GALISTEO BASIN HYDROLOGY REPORT
EXECUTIVE ORDER 2008-004 ASSESSMENT
OFFICE OF THE STATE ENGINEER

June 2008

I. Hydrology of the Galisteo Basin

a. Setting

The Galisteo Basin watershed lies in the central portion of Santa Fe County about 18 miles south of Santa Fe, NM (Figure 1). The watershed covers an area of approximately 730 square miles and is a sub-basin within the Rio Grande Basin. It is also a part of the Rio Grande Underground Water Basin as administered by the Office of the State Engineer (OSE). Galisteo Creek is the primary surface water feature within the basin; it flows from the southern end of the Sangre de Cristo Mountains to the Rio Grande near Santo Domingo Pueblo. The elevation of the watershed ranges from 10,500 to 5,200 feet.

Domestic, stock, and shared household wells are the most common type of water wells within the basin. Centralized water supply systems serve the communities of Madrid, Cerrillos, Galisteo, El Dorado, and Lamy, in addition to several subdivisions. Many of these community systems, in addition to domestic wells, have experienced water supply shortages in the past.

The highest water well densities are located in the central portion of the watershed between the communities of Cerrillos and Lamy, and along the I-25 corridor west of Lamy (Figure 2). Besides the wells located along the I-25 corridor, few wells have been completed in the upper watershed. Similarly, few water wells are on record for the lower watershed below Galisteo Dam. Most of these lands are owned by Santo Domingo Pueblo.

Along with having some of the highest water well densities in the basin, the central portion of the watershed has also been the primary area of oil and gas interests to date. The hydrogeology of this area is complex and conditions can vary significantly within a short distance. Dry holes have been drilled in close proximity to producing wells and the

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water quality is highly variable. Pockets of information are available for subdivided sites but these studies are generally of small scale and scattered. These investigations evaluate the water bearing zones near the land surface but fail to provide information on the formations between the shallow aquifers and deeper potential oil producing zones. A number of deep oil wells have been drilled in the central portion of the watershed but data collection efforts have been focused on the oil production potential of the deeper formations.

b. Hydrogeology

The area can be subdivided into three different geologic zones, which include the lower, central, and upper watersheds. The lower watershed extends from the Rio Grande eastward up the Galisteo Creek valley to near the gypsum mine located just east of Interstate 25. At this location, the north – south trending La Bajada Fault system marks the eastern edge of the lower watershed. The Santa Fe Group is the primary geologic formation west of the fault and is composed of a thick sequence of sands, gravels, clays and silts. The formation is the primary source of ground water along the Rio Grande corridor.

The central portion of the watershed extends from the La Bajada Fault eastward to near the community of Canoncito on I-25. The communities of Cerrillos, Galisteo, and Lamy lie within this area. The Tijeras – Canoncito fault zone trends generally southwest to northeast from the Ortiz Mountains toward the community of Lamy and has allowed volcanic rocks to intrude into the sedimentary formations deposited in the basin. The Ortiz Mountains and Cerrillos Hills are the prominent volcanic bodies in the area but numerous local features are also present.

The intrusion of the igneous rocks has altered the sedimentary formations by tilting, faulting, and fracturing these rocks to various degrees. The geology within the central watershed is complex and includes a wide variety of rock types including alluvium, sandstone, shale, siltstone, conglomerate, and limestone of various geologic ages (Figure 3).

Precambrian rocks are exposed within the portion of upper watershed draining the Sangre de Cristo Mountains. Ground water is primarily obtained from saturated fractures or from shallow alluvial zones resting upon the Precambrian rocks. Little information is available for the Glorieta Mesa portion of the upper watershed. Triassic rocks outcrop over a large portion of this area.

Available information suggests that the potential oil and gas production geologic targets within the central watershed include the Mancos Shale, Dakota Formation, Morrison Formation, and Entrada Formation. These units, in addition to the younger overlying units, are discussed below. The descriptions begin with the youngest formation and end with the oldest and deepest (Entrada Formation). Some of the formations, especially those of younger age, may not be present at a given site, as they have been removed by erosion.

