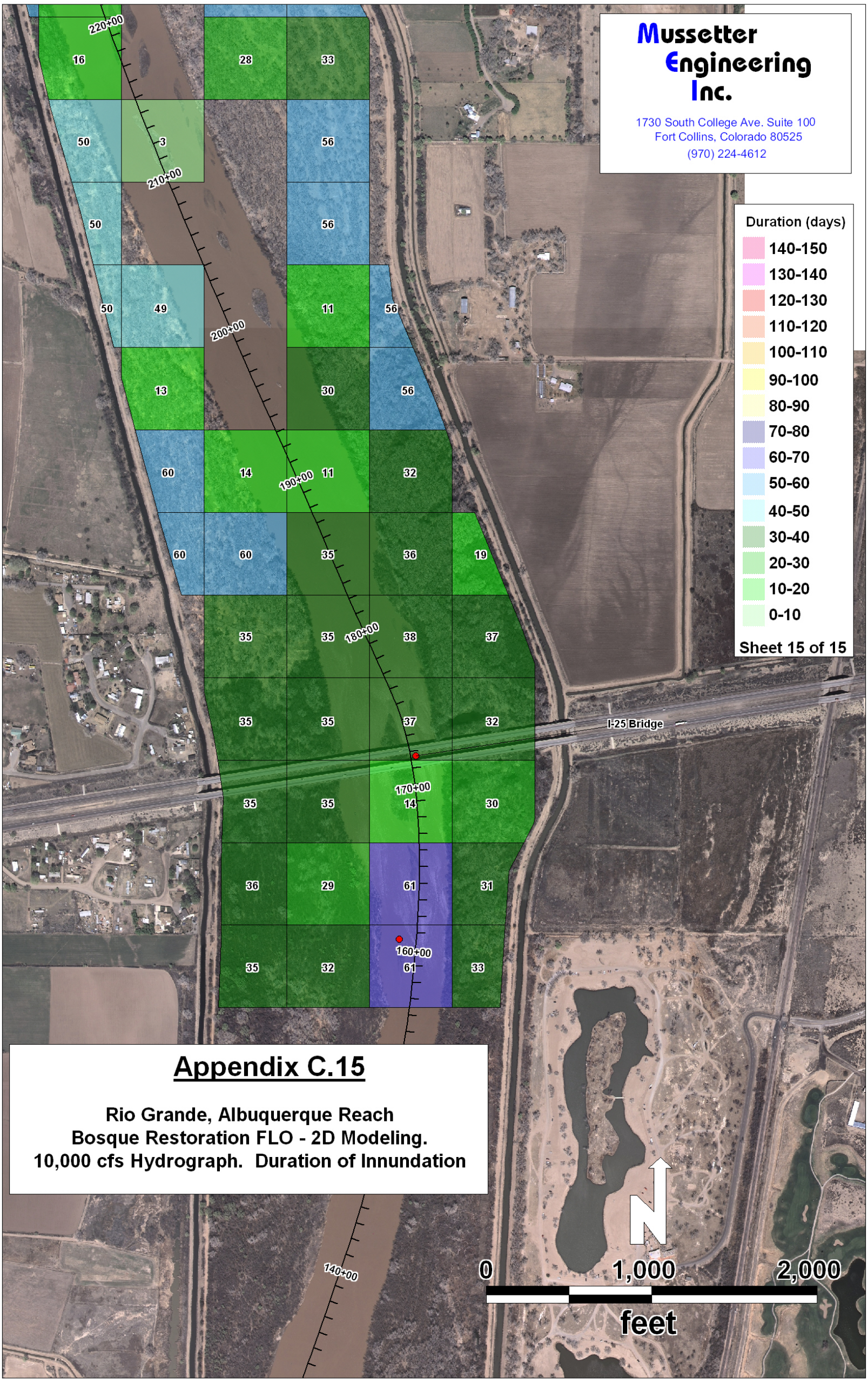
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
Sheet 14 of 15
Appendix C.14
Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation
N
0
1,000
2,000
feet
290+00
280+00
270+00
260+00
250+00
240+00
230+00
220+00
210+00



Appendix C.15

Rio Grande, Albuquerque Reach
Bosque Restoration FLO - 2D Modeling.
10,000 cfs Hydrograph. Duration of Innundation

REAL ESTATE REPORT

Bosque Revitalization @ Route 66
Albuquerque, New Mexico

PURPOSE: This Real Estate Report (RER) was prepared under the general guidelines of ER 405-1-12, Chapter 2 and Chapter 12, and is for planning purposes in support of a Feasibility Report. Final real estate property lines and estimates of value are subject to change after approval of this document. This report addresses the Governments need for project lands located along the Rio Grande, in Albuquerque, New Mexico.

