

CHAPTER 1 - INTRODUCTION

Preface

Purpose

At the request of the U.S. Environmental Protection Agency (USEPA), the Texas Water Development Board (TWDB) and the New Mexico Water Resources Research Institute (NMWRRI) undertook this study to characterize binational aquifers in parts of far west Texas, south central New Mexico, and northeastern Chihuahua, Mexico. The study area lies along a corridor centered at the City of El Paso/Ciudad Juarez metroplex and extending 62 mi (100 km) on either side of the international border. The study uses well-established hydrogeological, hydrochemical and numerical modeling techniques to trace ground-water flow-paths, to assess regional water quality, and to define aquifer recharge and discharge areas and areas susceptible to contamination.

Many of the surface and ground-water resources along the transboundary corridor are shared between the two nations, yet little binational study of these resources has been undertaken. A number of environmental and hydrologic problems have been identified that will require the cooperation of both nations to solve. Solutions to water-related problems can be derived only when a better understanding of transboundary water resources is attained. This study is an important step toward attaining a better understanding of these binational resources.

To complete this study, data from several sources had to be combined into one data base. GIS coverages of ground water, surface water, and land use attributes were developed from the new data base. This report provides results of the study. Appendix C provides documentation of GIS coverages.

Participating agencies

Key participants in the project included the TWDB and the NMWRRI. TWDB team-members included

Barry Hibbs, principal hydrogeologist and co-project manager; John Ashworth, geologist and co-project manager; Radu Boghici, assistant hydrogeologist; Mark Hayes, Erika Boghici, and Darrell Peckham, GIS analysts; Steve Moore and Frank Bilberry, engineering technicians; and Jay Galvan, Steve Gifford and Mike McCathern, layout and cartography. NMWRRI team-members included Bobby Creel, project manager; Adrian Hanson, environmental engineer; Zohrab Samani, hydrogeologist; John Kennedy, GIS analyst/geologist; and Pamela Hann and Kenny Stevens, research assistants. Several technical and support staff from the Texas Water Development Board, New Mexico Water Resources Research Institute, and New Mexico State University made ancillary contributions.

Assessments of the Mesilla Bolson aquifer, Jornada del Muerto Bolson aquifer, and Rio Grande aquifer (Leasburg Dam to the El Paso narrows) were performed by the New Mexico team. Assessments of the Hueco-Tularosa aquifer, southeastern Hueco aquifer, Diablo Plateau aquifer, and Rio Grande aquifer (El Paso narrows to Indian Hot Springs) were performed by the Texas team. Collation of regional GIS coverages from the Texas and New Mexico teams and report assembly and publication were performed by the Texas Water Development Board.

The Comision Nacional Del Agua (CNA), Mexico, and Junta Municipal de Agua y Saneamiento (JMAS) de Ciudad Juarez, provided hydrologic data and technical assistance. Logistics of international data transfers were facilitated by the U.S. and Mexican sections of the International Boundary and Water Commission (respectively, IBWC and Comision Internacional de Limites y Aguas, [CILA]).

Acknowledgments and disclaimer

Research supported by the U.S. Environmental Protection Agency under USEPA contract numbers X 996343-01-0 and X 996350-01-0. The views and conclusions in this report are those of the TWDB and

NMWRRI and should not be interpreted as necessarily representing the official opinions of the USEPA, IBWC, CILA, CNA, or JMAS.

Adjunct research institutions and public agencies are credited for providing technical and administrative assistance for this study. These include the University of Texas Bureau of Economic Geology (BEG); the Center for Environmental Research Management (CERM) at the University of Texas at El Paso (UTEP); the IBWC and CILA; the U.S. Geological Survey (USGS), New Mexico State District Office, Albuquerque; the Public Services Board (PSB), City of El Paso; the JMAS, Ciudad Juarez; the Texas Natural Resource Conservation Commission (TNRCC); the Texas Natural Resources Information System (TNRIS); and the New Mexico Environment Department (NMED). Several individuals are acknowledged for providing technical and administrative assistance and data. They include Chris King of the USEPA; Bruce Darling of LBG Guyton Associates; Jim Mayer of Georgia Southern University; Edward Collins and William Mullican of BEG; Nancy Lowery of CERM; Sylvia Waggoner, Cruz Ito, Rong Kuo, Carlos Pena, Jim Robinson, and Jose Valdez of IBWC; Antonio Rascon of CILA; Mike Kernodle, Brennon Orr, and Linda Beal of the USGS; Ernest Rebuck; Sayeed Joraat, and Roger Sperka of El Paso PSB; Francisco Nunez of Ciudad Juarez JMAS; and Miguel Pavon of TNRIS.

Regional Geographic Setting

Location

The area encompassed by this study lies between north latitudes 33° 24' 32" and 30° 30' 00" and west longitudes 107° 18' 18" and 104° 50' 31". The study area includes all of Doña Ana and Otero Counties, New Mexico and all of El Paso and Hudspeth Counties, Texas. Part of northeastern Chihuahua, Mexico is included in the study area (Figure 1.1). Total land surface area encompassed by the study is about 24,900 mi², of which nearly 8,800 mi² is in Mexico. Principal transboundary aquifers in the region include

the Hueco-Tularosa aquifer and the Mesilla Bolson aquifer (Figure 1.2). These aquifers are extensively developed and satisfy most of the municipal and industrial water demands in the City of Las Cruces, City of El Paso, and Ciudad Juarez. Other aquifers include the southeastern Hueco aquifer, the Diablo Plateau aquifer, the Rio Grande aquifer, and the Jornada del Muerto aquifer (Figure 1.2). Of the latter, only the Rio Grande aquifer is extensively developed and transboundary in extent.

