Santa Fe River Study

Report on Existing Environmental Conditions and Potential Natural Resources Restoration Projects

5 December 2007

Prepared for
U.S. Army Corps of Engineers, Albuquerque District
Delivery Order 0014, Contract No. DACW47-03-D-005

Prepared by
John S. Pittenger and Karen A. Yori
Blue Earth Ecological Consultants, Inc.
1345 Pacheco Street
Santa Fe, New Mexico 87505

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1.0 INTRODUCTION

This report describes existing environmental conditions and potential natural resources restoration projects for a segment of the Santa Fe River in and near the City of Santa Fe, New Mexico (Figure 1). The Santa Fe River was declared America's most-endangered river in 2007 by American Rivers (2007).

The report is part of a larger General Investigation Watershed Study by the U.S. Army Corps of Engineers, Albuquerque District, in cooperation with the City of Santa Fe and Santa Fe County. The purpose of the study is to 1) identify alternatives for restoration of the structure and function of the Santa Fe River and 2) determine the federal interest in watershed planning and water resources management in the study area.

1.1 The Study Area

The Santa Fe River study area is located in north-central Santa Fe County, New Mexico (Figure 1). The study area begins at the Camino Alire bridge crossing within Santa Fe city limits and extends downstream 7.16 miles to the N.M. Highway 599 bridge crossing. For the purposes of this report, the study area is defined as the area ecologically influenced by the river. This was interpreted in the field as the active river channel, established and nascent floodplain areas, and low terraces potentially subject to flooding under relatively commonplace flows. Field mapping and photo-interpretation were employed to delineate the area of river influence, which ended up encompassing about 83 acres. The boundary of the area of river influence is shown on figures depicting soil types and plant communities in the study area (*cf.* sections 2.4 and 2.8).

1.2 Past Restoration Projects That Currently Influence Existing Conditions

Two major grade control structures in the study area, while not constructed specifically for the purposes of ecological restoration, play a major role in arresting bed degradation and establishing channel equilibrium. These functions are critical with respect to development of riparian vegetation and other ecological attributes in the study area. The County Road 62 (CR 62) crossing was constructed in 1994 and the San Ysidro crossing was constructed in 1999. Both structures were designed by the U.S. Army Corps of Engineers, Albuquerque District.

A 1.5-mile restoration project on State Trust lands at the downstream end of the project area was implemented in 1999-2000. This project involved removal of a road-fill crossing, construction of a meander at the crossing site, installation of several root-wad revetments and extensive planting of riparian vegetation to promote narrowing of the channel and meander development.

Another restoration project was conducted on the reach between the San Ysidro crossing and CR 62 in 2005. This project involved excavation of steep, eroding banks and recontouring them to a more gentle slope, channel reconfiguration, installation of a grade control and energy dissipation structure, and riparian plantings.

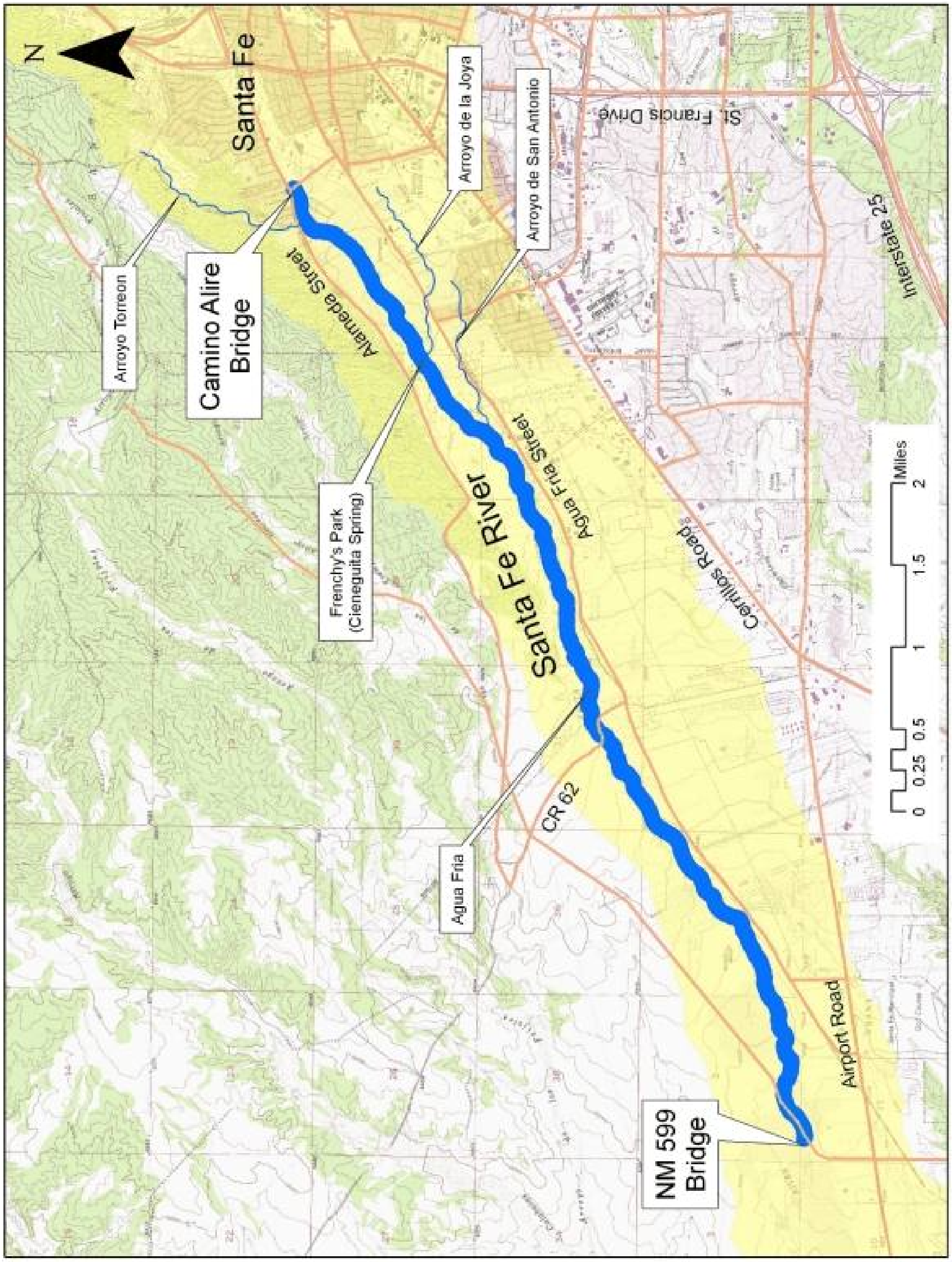


Figure 1. Location of the Santa Fe River study area (blue line) in north-central Santa Fe County, New Mexico. Major tributaries to the river in the study area are labeled. The portion of the Santa Fe River watershed on the mapped area is indicated by yellow shading.

2.0 EXISTING ENVIRONMENTAL SETTING

2.1 Climate

Climate of the study area is dry semi-arid (Köppen-Geiger classification BSk; Kottek *et al*., 2006). Precipitation is concentrated in the summer when southeasterly circulation of air masses brings moist air up from the Gulf of Mexico. Strong surface heating and orographic lifting causes these air masses to rise, resulting in condensation of moisture and rainfall. In contrast, winter precipitation derives primarily from Pacific Ocean storms that are strong enough to persist inland to New Mexico. Such frontal systems move from west to east across the state.

Average maximum summer temperatures are around 80°F, with associated average low temperatures in the mid-50s. Winter average high temperatures are in the low to mid-40s with lows typically near 20°F (Figure 2). Precipitation is concentrated in the summer months. Evapotranspiration increases markedly in April and stays high through the growing season (Figure 2). Average annual precipitation in the study area is about 13.7 inches but there is considerable variation from year to year. The lowest recorded annual precipitation, 5.03 inches, was in 1917 while the highest annual precipitation (21.75 inches) on record was in 1881 (Figure 3).

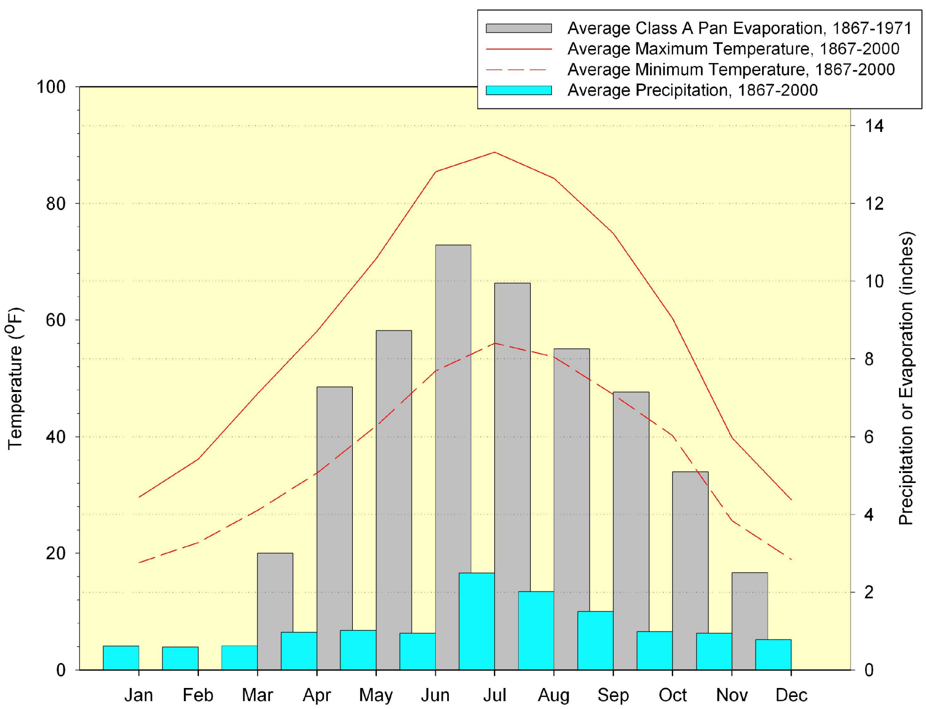


Figure 2. Climate characteristics for the Santa Fe area, 1867 to 2006. Data for 1867 to 1972 are from the Santa Fe station (298072), 1972 to 2006 data are from the Santa Fe 2 station (298085; Western Regional Climate Center, 2007). Class A pan evaporation data for 1867 to 1972 are from Oregon Climate Service (2007). Pan evaporation data for 1971 to 2006 were not available.

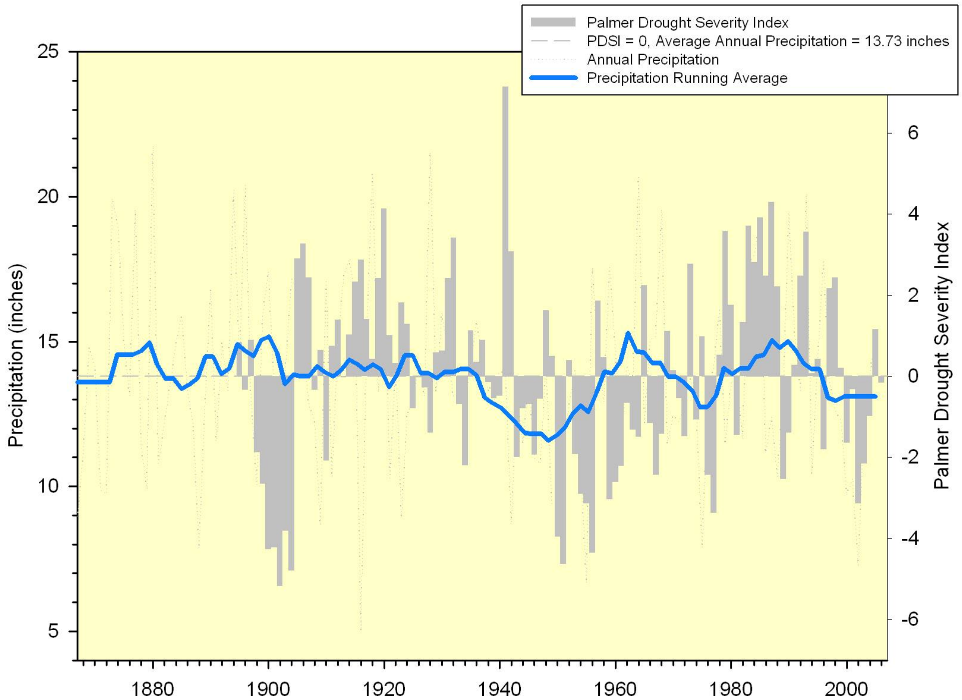


Figure 3. Precipitation and drought record for the Santa Fe area, 1867 to 2006. Precipitation data are from stations 298072 and 298085 (Western Regional Climate Center, 2007) as described in the caption for Figure 2. Palmer drought severity index data are annual averages. Monthly index data are from National Climatic Data Center (2007).

Since climate data in the Santa Fe area began being recorded in the late 1800s, drought conditions (*i.e.* a Palmer drought index of -4.0 or lower) were observed in the area around the turn of the 20th century, during the 1950s, from 1963 to 1964, in 1967, and from 2000 to 2004 (Figure 3; New Mexico Climate Center, 2007).

2.2 Physiography and Geology

Located in the Southern Rocky Mountains province of the Rocky Mountain System physiographic region (Fenneman and Johnson, 1946), the study area is situated on a broad plain or piedmont on the east side of a trough formed by the Rio Grande rift (Shroba *et al.*, 2005). The trough of the Rio Grande rift in the vicinity of Santa Fe is bounded on the east by the Sangre de Cristo Mountains and on the west by the Sierra Nacimiento (Spiegel and Baldwin, 1963: 6). The portion of the Rio Grande rift valley including the study area is known as the Santa Fe Embayment.

Erosion of the pre-Tertiary rocks of the Sangre de Cristo Mountains during the late Oligocene to Miocene (*ca.* 33 to 23 million years ago; Read *et al.*, 2000), initiated by uplift of the mountain mass, resulted in extensive deposition of detrital sediments in the subsiding valley basin. These deposited sediments are known as the Tesuque Formation of the Santa Fe Group and they comprise the major water-bearing geologic formation in the Santa Fe area (Spiegel and Baldwin, 1963: 133; Lewis and West, 1995; Shroba *et al.*, 2005: 11). The Tesuque Formation consists of light brown to red unconsolidated sediments and sandstone (Shroba *et al*., 2005: 15). The upper unit of the formation is unconsolidated to weakly consolidated sediments varying from slightly cobbly pebble gravel to silty sand, while the lower unit is very fine to fine sand, sandstone, and sandy pebble conglomerate in lenses and tabular beds (Shroba *et al*., 2005: 16-17). The Tesuque Formation in the study area overlies Proterozoic or Pennsylvanian rocks and is in excess of 3,700 feet thick (McAda and Wasiolek, 1988: 64).

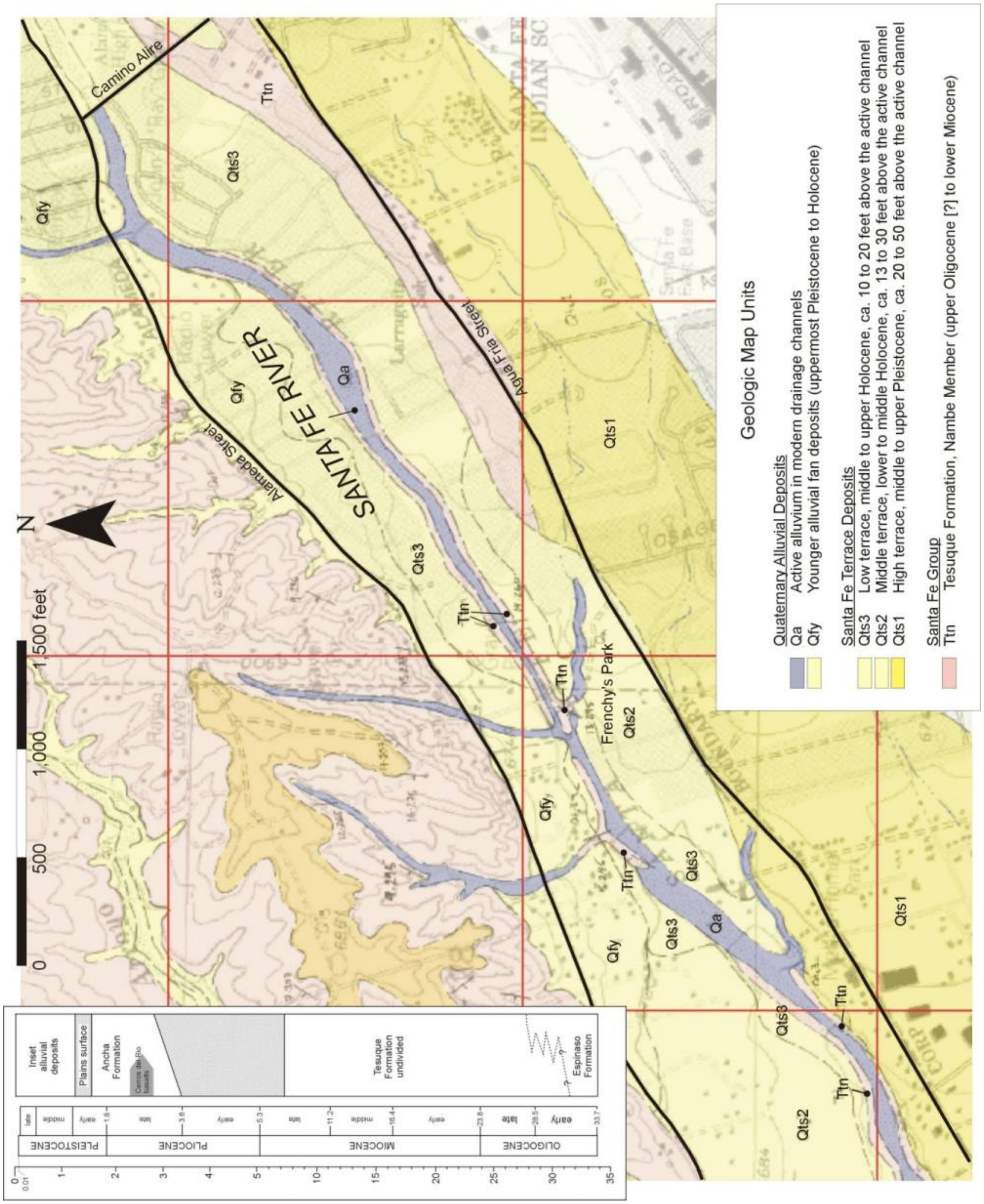
Aggradation of the Tesuque Formation ceased about eight million years ago (Konig *et al*., 2002). The Tesuque Formation is overlain on the piedmont surface north and south of the Santa Fe River by another depositional feature, the Ancha Formation (Konig *et al*., 2002). The Ancha Formation consists of light brownish gray to brown silty sand to pebbly sand with gravel and was deposited by streams draining the southern Sangre de Cristo Mountains during the late Pliocene to early Pleistocene time (Konig *et al*., 2002; Shroba *et al*., 2005). The Ancha Formation ceased aggrading between 1.48 and 1.25 million years ago (Konig *et al*., 2002: 83), probably because of incision of the Santa Fe River through the relatively resistant rocks of the Cerros del Rio volcanic field at La Bajada and its subsequent drainage of the Santa Fe embayment of the Española basin (Konig *et al*., 2002). The Ancha Formation ranges in thickness from about 10 to 200 feet (Shroba *et al*., 2005: 16). This formation has been eroded and reworked in the study area by the Santa Fe River.

A third stratigraphic unit was deposited on top of the Ancha Formation in the early Pleistocene (Kong *et al*., 2002; Shroba *et al*., 2005). This unit, mapped as sheetwash deposits by Shroba and others (2005). This unit may reach thicknesses of up to about 16 feet in the vicinity of the study area (Shroba *et al*., 2005: 7).

Surficial geology in the study area consists of modern alluvium associated with the active channel of the Santa Fe River and flanking terrace deposits sediments that represent floodplains formed at higher base levels by the ancestral Santa Fe River (Figures 4 and 5). Artificial fills associated with old gravel pits and landfills are common in the lower half of the study area, between County Road 62 (CR 62) and N.M. Highway 599 (NM 599; Figure 5).

Exposures of the Tesuque Formation are evident along the vertical banks of the incised river channel throughout the study area (Figure 6). Outcrops of consolidated Tesuque Formation sandstone in the bed of the river channel were encountered sporadically in the river channel from the old stream gage downstream from Camino Alire to below the CR 62 crossing (Figure 7). Outcrops of Tesuque Formation in the channel bed were absent in the remainder of the study area, from about 2,000 feet downstream from the CR 62 crossing to the NM 599 bridge.

Figure 4. Geologic map of the upstream half of the study area, excerpted from Read *et al.* (2000). The inset diagram of stratigraphic units was adapted from Figure 5 in Konig *et al.* (2002).



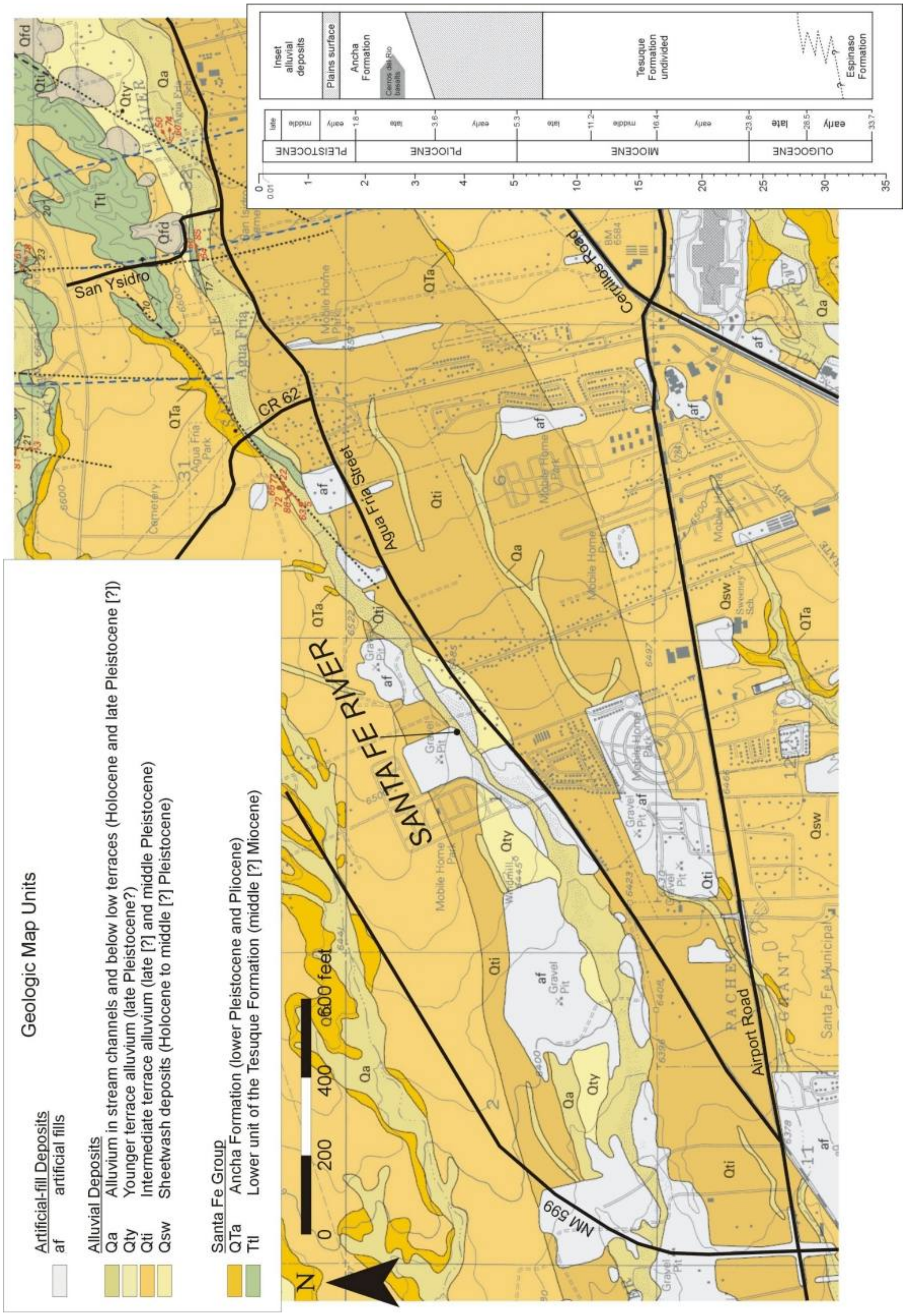


Figure 5. Geologic map of the lower half of the study area, excerpted from Shroba *et al*. (2005). The inset diagram of stratigraphic units was adapted from Figure 5 in Konig *et al.* (2002).