Valley Alluvium

The valley alluvium is composed of unconsolidated sands, gravels, clays, and silts derived from erosion of the highlands. The valley sediments are generally confined to areas adjacent to Galisteo Creek and the arroyos. Previous investigators have reported that the sediments may be up to 100 feet thick along Galisteo Creek.

The alluvium generally yields water easily to wells along the Galisteo Creek and other arroyos if the sediments are thick and saturated. Well yields up to 110 gallons per minute (gpm) have been reported (Hagerman 1973). Ground water supplies in the fill material are influenced directly by the magnitude of surface water flows and the thickness, areal extent, porosity and permeability of the sediments. Shallow alluvial wells in the area may be prone to failure under drought conditions.

The valley alluvium is an important aquifer near Cerrillos, Galisteo and Lamy, and is particularly vulnerable to contamination from surface activity due to the shallow depths to water and relatively high permeability. Alluvial wells with a total dissolved solids

(TDS) concentration of less than 2,000 mg/l have been reported along Galisteo Creek (Mourant, 1980).

Espinaso Formation

The Espinaso Formation is a light to dark grey or reddish volcanic formation composed primarily of conglomerate or andesite. The formation outcrops along the northern flanks of the Ortiz Mountains and in scattered areas north of Galisteo Creek. The thickness varies and may range up to 2,000 feet or more in the basin.

The Espinaso generally yields water from weathered zones and fractures beneath the top of the aquifer. Water availability within the formation is highly variable and dry wells are possible. Production is primarily from fractures. The TDS of water from the Espinaso has been reported to be less than 1,000 mg/l at several sites within the basin (Mourant, 1980).

Galisteo Formation

The Galisteo Formation is composed of sandstone, mudstone, and conglomerate. The coloration varies from grey, white, yellow, and pink to red. Nearly vertical sandstone beds within the formation form the Garden of the Gods along Highway 14 north of Cerrillos. The outcrop extends from Lamy to Cerrillos on both sides of Galisteo Creek.

The formation has been divided into the upper, middle, and lower units (Maynard and others, 2002) and may be more than 5,000 feet thick (Johnson, 1975). The lower unit is more consolidated compared to the upper zones.

Numerous wells produce from the Galisteo Formation but most of these are low yielding. Well yields are influenced by the degree of fracturing and dry holes may occur in the proximity to producing wells. The TDS content of water from the Galisteo Formation has been reported at one site to be less than 500 mg/l (Finch and Petronis, 2006). However, samples containing water up to 1,500 mg/l TDS are common and higher concentrations have been observed (Mourant, 1980).

Mesa Verde Group

The Mesa Verde Group is composed of alternating beds of yellowish sandstone and shale with numerous seams of coal. Wells producing from the Mesa Verde have been reported in the Madrid area. The Point Lookout Sandstone is the lowest unit in the Mesa Verde Group and is noted as one of the principle aquifers near Placitas (Read and others, 2005). When fractured, the formation may yield an adequate quantity of water for domestic and stock use (Glorieta Geoscience, 1998). Samples collected from area Mesa Verde wells have a measured TDS of less than 3,000 mg/l (Mourant, 1980).

Mancos Shale

The Mancos Shale consists of massive dark grey to black shale beds, and thin sandstone and limestone beds. The outcrop extends from south of Lamy southwestward past the village of Galisteo. A number of water wells in the basin produce from the formation and typically obtain water from fractured sandstone or shale. The Mancos is often considered a poor source of water and dry holes have been encountered. Water of less than 3,000 mg/l TDS was collected at a well just west of Galisteo (Mourant, 1980). Concentrations greater than this level are more common.

Dakota Formation

The Dakota Formation is composed of tan to yellow brown sandstone with dark shale and siltstone. It is exposed near Lamy and southeast of Galisteo. The unit is 90 to 150 feet thick (Bachman, 1975). The Dakota is listed as one of the principle aquifers south of the study area near Placitas (Johnson, 2002). No water supply wells are known to produce from the formation in the Galisteo Basin, likely due to the excessive depth of the formation in most parts of the basin.