AUTHORIZATION: This planning report is prepared under the authority of Section 1135 of the Water Resources Development Act (WRDA) 0f 1986, Public Law 99-662. The approved Detailed Project Report and Environmental Assessment is dated November 2005.

PROJECT LOCATION AND DESCRIPTION: The Study Area is a riparian area located within the middle reach of the Rio Grande (aka Middle Rio Grande), which is broadly described as extending from Cochiti Dam to Elephant Butte Reservoir. The actual Study Area encompasses a small portion of the Rio Grande within the City of Albuquerque, New Mexico.

The Study Area consists of 3.10 river miles along the Rio Grande stretching north and south from Central Avenue. Central Avenue is the longest intact segment of historic U. S. Route 66, which is the basis for the project name.

The north side of the Interstate 40 (I-40) Bridge is the upstream limit of the Study Area and the south side of Bridge Boulevard is the downstream limit. The Study Area is bounded on the east and west by levees and riverside drains, except for a small portion of the area north of the Central Avenue Bridge on the west side where there is no levee or riverside drain and the boundary is the adjacent bluff.

The Study Area includes approximately 643 acres. There are 370 acres within the active river channel and 273 acres of riparian woodlands, or "bosque", as it is commonly referred to in New Mexico, (derived from the Spanish word for woodland/forest). With the exception of the northwest corner of the Study Area, the lands are managed by the Middle Rio Grande Conservancy District (MRGCD) and the City of Albuquerque Parks and Open Space Division (AOSD) as part of the Rio Grande Valley State Park (RGVSP).

The MRGCD is the non-Federal sponsor for this study. The MRGCD was established in 1925 to provide irrigation water, river flood control and soil drainage in the Middle Rio Grande Valley, primarily for agriculture. The MRGCD is based in Albuquerque, New Mexico with similar facilities in other places along the Middle Rio Grande. The MRGCD manages most of the Bosque and controls and maintains the system of canals, drainage ways and other facilities along the Middle Rio Grande from Cochiti Dam downstream to the northern boundary of Bosque del Apache National Wildlife Refuge. The AOSD, within whom the MRGCD co-manages the bosque within the Study Area, is a critical partner in the development and implementation of this plan. The AOSD manages 29,000 acres of land in the Albuquerque area, of which the bosque is the largest portion. The team responsible for the planning process (the Project Development

Team) include representatives of the Albuquerque District, Corps of Engineers, MRGCD, AOSD and New Mexico State Parks and their consultants.

The land between the exterior boundaries of this project is generally riparian woodland with poorly maintained walking trails that will be renovated along with the proposed environmental restoration. Existing Kellner jetty jacks, which are essentially large metal rail X's, were placed by several different governmental agencies for nominal flood control. These items have outlived their purpose and removal was coordinated and approved by the governmental agencies. The highest and best use for lands within the Study Area is considered to be open space for scenic and recreational use. Lands within the Study Area are estimated to have a bulk acreage value of $9,850.00 per acre (25% of value) based upon an appraisal by the City of Albuquerque dated January 3, 2004 and adjusted to present value. The City acquired this land through negotiations at approximately 15% over the appraised value or $37,200.00 per acre. The property was zoned A-1, Rural Agricultural, as defined by the County of Bernalillo. The property within the Study Area is considered to be Bosque/Wetlands and is estimated to have a considerably lesser value due to lack of developmental potential and location within a flood zone.