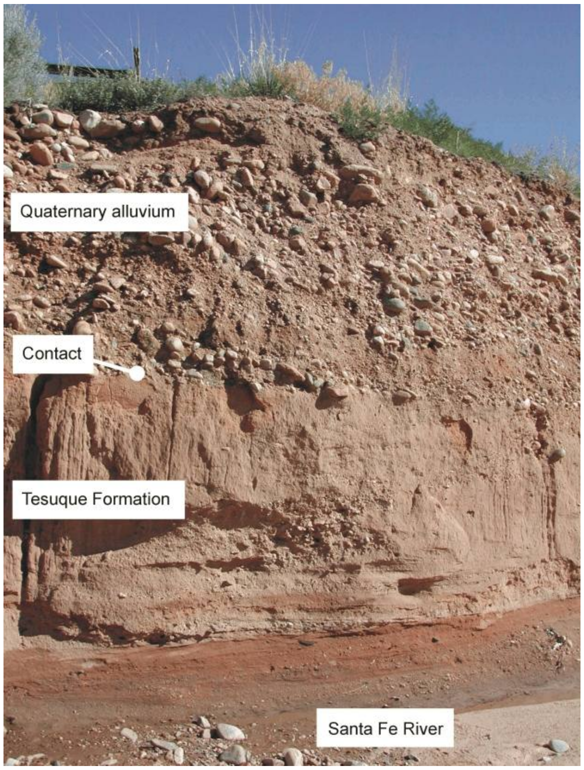


Figure 6. Exposure of the Tesuque Formation below Quaternary alluvium on the left (south) bank of the Santa Fe River upstream from Frenchy's Park, 15 June 2007 (photo by J. Pittenger).

Figure 7. Tesuque Formation outcrop in the bed of the Santa Fe River at San Ysidro River Park. View is downstream. 26 June 2007 (photo by J. Pittenger).

2.3 Groundwater

The following discussion presents basic information on groundwater characteristics that are relevant to ecological restoration in the study area, including depth to groundwater and groundwater flow patterns in the study area. It is not an exhaustive or comprehensive analysis of groundwater in the study area. The water-bearing geologic units in the study area, from oldest to youngest, are the Tesuque Formation, terrace deposits, and recent alluvium. Presence of water in recent alluvium is of most importance to restoration of riparian vegetation in the study area.

2.3.1 Tesuque Formation

The Tesuque Formation comprises a deep aquifer and, as discussed in section 2.2, is an important water source for the Santa Fe area. Recharge of the Tesuque Formation occurs at the mountain front where the formation outcrops, through alluvium in stream channels such as the Santa Fe River, and via areal recharge from percolation of precipitation through overlying sediments (McAda and Wasiolek, 1988: 29-30). A ridge in the potentiometric surface of the Tesuque aquifer under the Santa Fe River attest to the fact that infiltration of surface water flows and shallow groundwater moving through alluvium in the channel do recharge deep groundwater (Spiegel and Brewster, 1963: 131; Lewis and West, 1995). Groundwater flow in the Tesuque aquifer is from east to west-southwest in the study area (Lewis and West, 1995).

Groundwater in the Tesuque Formation discharged naturally into the Santa Fe River in at least two locations in the study area as recently as the early 1960s. Seeps and springs discharged into the Santa Fe River at Cieneguita (present-day location of Frenchy's Park; Figure 1) and at Agua Fria (Spiegel and Baldwin, 1963: 132; Figure 1). The occurrence of these springs was described by Spiegel and Baldwin (1963:132) as follows:

> *"The discharge* (of groundwater from the Tesuque Formation) *at Cieneguita is probably the result of impedance of ground-water flow through the permeable sand section of the Tesuque formation by compact red conglomeratic silts which crops out in the channel of the Santa Fe River just below the west limit of Santa Fe. The native growth of cottonwoods, the emergence of ground water, and the shallow water table in the Tesuque formation upstream – all indicate the existence of a partial barrier. Probably some ground water leaks through the barrier at depth, as well as flowing down the channel cut into it. Downstream from the barrier, the ground-water discharge probably returns to the Tesuque formation, as the water table there is deep again. Similar conditions prevail at Agua Fria, where also the ground water in a sandstone of the Tesuque formation flows across a barrier. The overflow emerges in the Santa Fe River channel because it is the lowest possible overflow line in the area"* (parenthesis added).

The Cieneguita Spring (Figure 8) and Agua Fria Spring sites on the Santa Fe River no longer have surface water except during periods of rainfall runoff , due to lowering of groundwater levels by groundwater withdrawal from municipal wells, reduced stream flow, and cessation of irrigation. Currently, groundwater in the Tesuque Formation is well below the surface in the study area (McAda and Wasiolek, 1988: 23) and therefore is not likely to influence existing plant growth or ecological function.

Figure 8. View upstream of the Cieneguita Spring site at present-day Frenchy's Park, 26 June 2007. Arrow indicates outcropping of compact, red conglomeratic silts of the Tesuque Formation (photo by J. Pittenger).

Groundwater may be present at the top of the Tesuque Formation within about 1.5 miles of the front of the mountains but is generally much deeper at locations farther out from the mountains (*i.e.* at depths greater than 50 feet; Lazarus and Drakos, 1995; Grant, 2002: 12), such as in the study area. Due to the complex, heterogeneous composition of the Tesuque Formation, depth to groundwater may vary considerably from one location to the next (Lewis and West, 1995). The occurrence of shallow groundwater at the top of the Tesuque aquifer is difficult to predict because is associated with the presence of discontinuous paleochannels eroded into the top of the formation (Lazarus and Drakos, 1995).

Groundwater from the Tesuque aquifer is hard due to high calcium and bicarbonate, which are the major chemical constituents in the water. Hardness generally ranges from 121 to 232 parts per million (ppm), total dissolved solids typically range from 90 to 500 ppm, and electrical conductivity is low and ranges from 150 to 800 micromhos per centimeter (Spiegel and Baldwin, 1963: 134; Lewis and West, 1995).

2.3.2 Terrace Deposits and Recent Alluvium

Terrace deposits and recent alluvium occur as thin (*ca.* five to 40 feet thick; Lazarus and Drakos, 1995) sheets of coarse, unconsolidated sediment overlying the Tesuque Formation in the study area. Historically, the alluvium held a perched or semi-perched water table maintained by rainfall and infiltration of surface water in the Santa Fe River in locations where the underlying Tesuque Formation is relatively impermeable (Spiegel and Baldwin, 1963: 138-143). Where alluvium is underlain by more permeable deposits of the Tesuque Formation, water infiltrates from the alluvium into the deeper aquifer (Spiegel and Baldwin, 1963: 141).

This alluvial aquifer was of sufficient volume that it discharged as springs and seeps at various locations along the river, most notably in the vicinity of Cienega Street in downtown Santa Fe (Spiegel and Baldwin, 1963: 139). Similarly, several pueblos were located along the river at cienegas or marshy areas that were supported by a high water table in the alluvium (Spiegel and Baldwin, 1963: 91-92). These sites, including Los Palacios, Pino, and Pueblo Quemado, were later settled by Spanish immigrants because of the water available for irrigation (Spiegel and Baldwin, 1963: 94). Many older homes along the Santa Fe River had shallow hand-dug wells completed in the alluvial aquifer (Lazarus and Drakos, 1995).

Perched water no longer occurs in the alluvium and springs, seeps, and wells supplied by this shallow aquifer have gone dry since the early 1960s (Lazarus and Drakos, 1995). Loss of the alluvial aquifer is attributable to elimination of flow in acequias and cessation of flood-irrigation, groundwater pumping, reduction of stream flow, and paving-over of recharge areas (Spiegel and Baldwin, 1963: 141-142; Lazarus and Drakos, 1995). Significant down-cutting of the channel of the Santa Fe River has reduced the potential volume of the alluvial aquifer. In many locations, the channel has scoured down to the top of the Tesuque Formation. Consequently, stream flow, whether arising from storm-water runoff or upstream reservoir releases, does not infiltrate but rather flows downstream. This situation prevents subsequent recharge of the Tesuque aquifer or maintenance of a high riparian water table in the study area.

2.4 Surface Water

This section describes existing physical conditions of the Santa Fe River in the study area. Biological attributes including vegetation, wetlands, fish, and wildlife are discussed in section 2.8. The Santa Fe River watershed encompasses about 160 square miles (Spiegel and Baldwin, 1963: 150). The headwaters of the river are at Santa Fe Lake, at an elevation of about 11,589 feet near the crest of the Sangre de Cristo Mountains. The river flows into Cochiti Reservoir and the channel continues below Cochit Dam to its confluence with the Rio Grande near Cochiti Pueblo.

The portion of the watershed below Nichols Dam that drains into the study area comprises about 17,195 acres, or about 17 percent of the entire watershed. Major tributaries to the Santa Fe River in the study area include Arroyo de la Joya, Arroyo Torreon, and Arroyo de San Antonio (Figure 1). Several other smaller arroyos draining the hill slopes on the north side of the river between Camino Alire and Agua Fria are also tributary to the river in the study area.

2.4.1 Hydrology

Before 1881 there were no surface water storage facilities on the Santa Fe River (Spiegel and Baldwin, 1963: 172). Diversions of surface water from the Santa Fe River began with Spanish settlement of the area, which started around 1609. Native Americans inhabiting the area prior to Spanish settlement likely did not divert water from the river for use in growing crops (Spiegel and Baldwin, 1963: 91-92).

Stone Dam was constructed in 1881 on the Santa Fe River upstream in the canyon reach of the river. The reservoir created by the dam filled with sediment in the span of a few years. Two-Mile Dam was then built at a downstream site in 1894. Increasing need for water prompted the construction of Granite Point Dam, about four miles upstream from Two-Mile Dam, in 1926. A third structure, Nichols Dam, was constructed between Two-Mile and Granite Point dams in 1943. The crest of Granite Point Dam was raised in 1935 and again in 1947, when the name was changed to McClure Dam. In 1992, Two-Mile Dam was found to be unstable and the dam was subsequently decommissioned in 1994.

Prior to upstream impoundment of stream flow, the Santa Fe River in the study area likely had considerable, sustained flow most of the time. Perennial flow characterized the reach of the river from its source at Santa Fe Lake downstream through downtown Santa Fe (Grant, 2002: 9-10). Surface water flow through the study area reach was likely reliable in most years, as indicated by the historic locations of 11 irrigation diversions on the river along this reach (Spiegel and Baldwin, 1963: 174).

Currently, flow through the study area occurs only in response to storm water runoff or releases from the upstream dams. There are at least 20 discrete storm water drain or arroyo confluences with the Santa Fe River in the study area (Figure 9; Plate 6). These inputs range from small-diameter (*e.g.* 1-foot diameter) pipes, to open arroyo channels, to large storm-water drain culverts.

The estimated 100-year recurrence interval flow in the study area is about 8,000 cubic feet per second (cfs; Lange, 1998). The 100-year recurrence interval flow is defined as a flow with a one percent probability of occurring in any given year. Analysis conducted for the lower segment of the study area estimated the 25-year recurrence interval flow in the Santa Fe River (*i.e.* the flow with a four percent probability of occurring in any given year) to be 1,800 cfs. Bankfull flow (1.5-year recurrence interval, 67 percent probability of occurring in any given year) was estimated to be 230 cfs (W.J. Miller Engineers, Inc., 2000).

Spiegel and Baldwin (1963: 173) estimated that a flow of 4 cfs at the mountain front would infiltrate entirely into the channel alluvium in the reach downstream to Cieneguita (*i.e.* current-day Frenchy's Park). It should be noted that this infiltration rate was estimated under conditions of a channel that was not as incised as the current channel and therefore a greater volume of alluvial sediments was available to hold water and allow it to penetrate into permeable sections of the underlying Tesuque Formation.

In 1998, it was estimated that a release from Nichols Reservoir of 1.5 to 3.0 cfs (three to six acre-feet per day) would be needed to maintain surface flow in the Santa Fe River down to the San Ysidro crossing (M. Hamman, Water Services Division Director, pers. comm., 10 June 1998). In spring 2007, a sustained release from Nichols Reservoir of about 10 cfs maintained flow through the entire study reach (Figure 10). A 10 cfs flow sustained for 24 hours equates to a volume of about 20 acre-feet of water.

Figure 9. Locations of storm water inputs to the Santa Fe River in the study area.

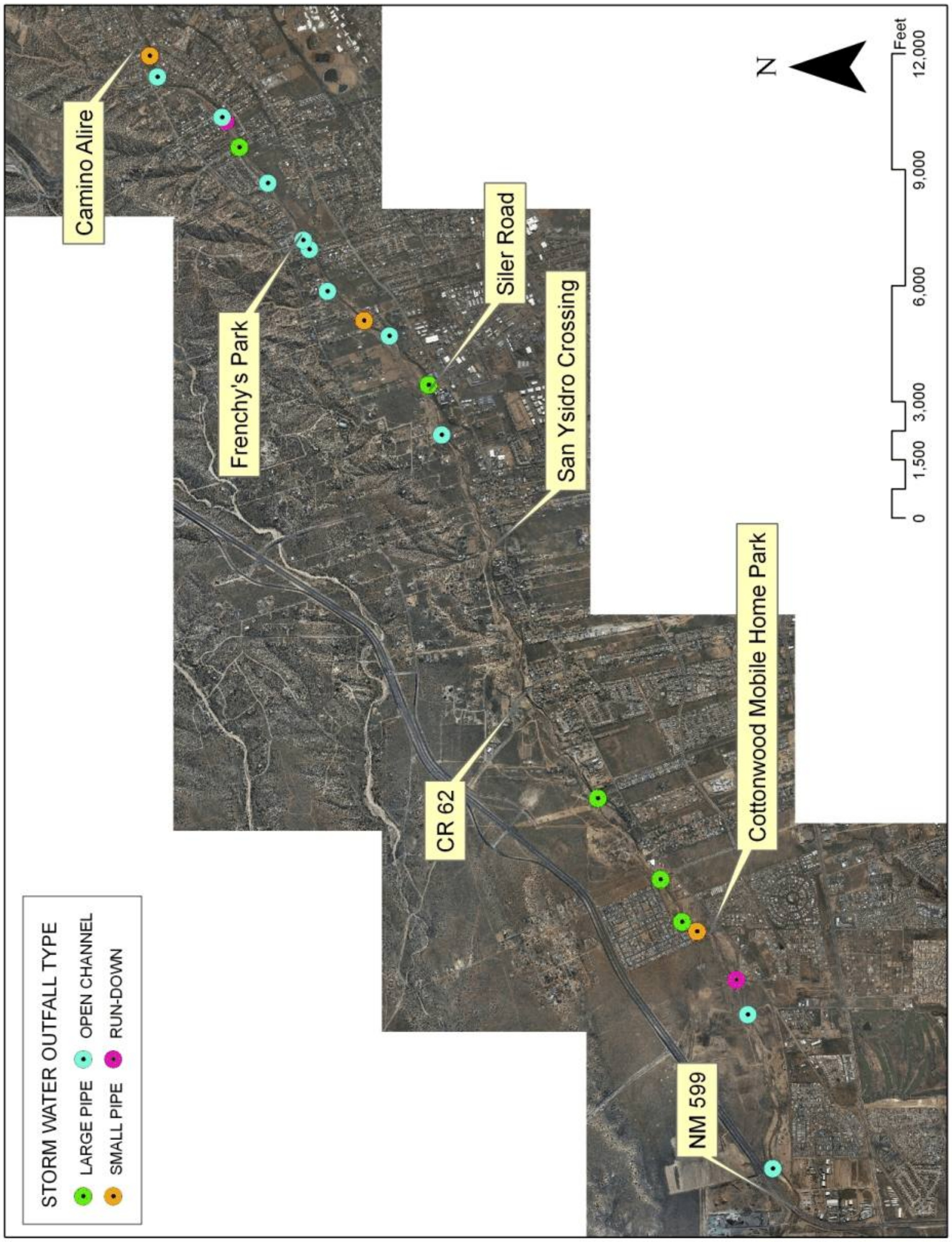


Figure 10. Flow in the Santa Fe River near the NM 599 bridge on 24 May 2007. View is upstream. Photo by J. Pittenger.

2.4.2 Santa Fe River Channel Morphology

Stream channel morphology is controlled by interaction of flow regime, sediment supply, valley slope, composition of channel bed and bank sediments, and riparian vegetation (Leopold and Miller, 1956: 28; Leopold *et al*., 1992: 198; Leopold, 1994: 5). Valley slope through the study area is about 1.35 percent. Historically, channel materials ranged from pebbly, medium to very coarse sand in the channel beds to poorly sorted, slightly pebbly, silty, very fine to medium sand on channel banks and floodplain (Shroba *et al*., 2005). Consequently, the historic channel likely had a meandering plan form with a pool-riffle or gravel bar-sand bed sequence repeated at a spacing of every five to seven channel widths (Leopold, 1994: 28). Such a meandering pattern in a sand-bed stream would be classified as a C5 channel (Rosgen, 1994). A photo of the Santa Fe River near the Alto Street well taken in the early 1960s shows an un-incised channel with an obvious meander pattern, which agrees with the presumption of a historic C5 channel in the study area (Spiegel and Baldwin, 1963:139). Similarly, a 1969 photo of the sewer line crossing of the river below St. Francis Drive shows an un-incised channel with an active, fairly wide floodplain (Heggen, 1997: 29).

2.4.2.1 Causes of Channel Incision and Destabilization

A series of human-induced impacts resulted in dramatic changes in the channel from its probable natural form. First, the hydrograph was radically changed with impoundment of stream flow by upstream reservoirs and loss of the shallow water table from groundwater pumping. These impacts started in the late 1800s and increased in magnitude through the late 1950s. Secondly, increased urbanization increased the area of impervious surfaces, which had the double effect of reducing recharge of the shallow aquifer and reducing the time of concentration of storm water runoff flows (Dunne and Leopold, 1978: 275-277; Heggen, 1997: 27). Consequently, storm water runoff peak flows increased in magnitude, with an associated decrease in duration. These flow spikes introduced powerful, highly erosive hydraulic forces in the channel. Peak storm water flows, coupled with a loss of riparian vegetation that historically made the stream banks more resistant to erosion relative to the stream bed, caused excessive bank erosion, bed scour and destabilization of the channel.

Third, the City of Santa removed or lowered existing grade control structures in the river, beginning in 1974, to increase flood-containment capacity in the channel (Heggen, 1997: 9-10). Grade control structures that were removed included culverts, sills constructed before the 1960s, and rock check dams that were probably built in the 1930s (Heggen, 1997: 9). This campaign of grade control structure removal initiated a period of rapid and dramatic channel degradation. For example, the channel bed below the St. Francis Drive crossing dropped about 12 feet in seven years after removal of downstream grade control structures (Heggen, 1997). This scour effect was exacerbated by sand and gravel mining in the channel, which locally lowered channel base level and initiated upstream-migrating headcutting. Sand and gravel mining in the river channel and floodplain was widespread from about the CR 62 crossing downstream to the NM 599 crossing. Degradation incised the channel bed through the recent alluvium and into the relatively soft sandstone and conglomerate at the top of the Tesuque Formation in many locations through the study area.

These impacts imposed new conditions to which the channel must adjust. Channel incision has been defined as a morphological expression of an imbalanced condition where sediment transport capacity exceeding sediment supply. To re-establish dynamic equilibrium, the channel undergoes changes in slope and cross-sectional area (Harvey and Watson, 1986). A characteristic sequence of changes in channel cross section occur following bed degradation (Harvey and Watson, 1986). The major stages in channel evolution following incision are associated with characteristic channel types (Harvey and Watson, 1986). Immediately following lowering of the base level, a Type II channel forms. Degradation is the dominant process. This channel type is characterized by increased depth, steep vertical banks, high channel slope, and variable sediment accumulation. Width-to-depth ratio of the channel is low. When critical bank height is exceeded by incision, rapid channel widening and development of Type III channel form occurs. Type III channels are characterized by accumulation of sediment in the channel bed and a increasing width-to-depth ratio. Rapid widening is the dominant process.

As channel widening slows due to increased cross-sectional area and reduced sediment transport capacity, a Type IV channel form develops. This channel form is characterized by increased sediment deposition on berms or nascent floodplains, decreasing channel slope, and increasing width-to-depth ratio. Finally, a state of dynamic equilibrium develops and Type V channel form develops. Type V channel is characterized by a relatively high width-to-depth ratio, flattening of channel slope, and continued aggradation and development of a floodplain. This channel type is in dynamic equilibrium, where erosion and deposition processes are in balance (Briggs, 1996: 82).

2.4.2.2 Classification of Stream Segments in the Study Area

Identification of the evolutionary stage of channel reaches in the study area was conducted by applying the Rosgen stream assessment technique and morphological classification system (Rosgen, 1996). The Rosgen stream morphology classification system lends itself well to assessing channel evolution status, as it provides standard method to compare stream segments to the probable natural, equilibrium form (*i.e.* the Type V channel discussed above).

Level II stream assessments were conducted by J. Pittenger of Blue Earth Ecological Consultants, Inc., in 1999 at two locations in the study area (Frenchy's Park and the State Trust land upstream from NM 599) and one location immediately upstream from the study area (the reach between St. Francis Drive and Camino Alire). These assessments involved surveying the slope of the channel, determination and measurement of bankfull channel width, measurement of stream substrate particle size distribution, and measurement of other channel morphology features (Rosgen, 1996: 5-15 through 5-29). Stream types delineated during these assessments were:

- F4b stream type in the reach between St. Francis Drive and Camino Alire;
- F5 stream type at Frenchy's Park;
- B5c stream type in the reach from NM 599 upstream to the meanders below the old Leeder river crossing;
- C5 stream type in the meandering reach below the old Leeder river crossing; and
- D5 steam type above the old Leeder river crossing.

These delineations were made prior to the restoration work at the State Trust reach, which resulted in removal of the Leeder stream crossing, and the project from St. Francis Drive to Camino Alire. The 1999 delineation data provided a basis or key for the following broad level I assessment conducted in the study area (Rosgen, 1996: 4-20 through 4-24).

The following level I assessment was conducted by walking the entire study area and recording observations of plan-view morphology (*i.e.* extent of meandering), channel width and depth at bankfull stage, channel slope, and bed features. These field observations, along with the 1999 delineation data, were then used to interpret and delineate stream segments on aerial photography.

The following delineation is presented from the upstream end of the study area, starting at Camino Alire bridge, and proceeding downstream to the NM 599 bridge. The thalweg of the river channel in the study area was first mapped and subdivided into 200-foot intervals to facilitate location and description of stream segments. The 200-foot interval stations start at the NM 599 bridge (station 0+00) and proceed upstream to the Camino Alire bridge (station 378+80).

Three stream types were delineated in the study area: B, C, and F. The C and F type channels were further subdivided according to dominant channel materials; either gravel or sand (Table 1). The B stream type in the study area had gravel-dominated bed material. Over half of the study area (54 percent) was characterized by C-type channel, which was delineated in five reaches. The F-type channel composed 38 percent of the river in the study area and was delineated in six reaches. One reach was delineated as B-type channel, which composed five percent of the river in the study area (Table 1; Plate 6).

Table 1. Rosgen stream type classification of channel segments in the study area.

Segment	Stream Type	Length (ft)	Station (ft)	
			Start	End
SFR-1	B4	1,767	360+35	378+02
SFR-2	F4	7,123	289+12	360+35
SFR-3	C4	4,614	242+97	289+12
SFR-4	F4	833	234+64	242+97
SFR-5	C4	1,000	224+64	234+64
SFR-6	F4	564	219+00	224+64
SFR-7	C4	1,458	204+42	219+00
SFR-8	F4	1,509	189+33	204+42
SFR-9	C5	2,664	162+69	189+33
SFR-10	F5	2,542	137+27	162+69
SFR-11	F5	1,799	119+28	137+27
SFR-12	C5	11,928	0+00	119+28

The B stream type is moderately entrenched with moderate bankfull width-to-depth ration and a relatively steep gradient (2 to 4 percent). The B-type channel in the study area has a bed dominated by gravel with some sand and cobbles. In the study area, the B4 stream segment is bounded on the downstream end by a grade control structure. This stream type was delineated in segment SFR-1, which is a 1,767-foot reach downstream from Camino Alire (Figure 11). Gabion basket walls line portions of the banks in this reach. Degradation is not occurring in the B-type channel segment in the study area. Furthermore, rapid channel widening is not occurring, as evidenced by vegetated banks and absence of raw, vertical cuts (Figure 12). Therefore, following the preceding discussion in section 2.4.2.1, the probable channel evolution stage of segment SFR-1 is IV or V, which is nearing equilibrium condition.

The C stream type is less entrenched than the B stream type, has a relatively high bankfull width-to-depth ratio, and has moderate sinuosity. This stream type was delineated in five locations in the study area: segments SFR-3, SFR-5, SFR-7, SFR-9, and SFR-12 (Figure 11). Segment SFR-3 is located in the vicinity of Siler Road and consists of a 4.614-foot reach with a relatively well-developed floodplain (Figure 13). The downstream end of segment SFR-5 is marked by the Vereda de San Antonio road crossing, which comprises a grade control for the reach. This segment has a relatively wide floodplain, compared to many other reaches in the study area (Figure 14). Segment SFR-7 is a borderline C4-F4 channel and extends from the Dos Antonios crossing downstream to the San Ysidro crossing.

Channel bed composition shifts from gravel-dominated to sand-dominated in segment SFR-9, which is the San Ysidro River Park restoration reach from the large grade control structure downstream to CR 62 (Figure 11). Finally, segment SFR-12 is a long reach extending from near the Cottonwood Mobile Home Park downstream through State Trust land to the NM 599 bridge. The lower portion of this segment in particular has a relatively wide floodplain and moderate sinuosity (Figure 15).

The C-type channel in the study area ranges in evolutionary stage from reaches that are still actively widening (Type III) to those that are nearing equilibrium (Type IV; Harvey and Watson, 1986).

Figure 11. Delineation of channel segments in the study area using the Rosgen classification system.