Morrison Formation

The Morrison Formation is composed of dark red to yellowish sandstone and grey to greenish clay stone and shale (Bachman, 1975). The formation is exposed west of Waldo and in the Lamy area. (West, 1968) indicates that Kerr-McGee reported two holes that encountered the Morrison Formation in the vicinity of Galisteo. One of the holes flowed

initially between 200 to 300 gpm but decreased to less than 100 gpm after a few days. The formation is listed as one of the principle aquifers south of the study area near Placitas (Johnson, 2002). Water of less than 1,500 mg/l TDS was collected at a well just west of Galisteo (Mourant, 1980).

Entrada Formation

The Entrada Formation is composed of grey to yellowish sandstone and is exposed west of Waldo and in the Lamy area. The Entrada is listed as one of the principle aquifers south of the study area near Placitas (Johnson, 2002). No water supply wells are known to produce from the formation within the study area. The water quality is unknown based on the information available for this study.

c. Surface Water Hydrology

Galisteo Creek is ephemeral and occasionally conducts high peaks of flood flow of relatively small volume. About 70 percent of the annual runoff occurs during the summer months, while less than 10 percent of the annual flow occurs during spring runoff (USCOE, 2006). The mean annual flow below Galisteo Dam is 6.13 cubic feet per second but no discharge is observed at this gauging site most of the year.

Surface water irrigation has not been reported in water use reports published recently by the OSE. Galisteo Dam was completed in 1970 and was not intended to serve as a source of water supply. The dam was built for flood and sediment control purposes.

Locally, Galisteo Creek gains inflow as ground water levels rise to the land surface in the alluvial sediments. Ground water levels are directly related to precipitation. The TDS of Galisteo Creek water is similar to the quality of the valley alluvial aquifer.

A number of springs are present in the central portion of the watershed and produce water of less than 600 mg/l TDS (White and Kues, 1992). Area springs are typically derived from the saturated alluvium where it pinches out upon underlying low permeable rocks.

Available studies suggest that runoff represents a very small percentage of the precipitation that falls on the watershed. A water supply study conducted by Fleming and others (1991) provides water budget estimates for the San Marcos watershed, which enters the Galisteo Creek valley at Cerrillos. The following values were based on the Fleming study and were provided in Abeita (1997):

Assumed precipitation	14.2 inches per year
Runoff	1.2 percent of precipitation
Groundwater Recharge	3 percent of precipitation
Evapotranspiration	95.8 percent of precipitation.

d. Groundwater Flow

Available water level data indicate that ground water moves from the highlands toward Galisteo Creek. Flows then proceed down gradient toward the Rio Grande. Ground water contours from Mourant (1980) for the watershed area are provided in Figure 4.

The majority of the wells in the basin are less than 500 feet deep, so the direction of groundwater flow within the deeper formations is uncertain. It should not be concluded that there is one continuous flow system between the various geologic formations. Wells may not encounter ground water at the elevations shown on Figure 4. The complexity of the geology makes it very difficult to predict well success. Fracturing controls water availability for the vast majority of wells within the study area. The degree of hydrologic connection both horizontally and vertically is very difficult to ascertain due to the complexity of the system and the lack of sufficient data.

II. Fresh Groundwater Resources

NMSA 1978, § 70-2-12 (B)(15) requires the Oil Conservation Commission to regulate the disposition of water produced or used in connection with the drilling for or producing of oil or gas or both, "in a manner that will provide reasonable protection against contamination of fresh water supplies designated by the state engineer". With respect to this statute, the state engineer has designated as fresh water supplies all underground water in the State of New Mexico containing 10,000 mg/l or less of dissolved solids and

all of the surface waters of all streams regardless of the quality of water, except the designation shall not include water for which there is no present or reasonably foreseeable beneficial use that would be impaired by contamination. (Ltr. Reynolds 1985)

Due to the geologic complexity of the area, the formations within the basin contain ground water with a wide water quality range. All of the formations from the valley fill down to the Entrada Formation may potentially contain water with less than 10,000 mg/l TDS. The water quality for each saturated zone will vary from site to site and cannot be determined until drilling samples have been collected and analyzed. Therefore, in the absence of site-specific data, all groundwater in the basin will be considered to fall within the State Engineer's designation of fresh water.