DESCRIPTION OF LANDS, EASEMENTS AND RIGHTS: There are three separate landowners within the Study Area. These properties were verified with the Bernalillo County Assessor's Office. The City of Albuquerque holds Fee Title to approximately 27 acres: Westland Development Co, Inc. holds Fee Title to approximately 89 acres and MRGCD holds Fee Title to approximately 554 acres. The property owned by the City of Albuquerque, within the Study Area, is known as Tingley Ponds and was recently restored/renovated under a project known as Albuquerque Biological Park Wetlands Restoration Project, therefore, these 27 acres are not included as part of the total acreage for the Study Area. MRGCD is a state entity and adheres to normal real estate practices and laws. For the purpose of this real estate plan, the real estate will be treated as if it were available to the open market. This will be necessary for the crediting issues of this project. Westland Development Company, Inc. is a land development company that holds approximately 57,000 acres of land in Albuquerque's west side. I 40 traverses the heart of Westland's property on an east –west run. Real estate values will be compared to similar type lands and estates. Minimum land requirements for this project are described by ER 405-1-12, paragraph 12-9b (6). Required lands are held under standard estates. MRGCD has been a non-Federal sponsor on several past district projects and has expressed strong support for this project and will provide appropriate easements for desired restoration areas. All construction access to the sites is by public roadway. All contractor staging is to be within the defined project boundaries. Excess material will be removed to an appropriate commercial dump site. Lands, easements, rights-of-way, relocations and disposal areas (LERRD's) and is estimated at $2,700,000.00 .

The life of the project is estimated at 25 years with the first year consisting of construction and the remaining time for monitoring and maintenance. Monitoring, by the Corps, will continue for the first five years.

PROPOSED NON-STANDARD ESTATES: None

EXISTING FEDERAL PROJECTS; Yes, Albuquerque Levees Project is in the Feasibility Phase and its limits are, on the west side of the Rio Grande, from La Orilla Road, south approximately 12.30 miles to a point approximately 2 miles south of Rio Bravo Boulevard and on the east side of the river from a point being the approximate south boundary of Sandia Pueblo (also the north side of the North Diversion Channel), south approximately 15.20 miles to the South Diversion Channel.

NAVIGABLE SERVITUDE: None

INDUCED FLOODING: None

REAL ESTATE BASELINE COST ESTIMATE:

LANDOWNER	ACREAGE	$/ACRE	ESTATE	TOTAL
MRGCD	273	$9,850.00	Fee	$2,700,000.00 (rounded)
Westland Develop-Ment Co., Inc.	N/A			
City of Albuquerque	N/A			
Land Cost Sub-total:				
Government Administration				
Real Estate Mapping Support				$8,500.00
Real Estate Coordination & Monitoring				$12,000.00
Real Estate Appraisals				$12,000.00
Admin. Sub-total:				$32,500.00
Estimated Contingency				$20,000.00
Total				**$2,752,500.00**

RELOCATION ASSISTANCE:

Facility/Utility Relocations: There are no facility relocations involved with the proposed project. In this instance, there is no requirement for any Preliminary Attorney's Opinion of Compensability. Any conclusion or categorization contained in this report that an item is a utility or facility relocation to be performed by the Non-Federal Sponsor as part of its LERRD responsibility is preliminary only. The government will make a final determination of the relocations necessary for the construction, operation or maintenance of the project after further analysis and completion and approval of Final Attorney's Opinion of Compensability for each of the impacted utilities and facilities, if any.

PL 91- Relocation Assistance Benefits: The project is not displacing usable or habitable structures. Also, there is not any personal property that requires relocation.

MINERAL ACTIVITY: There is no known or anticipated mineral activity in the vicinity of the project. If any arises, the value indicated in this plan may change.

HTRW: No known hazardous waste material sites are affected by this project, the potential to encounter previously undocumented hazardous materials and wastes originating from previous uses of the property that would affect the project, exists. If contamination is encountered during construction, work will cease in the vicinity of the contaminated area until the extent and type of contamination has been determined.

LAND OWNERS: The landowners, within the study area are, the City of Albuquerque, Westland Development Corporation and the Middle Rio Grande Conservancy District. As mention earlier, the only property affected by this project is MRGCD's. MRGCD has been a non-federal sponsor on several past district projects and they have expressed strong of this one and are willing to provide the necessary real estate for their portion of the project.

There are no known opposition to this project by other landowners in the vicinity.