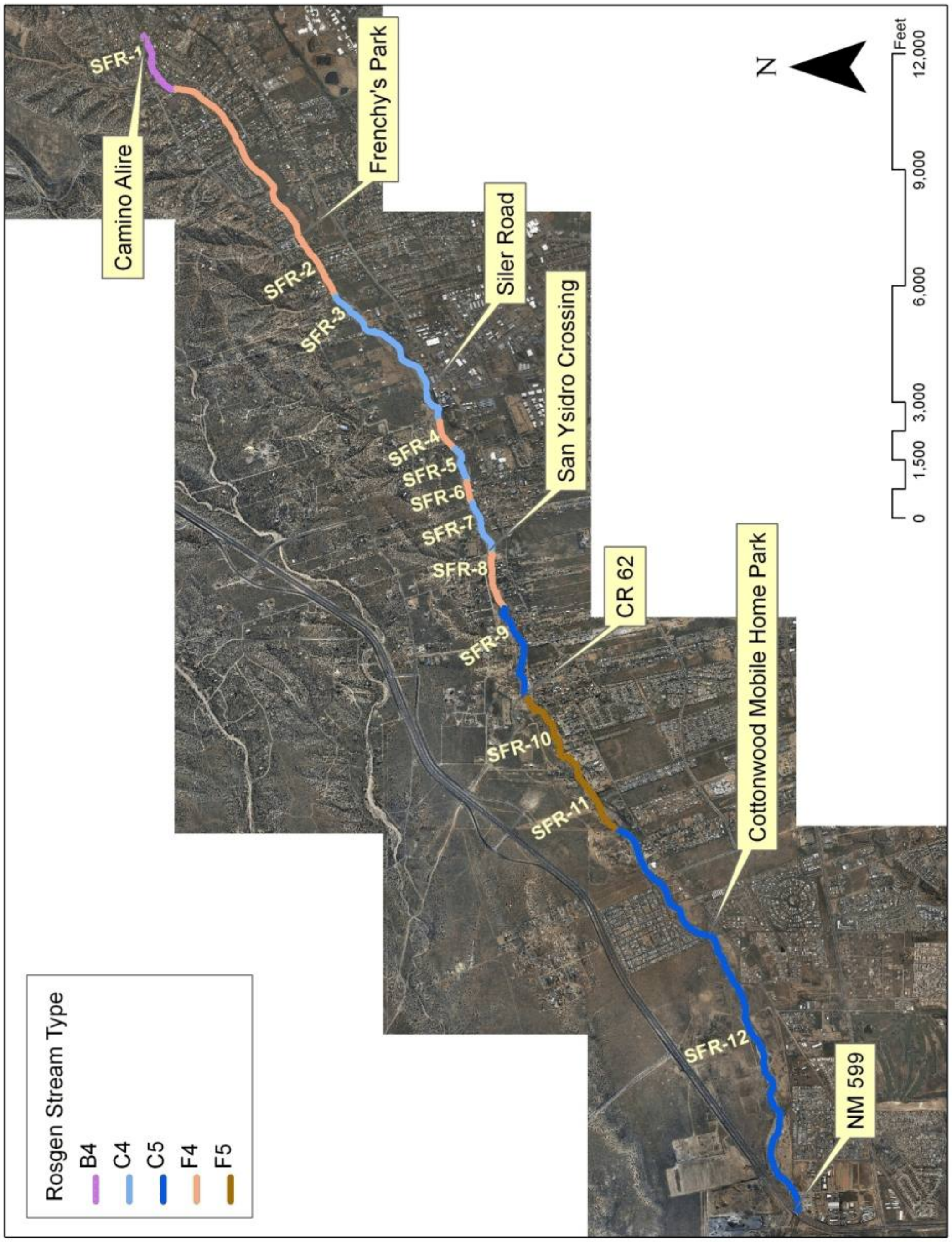


Figure 12. Stream type B4 below Camino Alire bridge. Arrow indicates field determination of bankfull stage. View is upstream, with the bridge in the background. Photo by J. Pittenger, 28 May 2007.

Figure 13. Stream type C4 near the Siler Road dead-end. Relatively well developed floodplain is visible in center-left. View is upstream. Photo by J. Pittenger, 24 May 2007.

Figure 14. Stream type C4 above the Vereda de San Antonio crossing. Note the wide, accessible, undeveloped floodplain area on the right and the absence of channel entrenchment. View is downstream. Photo by J. Pittenger, 26 June 2007.

Figure 15. Stream type C5 at the lower end of the study area. A relatively well developed floodplain, moderate sinuosity, and absence of entrenchment characterize the channel in this reach. View is upstream. Photo by J. Pittenger, 24 May 2007.

Type III (*i.e.* disequilibrium condition) C-channel reaches are characterized by rapidly eroding, often steep-walled banks. Examples of these are found in segment SFR-12 upstream from the Cottonwood Mobile Home Park and in segment SFR-7 (Figure 16).

The F stream type is characterized by an entrenched channel, moderate sinuosity, and a high bankfull width-to-depth ratio. Six stream segments were delineated in the study area as F channel, two of which are contiguous (Table 1). Segment SFR-2 is the longest reach of F-type channel in the study area (Table 1; Figure 11). This segment extended from the arroyo confluence near Nix Stables upstream through Frenchy's Park to station 360+35 (Figure 17). The downstream end is marked by a grade control structure (GCS-7 in Plate 6). Three relatively short segments of F4 channel were delineated from near Siler Road downstream to below the San Ysidro crossing (Table 1; Figure 11). Finally, two contiguous segments of F5 channel were delineated from the CR 62 crossing downstream to near Cottonwood Mobile Home Park (Figure 11).

The F-type channel segments have the greatest degree of disequilibrium condition in the study area. Some of these reaches, such as segment SFR-11, appear to be closer to equilibrium as indicated by vegetation establishing along the toe of eroded terrace escarpments. The F-channel character of segment SFR-4 may be a recent development resulting from dumping of fill and marked constriction of the floodplain (Figure 18). Other reaches, such the upper part of segment SFR-10 (below CR 62) and SFR-2 (upper reach in the study area), are in early stages of adjustment and are rapidly increasing channel width as indicated by erosion of high, vertical banks (Figure 19). The formation of a few lateral bars in these portions of SFR-10 are indicative of some degree of aggradation, which implies that bed degradation has slowed in this segment. These field indicators suggest that these reaches are at the Type II or III channel evolution stage (Harvey and Watson, 1986). Under current conditions of grade control, both reaches will likely continue to adjust toward equilibrium. However, integrity of the grade control structures influences these reaches greatly and if they are compromised the channels would begin degrading.

Figure 16. Type III (disequilibrium) C5 channel. Reach is located in segment SFR-7. Arrows indicate actively eroding bank and zone of rapid channel widening. View is downstream toward the San Ysidro crossing. Photo by J. Pittenger, 26 June 2007.

Figure 17. Stream type F4 upstream from Frenchy's Park. Coarse bed material and paucity of aggradation indicate the bed in this reach is still degrading. View is upstream. Photo by J. Pittenger, 15 June 2007.

Figure 18. Channel-narrowing fill along right bank in segment SFR-4. View is downstream. Photo by J. Pittenger, 26 June 2007.

Figure 19. Deeply-entrenched F5 channel below CR 62. View is downstream. Photo by J. Pittenger, 19 September 2007.

2.4.2.3 Grade Control Structures in the Study Area

Seventeen grade control structures are located in the study area (Table 2). Grade control structures are concentrated in the upstream half of the study area (Figure 20; Plate 6).

Table 2. Grade control structures in the study area. Types are GAB = concrete-capped gabion wall, ROCK = rock wall, CW = concrete wall, CSS = concrete step structure, and LWC = concrete low-water crossing.

Structure Number	Type	Downstream Drop (ft)	Station (ft)
GCS-1	GAB	1	99+67
GCS-2	CSS	15	162+69
GCS-3	CW	2	189+34
GCS-4	CSS	12	204+67
GCS-5	LWC	6	224+68
GCS-6	GAB	4	284+00
GCS-7	GAB	3	289+11
GCS-8	GAB	2	294+34
GCS-9	GAB	3	298+35
GCS-10	GAB	1	302+00
GCS-11	GAB	2	303+07
GCS-12	ROCK	4	344+00
GCS-13	GAB	2	360+35
GCS-14	GAB	3	366+48
GCS-15	GAB	3	367+61
GCS-16	GAB	2	369+85
GCS-17	GAB	3	377+29

Two of the grade control structures provide major control, in that their effect persists for considerable distances upstream. The CR 62 crossing (GCS-2) has a downstream drop of about 15 feet while the San Ysidro crossing (GCS-4) has a downstream drop of about 12 feet. The Vereda de San Antonio low-water crossing (GCS-5) is also a significant control of bed elevation in the study area.

2.4.3 Water Quality

Surface water flow in the study area occurs in response to upstream reservoir releases and storm-water runoff. There are no water quality standards established for the Santa Fe River in the study area. When there are surface water flows through the study area, water quality is affected by high levels of suspended sediment, chemical contaminants from urban storm-water runoff, and trash and debris that is dumped into the river throughout the study area (Grant, 2002: 26). The river in the study area was assessed in 2004 and found to not support aquatic life, secondary contact, and wildlife habitat designated uses due to polychlorinated biphenyls (PCB) in the water column during storm water runoff events (New Mexico Environment Department, 2007: 225).

Urban storm-water runoff is typically contaminated with sediments, nutrients, microbes, toxic metals, and organic compounds (Makepeace *et al*., 1995; Pitt *et al*., 1995). Runoff from the road network in the study area catchment likely is a major source of pollutants in storm water. Pavement surface wear, brake lining wear, tire wear, fuel and exhaust, oil, grease, hydraulic fluids, and engine and parts wear generate pollutants such as sulphate, asbestos, copper, nickel, chromium, particulates, rubber, zinc, lead, PCB, and petroleum compounds (Forman *et al.*, 2003: 202-206).

Figure 20. Grade control structures in the study area.

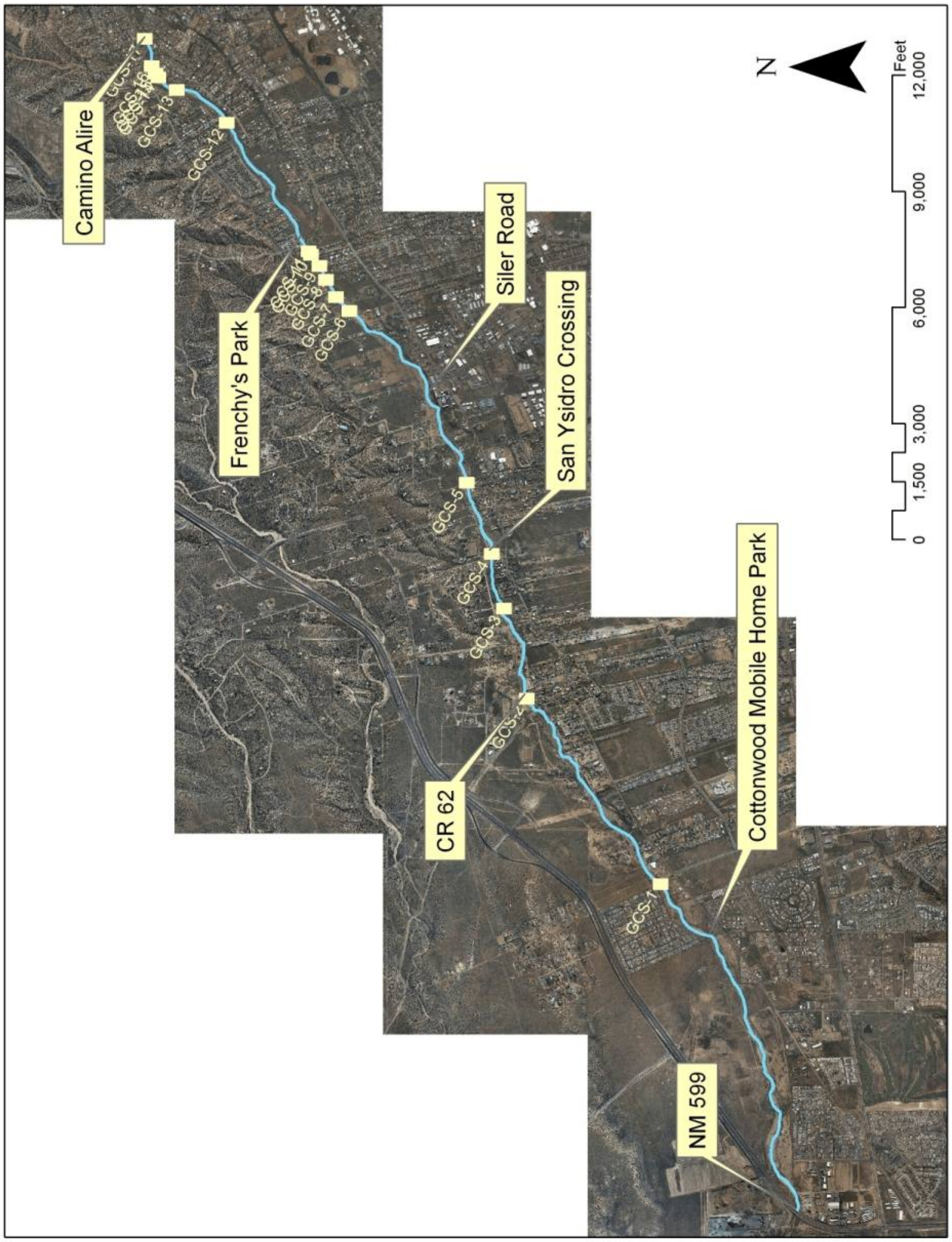


Figure 21. Grade control structure GCS-2 at the CR 62 crossing. View is upstream. Photo by J. Pittenger, 24 May 2007.

Figure 22. Grade control structure GCS-5 at the Vereda de San Antonio crossing. View is upstream. Photo by J. Pittenger, 26 June 2007.

2.5 Soils

Six soil mapping units occur in the study area (Table 3; Natural Resources Conservation Service, 2007). However, only two of these soil mapping units are common. These are Riverwash and Riovista gravelly loamy sand, which together comprise over 96 percent of the soils in the study area. The remaining four soil mapping units each comprise less than two percent of the study area and are eroded terrace remnants in the area of river influence (Figures 23-34).

Table 3. Soil mapping units in the study area.

Soil Mapping Unit	Acres
101 Zozobra-Jaconita complex	0.12
106 Pits	0.49
107 Riverwash	64.30
112 Riovista gravelly loamy sand	15.76
113 Delvalle-Uran land complex	1.31
116 Argents-Urban land-Orthents complex	0.98
Total	**82.97**

The Riverwash mapping unit consists of gravelly coarse sand and gravelly sandy loam formed from alluvium. These soils are frequently flooded and occur in the river channel and its nascent floodplain in the study area. The soils are excessively drained and have moderately high to high capacity to transmit water. Saturated transmissivity of Riverwash soils ranges from 0.57 inches/hour to 1.98 inches/hour. Consequently, available water capacity is very low (*ca.* three inches).

Riovista gravelly sandy loam occurs on floodplain and valley floor areas and is formed from alluvium derived from granite, gneiss, and schist. These soils are also excessively drained and have very high saturated hydraulic transmissivity (6.0 to 20 inches/hour). Available water holding capacity in Riovista sandy gravelly loam is about 1.7 inches.

The remaining four minor soil mapping units consist of soils formed from alluvium that occur on eroded fan remnants or stream terraces. These soils are gravelly coarse sandy loams to sandy loams. These soils are well drained but have slightly higher water holding capacity compared to the Riverwash and Riovista gravelly loamy sand soils because of a generally higher percentage of loam.

Figure 23. Soils in the study area, station 0+00 to 32+00.

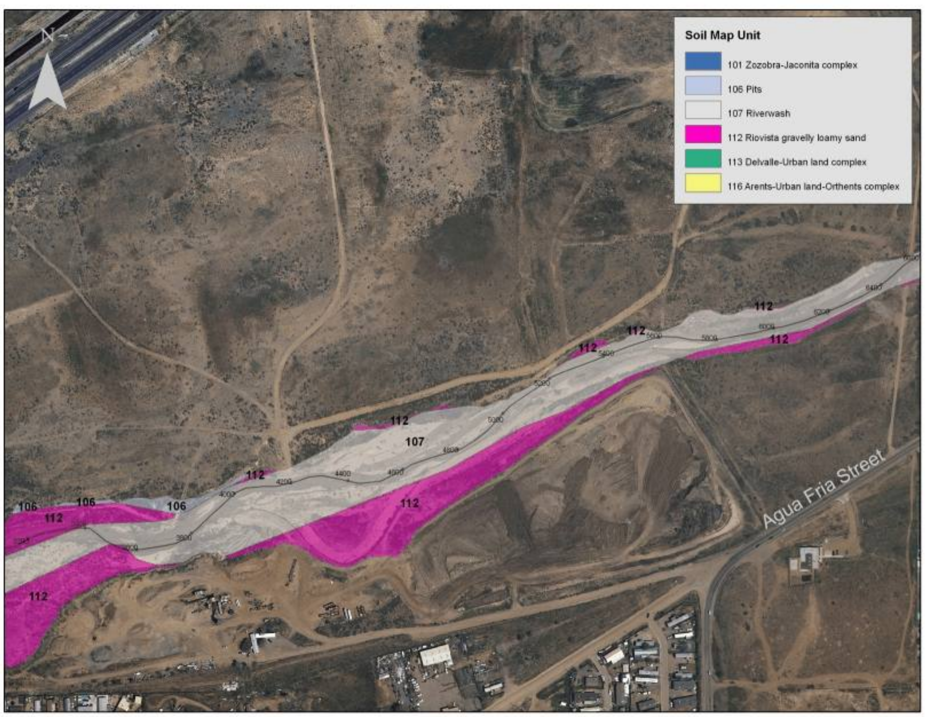


Figure 24. Soils in the study area, station 32+00 to 64+00.

Figure 25. Soils in the study area, station 64+00 to 32+00.

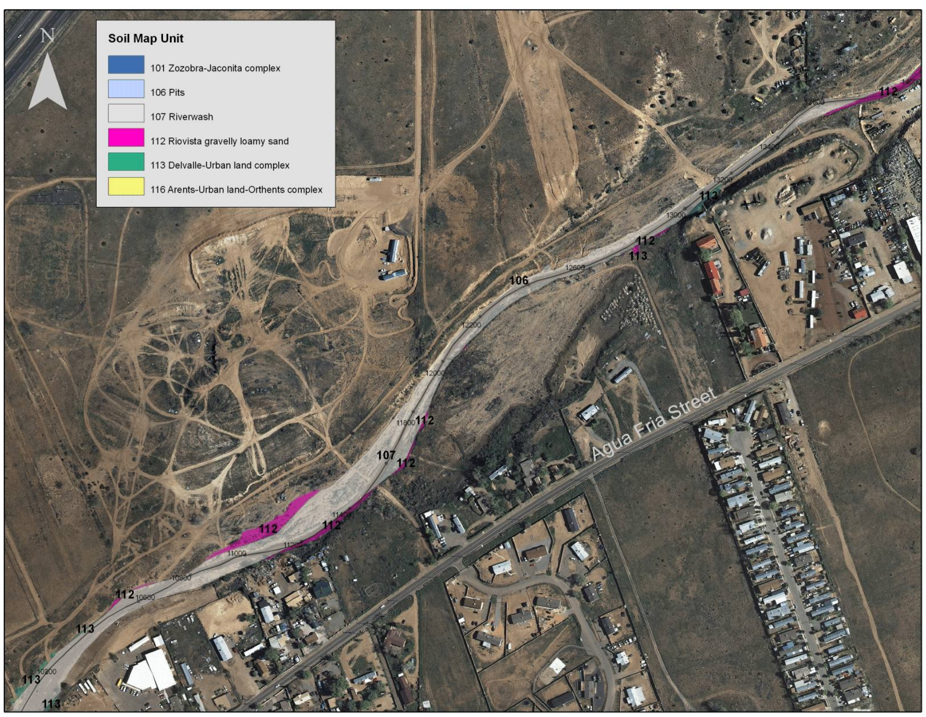


Figure 26. Soils in the study area, station 102+00 to 138+00.

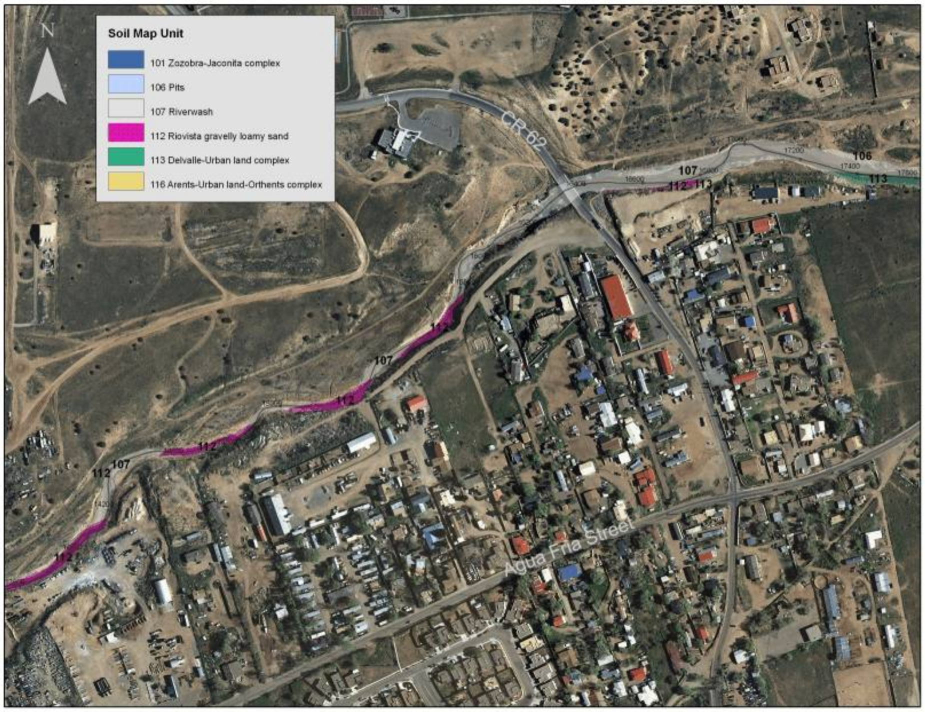


Figure 27. Soils in the study area, station 138+00 to 176+00.

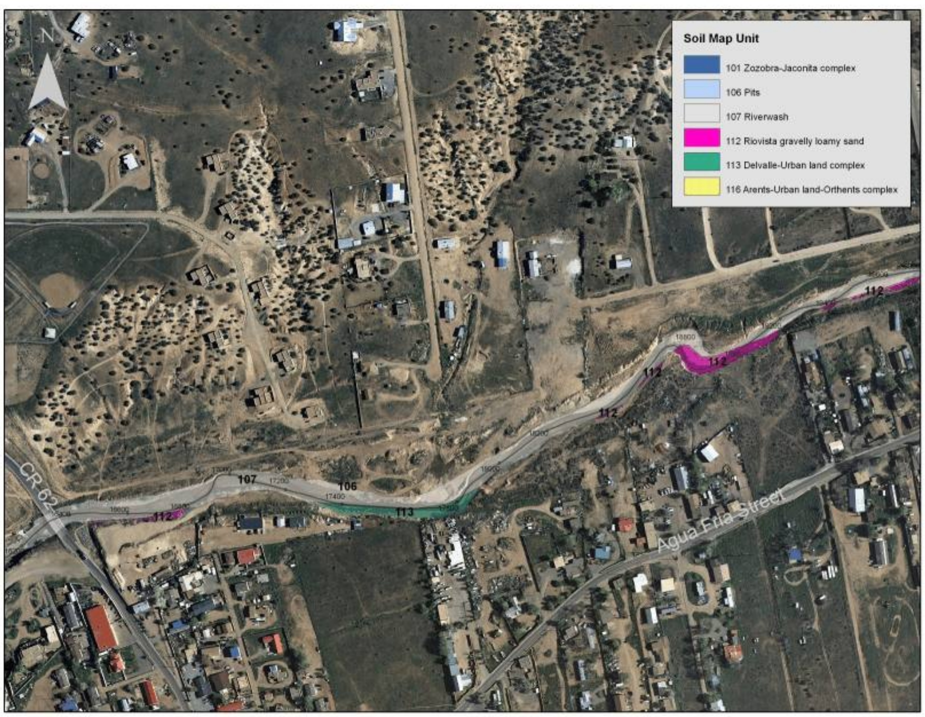


Figure 28. Soils in the study area, station 176+00 to 196+00.