In order to ensure that no oil and gas drilling activity occurs in the Galisteo Basin that would be contrary to the interests of the State of New Mexico and its citizens, it is recommended that any oil and gas drilling operators drilling in the Galisteo Basin be required to show that doing so will not contaminate fresh water supplies. The State Engineer presumes that fresh water supplies will be encountered in oil and gas drilling in the Galisteo Basin and due to the complex hydrogeology a site specific analysis is required in order to ensure the protection of the fresh water supplies.

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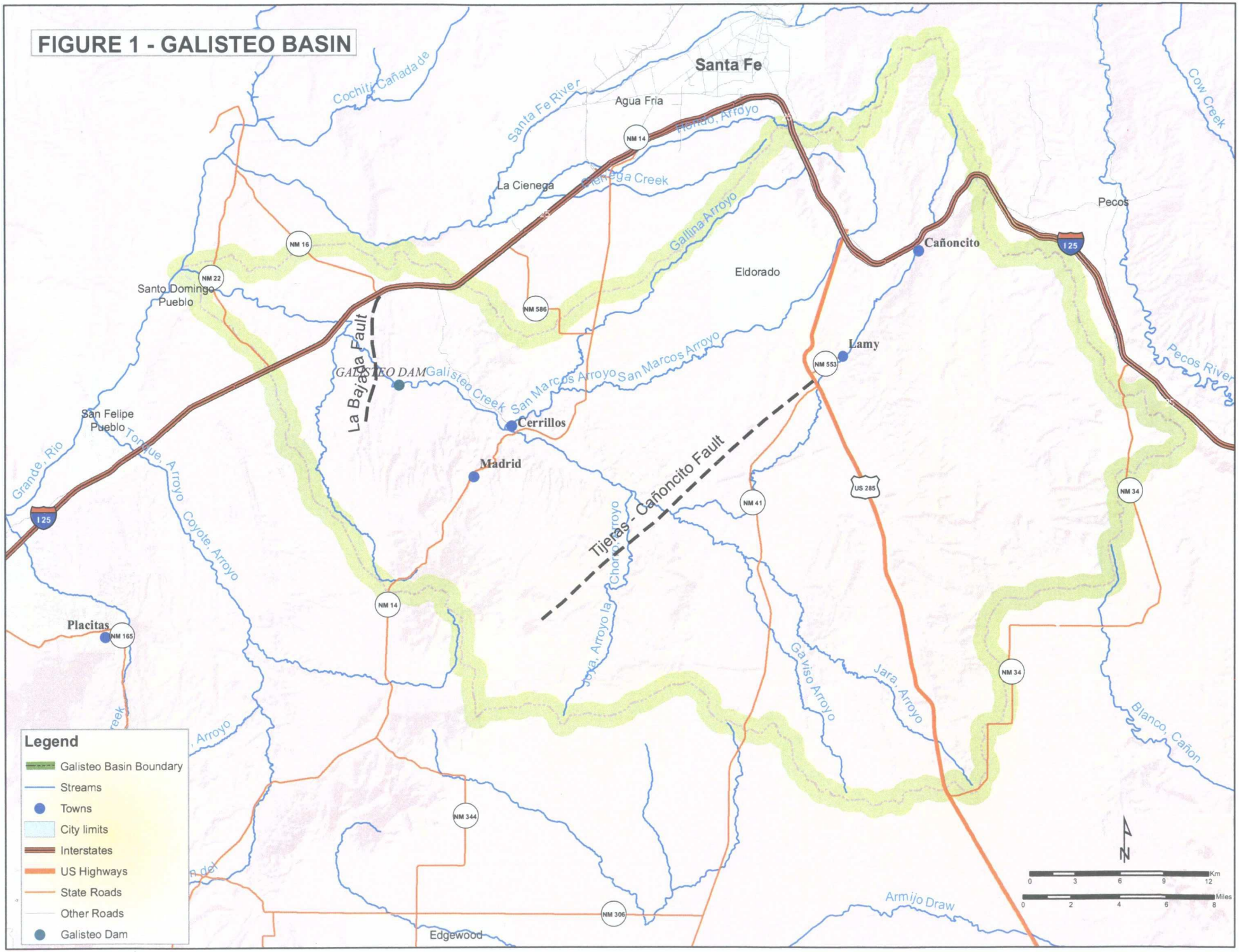
FIGURE 1 - GALISTEO BASIN
Santa Fe
Agua Fria
Cochiti Cañada de
Santa Fe River
Arroyo Hondo
La Cienega
Cienega Creek
Gallina Arroyo
Cow Creek
Pecos
Cañoncito
Eldorado
Santo Domingo Pueblo
La Bajada Fault
GALISTEO DAM
Galisteo Creek
San Marcos Arroyo
San Marcos Arroyo
Lamy
Pecos River
San Felipe Pueblo
Cerrillos
Madrid
Tijeras - Cañoncito Fault
Grande, Rio
Tonque, Arroyo
Coyote, Arroyo
Placitas
Joya, Arroyo la
Chorro, Arroyo
Gaviso Arroyo
Jara, Arroyo
Blanco, Cañon
Armijo Draw
Edgewood
NM 14
NM 16
NM 22
NM 586
NM 553
NM 41
NM 34
NM 165
NM 344
NM 306
US 285
I 25
Legend
Galisteo Basin Boundary
Streams
Towns
City limits
Interstates
US Highways
State Roads
Other Roads
Galisteo Dam
N
Km
0 3 6 9 12
Miles
0 2 4 6 8