NON-FEDERAL SPONSOR: The non-federal sponsor is the Middle Rio Grande Conservancy District MRGCD. They do not have an experienced real estate department nor condemnation authority. Their Capability Assessment checklist is as follows: N/A

REAL ESTATE ACQUISITION SCHEDULE: MRGCD is the current owner of the lands within the study area.

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPAPILITY

Project: Bosque Revitalization @ Route 66
Non-Federal Sponsor: Middle Rio Grande Conservancy District

I. Legal Authority:

a. Does the sponsor have the legal authority to acquire and hold and hold title project purposes? Yes
b. Does the sponsor have the power of eminent domain for this project? No
c. Does the sponsor have "quick take" authority for this project? No
d. Are any of the lands/interests in land for the project located outside the sponsor's political boundary? No
e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? No

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? No
b. If the answer to II a. is "yes", has a reasonable plan been developed to provide such training? N/A
c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibility for the project? N/A
d. Is the sponsor's projected in-house staffing level sufficient considering its other workload, if any, and the projected schedule? N/A
e. Can the sponsor obtain contractor support, if required, in a timely fashion? Yes
f. Will the sponsor likely request USACE assistance in acquiring real estate? No

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximate to the project site? Yes
b. Has the sponsor approved the project/real estate schedule/milestones? N/A

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? Yes
b. With regard to this project, the sponsor is anticipated to be highly capable.

V. <u>Coordination:</u>

a. Has the assessment been coordinated with the sponsor? Yes

b. Does the sponsor concur with this assessment? No

Prepared by:

Louie Gurule
Realty Specialist

Reviewed and approved by:

John M. Baker
Chief, Real Estate Division

_____ _____
Louie Gurulé, Realty Specialist

Attached Maps, Photos, Project Drawings, etc……..

Route 66 Project
DACW47-09-08-0189

TEMPORARY EASEMENT
for STAGING AREA

The City of Albuquerque, a New Mexico municipal corporation, hereinafter referred to as the Grantor, in consideration of the benefit to the community, hereby convey to the U.S. Army, Corps of Engineers, Albuquerque District, hereinafter referred to as the Corps, a Temporary Easement for Staging area, in, on, over and across the land hereinafter described and as shown on Exhibit "A", attached hereto and made a part hereof, for a period of twelve (12) months, beginning with the date possession of the land is granted to the Corps, its representatives, agents or contractors, and automatically terminating on ??????????????, reserving, however, to the Grantors, their heirs and successors, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired. The Corps shall be responsible for damages arising from the activities of the Corps, its officers, employees or representatives on said land, in the exercise of rights under this Temporary Easement, either by repairing such damages or at the option of the Corps, by making an appropriate settlement with the Grantors in lieu thereof. Said land being within the County of Bernalillo, State of New Mexico.

<u>Temporary Easement for Staging Area.</u>

A strip of land situated within the Section 30, Township 10 North, Range 3 East of the New Mexico Principal Meridian, County of Bernalillo, State of New Mexico,

1. Said strip of land is located at 3901 Central ave. N.W, Albuquerque, New Mexico.

2. Said strip of land is located at New Bridge Acres Addition, Block 1, Lots 12, 13, & 14. Albuquerque, New Mexico.

Signed and executed this _____ day of _____ 2008.

City of Albuquerque

The United States of America

_____

_____

Ed Adams, P.E.

JOHN M. BAKER
Acting Chief Administrative Officer
Chief, Real Estate Division
Albuquerque District, Corps of Engineers

(Notary Blocks?????????)

M.R.G.C.D. CONTRACT NO. _____

USBR CONTRACT NO. _____

M.R.G.C.D. MAP NO's. 38, 39, 40, & 41

RIO GRANDE BOSQUE

RIVER MILE STATION 183.4± TO 185.0±

MIDDLE RIO GRANDE PROJECT
SPECIAL USE APPROVAL
FOR THE USE OF DISTRICT WORKS

APPROVAL TO ALLOW THE UNITED STATES CORPS OF ENGINEERS TO INGRESS AND EGRESS THE RIO GRANDE BOSQUE FOR THE PURPOSE OF DEVELOPING THE BOSQUE REVITALIZATION AT ROUTE 66 PROJECT

This Agreement is made and entered into this _____ day of _____, 20_____, by and between the Middle Rio Grande Conservancy District, (the District), the United States Department of the Interior, Bureau of Reclamation (Reclamation) and the United States Corps of Engineer (the Corps of Engineers).