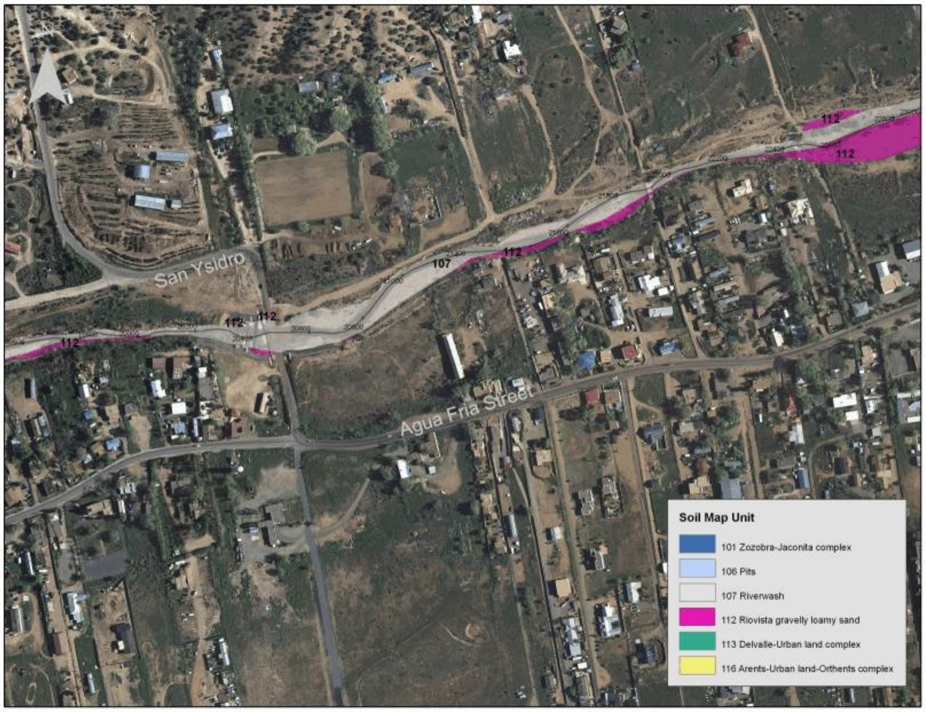


Figure 29. Soils in the study area, station 196+00 to 228+00.

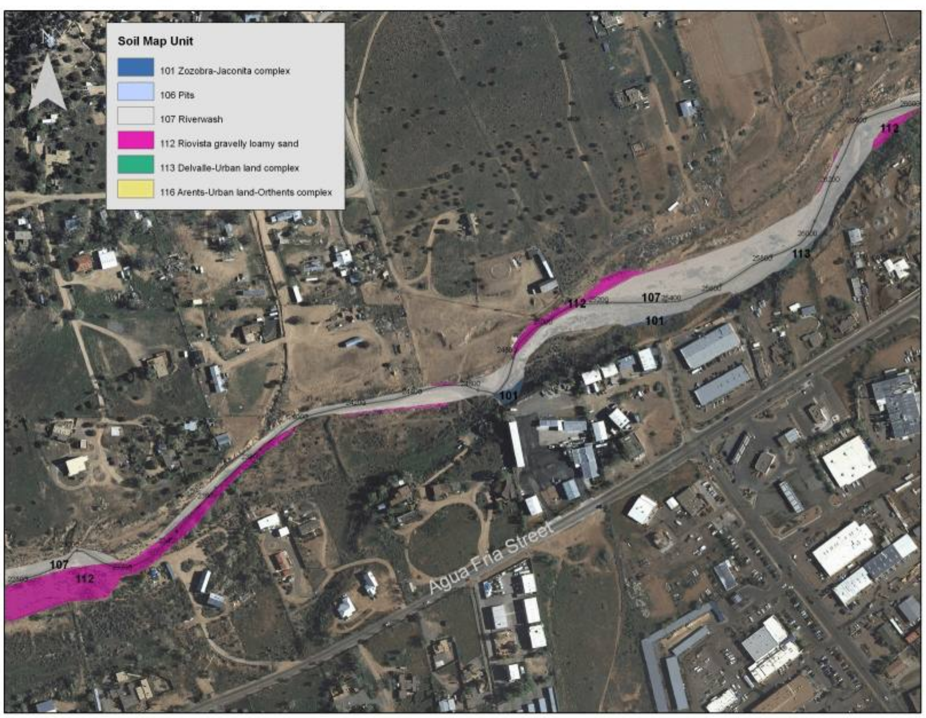


Figure 30. Soils in the study area, station 228+00 to 264+00.

Figure 31. Soils in the study area, station 264+00 to 298+00.

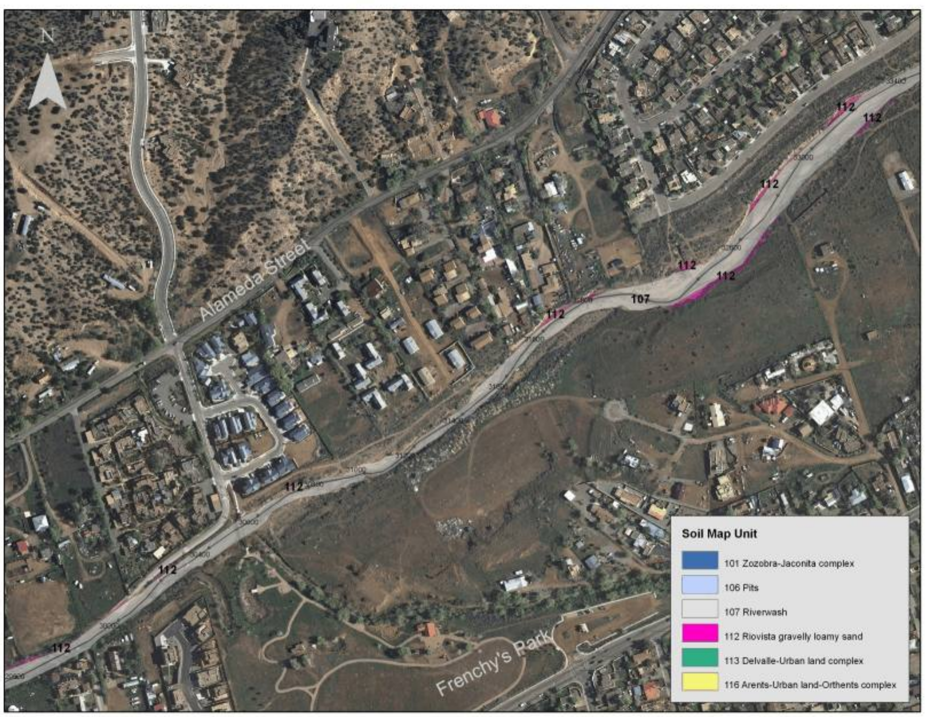


Figure 32. Soils in the study area, station 298+00 to 334+00.

Figure 33. Soils in the study area, station 334+00 to 364+00.

Figure 34. Soils in the study area, station 364+00 to 378+02.

2.6 Air Quality and Noise

2.6.1 Air Quality

The Clean Air Act of 1970, as amended, established National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants: ozone, airborne particulates, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead. If the concentrations of any of these six pollutants exceeds the standard, the area where the exceedance occurs is considered non-attainment for that pollutant. No violations of the NAAQS have occurred in Santa Fe County, which is classified as attainment for all six criteria air pollutants by the Environmental Protection Agency (U.S. Environmental Protection Agency, 2007).

2.6.2 Noise

In considering potential effects of increased noise levels, sensitive noise receptors are identified in a study area. Sensitive receptors include, but are not limited to, homes, lodging facilities, hospitals, parks, and undeveloped natural areas. Sensitive receptors in the study area homes, parks, and undeveloped natural areas.

Existing noise levels throughout the study corridor are both natural and manmade, including rushing water (when the river is running), rustling leaves, domestic and wild animals (*e.g.* birds, dogs, insects), human voices (*e.g.* children at play, trail user talking on a cell phone) and activities (*e.g.* hammering, unloading building materials), and vehicles and other machines (*e.g.* bicycles crossing metal bridge, lawn mowers, power saws, gravel-mining equipment).

In the eastern-most portion of the study area on a summer weekday morning, there was surprisingly little noise filtering into the study area from surrounding streets and homes along some portions of the corridor. In the central portion of the corridor, sounds from businesses can be heard, such as fans at a door manufacturing plant and trucks being loaded, as well as human voices and traffic on Agua Fria Street and side streets. At the west end of the corridor, the most prominent sound is traffic on N.M. Highway 599.

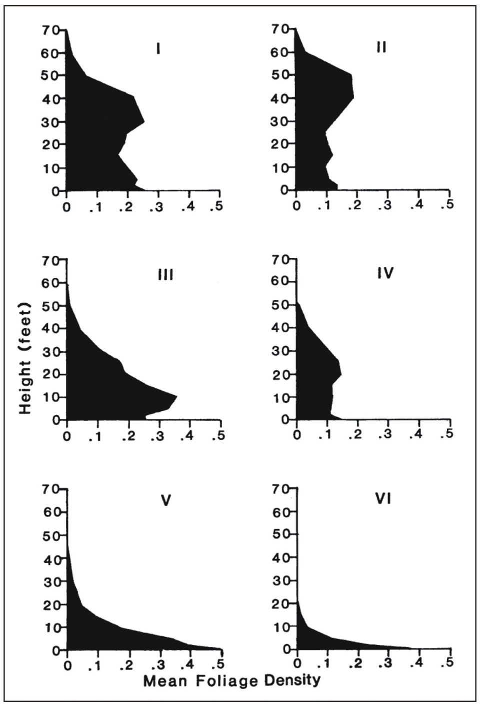
2.7 Ecological Setting

2.7.1 Plant Communities

Plant communities in the study area were mapped using the community-structure (C-S) classification scheme developed by Hink and Ohmart (1984). This classification combines identification of community dominants in the tree and shrub strata with the structural character of the stand being delineated, where structural character is defined as the variation in foliage density with height above the ground surface.

Six structure types are used in the classification. These range from structure type I, characterized by an overstory canopy provided by mature trees (*i.e.* 50 to 60 feet tall) and understory foliage to type VI, characterized by sparse herbaceous and shrubby vegetation (Figure 35). A seventh structure type, X, was added to the classification to describe lacking woody dominants and with foliage restricted to three feet above the ground and lower.

Figure 35. Vegetation structure types in the Hink and Ohmart classification scheme. The figures are graphical representations of the variation in foliage density with height above the ground surface. Excerpted from Figure 3 in Hink and Ohmart (1984: 38).



Plant community types were classified using a combination of 13 codes for dominant or co-dominant species or cover type. Six of the codes were for native woody or suffrutescent plant species: C for cottonwood (including Rio Grande, narrowleaf, and lance-leaf), CW for coyote willow, GW for Goodding's willow, J for one-seed juniper, LO for New Mexico locust, and RB for rubber rabbitbrush (Table 4). Another five codes were for non-native woody plants: HL for honey-locust, RO for Russian olive, SC for saltcedar, SE for Siberian elm, and TH for tree-of-heaven (Table 4).

Two miscellaneous cover classes were used for area lacking woody vegetation. The code BARE was used for areas with sparse herbaceous cover and greater than 70 percent bare ground. The code HERB was used for areas dominated by herbaceous plants.

Dominant herbaceous species in areas delineated as HERB included hairy golden-aster (*Heterotheca villosa*), horseweed (*Conyza canadensis*), smooth oxeye (*Heliopsis helianthoides*), sand-daisy (*Dieteria canescens*), rough cocklebur (*Xanthium strumarium*), prickly lettuce (*Lactuca serriola*), bur ragweed (*Ambrosia acanthicarpa*), Russian-thistle (*Salsola tragus*), white sweet-clover (*Melilotus albus*), sorrel wild-buckwheat (*Eriogonum polycladon*), cañaigre (*Rumex hymenosepalus*), Canada wildrye (*Elymus canadensis*), Indian ricegrass (*Achnatherum hymenoides*), cheatgrass (*Bromus tectorum*), Carolina lovegrass (*Eragrostis pectinacea* var. *pectinacea*), and foxtail barley (*Hordeum jubatum*).

Major factors influencing the current condition of riparian vegetation in the study area are 1) significantly reduced surface water flow; 2) loss of the shallow alluvial aquifer; 3) massive bed degradation throughout the reach initiated in the mid 1970s by removal or lowering of grade control structures; and 4) scouring peak flows associated with storm-water runoff that are now contained within a narrow, entrenched valley throughout most of the study area. Because of these factors, riparian vegetation is sparse throughout the study area and where it is found it is typically characterized by early successional stages.

Table 4. Species/cover codes used in describing plant community types in the study area. Scientific and common names follow Allred (2006). Those species marked with an asterisk (*) are non-native.

CODE	SPECIES/COVER
BARE	Mostly bare ground with scattered herbaceous plants
HERB	Herbaceous vegetation
C	Rio Grande, narrowleaf, and/or lance-leaf cottonwood; lance-leaf is a hybrid between Rio Grande and narrowleaf (*Populus deltoides wislizenii*, *P. angustifolia,* and/or *P.* x *acuminata*)
CW	coyote willow (*Salix exigua*)
GW	Goodding's willow (*Salix gooddingii*)
J	one-seed juniper (*Juniperus monosperma*)
LO	New Mexico locust (*Robinia neomexicana*)
RB	rubber rabbitbrush (*Ericameria nauseosa*)
HL*	honey-locust (*Gleditsia triacanthos*)
RO*	Russian olive (*Elaeagnus angustifolia*)
SC*	saltcedar (*Tamarix chinensis*)
SE*	Siberian elm (*Ulmus pumila*)
TH*	tree-of-heaven (*Ailanthus altissima*)

Over half (51.32 percent) of the study area consisted of bare ground areas or herbaceous plant cover (C-S types BARE X or HERB X; Table 5). Structure type VI stands, which are plant communities with a majority of the foliage less than 10 feet high, made up another 41 percent of the study area (Table 5). Structure type VI stands were highly variable in terms of dominants. A total of 17 different community types with this structural stage were delineated in the project area (Table 5). Structure type II vegetation, which is characterized by mature trees (*cf.* Figure 35) comprises only 0.03 percent of the study area and consists of a single C II stand along the left bank between CR 62 and Cottonwood Village.

Aside from the single C II stand described above, plant C-S types dominated by native woody species included: C,GW VI; C,GW/CW VI; C/CW IV; C/CW V; C/CW VI; C/CW,RB VI; C/RB VI; and CW VI (Table 5). These native riparian C-S types are concentrated in three main areas:

1. the lower end of the project area upstream from NM 599 to just upstream from Cottonwood Drive, with most occurring in the section from the old Leeder batch plant lease downstream to the NM599 bridge (Plate 1);

2. the Siler Road area, from the Vereda de San Antonio crossing (Plate 3) upstream to the lower end of the Boylan property (Plate 4); and

3. a small area near the confluence of Arroyo Torreon downstream from the Camino Alire bridge (Plate 5).

These patches of native woody riparian ranged in structural type from small trees (type IV and V; Figures 36 and 37) to stands of saplings or willow shrubs (type VI; Figure 38). Vegetation patches dominated by native woody riparian species totaled 11.67 acres, or about 14 percent of the vegetation in the study area.

Sites of native woody riparian vegetation establishment are characterized by stream reaches with sediment deposition on lateral or point bars adjacent to the active channel. The Siler Road area and the downstream portion of the study area both are relatively long stream reaches that appear to be at or near equilibrium state, with developing meander patterns and floodplains. The absence of substantial establishment of native woody riparian vegetation in most other portions of the study area are indicative of disequilibrium channel conditions.

Rubber rabbitbrush vegetation on floodplain and bar sites is common in the study area (Figure 38). This vegetation, mapped as C-S type RB VI, makes up about 22 percent of the vegetation in the study area (Table 5).

The most common non-native woody plant in the study area is Siberian elm. Vegetation stands with Siberian elm totaled about nine acres, or 11 percent of the vegetation in the study area. Other non-native woody species were more localized in their distribution in the study area and included honey-locust, tree-of-heaven, and saltcedar (Figure 39). Saltcedar was found as a dominant in only one location, between stations 66+00 and 74+53, below the Cottonwood Drive crossing. Saltcedar occurred on both the right and left banks at this location in sparse sapling stands with Russian olive and coyote willow (Plate 1).

Table 5. Coverage, in acres, of plant community-structure (C-S) types mapped in the study area. A slash "/" separates overstory dominants (left of slash) from understory woody dominants. Codes separated by commas indicate co-dominants in a strata. For example, C-S type C/CW,RB is a plant community with an overstory dominated by cottonwood and an understory shrub strata dominated by coyote willow and rubber rabbitbrush.

COMMUNITY TYPE	STRUCTURE TYPE					TOTAL	PERCENT OF TOTAL
	II	IV	V	VI	X		
BARE	---	---	---	---	37.98	37.98	45.78%
HERB	---	---	---	---	4.06	4.06	5.54
C	0.02	0.35	0.27	0.19	---	0.83	1.01%
C,GW	---	---	0.09	---	---	0.09	0.11%
C,GW/CW	---	---	0.84	---	---	0.84	1.01%
C,SE	---	0.27	---	---	---	0.27	0.33%
C,SE/CW	---	1.31	0.09	0.08	---	1.48	1.78%
C/CW	---	1.01	0.42	1.99	---	3.42	4.13%
C/CW,RB	---	---	---	1.04	---	1.04	1.25%
C/RB	---	---	---	2.53	---	2.53	3.05%
CW	---	---	---	2.95	---	2.95	3.55%
CW,SE/RB	---	---	---	0.66	---	0.66	0.79%
HL	---	---	---	0.03	---	0.03	0.03%
HL,SE/CW	---	---	---	0.06	---	0.06	0.07%
HL,TH,SE	---	---	0.11	---	---	0.11	0.13%
J/RB	---	---	---	1.12	---	1.12	1.35%
LO	---	---	---	0.14	---	0.14	0.17%
RB	---	---	---	18.03	---	18.03	21.73%
SC,RO,CW/RB	---	---	---	0.25	---	0.25	0.30%
SE	---	0.75	0.03	1.14	---	1.93	2.33%
SE,C	---	0.10	---	0.08	---	0.18	0.22%
SE,RO,CW/RB	---	---	---	0.32	---	0.32	0.39%
SE/CW	---	0.42	---	---	---	0.42	0.51%
SE/RB	---	---	---	3.43	---	3.43	4.14%
TH,SE	---	---	0.02	---	---	0.02	0.02%
TH,SE/RB	---	---	0.24	---	---	0.24	0.29%
TOTAL	0.02	4.22	2.12	34.03	42.58	82.97	
PERCENT OF TOTAL	0.03%	5.08%	2.55%	41.02%	51.32%		

Figure 36. A C IV stand near the Siler Road dead end, 26 June 2007. Trees are lance-leaf cottonwood. Photo by J. Pittenger.

Figure 37. A C/CW VI stand on the State Trust reach above NM 599, 28 May 2007. Vegetation restored in this reach is initiating channel narrowing. Photo by J. Pittenger.

Figure 38. Rabbitbrush (RB VI) vegetation on a floodplain site downstream from Siler Road, 24 May 2007. View is downstream. Photo by J. Pittenger.

Figure 39. Stand of Siberian elm, honey-locust, and tree-of-heaven below Camino Carlos Rael, 26 June 2007. View is downstream. Photo by J. Pittenger.

2.7.2 Wetlands and Water of the U.S.

No wetlands are mapped in the area and none were documented during the field surveys conducted in 2007. However, wetlands historically occurred along the river in the study area, most notably in the vicinity of Frenchy's Park (historic site of Cieneguita Spring) and Agua Fria (Spiegel and Baldwin, 1963: 132) and at several pueblo sites including Los Palacios, Pino, and Pueblo Quemado (Spiegel and Baldwin, 1963: 94).

Remnant indicators of hydric soils were found in a vertical cut-bank below CR 62 at Agua Fria during field surveys in 2007. These indicators included a thin organic carbon strata overlaid by a band of iron oxide staining (Figure WET). These features were present in the cut bank about 10 feet above the current channel bed.

The Santa Fe River is considered a water of the United States. Consequently, dredge and fill activities conducted below the ordinary high water mark in the river are regulated by the U.S. Army Corps of Engineers pursuant to section 404 of the federal Clean Water Act and section 10 of the Rivers and Harbors Act.

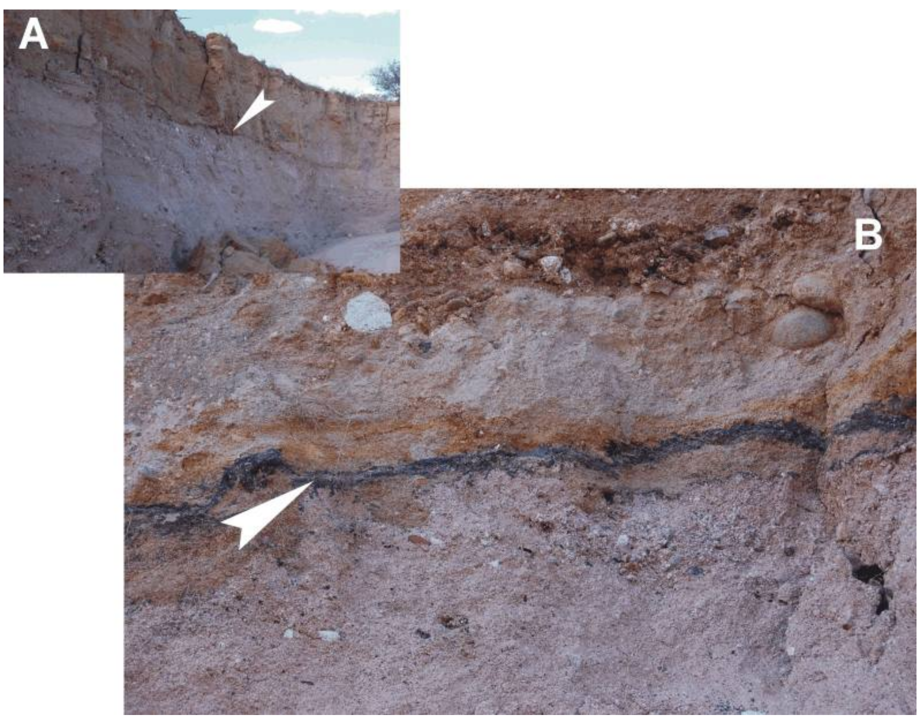


Figure 40. Remnant hydric soil indicators in a cut bank below CR 62 at Agua Fria. Inset photo "A" shows the location of the indicator strata about 10 feet above the current channel bed. Photo "B" shows the thin black carbon strata overlaid by iron oxide-stained sediments. Photo by J. Pittenger, 19 September 2007.

2.7.3 Fish

The historic occurrence of fish in the Santa Fe River through the study area is poorly documented. The most notable record is of American eel (*Anguilla rostrata*), an anadromous species, which was collected from the Santa Fe River somewhere between present-day Frenchy's Field and Agua Fria on 2 June 1925 by the noted ichthyologist H. Yarrow. The eel specimens from the Santa Fe River are accessioned at the Smithsonian Museum (USNM 16754). No other fish collection records are available for the study area. Trout (*Oncorhynchus* sp.) historically occurred in the Santa Fe River in the downtown area (Grant, 2002: 10) and may have been at least a seasonal part of the ichthyofauna of the study area before major changes in the hydrograph and habitat of the river. Rio Grande sucker (*Pantosteus plebeius*) occurs downstream from the study area, where perennial flow is maintained by wastewater treatment plant effluent (J. Pittenger, unpubl. data). Rio Grande sucker and fathead minnow (*Pimephales promelas*) were collected from the river further downstream, in the vicinity of La Cienega , in 1958 (Kansas University museum records KU 4260 and KU 4262, respectively). Other species that potentially may have occurred in the Santa Fe River in the study area include longnose dace (*Rhinichthys cataractae*), and Rio Grande chub (*Gila pandora*). These species are common in north-central New Mexico streams at the same elevation range as the Santa Fe River in the study area (*cf.* Appendix).

2.7.4 Wildlife

The study area provides limited habitat for terrestrial wildlife, due to the narrowness of the corridor and paucity of vegetation. Thirty-one bird species were observed during the field surveys conducted from May through September 2007 (Table 6). Bird species richness was highest in habitats with structural diverse vegetation, particularly the reach from Camino Alire downstream to the old stream gage, the vicinity of Siler Road, and the downstream end of the study area between NM 599 and Cottonwood Drive. Scaled quail were relatively common in undeveloped portions of the study area and around horse stables adjacent to the river corridor.

Mammals observed in the study area during the field surveys included desert cottontail (*Sylvilagus audubonii*), black-tailed jackrabbit (*Lepus californicus*), Gunnison's prairie dog (*Cynomys gunnisoni*), striped skunk (*Mephitis mephitis*), and feral cat (*Felis catus*). Prairie lizard (*Sceloporus undulatus*) and plateau striped whiptail (*Cnemidophorus velox*) were common reptiles in the study area.

Animal species that may potentially occur in riparian and aquatic habitats in similar landscape settings as the study area in Santa Fe County are listed in the Appendix.

2.8 Endangered and Protected Species

No federal or state listed species were observed in the study area. Suitable habitat for the federal endangered Southwestern Willow Flycatcher (*Empidonax traillii extiimus*) is not found in the study area. Suitable habitat is also lacking in the study area for Bald Eagle (*Haliaeetus leucocephalus*).

Table 6. Bird species observed in the study area during summer 2007 field surveys.