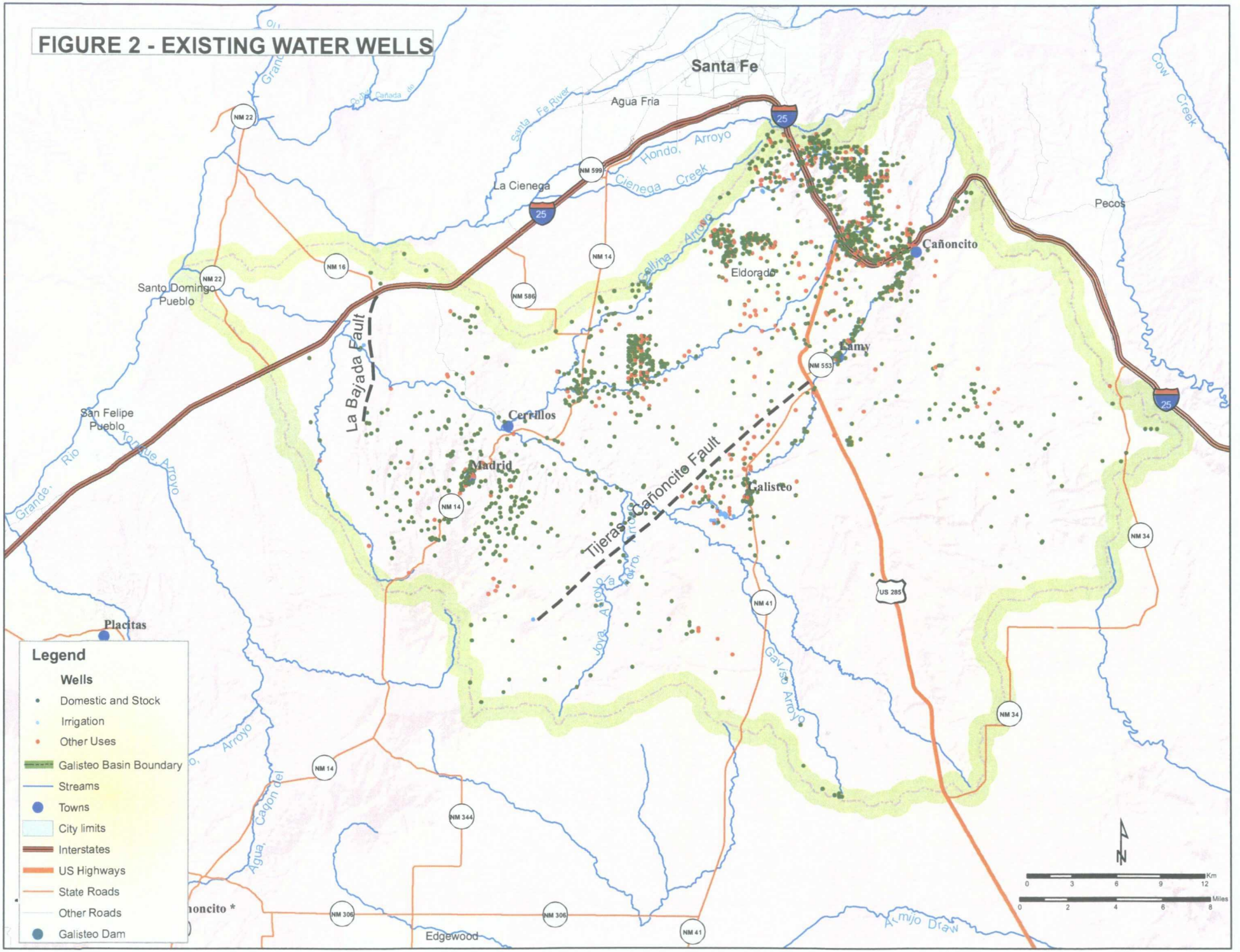
FIGURE 2 - EXISTING WATER WELLS
Santa Fe
Agua Fria
Santa Fe River
Hondo, Arroyo
Cienega Creek
La Cienega
Cow Creek
Pecos
Cañoncito
Eldorado
Galisteo Basin Boundary
Santo Domingo Pueblo
La Bajada Fault
Cerrillos
Madrid
Galisteo
Tijeras-Cañoncito Fault
Lamy
San Felipe Pueblo
Rio Grande
Placitas
Edgewood
Arroyo
Gavilan Arroyo
Almijo Draw
NM 22
NM 16
NM 14
NM 586
NM 599
NM 553
NM 41
NM 344
NM 306
NM 34
US 285
25
Legend
Wells
Domestic and Stock
Irrigation
Other Uses
Galisteo Basin Boundary
Streams
Towns
City limits
Interstates
US Highways
State Roads
Other Roads
Galisteo Dam
N
Km
0 3 6 9 12
Miles
0 2 4 6 8