WHEREAS, the Rio Grande Bosque (the property) is held for the works of the District, in fee simple estate and the District operates and maintains the property as an integral part of the works of the District; and

WHEREAS, the Corps of Engineers has requested permission from the District and Reclamation, to the extent of the Districts and Reclamations property interest, to ingress and egress the property for the purpose of developing and implementing plans for the Bosque Revitalization at Route 66 Project (the Project) in a manner more particularly specified herein; and

WHEREAS, the District and the Reclamation are willing to agree, to the project and use of the property and encroachment upon the property pursuant to the conditions more particularly specified herein;

NOW THEREFORE, the District and Reclamation agree to use of, and encroachment upon the property by the Corps of Engineers only to the extent and for the purpose set forth below:

1. The Corps of Engineers shall INGRESS AND EGRESS THE BOSQUE ON THE WEST SIDE OF THE RIO GRANDE, SOUTH OF INTERSTATE 40 TO BRIDGE BOULEVARD FOR THE PURPOSE OF PLANNING, DEVELOPING, AND IMPLEMENTING RECREATIONAL TRAILS AND BOARDWALK, INTERPRETIVE SIGNAGE, REST AREAS, WILDLIFE OBSERVATION AREAS AND RIVER ACCESS PLATFORMS WHICH WILL BE FUNDED IN ACCORDANCE WITH THE CORPSS OF ENGINEERS SECTION 1135, WATER RESOURCES DEVELOPMENT ACT OF 1986, hereinafter referred to as "the installation", across the property which will serve AS RECREATIONAL

FACILITIES. The District and Reclamation agrees to the installation set forth in this paragraph only pursuant to the approved PLANS FOR BOSQUE REVITALIZATION @ ROUTE 66, AND APPROVED DETAILED PROJECT REPORT AND ENVIRONMENTAL ASSESSMENT FOR THE BOSQUE REVITALIZATION @ROUTE 66 PROJECT, and any and all other attached drawings and/or specifications which by this reference are made a part of this Agreement.

2. The Corps of Engineers shall prepare and coordinate with the contractor the approval of all engineering, property appraisals, environmental reviews, and inspection of the Project during construction.

3. This agreement shall be null and void if the Project is not constructed and inspected for approval by December 2010.

4. The Corps of Engineers shall be responsible to coordinate the approval of the Project plans with the District and Reclamation. Upon approval of the Project plans the Corps of Engineers shall locate, install, construct, maintain and/or repair any structures, accessories, or any installation approved in the Project plans at the expense of the Corps of Engineers during construction. Upon completion of construction, the Corps of Engineers shall contact the District and Reclamation to inspect the Project. If the District and Reclamation agree the Project has been constructed in compliance with the approved plans, the District shall take over the maintenance of the Project.

5. The privilege granted by this Agreement shall not be exercised, nor shall any structure, accessory, or installation be constructed or maintained so as to obstruct in any manner the flow of water into or through the works of the District, or to interfere in any manner whatsoever with the construction, operation, maintenance and functions of the District or the Reclamation. Should any culvert pipes, maintenance roads, bridge crossings, fences, gates, structures or any installations permitted under this Agreement become damaged or require removal, relocation, or protection as a result of the Corpss of Engineers construction activities, the Corps of Engineers shall, at its own expense, repair, remove, relocate, or protect the installation.

7. This Agreement is not intended by any of the provisions of any part of the License to create in the public, or any member thereof, a third-party beneficiary or to authorize anyone not a party to this Agreement to maintain a suit for wrongful death, bodily and/or personal injury to person, damage to property and/or any other claim(s) whatsoever pursuant to the provisions of the Agreement.