Common Name	Scientific Name
Killdeer	*Charadrius vociferus*
Scaled Quail	*Callipepla squamata*
Turkey Vulture	*Cathartes aura*
American Kestrel	*Falco sparverius*
Rock Dove	*Columba livia*
White-winged Dove	*Zenaida asiatica*
Mourning Dove	*Zenaida macroura*
Black-chinned Hummingbird	*Archilochus alexandri*
Cassin's Kingbird	*Tyrannus vociferans*
Black Phoebe	*Sayornis nigricans*
Say's Phoebe	*Sayornis saya*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Bank Swallow	*Riparia riparia*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Petrochelidon pyrrhonota*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax*
Bewick's Wren	*Thryomanes bewickii*
American Robin	*Turdus migratorius*
Northern Mockingbird	*Mimus polyglottos*
Curve-billed Thrasher	*Toxostoma curvirostre*
European Starling	*Sturnus vulgaris*
Yellow Warbler	*Dendroica petechia*
Black-throated Sparrow	*Amphispiza bilineata*
Bullock's Oriole	*Icterus bullockii*
Western Meadowlark	*Sturnella neglecta*
Brown-headed Cowbird	*Molothrus ater*
Canyon Towhee	*Pipilo fuscus*
Spotted Towhee	*Pipilo maculatus*
Black-headed Grosbeak	*Pheuticus melanocephalus*
House Finch	*Carpodacus mexicanus*

2.9 Socioeconomic Environment

The Santa Fe River study area is located in Santa Fe County, New Mexico. Approximately 1.5 miles of the 7.16-mile study area are within the city limits of Santa Fe, New Mexico. Santa Fe, with a January 2007 population estimate of 68,359 (City of Santa Fe, 2007), is the capital of New Mexico and the seat of the state government. It is a full-service community with emergency services (fire, police, medical), a hospital, public and private schools, churches, museums, retail shops, restaurants, and other services. According to Santa Fe Trends (City of Santa Fe, 2007), the city's largest employment sectors are government (29 percent), retail/wholesale (15 percent), hospitality/food service (13 percent), health care/social assistance (10 percent), and construction (7 percent). The remainder of the study area is located in unincorporated Santa Fe County.

As of July 2006, the County's estimated population was 142,407 (U.S. Census Bureau, 2007*e*). The study area includes portion of Santa Fe County Census Tracts 8, 12.01, 12.02, and 12.03. (U.S. Census Bureau, 2007*a*). Using Census 2000 data, some population demographics of these four census tracts are compared to those of the City of Santa Fe, Santa Fe County, and the State of New Mexico in Table 7. The data show that the combined population of the four Santa Fe County census tracts that include the study area have a slightly lower percentage of white persons, and conversely, fewer ethnic minorities, than are found in the City of Santa Fe, Santa Fe County, and the State of New Mexico. These four census tracts also have a much higher percentage of persons (74 percent) identifying themselves as Hispanic or Latino than do the total populations City of Santa Fe, Santa Fe County, or the State of New Mexico, all three of which have less than half of their populations identifying themselves as Hispanic or Latino (Table 8).

Table 7. Comparison of racial demographics for the State of New Mexico, Santa Fe County, City of Santa Fe, and combined data for Santa Fe County Census Tracts 8, 12.01, 12.02, and 12.03, which include the study area. Data are from Census 2000.

	New Mexico	Santa Fe County	City of Santa Fe	Santa Fe County Census Tracts
Total population	1,819,046	129,292	62,203	19,104
White	66.8 %	73.5 %	76.3%	62.4 %
American Indian	9.5 %	3.1 %	2.2%	2.2 %
Back or African American	1.9 %	0.6 %	0.7%	0.6 %
Asian	1.1 %	0.9 %	1.3%	0.4 %
Native Hawaiian/Pacific Islander	0.1 %	0.1 %	0.1%	0.2 %
Some other race	17.0 %	17.7 %	15.3%	29.7 %
Two or more races	3.6 %	4.1 %	4.2%	4.6 %

U.S. Census Bureau (2007*a*)

Table 8. Proportion of Hispanic or Latino and non-Hispanic or non-Latino residents of the State of New Mexico, Santa Fe County, City of Santa Fe, and combined data for Santa Fe County Census Tracts 8, 12.01, 12.02, and 12.03, which include the study area. Data are from Census 2000.

	New Mexico	Santa Fe County	City of Santa Fe	Santa Fe County Census Tracts
Total population	1,819,046	129,292	62,203	19,104
Hispanic or Latino	42.1%	49.0%	47.8%	74.3%
Not Hispanic or Latino	57.9%	51.0%	52.2%	25.7%

U.S. Census Bureau (2007*b*)

The population of the four census tracts that include the study area is most similar to New Mexico overall when comparing income data to the various political entities. As shown in Table 9, the percentage of persons living below the poverty level in 1999 within the four census tracts encompassing the study area (17.6 percent) was about 1.5 times higher than similar populations in Santa Fe County (12.0 percent) or the City of Santa Fe (12.3 percent) but about the same level as the statewide below-poverty level population.

The per capita income of residents of the study area census tracts in 1999 was only 62 percent of the per capita income of the City of Santa Fe residents and just 67 percent of that of Santa Fe County residents overall.

Table 9. Comparison of selected income data for the State of New Mexico, Santa Fe County, City of Santa Fe, and combined data for Santa Fe County Census Tracts 8, 12.01, 12.02, and 12.03, which include the study area. Data are based on 1999 income statistics.

	New Mexico	Santa Fe County	City of Santa Fe	Santa Fe County Census Tracts
Per capita income[1]	$17,261	$23,594	$25,454	$15,851
Persons below poverty level[2]	18.4%	12.0%	12.3%	17.6%

[1] U.S. Census Bureau (2007*c*)
[2] U.S. Census Bureau (2007*d*)

2.10 Land Use, Recreation, and Aesthetics

Land use, recreation, and aesthetics in the study area are first summarized in this section and then followed by more detailed descriptions organized by river reach. For the purpose of this discussion, four reaches were used:

1. Camino Alire to Camino Carlos Rael (*ca*. 1.5 miles);
2. Camino Carlos Rael to CR 62 (*ca*.2.6 miles);
3. CR 62 to Cottonwood Drive (*ca*. 1.5 miles); and
4. Cottonwood Drive to NM 599 (*ca*. 1.5 miles).

The 7.16-mile Santa Fe River study area, defined as the area ecologically influenced by the river (*cf.* section 1.1), includes private, federal, state, county, and city lands comprising about 83 acres (Table 10). These various ownerships are depicted in Figures 41 through 45. Approximately 1.48 miles of the river study area are within the Santa Fe city limits, and the remainder (5.68 miles) is within unincorporated Santa Fe County.

As seen in Figures 41 through 45, in general, lands adjacent to the study area that are under county jurisdiction are less-densely developed than lands in the city segment. The city-county boundary is approximately at the Camino Carlos Rael crossing. This is particularly true the farther one moves downstream (away from the city) and on the north side of the river in the unincorporated county reach.

Table 10. Acreage by land ownership in the study area.

Land Ownership	Acres	Percent
City of Santa Fe	0.44	0.53
Santa Fe County	33.12	39.92
State of New Mexico	3.19	3.84
Bureau of Land Management	1.17	1.41
“Common Area”	8.33	10.04
Public Lands Subtotal	**46.25**	**55.74**
Private	36.72	44.26
Study Area Total	**82.97**	**100.00**

Figure 41. Land use and ownership features, Camino Alire to Camino Carlos Rael.

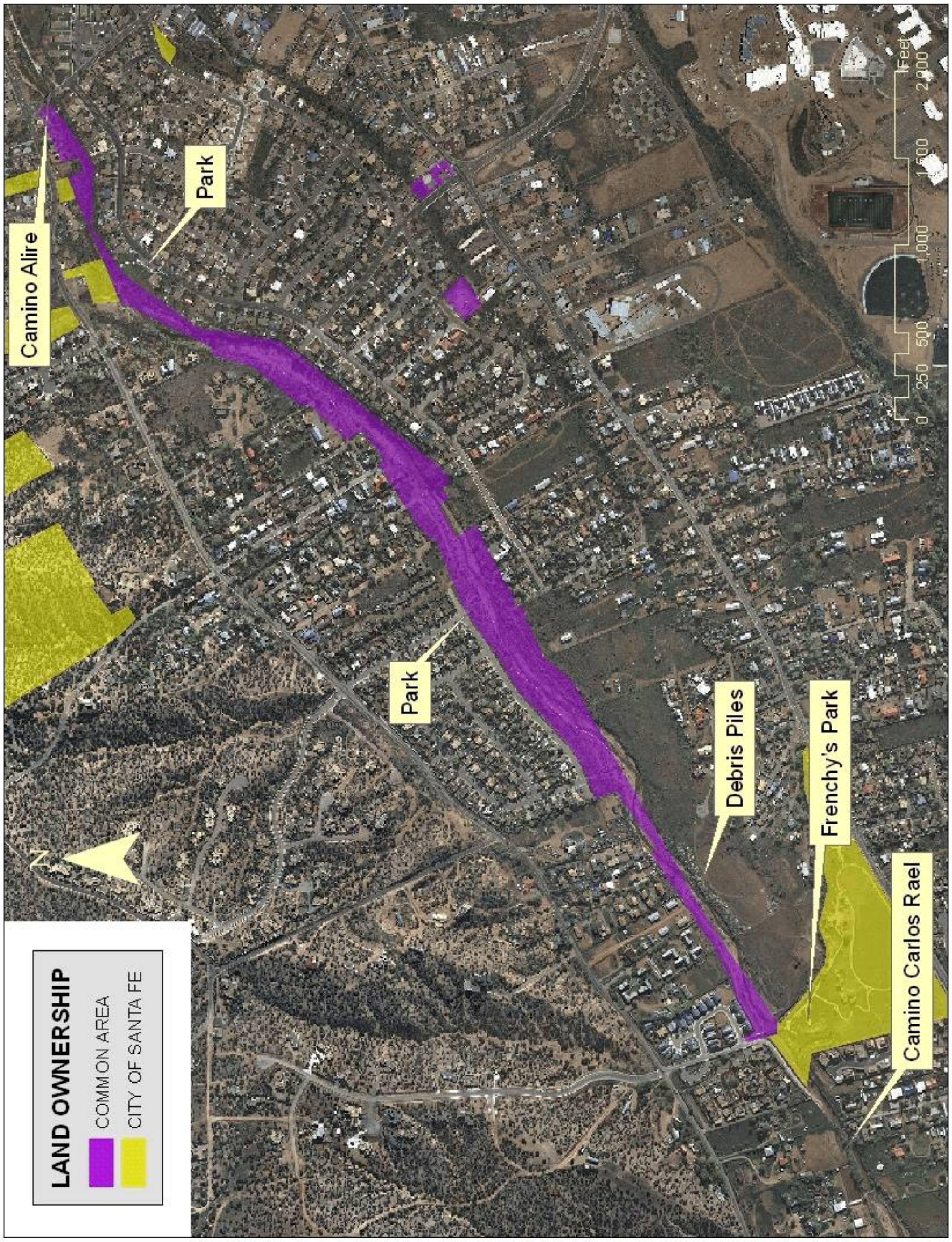


Figure 42. Land use and ownership features, Camino Carlos Rael to below Siler Road.

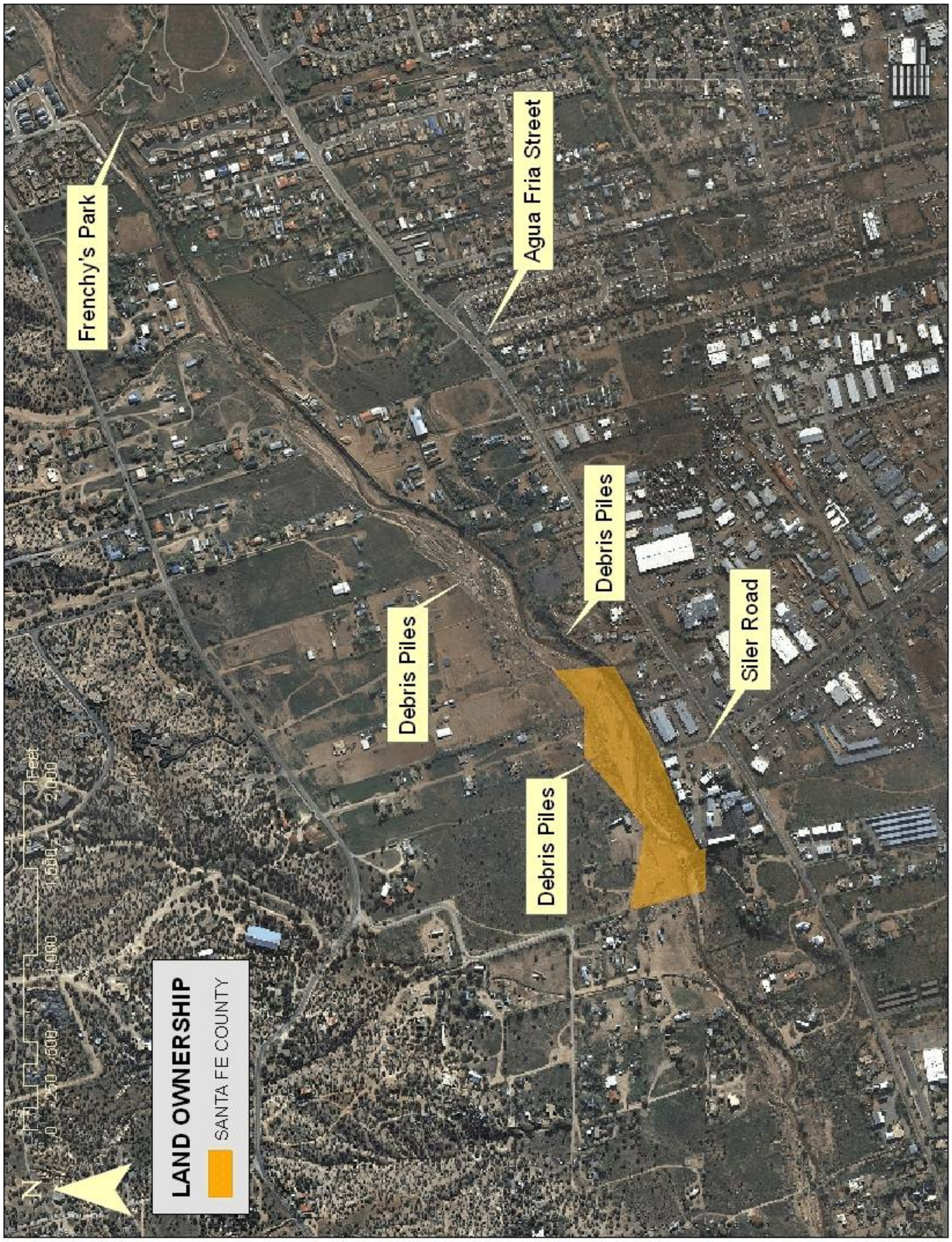


Figure 43. Land use and ownership features, below Siler Road to below CR 62.

Figure 44. Land use and ownership features, below CR 62 to Cottonwood Drive.

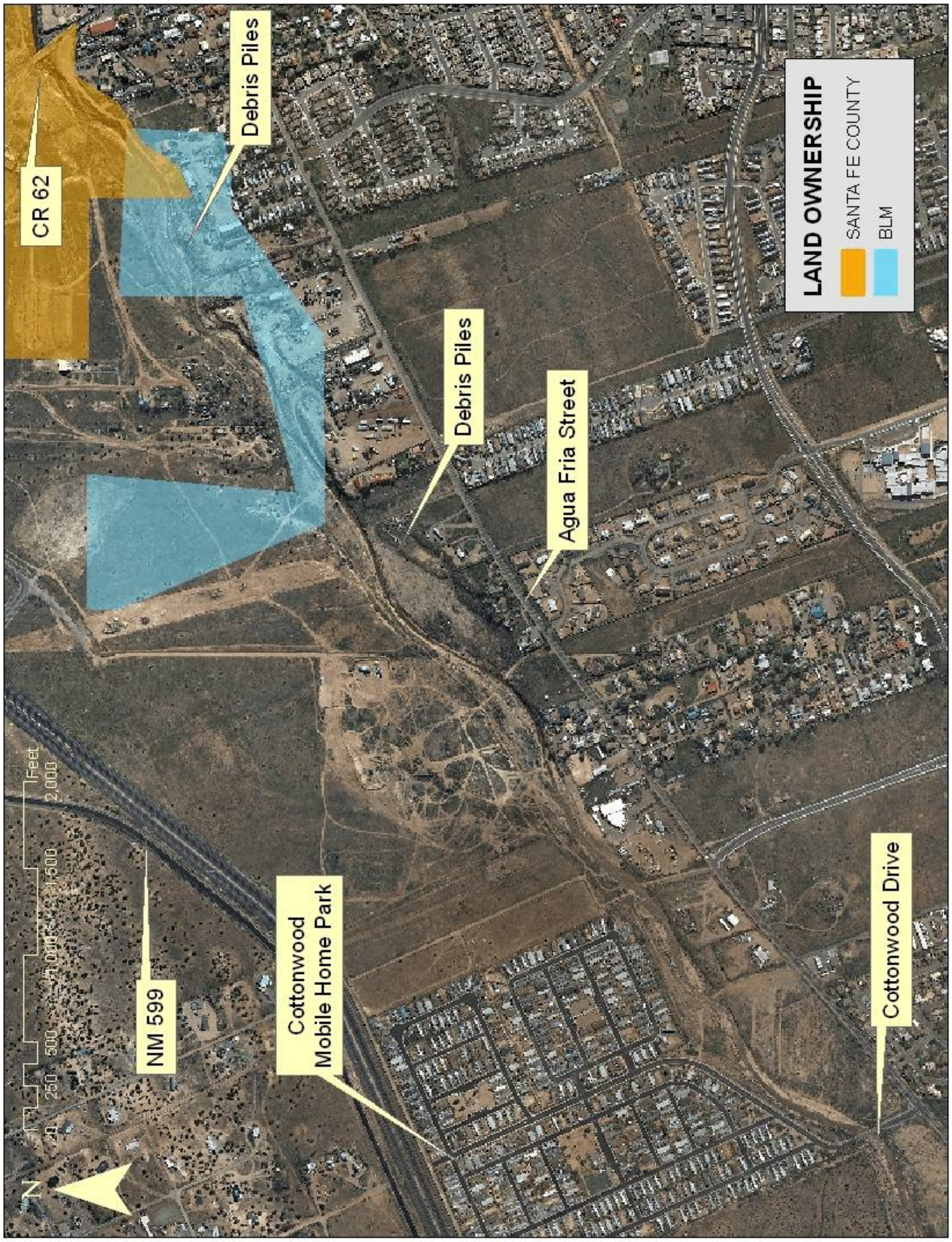
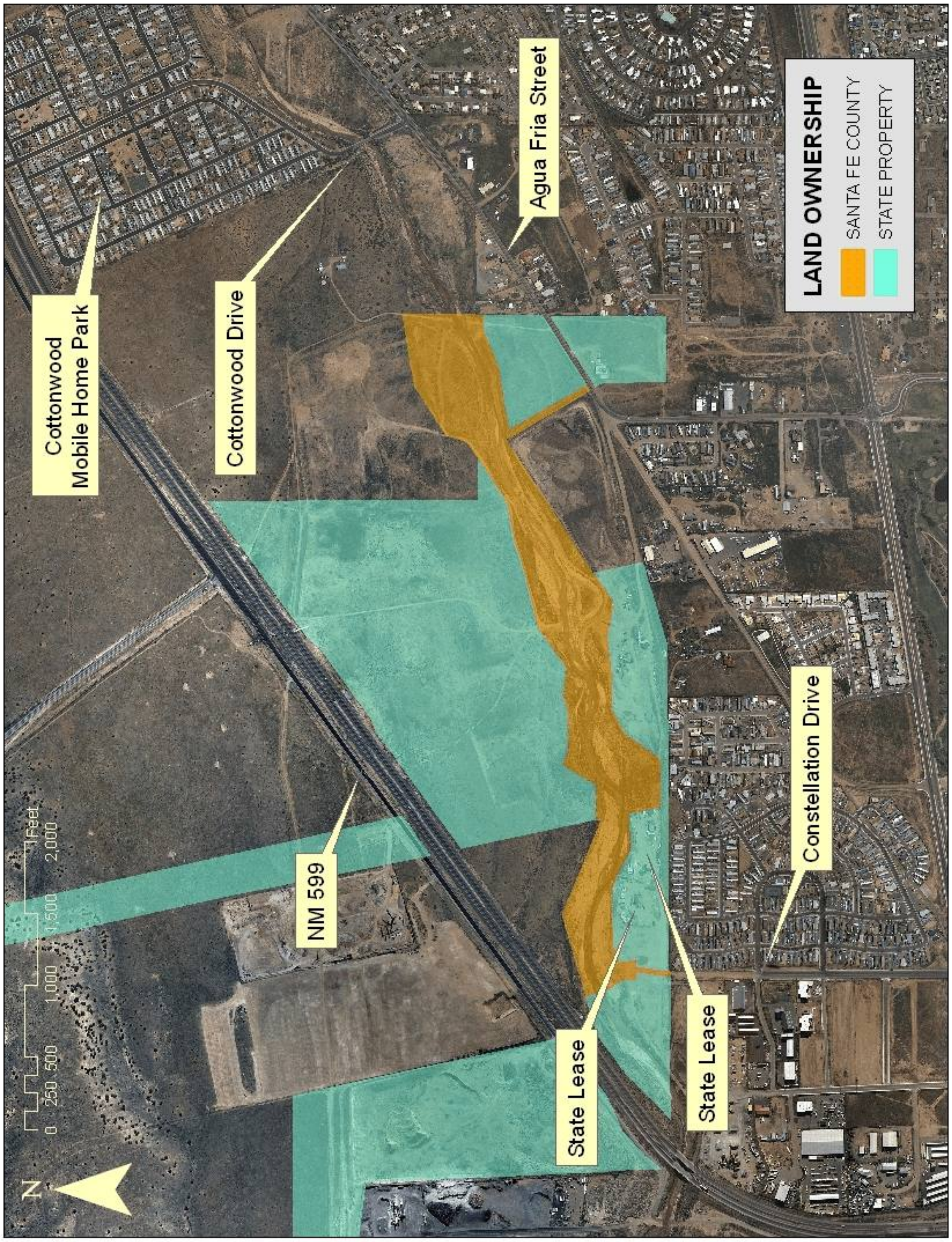


Figure 45. Land use and ownership features, Cottonwood Drive to NM 599.



The Santa Fe River Trail Corridor Project, a collaborative project between the City and County, is currently underway to develop a continuous trail within the river corridor from Camino Alire to NM 599. According to a City press release (28 March 2007), the river trail would be one of three major urban trails in the Santa Fe metropolitan area, providing open space, an alternative transportation route, and recreation opportunities for residents and visitors by using the trail to connect a series of parks.

The County does not currently have special zoning or a management plan for the river. Their goal is to purchase land or easements from the county boundary with the city at Camino Carlos Rael to NM 599 for protection and restoration of the river as well as for recreation uses (C. Baker, Project Manager, Santa Fe County Open Space and Trails Division, 28 Sept. 2007, pers. comm.). Some projects have already been completed or are currently in the works, including construction of the new San Ysidro River Park, plans for several new pedestrian and traffic bridges, and a new trail construction project near NM 599.

Currently, recreationists primarily use the study area for walking and related activities (*e.g.* dog walking, bird watching) , jogging, and horseback riding along user-created trails or in the river bed. Walking and jogging use is heaviest in the portion of the study area that is easily accessed on foot from higher-density city neighborhoods at the east end of the study area. Horseback riding occurs primarily at the western end of the study area where the river bed is more sandy with fewer cobbles and can be accessed from horse properties on the north side of the river.

There is vegetation buffer on either side of the study area for its entire length. In some places, the distance to the nearest building, wall, or other development is as little as 25 feet. In other places, development within a quarter-mile or more is limited to two-track roads, utility lines, and barbed-wire fences. Vegetation is densest and tallest at the eastern end of the study area where the river is restricted to a narrow, entrenched corridor. As the river bed widens downstream, vegetation is sparser and lower (*i.e.* mostly grasses, shrubs, and small trees).

Aesthetic qualities of the study area have been impacted by land-use practices over many decades. These land use practices have included sand and gravel mining, construction of road crossings, dam and diversion construction, dumping of solid waste and debris, bank armoring, grading of slopes, and vegetation removal. In more recent years, off-road vehicle use has detrimentally affected river banks and adjacent land forms by destroying vegetation, breaking down the river banks, and causing erosion and sedimentation. It was not one group of people, a certain time period, or a specific action that caused these changes. It is the cumulative effect of human activities over several hundred years, but mostly in the 20th century, that have brought the Santa Fe River to its current state.

Along with changes to the natural environment, the biggest aesthetic impacts in the study area are the ubiquitous solid waste debris deposits along the river. Piles of various waste materials have been accumulating over many years,. Some of these solid waste debris accumulations now cover several acres along the river banks and adjacent land and extend into the river bed (Figure 46). A fair amount of solid waste debris is still dumped directly into the river but is somewhat less noticeable when flows have moved it downstream. Within the study area are half-buried car bodies and car parts, household appliances, construction waste (*e.g.* concrete, asphalt, lumber, silt fence, and plastic sheeting), 55-gallon drums, and smaller items normally found in household trash - cans and bottles, paper, plastic grocery bags, and the black trash bags which once held this trash.

The County anti-dumping ordinance has only limited law enforcement backing. The County is trying to limit access to the river as one method of combating dumping, and volunteers are often utilized to remove trash from the river (C. Baker, Project Manager, Santa Fe County Open Space and Trails Division, 28 Sept. 2007, pers. comm.).

2.10.1 Camino Alire to Camino Carlos Rael (City of Santa Fe)

The study area within the City's jurisdiction is the approximately 1.5-mile segment from Camino Alire to Camino Carlos Rael and includes about 20 percent of the total river length in the study area (Figure 41). Land ownership along the study area as shown on the City of Santa Fe GIS database is primarily as either private or "common area" with a few parcels of city land.

Land uses adjacent to the river in this stretch are primarily residential dwellings and urban streets. There are three city parks along the river: Rio Grande ("pocket") Park, John F. Griego Park on Paseo de la Conquistadora, and Frenchy's Field Park on Agua Fria Street (Figure 41).