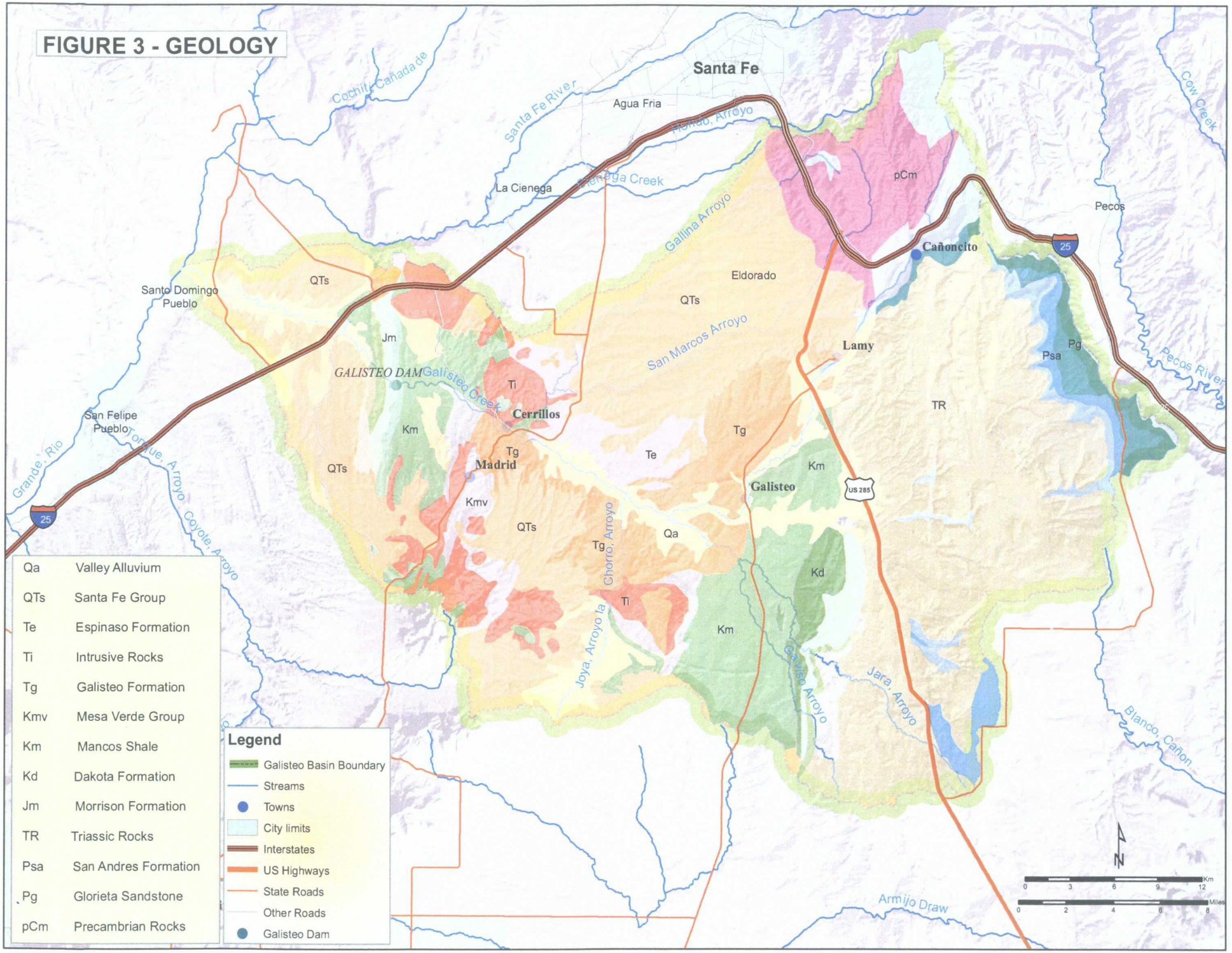
FIGURE 3 - GEOLOGY
Santa Fe
Agua Fria
Cochiti Cañada de
Santa Fe River
Arroyo Hondo
La Cienega
Cienega Creek
Gallina Arroyo
Cow Creek
Pecos
Cañoncito
Eldorado
pCm
QTs
Santo Domingo Pueblo
Jm
GALISTEO DAM
Galisteo Creek
Ti
Cerrillos
San Marcos Arroyo
Lamy
Pg
Psa
Pecos River
TR
San Felipe Pueblo
Km
Tg
Madrid
Te
Galisteo
US 285
Tonque Arroyo
Grande, Rio
Coyote Arroyo
Kmv
Qa
Chorro, Arroyo
Joya, Arroyo la
Kd
Galisteo Arroyo
Jara, Arroyo
Blanco, Cañon
Armijo Draw
25
Qa Valley Alluvium
QTs Santa Fe Group
Te Espinaso Formation
Ti Intrusive Rocks
Tg Galisteo Formation
Kmv Mesa Verde Group
Km Mancos Shale
Kd Dakota Formation
Jm Morrison Formation
TR Triassic Rocks
Psa San Andres Formation
Pg Glorieta Sandstone
pCm Precambrian Rocks
Legend
Galisteo Basin Boundary
Streams
Towns
City limits
Interstates
US Highways
State Roads
Other Roads
Galisteo Dam
N
0 3 6 9 12 Km
0 2 4 6 8 Miles