8. By entering into this Agreement, each party shall be responsible for liability arising from personal injury or damage to person and property occasioned by its own agents or employees in the performance of this Agreement, subject in all cases to the immunities and limitations of the New Mexico Tort Claims Act (NMSA 1978, Section 41-4-1, et seq.) and any amendments thereto. This paragraph is intended only to define the liabilities as governed by common law or the New Mexico Tort Claims Act. The District and its "public employees" as defined in the New Mexico Tort Claims Act, do not waive sovereign immunity, do not waive any defense and/or do not waive any limitations of liability pursuant to law. No provision in this License modifies and/or waives any provision of the New Mexico Tort Claims Act. Likewise, the Corps is subject to the Federal Tort Claims Act (28 U.S.C. 1346(b) and 2671-2680) and the immunities and limitations therein. The Corps does not waive sovereign immunity or any defense and/or limitation of liability pursuant to federal law.

9. Where the property that is the subject of this Agreement is held for the works of the District other than as a fee simple estate, the Corps of Engineers shall be solely responsible for ascertaining whether the Project will encroach upon property belonging to other entities or persons other than the District and/or Reclamation and for obtaining any additional permission or licenses that may be required from property owners other than the District. The Corps of Engineers shall obtain the requisite permission prior to the use and or construction of the Project upon the property.

10. By this Agreement, the District/Reclamation does not warrant its fee simple estate interest. This Agreement serves solely to define the conditions pursuant to which the Corps of Engineers will be permitted to ingress and egress and construct upon the property as evidenced by existing records and as defined by this Agreement.

11. This Agreement shall be revocable by the District and/or Reclamation, upon thirty (30) days written notice to the Corps of Engineers if the District and/or Reclamation determines that the continuation of this Agreement is detrimental to the interest of the works of the District. Upon such revocation, all structures, accessories, and installations shall be removed by the Corps of Engineers without delay at the expense of the Corps of Engineers. Any rights that the Corps of Engineers may have under this Agreement shall terminate immediately upon receipt of written notice of revocation. Revocation shall not release the Corps of Engineers from any obligation that may have attached, accrued, or was accruing at the time of such revocation. Notice of revocation shall be sufficient if mailed to Licensee at: _____

_____

12. The Corps of Engineers shall comply with all applicable laws, ordinances, rules, and regulations enacted or promulgated by any federal, state, or local government body having jurisdiction over the real property for which the Agreement is granted.

13. The provisions of this agreement shall inure to the benefit of and be binding upon the heirs, executors, administrators, personal representatives, successors, and assigns of the parties hereto; provided, however, that no such heir, executor, administrator, personal representative, successor or assign of the Corps of Engineers shall have the right to use, alter, or modify the access / encroachment in a manner which will increase the burden of the encroachment on the property. This Agreement shall not be assignable by the Corps of Engineers without prior written approval from the District and Reclamation.

14. All design work to be done within the property must be coordinated with the District prior to commencing work, and shall be closely coordinated with the District's Engineering Department and appropriate field offices, **Phone: (505) 247-0234.**

15. The Corps of Engineers shall not perform work on the property or upon structures belonging to, or operated by the District between March 1 and October 31 inclusive. However, the District may permit work if the Licensee demonstrates to the District, prior to commencing work, that the work will not interfere with the District operations and maintenance of the property.

16. The Corps of Engineers, its employees, agents, contractors or subcontractors shall not store equipment, materials and/or debris on the property which may interfere with operations and maintenance of the property and shall not service vehicles or equipment on the property.

17. Seeding of disturbed areas within the right-of-way is required per District seeding specifications and must meet the satisfaction of the District staff.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the day and year first above written.

APPROVED:
MIDDLE RIO GRANDE CONSERVANCY DISTRICT

_____DATE:_____
Subhas K. Shah, Chief Executive Officer

APPROVED:
UNITED STATES BUREAU OF RECLAMATION

_____DATE:_____

ACCEPTED:
UNITED STATES CORPS OF ENGINEERS

_____DATE:_____

ACKNOWLEDGMENT OF THE CORPS OF ENGINEERS

State of)
)ss.
County of)

On the _____ day of _____, 20____, the above noted personally appeared before me, known to me to be the individual described in and who executed the within and foregoing instrument, and acknowledged that he / she signed the within and foregoing instrument as his / her free and voluntary act and did for the uses and purposes therein mentioned.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed my official seal the day and year first above written.

_____

_____
Notary Public in and for the
State of
Residing at
My commission expires:

FINAL CONSTRUCTION INSPECTED:
MIDDLE RIO GRANDE CONSERVANCY DISTRICT

_____DATE:_____