Figure 46. Waste piles spilling into the river channel. View is downstream in the reach below Camino Carlos Rael, 22 June 2007. Photo by J. Pittenger.

Homes, property boundary walls, streets, or other structures along this reach are generally set back from the river banks between 25 and 100 feet. Figure 41 shows that there is generally a buffer strip of vegetation between city streets and the river. A few private parcels with little structural development can still be seen in Figure 41.

At beginning of the study area near Camino Alire, a few mature cottonwoods and elms provide shade in the relatively-narrow drainage for wildlife, humans, and pets. In some places, tree canopies nearly span the river, providing a sense of privacy and security for river users. Trees and shrubs obscure the walls and fences that border the backyards of residences adjacent to the river and obstruct views into and from those yards, creating an additional physical barrier between home owners and recreationists. When the river is flowing, the gurgling water combined with sounds of wind in the trees and birds chirping provides a pleasing respite from the highly-developed urban setting surrounding it. When visited on a warm summer weekday, sounds from nearby homes and streets were surprisingly muffled.

Just a few hundred feet downstream from the Camino Alire crossing, mature trees give way to shrubs and grasses and the river floodplain widens so that residential properties and recreationists are openly visible, giving the corridor a less "private" feel. Private lands vary from tidy, attractive properties to the less well-kept with dilapidated buildings and old vehicles cluttering the sites.

Solid waste debris dumping is evident throughout the length of the study area, particularly at vehicle access locations that are at least partially hidden from public view, such as in arroyos and along dirt roads. Dumping is the most obvious aesthetic impact in the study area. An example in this segment of the study area is a location with piles of concrete, asphalt, and other construction materials and many rusting car bodies that covers about 700 feet of bank and extends into the river channel (Figure 41).

During visits to the study area in May and June of 2007, this segment appeared to have the highest amount of recreational use. People using the area were most often seen walking (alone or with a dog) or jogging along the user-created trails that are found on one or both sides of the river in this area or in the river bed itself when the flows had ceased.

2.10.2 Camino Carlos Rael to CR 62 (Santa Fe County)

The river segment between Camino Carlos Rael and CR 62 is about 2.6-miles long and covers about 35 percent of the study area. Most of the land in the study area along this segment is either privately owned or owned by Santa Fe County (Figures 42 and 43). Private lands adjacent to the study area are on the north side of the river are commonly used for agricultural purposes, such as horse pastures and truck farms.

Agua Fria Street roughly parallels the river to the south, although it is separated from the river by private lots (Figures 42 and 43). As Agua Fria is an arterial street in Santa Fe, it is nearly fully-developed commercial and residential interspersed along its length. Commercial enterprises whose properties are adjacent to the south side of the river range from agricultural to light industrial. Some examples of these businesses are a door manufacturing plant, dentist office, plant nursery, truck rental service, auto repair, liquor sales, well-drilling service, landscaping and excavating services, roofing service, portable toilet supplier, retail window sales, screen printing, accounting service, and a feed supplier.

Since 2000, Santa Fe County has purchased four parcels of land (Figures 42 and 43) along this segment of the study area (C. Baker, Project Manager, Santa Fe County Open Space and Trails Division, 28 Sept. 2007, pers. comm.). These properties range between eight and 15 acres in size and extend to both sides of the river for a total length of about 1.1 miles. The eastern-most of these parcels extends both upstream and downstream from the end of Siler Road (Figure 42). County plans for this parcel are a new traffic and pedestrian bridge to facilitate elimination of the low-water crossing at Camino Carols Rael.

A fifth parcel of County land, approximately 70 acres, was formerly federal land managed by the U.S. Bureau of Land Management (BLM). This parcel was patented in 1972 for "Agua Fria Park" (F. Martinez, Real Estate Specialist, BLM-Taos Field Office, 11October 2007, pers. comm.). The land extends upstream and downstream from the CR 62 crossing (Figure 43). Above CR 62, this parcel is on the north side of the river only for 500 feet.

Portions or all of three of these five County parcels are located between the San Ysidro crossing and CR 62 (Figures 42 and 43) and form the basis of the newly-created San Ysidro River Park. The County began construction of the park, which stretches for about three-quarters of a mile along both sides of the river, in 2005 (C. Baker, 28 Sept. 2007, pers. comm.). Although nearly finished, some rock work near the San Ysidro crossing will be completed in the fall of 2007.

The San Ysidro River Park provides recreational opportunities such as walking, horseback riding, and picnicking. Other recreation use along this study area segment is mostly limited to walking or horseback riding in river bed or along occasional two-track dirt roads above the river.

Decades of trash dumping is evident along the river, particularly on some several undeveloped stretches. One trash dump extends for about 1,000 feet along the north bank, covering about three acres. Just one-tenth mile downstream on the same side of the river is another dump of encompassing almost two acres (Figure 42). Recent dumping by businesses along Agua Fria Street whose properties back to the river can be witnessed around the Siler Road area. It appears that this dumping over the steep south bank (about 20 feet above the river bed) is occurring on Santa Fe County property (Figure 42).

2.10.3 CR 62 to Cottonwood Drive (Santa Fe County)

The segment from CR 62 to Cottonwood Drive is about 1.5 miles and constitutes about 20 percent of the study area length. Landownership along segment is primarily private (Figure 44). A small amount of the government-managed lands occur along this segment near the CR 62 crossing. Below the crossing, County land purchased from the BLM encompasses both sides of the river for roughly 0.2 miles. More BLM land is adjacent to the downstream end of the County land. This parcel is on the north side of the river and extends about 0.2 miles downstream (Figure 44).

Uses of private land on the south side of the river are primarily industrial or commercial with a few homes scattered among them. Businesses include a septic tank construction company, paving and asphalt supplier, landscaping service, and auto and appliance salvage yards. Santa Fe Baptist Church is a large building on property that is adjacent to the river near South Meadows Road.

The north side of the river is largely undeveloped with the major exception of Cottonwood Mobile Home Park which occupies about 80 acres between the river and NM 599 (Figure 44). The undeveloped land is not in a natural state, however. A 40-acre parcel east of the mobile home park appears to be used for off-road vehicle (ORV) trails, and a five-acre parcel is completed devoid of vegetation (Figure 44). Many other user-created dirt trails criss-cross the landscape on this side of the river. Some of these trails parallel the north river bank and are used for access to the river bed, as evidenced in Figure 44.

Santa Fe County has plans for another traffic bridge in this area by extending South Meadows Road from its current terminus on the south side of the river to the north (C.Baker, Project Manager, Santa Fe County Open Space and Trails Division, 28 Sept. 2007, pers. comm.). This road extension would presumably be to connect to the NM 599 at the CR 62 intersection.

Trash dumps are frequent along the stretch. On the south side of the river, across from the BLM land, a dumping area covers approximately 1.7 acres of private land adjacent to the river. Several more slightly smaller dumps are on the same side of the river. Many commercial properties appear to use the back area of their lots (*i.e.* nearest the river) for piling trash as well.

Aesthetically, this segment appears “beaten down” by decades of human use. There is little vegetation for screening so dilapidated buildings and junked vehicles are easily observed. The parcel with ORV trails is a particular assault on the senses with little to no vegetation and numerous dirt trails extending over 40 acres, as well as being the source of much noise.

2.10.4 Cottonwood Drive to NM 599 (Santa Fe County)

The western-most segment of the study area includes apporixmately1.5-miles of the river. Land in and adjacent to the study area is largely undeveloped. About 1.2 miles of the river in this segment flows through state land managed by the New Mexico State Land Office (Figure 45). The remaining land is private.

Mineral leases records indicate that sand and gravel mining was permitted along this segment by the State Land Office as early as 1928. Currently, there are no mineral leases along the river in the study area, but there are a number of active commercial leases. Along with several right-of-way leases for roads and utilities in the study area, the State Land Office issued a right-of-way lease in December 2002 for 30 acres to Santa Fe County for protecting open space along the Santa Fe River. The lease straddles the river bed for about one mile (Figure 45) and is valid for as long as the land is used for the leased purpose.

Two other commercial leases for businesses are located in this segment. Both businesses are located on the south side of the river, east of Constellation Drive (Figure 45). The leases are:

1. 1.5 acres for a hot mix plant and related facilities; and
2. 3.4 acres lease for a construction and trucking business.

The latter permit, which also includes a residence and related utilities, was issued in 2005 and will expire in 2010. The hot mix plant site has been leased for the same purpose at least since 1987 and has been renewed regularly since then. The latest lease renewal was in October 2004 and will expire after five years. These leases are not very compatible with plans to develop a recreational trail through the area because of the chronic noise from vehicles and machinery and odors (*e.g.* diesel fumes, asphalt processing) associated with the industrial uses.

Santa Fe County will soon undertake construction of a new pedestrian bridge and trail along the land that they have leased from the State Land Office (Figure 45). The bridge will be constructed across the river approximately in line with the end of Constellation Drive. The trail will be built on the north side of the river for about one mile. The County hopes to construct a second pedestrian bridge at the eastern end of this trail and eventually connect it to the Santa Fe River Trail.

In addition, there is a goal of extending the eastern terminus of the trail north towards NM 599 where it would cross under the highway through existing box culverts and tie into a trail leading to the Caja del Rio Recreation Complex (C. Baker, Project Manager, Santa Fe County Open Space and Trails Division, 28 Sept. 2007, pers. comm.) .

Dumping appears be less prevalent along this segment, possibly because much debris was removed as part of the river restoration project undertaken in 2000 as described in section 1.2. However, unauthorized heavy-equipment grading in the river channel was conducted sometime after 2000 and the meander created at the restoration site was intentionally cut off by pushing up a channel plug and a pilot channel was excavated through the newly-constructed point bar (Figures 47 and 48). The result of this unauthorized grading was abandonment of the meander and loss of an interesting visual feature that created a sense of a natural river channel in the area.

Figure 47. Unauthorized grading plugged the restored meander constructed in 2000 on State Trust land at the downstream end of the study area. Arrows indicate berm that was pushed up to block off the meander from the river. View is downstream. Current river channel bank is to the right of the berm, the restored meander channel, now cut-off from the river, is to the left of the berm. Photo by J. Pittenger, 24 May 2007.

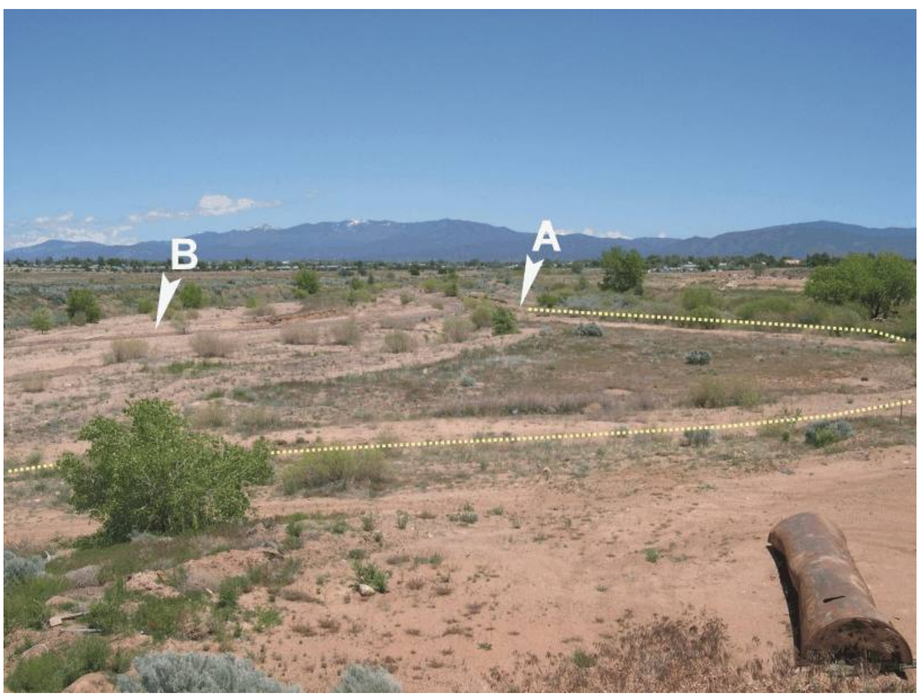


Figure 48. View upstream of the restored meander now isolated from the river. The meander channel is indicated by the dotted line. Arrow "A" shows the location of the channel plug shown in Figure 47. Arrow "B" shows the meander cut-off channel created by unauthorized heavy-equipment grading at the site. View is upstream. Photo by J. Pittenger, 24 May 2007.

3.0 FUTURE CONDITIONS WITHOUT RESTORATION

3.1 Climate

Assuming current trends in human-influenced global climate change continue unchecked, effects in New Mexico will likely include substantially warmer average air temperatures (*i.e.* increases of 6º to 12º F), higher average minimum temperatures, more frequent episodes of extreme heat, fewer episodes of extreme cold, and a longer frost-free period. Effects of global climate change on precipitation patterns in New Mexico are uncertain and could be either increased or decreased annual precipitation amounts. However, it is likely that snowfall amounts would decrease, spring snow-melt runoff would occur earlier in the year, and more of the total precipitation would occur as rainfall (New Mexico Environment Department, 2005).

3.2 Groundwater and Surface Water

3.2.1 Hydrology and Water Quality

Without any restoration projects, stream flow in the Santa Fe River through the study area would continue to occur only sporadically, in response to upstream reservoir releases and storm water runoff. Storm-water runoff peak flows in the river may increase as more of the watershed is urbanized, particularly in the far northwestern portion of the catchment basin that is undergoing development. Also, climate change patterns may result in increased summer precipitation and less snow-melt runoff (*cf.* section 3.1). Under this scenario, sustained spring flow through the study area, similar to that which occurred in 2007, would become more infrequent. On the other hand, short-duration, intense storm-water runoff flows would become more frequent. These conditions would likely result in less storage in the available shallow alluvium, more bed scour, and less infiltration into the Tesuque Formation aquifer from the river channel. Surface water quality, during the periods when the river is flowing, will continue to be affected by pollutants in storm-water runoff. The underlying alluvium would continue to be dry throughout most of the study area except for brief periods when it is saturated by infrequent surface water flows in the river.

3.2.2 Santa Fe River Channel Morphology

The channel of the Santa Fe River in the study area would continue to be influenced by peak flows associated with storm-water runoff and the condition of grade control structures. Assuming that existing grade controls remain in place, the channel of the Santa Fe River through the study area should continue to tend toward equilibrium. Some areas, such as the reach below CR 62 (SFR-10) and the reach at and above Frenchy's Park (SFR-2; Plate 6), would continue to widen and erode the steep-walled banks. In other locations, F channel form may continue to adjust to sediment load and discharge to develop C-type channel (meandering) form. However, given the past record of river management actions it is plausible that additional impacts to the river may occur, which could jolt the system back into a disequilibrium state (*e.g.* constriction of floodplain or channel width through placement of fills, loss of grade control, bank armoring, changes in routing of storm-water flows). Under this scenario, the channel evolution process would be re-set to an early stage and the process of channel adjustment would begin anew.

Grade control structures in the study area are variable in terms of their apparent integrity. The two largest structures, at San Ysidro crossing (GCS-4) and CR 62 (GCS-2; Figure 21) have small scour pools on the downstream side but do not appear to be in danger of becoming undermined in the near future. The San Antonio de Vereda crossing (GCS-5; Plate 6), on the other hand, has a relatively deep scour pool on the downstream side and is crumbling (Figure 22). The long-term persistence of this structure is questionable. The San Antonio de Vereda crossing structure is important in maintaining equilibrium conditions in the upstream reach, which is one of the two main sites in the study area where native woody riparian vegetation is becoming established.

Some of the grade control structures downstream from Frenchy's Field appear to be susceptible to undermining and failure. Most notable of these is structure GCS-7 downstream from Camino Carlos Rael (Figure 49). Assuming a bed slope of about one percent and given the drop below the structure of about three feet, the effect of loss of this structure could potentially extend upstream about 300 feet. The effect would likely persist for many years as the stream channel adjusts its slope and width to the new conditions.

3.3 Air Quality and Noise

If no restoration activities are undertaken in the Santa Fe River study corridor, air quality would not be expected to change measurably. Existing noise levels - human and natural - would also continue at about the same level. The most likely increase in noise levels would come from sounds generated outside of the study area, such as increase traffic on N.M. Highway 599 and city streets.

3.4 Ecological Setting

Development of native riparian vegetation in the study area would continue to be limited to those channel areas in or near equilibrium state, where deposition of sediment on lateral or point bars occurs and there is sufficient floodplain area to allow the spreading of water and dissipation of energy of flood flows. If existing trends continue, these areas are likely to be limited to the C-type channels segments near Siler Road, the San Ysidro River Park between the San Ysidro crossing and CR 62, and the lower end of the study area from Cottonwood Drive downstream to NM 599. For example, occurrence of seedlings and saplings in the lower reach of the study area, from the NM 599 bridge upstream to Cottonwood Drive indicates that conditions are at least periodically suitable for regeneration of cottonwood and willow (Figure 50). Similarly, cottonwood seedlings and saplings and coyote willow seedlings and root-sprouts are common in the reach near Siler Road.

Figure 49. Grade control structure GCS-7, downstream from Camino Carlos Rael, showing failure of the erosion control apron and undermining of the structure. View is upstream. Photo by J. Pittenger, 26 June 2007.

Figure 50. Coyote willow establishment on a point bar at the lower end of the study area. View is upstream in a secondary channel on a point bar that was restored in 2000. Photo by J. Pittenger, 20 September 2007.

Development of native woody riparian vegetation in other segments will continue to be hampered by lack of soil moisture, scouring peak flows, and expansion of non-native invasive species such as Siberian elm, honey-locust, tree-of-heaven, and saltcedar. Lack of soil moisture, in this context, results from sporadic surface flows combined with fast runoff, very narrow of absent floodplains, and scant deposits of permeable alluvium to absorb and store water.

Development of aquatic habitat in the study area is very unlikely in the absence of restoration actions because of the hydrologic and geomorphic trends discussed above. Similarly, wildlife habitat in the study area will continue to be very limited in terms of quality (*i.e.* the capacity to support a diverse assemblage of native species) and areal extent. Patches of native woody riparian vegetation will continue to provide the highest quality habitat and these will likely be restricted primarily to the Siler Road vicinity and the lower end of the study area.

Development of suitable habitat for threatened or endangered species such as Southwestern Willow Flycatcher in the absence of restoration is not likely to occur. This is because surface water flow through the study area will continue to be irregular and geomorphic constraints will restrict locations where native woody riparian vegetation will develop. Consequently, evolution of wetlands and dense riparian vegetation in close proximity to persistent surface water (*i.e.* habitat suitable for Southwestern Willow Flycatcher) is not likely to occur.

3.5 Socioeconomic Environment

Much of the private property adjacent to the study corridor is already developed for residential, commercial, or industrial uses. Without river restoration activities it is unlikely, therefore, that future socioeconomic conditions in the study corridor would change substantially.

3.6 Land Use

If no ecological restoration action is undertaken in the study area, current trends for land use, recreation, and aesthetics would continue. Land uses in the study area would continue to be similar to current uses. It is likely that lands leased by State Land Office for commercial uses (*i.e.* hot mix plant and construction company) would continue.

These uses would remain as an aesthetic intrusion to the County's new recreation trail in that area. Trash dumps, off-road vehicle impacts to the stream banks and river bed, eroding river banks devoid of vegetation, and a dry river bed with an abundance of visible trash would continue to be aesthetic impairments in the study area, particularly from the perspective of recreationists expecting to enjoy a walk or horseback ride through a natural river environment.

4.0 POTENTIAL NATURAL RESOURCES RESTORATION PROJECTS

4.1 What is Ecological Restoration?

This chapter presents an overview of ecological restoration issues in the study area and potential projects that would contribute to restoring ecological integrity to the river. In the context of this report, restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration, 2004). In this sense, the potential restoration projects identified below are not intended to maximize aesthetic qualities or improve conditions for specific human activities. For example, the discussion does not address developing sports facilities or off-road vehicle use areas. It focuses on the ecological integrity of the river corridor.

4.2 Restoration Goal and Objectives

The need for ecological restoration in the study area is obvious. The river ecosystem has been damaged by flow regulation, channel modification, and establishment of non-native species. Once the need for restoration is established, it is critical to define a goal and objectives to focus efforts. This is particularly important in an urban/semi-urban setting such as Santa Fe, where there is strong public interest in restoring the river. Clear definition of a goal and supporting objectives will go a long way towards coordinating efforts of all stakeholders and prevent parties working at cross-purposes. Establishing a clear goal and objectives also contributes to ensuring success of the restoration program by concentrating efforts where they are needed most.

In this light, the following goal and objectives for ecological restoration in the study area are offered as a starting point for discussion. The goal is stated as a desired future condition, which provides a narrative picture of where we want restoration to go.

4.2.1 Preliminary Restoration Goal

The desired future condition of the Santa Fe River in the study area is a riverine corridor with natural structure and function, including a stream channel in equilibrium with discharge and sediment supply, flowing surface water during at least part of the year, and riparian and wetland communities dominated by native plant species.

4.2.2 Preliminary Restoration Objectives

Some potential objectives to achieve this goal include the following. The first object, addressing stream flow, is not addressed any further in this report as it is an ongoing effort by the City administration and other interested parties. Similarly, objective number 4, increasing floodplain area, is a land acquisition issue and is not addressed in this report.

1. Manage water supplies to enhance stream flow in the Santa Fe River.

2. Reduce flood peaks from storm-water run-off and enhance infiltration of run-off into alluvium.
3. Assist natural evolution of the stream channel to an equilibrium state.
4. Increase floodplain area within the corridor.
5. Promote development of riparian and wetland plant communities

4.3 Potential Restoration Strategies and Projects

Using the goals and objectives described above as a guide for actions needed to restore the Santa Fe River in the study area, potential strategies and projects were identified. These strategies and projects are grouped in categories that address each of the non-flow related objectives (numbers 2 through 5 above in section 4.2.2). The primary factors limiting ecological restoration in the study area are hydrologic and geomorphic. Consequently, these issues should be addressed first.

4.3.1 Storm-Water Runoff

This restoration strategy, along with the following strategy (4.3.2 Channel Equilibrium) are the two primary restoration actions needed in the study area. The aim of the storm-water runoff strategy is to slow down run-off, reduce flood peaks, and increase infiltration of storm water into the shallow alluvium of the Santa Fe River.

Potential restoration projects in the study area that are consistent with this strategy deal with detention of storm-water flows at outfall points within the corridor (*cf.* Plate 6). However, it should also be recognized that perhaps a more important set of restoration projects should be implemented in the larger watershed area. Examples of the latter types of projects include: capturing run-off from roof areas on individual properties and directing the water into French drains or similar structures; replacing impervious paving with porous surfacing; construction seepage basins along arroyos; and installing check dams in head-cutting gullies (Riley, 1998: 340-354).

The major arroyo confluence points or storm-water outfalls in the study area (*cf.* Plate 6) that lend themselves to creation of retention basins are:

1. SW-1, the Arroyo Torreon confluence (Station 366+00);
2. SW-2, the storm-water drainage confluence at Frenchy's Park (302+61);
3. SW-9, the arroyo confluence near Nix Stables; (Station 290+72);
4. SW-12, storm drain outfall below the Siler Road dead end (Station 253+62);
5. SW-15, storm drain outfall near the intersection of South Meadows Road and Agua Fria Street (Station 99+88);
6. SW-19, storm-water channel confluence (Station 56+00); and
7. SW-20, NM 599 storm-water drainage channel confluence (Station 12+45).

Retention basins would serve as excellent sites for establishing stands of coyote willow and cottonwood or improving existing stands by retaining run-off and allowing it to percolate into the alluvium (Figures 51 and 52). Development of wetlands dominated by herbaceous plants (*e.g.* sedges, bulrushes, rushes, obligate and facultative wetland forbs) may also be possible if retention basins are not subject to excessive sediment deposition or scour.

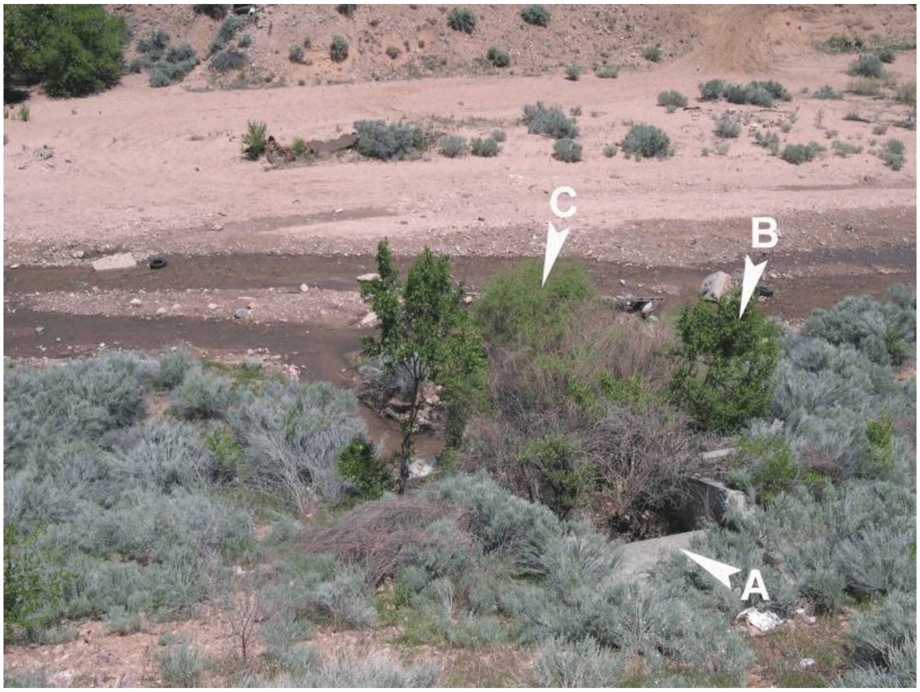


Figure 51. Storm drain outfall SW-12 at Siler Road. The culvert outfall (A) is shadowed by vegetation. Cottonwood saplings (B) and coyote willow (C) are growing amongst Siberian elm and rabbitbrush at the site. Photo by K. Yori, 12 July 2007.