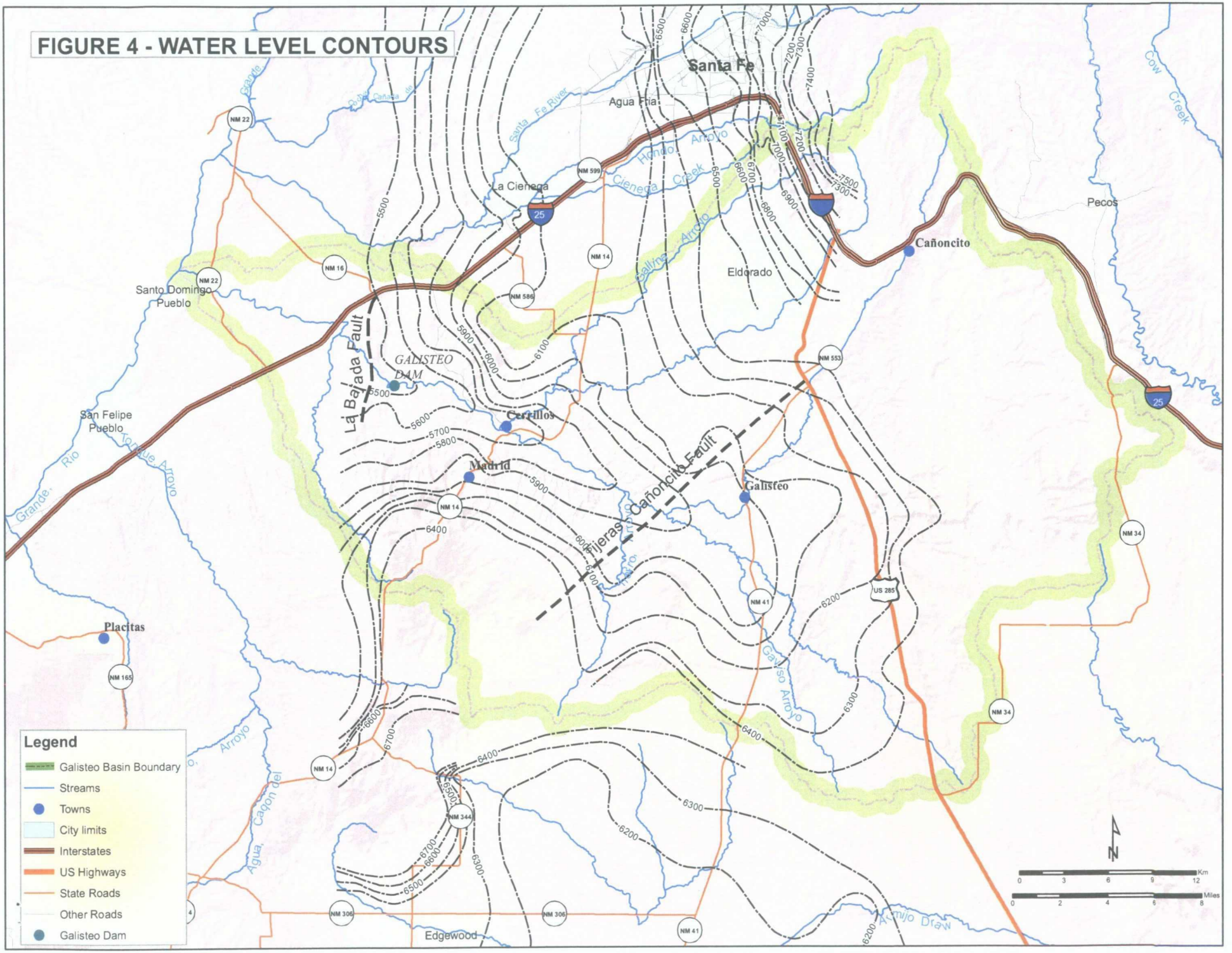
FIGURE 4 - WATER LEVEL CONTOURS
Santa Fe
Agua Fria
La Cienega
Pecos
Cañoncito
Eldorado
Santo Domingo Pueblo
San Felipe Pueblo
Cerrillos
Madrid
Galisteo
Placitas
Edgewood
GALISTEO DAM
La Bajada Fault
Tijeras-Cañoncito Fault
Santa Fe River
Cienega Creek
Hondo Arroyo
Galisteo Arroyo
Tonque Arroyo
Arroyo Draw
Cow Creek
Rio Grande
NM 22
NM 16
NM 599
NM 14
NM 586
NM 553
NM 34
NM 41
NM 165
NM 344
NM 306
US 285
25
Legend
Galisteo Basin Boundary
Streams
Towns
City limits
Interstates
US Highways
State Roads
Other Roads
Galisteo Dam
Km
Miles