Figure 52. Stand of narrowleaf cottonwood at structure SW-5. View is downstream. Photo by J. Pittenger, 15 June 2007.

Important design considerations include expected run-off volumes, water velocity, sediment loading, and grade control. These parameters should be carefully assessed and incorporated into design. A conceptual design for storm-water retention basins is shown in Figure 53.

The potential for creation of a wetland with herbaceous plants would be greatest at the Arroyo de la Joya confluence at Frenchy's Park (SW-2, Plate 6). An existing excavated pond area could be reconstructed at this site by enlarging it significantly, grading the excavated area to configure several sub-basins, and directing storm-water flows from the drainage into the wetland and then from the wetland into the river.

An impervious liner was installed in the existing depression; this should be removed to allow retained storm-water to infiltrate into the alluvium. Willow, cottonwood, and herbaceous plants should be planted in the excavated area. Anticipated storm-water runoff volume, sediment input, and scour characteristics should be evaluated carefully and incorporated into the design. If sediment loading is expected to be substantial, one or more settling sub-basins should be planned. These would likely require periodic maintenance to remove accumulated material and maintain sediment-trapping capacity. The resulting storm-water detention basin may have standing water for sustained periods, similar to the existing storm-water detention pond just upstream from the NM 599 bridge on the left terrace (Figure 54).

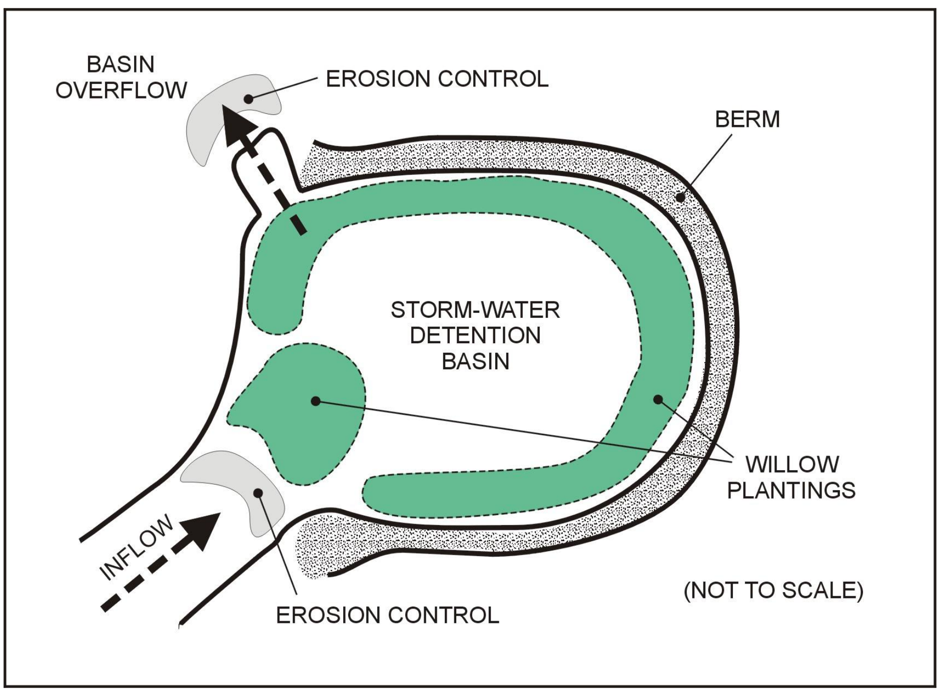


Figure 53. Conceptual design of a storm-water detention basin.

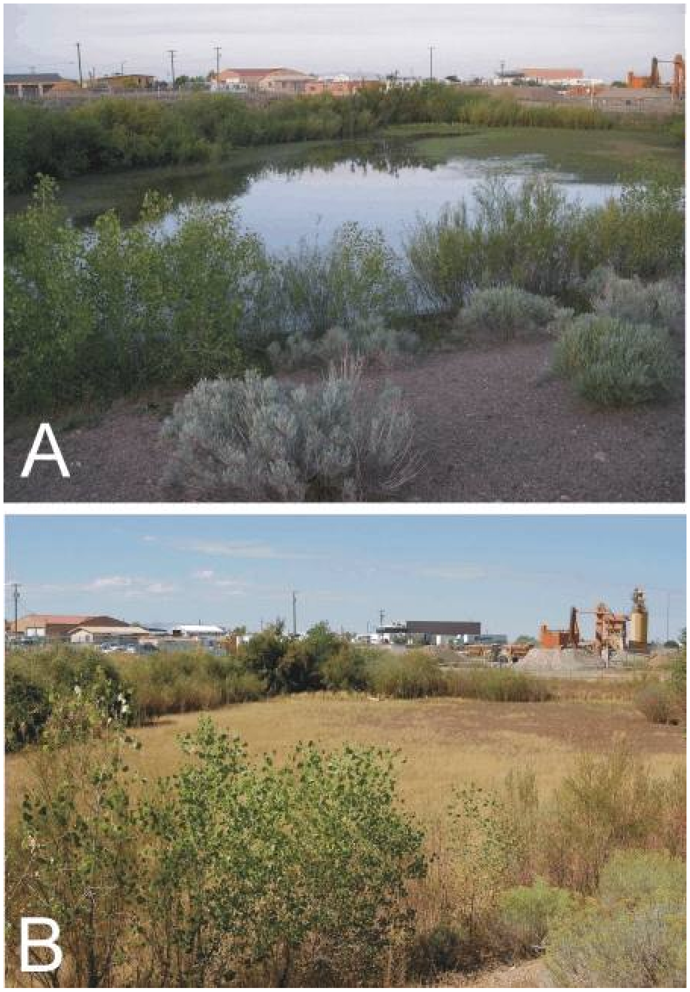


Figure 54. Storm-water detention pond near the NM 599 bridge. The pond held water (photo A, 24 May 2007) for a considerable period in spring 2007. After water levels receded, the bottom of the pond was colonized by annual plants (B, 19 September 2007). Woody vegetation on the pond banks includes coyote willow and Rio Grande cottonwood. Photos by J. Pittenger.

4.3.2 Channel Equilibrium

Establishing channel equilibrium conditions in the study area is a vital prerequisite for effective ecological restoration. As long as channel bed degradation and channel widening are dominant geomorphic processes, woody riparian vegetation cannot become established at persist at a site.

Potential restoration projects that apply to this strategy address developing an understanding of current conditions and rectifying obvious factors contributing to disequilibrium in the study area. The former action is of utmost importance. The services of a professional geomorphologist should be employed in a comprehensive assessment of the channel in the study reach, including a controlled survey of the longitudinal profile and an appropriate number of cross sections. In particular, evaluation of channel evolution stage, current condition of grade controls, need for modification or replacement of controls, and sediment transport characteristics should be thoroughly addressed.

Potential channel restoration projects that could be implemented now include reconnecting the restored meander at the downstream end of the study area and installation of a novel grade control structure in the Frenchy's Park reach.

As discussed in section 2.10.4, a meander restored in 2000 between stations 39+00 and 49+00 was cut-off by unauthorized grading and excavation in the river channel sometime after 2000 (Figures 47 and 48). The abandoned meander could be reconnected to the river by removing the berms at the inlet and outlet of the channel, filling the cut-off channel, and restoring the large point bar that had been created at the site by placement of fill, seeding native herbaceous plant species, and planting with willow and cottonwood cuttings.

Another project that may be considered is construction of a new grade control structure to replace existing structures GCS-10 and GCS-11 at Frenchy's Park (between stations 302+00 and 306+00, Plate 6).

This could be implemented in conjunction with construction of a storm-water detention basin at the site (*cf.* section 4.3.2). The conceptual design is to replace the existing concrete and gabion grade control structures with slab structures that emulate in appearance and function the outcropping of relatively impermeable Tesuque Formation red conglomeratic silts (*cf.* Figure 8). The intent would be to restore a shallow alluvial water table and conditions similar to what may have been present at historic Cieneguita Spring (see discussion on pages 9-10). The intent would be for the structure to serve as a grade control and also to retain shallow groundwater moving through the alluvium. which would be charge at the site by the storm-water input from the detention basin (Figure 55). The crest of the structure sill should be placed at a sufficient elevation to cause deposition of sediment (aggradation) upstream because the bed has scoured down to relatively impermeable strata and storage volume for shallow groundwater is limited.

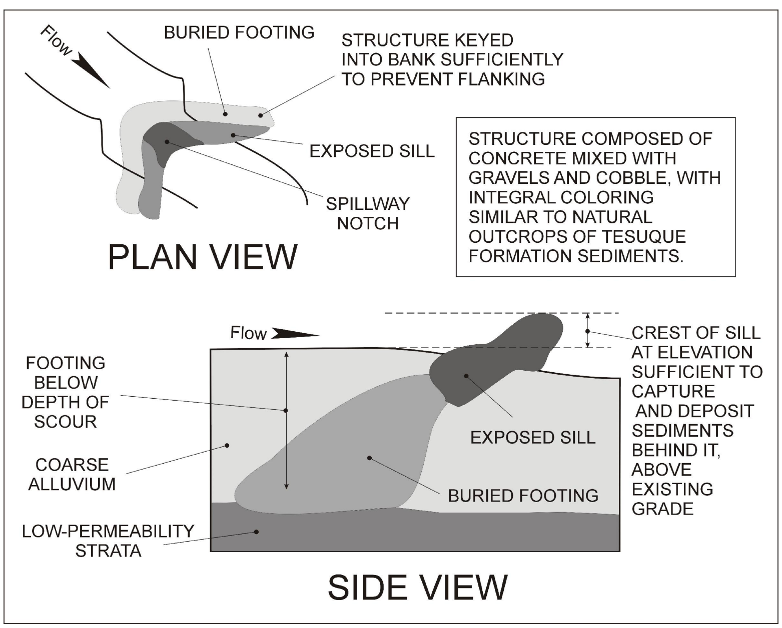


Figure 55. Conceptual design for simulated conglomerate outcrop grade-control structure. The structure would also serve to retain shallow groundwater moving through the coarse alluvium, potentially bringing it to the surface during wet periods.

Major channel restoration work should not be conducted in the study area until a thorough geomorphic analysis is conducted. This is particularly relevant to the reach downstream from CR 62, which is deeply incised and unstable. Channel restoration should be carefully planned using regional curves and a suitable reference site to determine average values and range of variability in design criteria for morphological features such as channel slope, bankfull width and depth, meander wavelength, belt width. For example, the restoration project at the downstream end of the study area involved developing a regional curves for the relationship between drainage area and channel morphology parameters at gaged and un-gaged sites in the Santa Fe County area (Blue Earth Ecological Consultants, Inc., unpubl. data). A reference reach was identified and field measurements were made to develop design criteria. These included a channel slope of 0.73 percent, average bankfull width of 45.5 feet, average bankfull depth of 1.27 feet, and sinuosity of 1.54, in a project reach that had channel bed material with a D_{50} of 1-2 mm (Blue Earth Ecological Consultants, Inc., unpubl. data). Use of inappropriate materials (*e.g.* large boulders) and methods (*e.g.* construction of over-widened channel) should be avoided.

4.3.3 Native Riparian Vegetation

This strategy is directed at increasing the extent of native riparian vegetation in the study area. Two main actions can be undertaken that would contribute to this objective. First, supplemental planting of native woody riparian species can be implemented in areas that are in equilibrium condition. Planting in unstable reaches should be avoided until geomorphic factors influencing stability area addressed (*e.g.* Briggs, 1996: 100-101). Second, removal of non-native species can be conducted and the plants replaced with native species. The areas of focus for supplemental planting actions should be 1) the Siler Road area and 2) the downstream end of the study area, where restoration work conducted in 2000 resulted in dramatic increases in cover by cottonwood and willow. The Siler Road area is a good candidate for the initial focus, as it appears to have good potential as indicated by natural recruitment of cottonwood and willow.

Planting of cottonwood and coyote willow can be most easily accomplished by using dormant pole or whip cuttings (*e.g.* Briggs, 1996: 71-77). Planting techniques should follow guidance developed by the Natural Resources Conservation Service, Plant Materials Center in Los Lunas (Appendix B). A rotary hammer fitted with a one-inch diameter, three-foot long bit or a backhoe fitted with a "stinger" on the excavator arm are suitable methods for auguring deep holes for planting whips or small-diameter poles. These methods should work well in the soil types found in the study area.

4.3.4 Community Involvement

As an end note, the need to involve the community in restoration planning and implementation cannot be stressed enough. Through involvement in removing trash from the river, planting vegetation, removing non-native plants, monitoring river conditions, and other activities, community awareness of the value of a living river increases. Through involvement with restoration, the community gains an appreciation of place and the river becomes a meaningful part of their lives. Community interest in restoration can be fostered by communicating benefits such as enhancing neighborhoods, preserving history and culture, increasing recreational opportunities, creating jobs, and providing unique educational opportunities (Riley, 1998: 12-22).

5.0 PREPARATION, COORDINATION, AND CONSULTATION

5.1 Preparation

John Pittenger, Senior Ecologist
Blue Earth Ecological Consultants, Inc.

Karen Yori, Senior Planner
Blue Earth Ecological Consultants, Inc.

5.2 Coordination and Consultation

Colleen Baker, Project Manager
Santa Fe County Open Space and Trails Division

Gilbert Borrego, Youth Works Consultant
City of Santa Fe

Mary Ellen Carroll, Minerals Management Analyst
State Land Office, Oil, Gas and Minerals Division

David Chapman, (Acting River Coordinator)
City of Santa Fe

Francina Martinez, Realty Specialist
Bureau of Land Management, Taos Field Office

6.0 REFERENCES

Allred, K. 2006. *A Working Index of New Mexico Vascular Plant Names*. http://web.nmsu.edu/~kallred/herbweb/Working%20Index-title.htm.

American Rivers. 2007. *America's Most Endangered Rivers, 2007.* http://www.americanrivers.org/site/PageServer?pagename=AR7_MER2007

Briggs, M. K. 1996. *Riparian Ecosystem Recovery in Arid Lands: Strategies and References*. The University of Arizona Press, Tucson, Arizona.

City of Santa Fe. 2007. *Santa Fe Trends 2007.* City of Santa Fe Planning and Land Use Department, Santa Fe, New Mexico.

Dunne, T. and L. B. Leopold. 1978. *Water in Environmental Planning*. W.H. Freeman and Company, New York.

Fenneman, N. M. and D. W. Johnson. 1946. *Physiographic Divisions of the Conterminous U.S.*, scale 1:7,000,000. U.S. Geological Survey, Washington, D.C.

Forman, R. T. T., D. Sperling, J. A. Bisonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. *Road Ecology, Science and Solutions*. Island Press, Washington, Covelo, London.

Grant, P. 2002. *Santa Fe River Watershed Restoration Action Strategy*. Santa Fe Watershed Association, Santa Fe, New Mexico.

Harvey, M. D. and C. C. Watson. 1986. Fluvial processes and morphological thresholds in incised channel restoration. *Water Resources Bulletin* 22(3): 359-368.

Heggen, R. J. 1997. *Lessons Learned, Channel Stabilization in Santa Fe, New Mexico*. Unpublished report prepared for the U.S. Army Corps of Engineers, Albuquerque District, Albuquerque, New Mexico.

Hink, V. D. and R. D. Ohmart. 1984. *Middle Rio Grande Biological Survey, Final Report*. Report prepared for the U.S. Army Corps of Engineers, Albuquerque District, in fulfillment of contract no. DACW47-81-C-0015.

Konig, D. J., S. D. Connell, F. J. Pazzaglia, and W. C. McIntosh. 2002. Redefinition of the Ancha Formation and Pliocene-Pleistocene deposition in the Santa Fe embayment, north-central New Mexico. *New Mexico Geology* 24(3): 75-87.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15: 259-263.

Kottlowski, F. E. 1995. Geologic synopsis of La Villa Real de la Santa Fe de San Francisco de Assisi. Pages 2-4 *in*: Bauer, P. W., B. S. Kues, N. W. Dunbar, K. E. Karlstrom, and B. Harrison (eds.). *Geology of the Santa Fe Region, New Mexico*. New Mexico Geological Society Guidebook, 46th Field Conference, September 27-30, 1995.

Lange, C. 1998. *Clean Water Act Section 404 Permit Application for the Santa Fe River Channel Trail and Greenway Improvements Project, Santa Fe County, New Mexico*. City of Santa Fe Public Works Department, Engineering Project Division, Santa Fe, New Mexico. 4 February 1998.

Lazarus, J. and P. Drakos. 1995. Geohydrologic characteristics and hydrocarbon contamination of the shallow alluvial/Tesuque Formation aquifer, Santa Fe, New Mexico. Pages 307-311 *in*: Bauer, P. W., B. S. Kues, N. W. Dunbar, K. E. Karlstrom, and B. Harrison (eds.). *Geology of the Santa Fe Region*. New Mexico Geological Society, Forty-Sixth Annual Field Conference, September 27-30, 1995.

Leopold, L. B. 1994. *A View of the River*. Harvard University Press, Cambridge, Massachusetts and London, England.

Leopold, L. B. and J. P. Miller. 1956. *Ephemeral Streams – Hydraulic Factors and Their Relation to the Drainage Net*. U.S. Geological Survey, Geological Survey Professional Paper 282-A.

Leopold, L. B.,M. G. Wolman, and J. P. Miller. 1992. *Fluvial Processes in Geomorphology*. Dover Publications, Inc., New York.

Lewis, A. C. and F. West. 1995. Conceptual hydrologic systems for Santa Fe County. Pages 299-306 *in*: Bauer, P. W., B. S. Kues, N. W. Dunbar, K. E. Karlstrom, and B. Harrison (eds.). *Geology of the Santa Fe Region*. New Mexico Geological Society, Forty-Sixth Annual Field Conference, September 27-30, 1995.

Makepeace, D. K., D. W. Smith, and S. J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. *Critical Reviews in Environmental Science and Technology* 25(2): 93-139.

McAda, D. P. and M. Wasiolek. 1988. *Simulation of the Regional Geohydrology of the Tesuque Aquifer System Near Santa Fe, New Mexico*. U.S. Geological Survey Water-Resources Investigations Report 87-4056.

National Climatic Data Center. 2007. *Climate Monitoring Reports and Products*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration - Satellite and Information Service. http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html

Natural Resources Conservation Service. *Web Soil Survey*. Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture. http://websoilsurvey.nrcs.usda.gov/

New Mexico Climate Center. 2007. *Climate of New Mexico*. Climate Center, New Mexico State University, Las Cruces, New Mexico. http://weather.nmsu.edu/

New Mexico Environment Department. 2005. *Potential Effects of Climate Change on New Mexico*. Agency Technical Work Group, State of New Mexico. http://www.nmenv.state.nm.us /aqb/cc/ Potential_Effects_Climate_Change_NM.pdf

New Mexico Environment Department. 2007. *2006-2008 State of New Mexico Integrated Clean Water Act §303(d)/§305(b) Report*. New Mexico Environment Department, Surface Water Quality Bureau, Santa Fe, New Mexico.

Oregon Climate Service. 2007. *Comparative Climate, New Mexico*. Oregon State University, Corvallis, Oregon. http://www.ocs.orst.edu/page_links/comparative_climate/new_mexico/new_mexico.html

Pitt, R., R. Field, M. Lalor, and M. Brown. 1995. Urban stormwater toxic pollutants: assessment, sources, and treatability. *Water Environment Research* 67(3):260-275.

Read, A. S., D. J. Konig, G. A. Smith, S. Ralser, J. Rogers, and P. W. Bauer. 2000. *Preliminary Geologic Map of the Santa Fe 7.5-minute Quadrangle*. New Mexico Bureau of Geology, New Mexico Tech, Socorro, New Mexico.

Riley, A. L. 1998. *Restoring Streams in Cities, A Guide for Planners, Policymakers, and Citizens.* Island Press, Washington, D.C. and Covelo, California.

Rosgen, D. L. 1994. A classification of natural rivers. *Catena* 22(3): 169-199.

Rosgen, D. L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, Colorado.

Shroba, R. R., R. A. Thompson, S. A. Minor, V. J. S. Gauch, and T. R. Brandt. 2005. *Geologic Map of the Agua Fria Quandrangle, Santa Fe County, New Mexico*. U.S. Geological Survey Scientific Investigations Map 2896.

Society for Ecological Restoration. 2004. *The SER International Primer on Ecological Restoration*. Society for Ecological Restoration International, Science and Policy Working Group, Tucson, Arizona.

Spiegel, Z. and B. Baldwin. 1963. *Geology and Water Resources of the Santa Fe Area, New Mexico*. U.S. Geological Survey Water-Supply Paper 1525.

U.S. Census Bureau. 2007*a*. *American Fact Finder. P7. Race [8]* - universe: total population; data set: Census 2000 summary file 1(SF 1) 100-percent data.. http://factfinder/census.gov/

U.S. Census Bureau. 2007*b*. *American Fact Finder. P8. Hispanic or Latino by race [17]* - universe: total population; data set: Census 2000 summary file 1(SF 1) 100-percent data.. http://factfinder/census.gov/

U.S. Census Bureau. 2007*c*. *American Fact Finder. P82. Per capita income in 1999 (dollar) [1]* - universe: total population; data set: Census 2000 summary file 3 (SF 3) - sample data. http://factfinder.census.gov/

U.S. Census Bureau. 2007*d*. *American Fact Finder. P87. Poverty status in 1999 by age [17]* - universe: population for whom poverty status is determined; data set: Census 2000 summary file 3 (SF 3) - sample data. http://factfinder.census.gov/

U.S. Census Bureau. 2007*e*. *American Fact Finder. T1 Population estimates [9]*; data set: 2006 population estimates. http://factfinder.census.gov/

U.S. Environmental Protection Agency. 2007. *Air data. Non-attainment Areas Map - Criteria Air Pollutants.* http://www.epa.gov/air/data/reports.html

Western Regional Climate Center. 2007. *New Mexico Climate Summaries for Cooperator Stations*. Western Regional Climate Center, National Oceanic and Atmospheric Administration, Reno, Nevada. http://www.wrcc.dri.edu/index.html

W.J. Miller Engineers, Inc. 2000. *Santa Fe River Demonstration Project, State Trust Reach, Sediment Transportation and Hydraulics Analysis*. Prepared by William J. Miller Engineers, Inc. and Blue Earth Ecological Consultants, Inc. for the New Mexico State Land Office, 1 May 2000.

APPENDIX A

Animal Species Potentially Occurring in Riparian or Aquatic Habitats in Santa Fe County

The following list of vertebrate animal species potentially occurring in riparian and aquatic habitats was generated from a query of the Biota Information System of New Mexico (BISONM) database, which is maintained by the New Mexico Department of Game and Fish and is located on the world-wide web at www.bison-m.org. The database was accessed on 14 November 2007 and was queried using the following search terms:

County Name = Santa Fe
Habitat = Aquatic; Semi-Aquatic; Fully Aquatic; Riparian
Gap Veg = Lowland Riparian (cottonwood/sycamore); Aquatic: Riverine/Lacustrine

COMMON NAME	SCIENTIFIC NAME
AMPHIBIANS (4 species)	
tiger salamander	*Ambystoma tigrinum*
Great Plains toad	*Bufo cognatus*
Woodhouse's toad	*Bufo woodhousii*
canyon tree frog	*Hyla arenicolor*
REPTILES (23 species)	
ornate box turtle	*Terrapene ornata*
collared lizard	*Crotaphytus collaris*
leopard lizard	*Gambelia wislizenii*
lesser earless lizard	*Holbrookia maculata*
roundtail horned lizard	*Phrynosoma modestum*
prairie lizard	*Sceloporus undulatus*
northern tree lizard	*Urosaurus ornatus*
Chihuahuan spotted whiptail	*Aspidocelis exsanguis*
Colorado checkered whiptail	*Aspidoscelis tesselata*
Plateau spotted whiptail	*Aspidocelis velox*
many-lined skink	*Eumeces multivirgatus epipleurotis*
Great Plains skink	*Eumeces obsoletus*
glossy snake	*Arizona elegans*
corn snake	*Elaphe guttata*
western hognose snake	*Heterodon nasicus*
night snake	*Hypsigiena torquata*
desert kingsnake	*Lampropeltis getula splendida*
milk snake	*Lampropeltis triangulum celaenops*
smooth green snake	*Opheodrys vernalis blanchardi*
coachwhip	*Masticophis flagellum*
desert striped whipsnake	*Masticophis taeniatus taeniatus*

COMMON NAME	SCIENTIFIC NAME
gopher snake	*Pituophis cantifer*
western blackneck garter snake	*Thamnophis cyrtopsus cyrtopsis*
wandering garter snake	*Thamnophis elegans*
checkered garter snake	*Thamnophis marcianus marcianus*
New Mexico garter snake	*Thamnophis sirtalis dorsalis*
western diamondback rattlesnake	*Crotalus atrox*
BIRDS (143 species)	
Double-crested Cormorant	*Phalacrocorax auritus*
Great Blue Heron	*Ardea herodias herodias*
Wood Duck	*Aix sponsa*
Turkey Vulture	*Cathartes aura*
Northern Harrier	*Circus cyaneus hudsonius*
Cooper's Hawk	*Accipiter cooperii*
Sharp-shinned Hawk	*Accipiter striatus velox*
Northern Goshawk	*Accipiter gentilis*
Zone-tailed Hawk	*Buteo albonotatus*
Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Ferruginous Hawk	*Buteo regalis*
Bald Eagle	*Haliaeetus leucocephalus alascanus*
American Kestrel	*Falco sparverius sparverius*
Peregrine Falcon	*Falco peregrinus anatum*
Sandhill Crane	*Grus canadensis*
Spotted Sandpiper	*Actitis macularia*
Rock Dove	*Columba livia*
Band-tailed Pigeon	*Columba fasciata fasciata*
Mourning Dove	*Zenaida macroura*

COMMON NAME	SCIENTIFIC NAME
Yellow-billed Cuckoo	*Coccyzus americanus occidentalis*
Greater Roadrunner	*Geococcyx californianus*
Barn Owl	*Tyto alba pratincola*
Long-eared Owl	*Asio otus*
Flammulated Owl	*Otus flammeolus*
Western Screech Owl	*Otus kennicotti*
Great-horned Owl	*Bubo virginianus*
Mexican Spotted Owl	*Strix occidentalis lucida*
Northern Pygmy Owl	*Glaucidium gnoma californicum*
Burrowing Owl	*Athene cunicularia hypugaea*
Common Nighthawk	*Chordeiles minor*
Belted Kingfisher	*Ceryle alcyon*
Black-chinned Hummingbird	*Archilochus alexandri*
Broad-tailed Hummingbird	*Selasphorus platycercus platycercus*
Rufous Hummingbird	*Selasphorus rufus*
Northern Flicker	*Colaptes auratus*
Lewis's Woodpecker	*Melanerpes lewis*
Downy Woodpecker	*Picoides pubescens leucurus*
Hairy Woodpecker	*Picoides villosus*
Ladder-backed Woodpecker	*Picoides scalaris*
Williamson's Sapsucker	*Sphyrapicus thyroideus nataliae*
Red-naped Sapsucker	*Sphyrapicus nuchalis*
Olive-sided Flycatcher	*Contopus cooperi*
Western Wood-Pewee	*Contopus sordidulus*
Southwestern Willow Flycatcher	*Empidonax traillii extimus*
Dusky Flycatcher	*Empidonax oberholseri*
Cordilleran Flycatcher	*Empidonax occidentalis*

COMMON NAME	SCIENTIFIC NAME
Black Phoebe	*Sayornis nigricans semiatra*
Say's Phoebe	*Sayornis saya*
Ash-throated Flycatcher	*Myiarchus cinerascens cincerascens*
Cassin's Kingbird	*Tyrannus vociferans vociferans*
Western Kingbird	*Tyrannus verticalis*
Loggerhead Shrike	*Lanius ludovicianus*
Northern Shrike	*Lanius excubitor invictus*
Cassin's Vireo	*Vireo cassinii*
Plumbeous Vireo	*Vireo plumbeus*
Solitary Vireo	*Vireo solitarius*
Warbling Vireo	*Vireo gilvus swainsonii*
Blue Jay	*Cyanocitta cristata bromia*
Steller's Jay	*Cyanocitta stelleri macrolopha*
Western Scrub Jay	*Aphelocoma californica*
Black-billed Magpie	*Pica hudsonia*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax sinuatus*
Tree Swallow	*Tachycineta biclor*
Violet-green Swallow	*Tachycineta thalassina lepida*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis serripennis*
Barn Swallow	*Hirundo rustica erythrogaster*
Cliff Swallow	*Petrochelidon pyrrhonota*
Juniper Titmouse	*Baeolophus ridgwayi*
Black-capped Chickadee	*Poecile atricapilla*
Mountain Chickadee	*Poecile gambeli gambeli*
Bushtit	*Psaltriparus minimus*
White-breasted Nuthatch	*Sitta carolinensis nelsoni*

COMMON NAME	SCIENTIFIC NAME
Pygmy Nuthatch	*Sitta pygmaea melanotis*
Red-breasted Nuthatch	*Sitta canadensis*
Brown Creeper	*Certhia americana*
Bewick's Wren	*Thryomanes bewickii*
House Wren	*Troglodytes aedon parkmannii*
Canyon Wren	*Catherpes mexicanus conspersus*
Golden-crowned Kinglet	*Regulus satrapa*
Ruby-crowned Kinglet	*Regulus calendula calendula*
Blue-gray Gnatcatcher	*Polioptila caerulea amoenissima*
Mountain Bluebird	*Sialia currucoides*
Western Bluebird	*Sialia mexicana bairdi*
Townsend's Solitaire	*Myadestes townsendii townsendii*
American Robin	*Turdus migratorius*
Swainson's Thrush	*Catharus ustulatus*
Hermit Thrush	*Catharus guttatus*
Gray Catbird	*Dumetella carolinensis ruficrissa*
Northern Mockingbird	*Mimus polyglottos leucopterus*
Sage Thrasher	*Oreoscoptes montanus*
American Pipit	*Anthus rubescens*
Cedar Waxwing	*Bombycilla cedrorum*
European Starling	*Sturnus vulgaris*
Orange-crowned Warbler	*Vermivora celata*
Virginia's Warbler	*Vermivora virginiae*
Nashville Warbler	*Vermivora ruficapilla ridgwayi*
Yellow Warbler	*Dendroica petechia*
Townsend's Warbler	*Dendroica townsendi*
Black-throated Gray Warbler	*Dendroica nigrescens*

COMMON NAME	SCIENTIFIC NAME
Black-throated Green Warbler	*Dendroica virens virens*
Yellow-rumped Warbler	*Dendroica coronata*
Grace's Warbler	*Dendroica graciae graciae*
Bay-breasted Warbler	*Dendroica castanea*
Macgillivray's Warbler	*Oporornis tolmiei*
Common Yellowthroat	*Geothlypis trichas*
Wilson's Warbler	*Wilsonia pusilla*
Yellow-breasted Chat	*Icteria virens auricollis*
Western Tanager	*Piranga ludoviciana*
Hepatic Tanager	*Piranga flava*
Indigo Bunting	*Passerina cyanea*
Lazuli Bunting	*Passerina amoena*
Blue Grosbeak	*Pheuticus caerulea interfusa*
Black-headed Grosbeak	*Pheuticus melanocephalus*
Rose-breasted Grosbeak	*Pheuticus ludovicianus*
Canyon Towhee	*Pipilo fuscus*
Spotted Towhee	*Pipilo maculatus*
Green-tailed Towhee	*Pipilo chlorurus*
Chipping Sparrow	*Spizella passerina arizonae*
Brewer's Sparrow	*Spizella breweri*
Clay-colored Sparrow	*Spizella pallida*
Lark Sparrow	*Chondestes grammacus strigatus*
Vesper Sparrow	*Pooecetes gramineus*
Song Sparrow	*Melospiza melodia*
Lincoln's Sparrow	*Melospiza lincolnii*
Harris's Sparrow	*Zonotrichia querula*
White-crowned Sparrow	*Zonotrichia leucophrys*

COMMON NAME	SCIENTIFIC NAME
Golden-crowned Sparrow	*Zonotrichia atricapilla*
White-throated Sparrow	*Zonotrichia albicollis*
Dark-eyed Junco	*Junco hyemalis*
Bullock's Oriole	*Icterus bullockii*
Baltimore Oriole	*Icterus galbula*
Scott's Oriole	*Icterus parisorum*
Red-winged Blackbird	*Agelaius phoeniceus*
Brewer's Blackbird	*Euphagus cyanocephalus*
Common Grackle	*Quisicalus quiscula versicolor*
Great-tailed Grackle	*Quisicalus mexicanus*
Brown-headed Cowbird	*Molothrus ater*
Evening Grosbeak	*Coccothraustes vespertinus*
House Finch	*Carpodacus mexicanus frontalis*
Lesser Goldfinch	*Carduelis psaltria psaltria*
American Goldfinch	*Carduelis tristis pallidus*
Pine Siskin	*Carduelis pinus pinus*
MAMMALS (37 species)	
Virginia opossum	*Didelphis virginiana virginiana*
dusky shrew	*Sorex monticolus*
southwestern myotis	*Myotis auriculus apache*
fringed myotis	*Myotis thysanodes thysanodes*
long-legged myotis	*Myotis volans interior*
western small-footed myotis	*Myotis ciliolabrum melanorhinus*
big brown bat	*Eptesicus fuscus pallidus*
hoary bat	*Lasiurus cinereus cinereus*
pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*
pallid bat	*Antrozous pallidus pallidus*

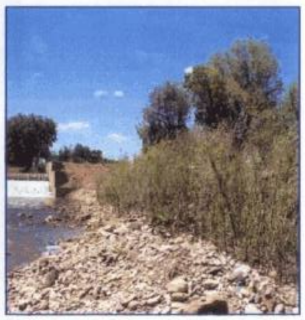
COMMON NAME	SCIENTIFIC NAME
desert cottontail rabbit	*Sylvilagus audubonii*
black-tailed jack rabbit	*Lepus californicus*
spotted ground squirrel	*Spermophilus spilosoma*
rock squirrel	*Spermophilus variegatus grammurus*
Botta's pocket gopher	*Thomomys bottae*
silky pocket mouse	*Perognathus flavus*
Ord's kangaroo rat	*Dipodomys ordii*
white-throated woodrat	*Neotoma albigula*
beaver	*Castor canadensis*
western harvest mouse	*Reithrodontomys megalotis*
deer mouse	*Peromyscus maniculatus*
white-footed mouse	*Peromyscuc leucopus*
brush mouse	*Peromyscus boylii rowleyi*
northern grasshopper mouse	*Onychomys leucogaster*
house mouse	*Mus musculus*
common porcupine	*Erethizon dorsatum*
coyote	*Canis latrans*
gray fox	*Urocyon cineroargenteus scottii*
black bear	*Ursus americanus amblyceps*
ringtail	*Bassariscus astutus*
common raccoon	*Procyon lotor*
American badger	*Taxidea taxus*
western spotted skunk	*Spilogale gracilis*
striped skunk	*Mephitis mephitis*
mountain lion	*Felis concolor*
bobcat	*Lynx rufus baileyi*
mule deer	*Odocoileus hemionus*

APPENDIX B

Guidelines for Riparian Planting

New Mexico Plant Materials Center Brochure #7105, Guidelines for Planting Dormant Whip Cuttings to Revegetate and Stabilize Stream Banks, available on-line at: http://www.plant-materials.nrcs.usda.gov/pubs/nmpmcbr7105.pdf

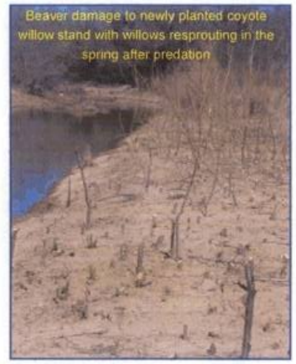
New Mexico Plant Materials Center Brochure #7106, Guidelines for Planting Longstem Transplants for Riparian Restoration in the Southwest, available on-line at: http://www.plant-materials.nrcs.usda.gov/pubs/nmpmcbr7106.pdf



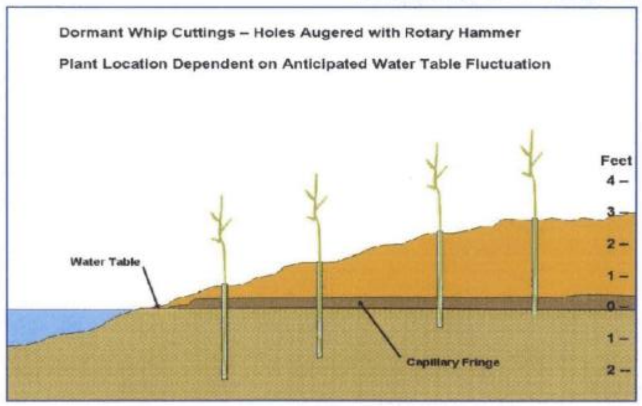
Before and after: Streambank stabilization is achieved by "deep planting" coyote willow whips; planting holes were augered in the rocky soil by using rotary hammers.

Coyote willow can form dense stands from root sprouts. Because low density plantings can fill in rapidly, coyote willow can be very useful for streambank stabilization on lower elevation sites. On higher elevation sites, most willow species are multi-stem shrubs which can resprout from root crowns, but they do not root sprout to form thickets. For this reason, higher density plantings of these willow species may be necessary to rapidly stabilize eroding streambanks in montane environments. One montane species, red osier dogwood, does propagate by stem layering which allows rapid spread on streambanks.

If additional information is needed regarding planting dormant whip cuttings for streambank revegetation, contact the Los Lunas Plant Materials Center at 505-865-4684.

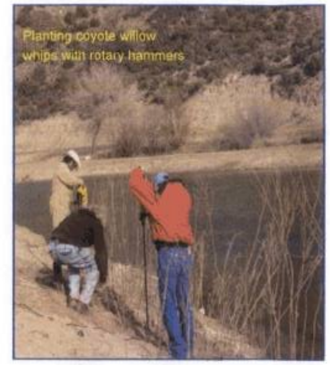


Beaver damage to newly planted coyote willow stand with willows resprouting in the spring after predation



Deep Planting

The Ground Water Connection



Planting coyote willow whips with rotary hammers

Guidelines for Planting Dormant Whip Cuttings to Revegetate and Stabilize Streambanks

NRCS Natural Resources Conservation Service

Plant Materials Program

The USDA is an equal opportunity provider and employer

The Los Lunas Plant Materials Center

(LLPMC) has developed revegetation techniques involving "deep planting" for disturbed riparian areas; these methodologies allow rapid root extension into the capillary fringe which is the permanent soil moisture above the water table. These deep-planting techniques allow the establishment of obligate riparian species (phreatophytes) with little or no need for follow-up irrigation.

Dormant pole cuttings of riparian overstory trees, typically cottonwood and willow stems 12 to 16 feet long, and longstem container stock of understory shrubs have been successfully established by deep planting them into the capillary fringe. The capillary fringe provides moist but unsaturated soil for root proliferation.

Streambanks prone to erosion during high-flow events can be stabilized by establishing a dense, woody cover to armor the banks, and prolific root systems to stabilize the streambank soils.

In lower elevations of the southwestern United States, the following native species frequently serve this role:

- coyote (narrowleaf) willow (*Salix exigua*)
- seepwillow baccharis (mule's fat) (*Baccharis salicifolia*)
- desert false indigo (*Amorpha fruticosa*)
- occasionally arrowweed (*Pluchea sericea*)

At higher elevations, a variety of shrub willows (*Salix* sp.), redosier dogwood (*Cornus sericea*), thinleaf alder (*Alnus incana*), and occasionally water birch (*Betula occidentalis*) serve the same purpose.

Some of these species will root readily from dormant cuttings including most willows and dogwood. Baccharis and false indigo will root from cuttings but not consistently. The remaining species do not root from cuttings or their rooting propensity is unknown. Those species that root easily are good candidates for planting as dormant cuttings for streambank stabilization.

The key to successful establishment is to place the base of the dormant cutting into the water table to assure the cutting is well hydrated while it forms adventitious roots that will extend into the capillary fringe. Another crucial factor is that the dormant cutting is planted deep into the alluvium to resist extraction by flood flows.

Attributes of shrub willow and dogwood whip cuttings include small base diameter (less than 1-inch caliper) and relatively short length (5 to 8 feet) compared with dormant pole cuttings. This is the natural growth form of young vigorous shoots (whips) which are the most likely to root readily.

The LLPMC's typical method of augering the holes to plant dormant whip cuttings is to use a spline drive rotary hammer with a 1-inch diameter bit that is 36 inches long. The 30-inch-plus deep holes have a sufficient diameter to accept most whip cuttings. A portable generator can provide sufficient power for several hammers via extension cords outfitted with ground fault circuit interrupters. A team of two persons, one doing the augering and one planting the cuttings, can plant up to 800 whip cuttings per day provided the soil is cohesive sand with only small amounts gravel or cobble. Heavy soils take much longer to auger because it is often difficult to pull the bit from the wet clay sediments. Rotary hammers can penetrate several inches of frozen surface soil that is frequently encountered during the late-winter or early-spring planting window for dormant cuttings. If cobbles are present in moderate numbers, it is possible through trial and error to auger deep holes if care is taken to not exert excessive lateral force on the bit which may result in breakage.

If the soil contains dense cobble or has a riprap cover, using a long, sharpened rod (referred to as a stinger) attached to a backhoe or excavator arm often can be successful in driving holes of sufficient depth. For fine-textured soils, you can use a jet of high pressure water to excavate a hole; this method requires a pump and an easily accessible water source because appreciable water is consumed to jet each hole. Another successful method for planting whip cuttings is to use a large diameter auger to reach the water table and place several whips in each hole to assure survival. This produces a clump of plants rather than an individual stem.

Before and after: Coyote willows "deep planted" along drainage ditch

The following factors may influence the success of a planting:

- Hydration–As with all dormant cuttings, it is important to keep the whips hydrated by storing newly harvested cuttings in water and minimizing desiccation during transport.
- Beaver damage–Willow whip cuttings can be damaged by beaver predation. Even though the entire aboveground portion of a newly planted whip might be consumed, the below-ground stem often has sufficient reserves to sprout and form new shoots.
- Groundwater fluctuation–In situations where the groundwater depth fluctuates significantly, planting along the streambank at different elevations above the water level may be advisable as long as the base of the cutting is in contact with the capillary fringe or preferably in the saturated zone. Those cuttings close to the water's edge and inserted into very shallow groundwater may endure if the water level recedes drastically. However, if water levels stay elevated for long periods of time, the higher cuttings may be the only ones to survive.

The density of a planting depends on these factors:

- The urgency of stabilizing the streambank
- The spreading potential of the species planted
- The cost per unit area

same three species previously mentioned were installed in later comparison plantings along with deep planted tallpot stock. Similar survival rates, growth rates, and adventitious root development were observed.

One advantage of producing a one-gallon, longstem treepot is it takes less time to grow than tallpot stock. Other advantages include an inexpensive container, ease of transplanting seedlings into the container, ease of watering and moving plants, and the simplicity of supporting and insulating treepots in the nursery. These efficiencies result in reducing the production cost of longstem treepots by at least 50% relative to tallpot stock.

Other species of the cottonwood floodplain forests that are amenable to longstem deep plantings include golden currant (*Ribes aureum*), screwbean mesquite (*Prosopis pubescens*) and skunkbush sumac (*Rhus trilobata*). We have recently tried this technique with tree species including netleaf hackberry (*Celtis reticulata*) and boxelder (*Acer negundo*), but it is too soon to evaluate success. Some understory riparian species are not amenable to this technique because of the difficulty in growing stock with long stems in containers; wolfberry (*Lycium torreyi*) is a prime example.

After the initial longstem deep burial trials were installed, we became aware of some restoration research from Australia that has taken a similar approach, and which they call "longstem tubestock." Their work acknowledges the longstem approach runs counter to conventional horticultural recommendations regarding deep burial and establishment of plants with long stems in small containers. Their approach uses smaller container sizes, 2"x5" forestry tubes, and attempts to produce stock with stem heights of 3 to 4 feet. Much of their deep planting has been in riparian environments, but they also have used this stock type for arid region plantings in areas with high salinity in surface soils as well as sand dune restoration.

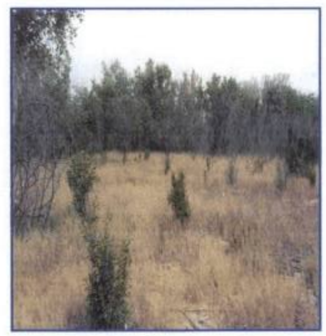
The deep planting of longstem stock can preclude or drastically reduce the need to apply irrigation water to establish riparian shrubs and trees. The cost savings of minimal or no watering and high percentages of transplant success will in most situations, far outweigh the added expense of the planting stock and deep planting. If you are revegetating a riparian site that lacks overbank flooding and has a deep water table, contact the LLPMC to see if deep planting of longstem riparian species might work for your restoration project.

For additional information contact the Los Lunas Plant Materials Center at (505) 865-4684.

GUIDELINES FOR DEEP PLANTING LONGSTEM STOCK

- If possible, insert the auger to the depth of the water table to disrupt any compacted zones that might restrict rapid root extension into the capillary fringe. Add enough backfill to the hole so the bottom portion of the root ball is in contact with the capillary fringe.
- Set the root ball to the desired depth and place a watering tube in the planting hole to allow deep irrigation if the water table declines or if a severe drought occurs.
- Backfill carefully around the root ball and stem to the ground surface. If sufficient water is available, thoroughly water the backfilled material immediately after planting. This is beneficial to collapse voids in the backfill and enhance soil-to-rootball contact.

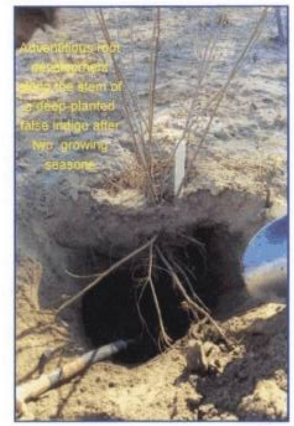
Inserting watering tubes into the planting hole next to the longstem plant



False willow established using deep-planted stock

Deep Planting

The Ground Water Connection



Guidelines for Planting Longstem Transplants for Riparian Restoration in the Southwest

NRCS Natural Resources Conservation Service

Plant Materials Program

The USDA is an equal opportunity provider and employer

Many Southwestern riparian sites

require revegetation following the removal of invasive woody species such as saltcedar and Russian olive. To establish riparian vegetation with minimal or no follow-up irrigation, to improve survival and growth rates, and to reduce long-term revegetation costs, the Los Lunas Plant Materials Center (LLPMC) has focused its efforts on developing new, deep planting techniques for use in riparian restoration in the Southwest.

Some of these disturbed sites have relatively deep water tables because flood control structures and flow regulation have altered the surface and ground water hydrology. On many of these sites, the natural regeneration of cottonwood floodplain forests can no longer occur due to the lack of overbank flooding events.

The establishment of obligate riparian woody plants (that is phreatophytic overstory trees and understory shrubs) requires either lengthy irrigation until the transplant's root system can extend into the permanent soil moisture above the water table (capillary fringe), or planting techniques that allow immediate or rapid root extension into this water source by utilizing deep planting methods.

The LLPMC began investigating deep planting methods over two decades ago with studies to improve planting methods for cottonwood and willow dormant pole cuttings. The influence of ground water depth relative to pole placement, salinity, and stock attributes were evaluated regarding establishment success.

The establishment of other important woody riparian species (particularly understory shrubs) has not been generally successful using pole cuttings. As a result, the LLPMC began producing riparian understory transplants in 30-inch deep pots (known as tallpots) about 10 years ago as a means to allow rapid root extension into the capillary fringe and minimize irrigation requirements.

Success rates of 90% or more were achieved in many situations where the lower portion of the root ball was placed in contact with the capillary fringe. If the top of the capillary fringe was just below the rootball, a few irrigations using embedded watering tubes placed in the planting hole provided deep soil moisture and allowed rapid root extension into the capillary fringe. If extreme conditions such as drought and/or moderately deep water tables were encountered, a maximum of three irrigations per year were applied for the first two years using the watering tubes.

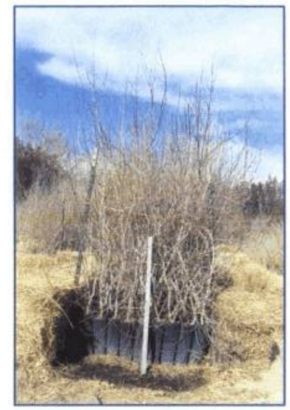
In the last several years, the LLPMC has attempted to revegetate riparian sites that have fairly deep water tables where the bottom of a 30-inch root ball is still quite distant from the capillary fringe. Some initial trials with deep burial of tallpot stock in holes up to 6 feet deep showed positive results using transplants with stem heights of up to 6 feet and with total plant heights of 8½ feet. This approach violates several basic horticultural tenets which consider the deep burial of the root crown and the use of transplants with large shoot-to-root ratios as deleterious practices.

Samples of the first species planted using this technique [New Mexico olive (*Forestiera pubescens*), false indigo (*Amorpha fruticosa*), and false willow (*Baccharis salicina*)] were excavated after one or two growing seasons to ascertain the development of adventitious roots above the root ball. Impressive shoot growth and root observations indicate that the extension of roots into the capillary fringe had occurred as well as the development of adventitious roots in shallow soil horizons.

The success of these deep planting techniques seems reasonable considering that riparian species should be adapted to burial by sediments deposited by flood events, which is a common occurrence in properly functioning riparian systems.

As soon as it became apparent that deep planting of longstem planting stock might hold promise for improved establishment on sites with deeper water tables, the LLPMC tested the same procedure with one-gallon treepot (4"x4"x14") longstem stock. The expense and inconvenience of producing 30-inch tallpots makes treepots an attractive alternative stock type. Longstem treepots of the

Golden currant grown in 30-inch deep tallpots



New Mexico olive longstem stock in one-gallon treepots