Topography and drainage

The study area lies primarily within the southeastern segment of the physiographic Basin and Range Province. The topography is dominated by long, narrow mountain ranges, intermontane basins (flats and draws), and gently sloping plateaus (Figure 1.3). The most prominent topographic feature in the New Mexico part of the study area is the Sacramento Mountains in Otero County. The highest peak in the Sacramento Mountains is Sierra Blanca at 12,003 ft above sea level. The Organ Mountains of Doña Ana County reach a peak elevation of 9,012 ft. The Franklin Mountains of El Paso County, Texas, and the Eagle Mountains of Hudspeth County, Texas, attain respective elevations of 7,192 and 7,484 ft. The Sierra de Las Vacas, the highest topographic mountain range in the Mexican part of the study area, reach a peak elevation of 7,218 ft.

Surface drainage for the Sacramento Mountains and Otero Mesa is to the Tularosa Basin and Salt Basin, two internal drainage, closed basins (Figures 1.3 and 1.4). Surface drainage for the U.S. parts of the Mesilla and Hueco Basins is mostly captured by the Rio Grande, the principal surface drainage in the study area. The Mexican portion of the Hueco Basin is also drained by the Rio Grande. The Mesilla Basin (referred to as Bolson de Mesilla - Samalayuca in Mexico [de La O Carreno, 1957]) is drained partly by the Rio Grande and partly by Laguna Coyames in Mexico. The Diablo Plateau drains mostly into the Salt Basin to the east and

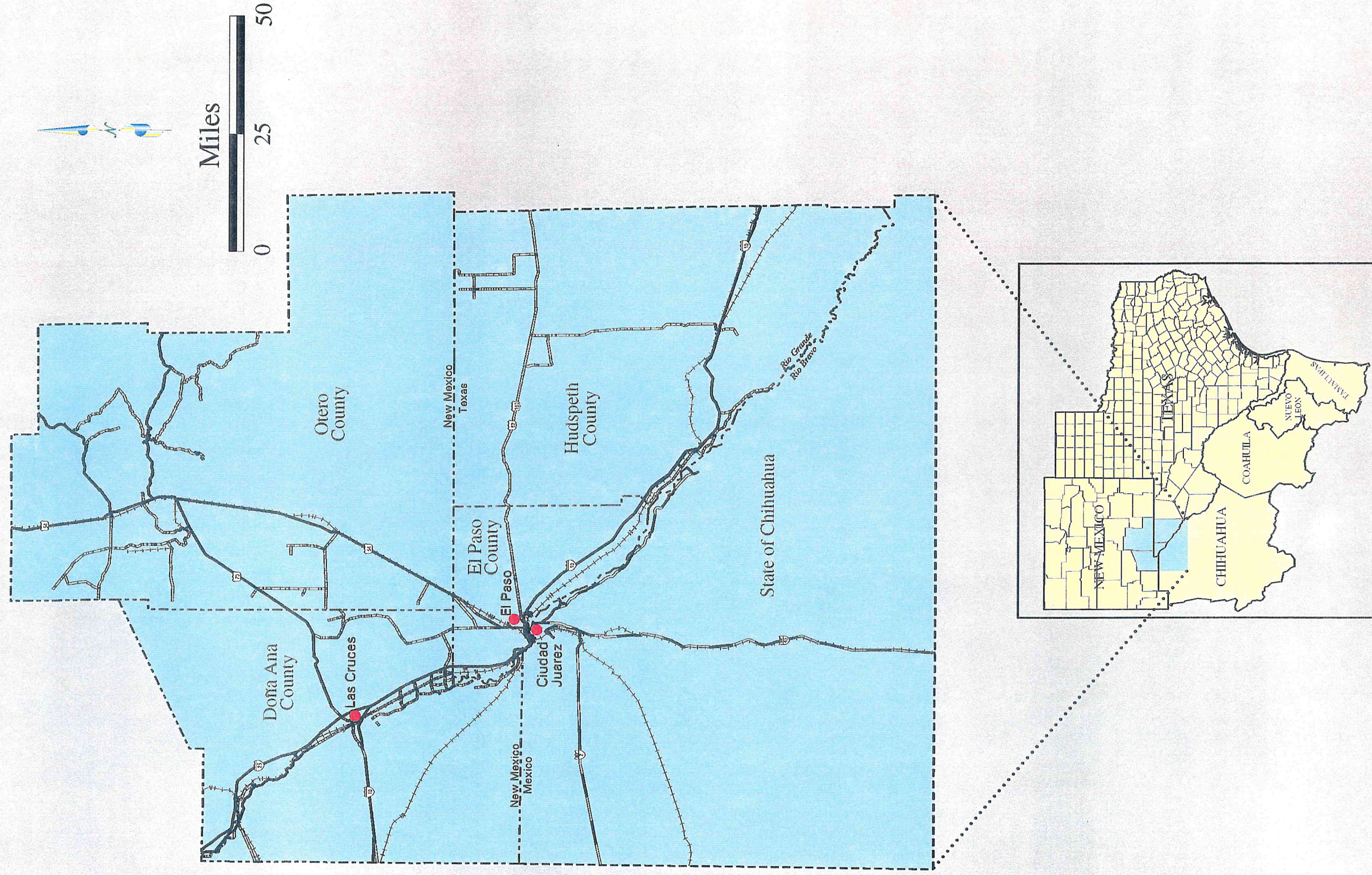
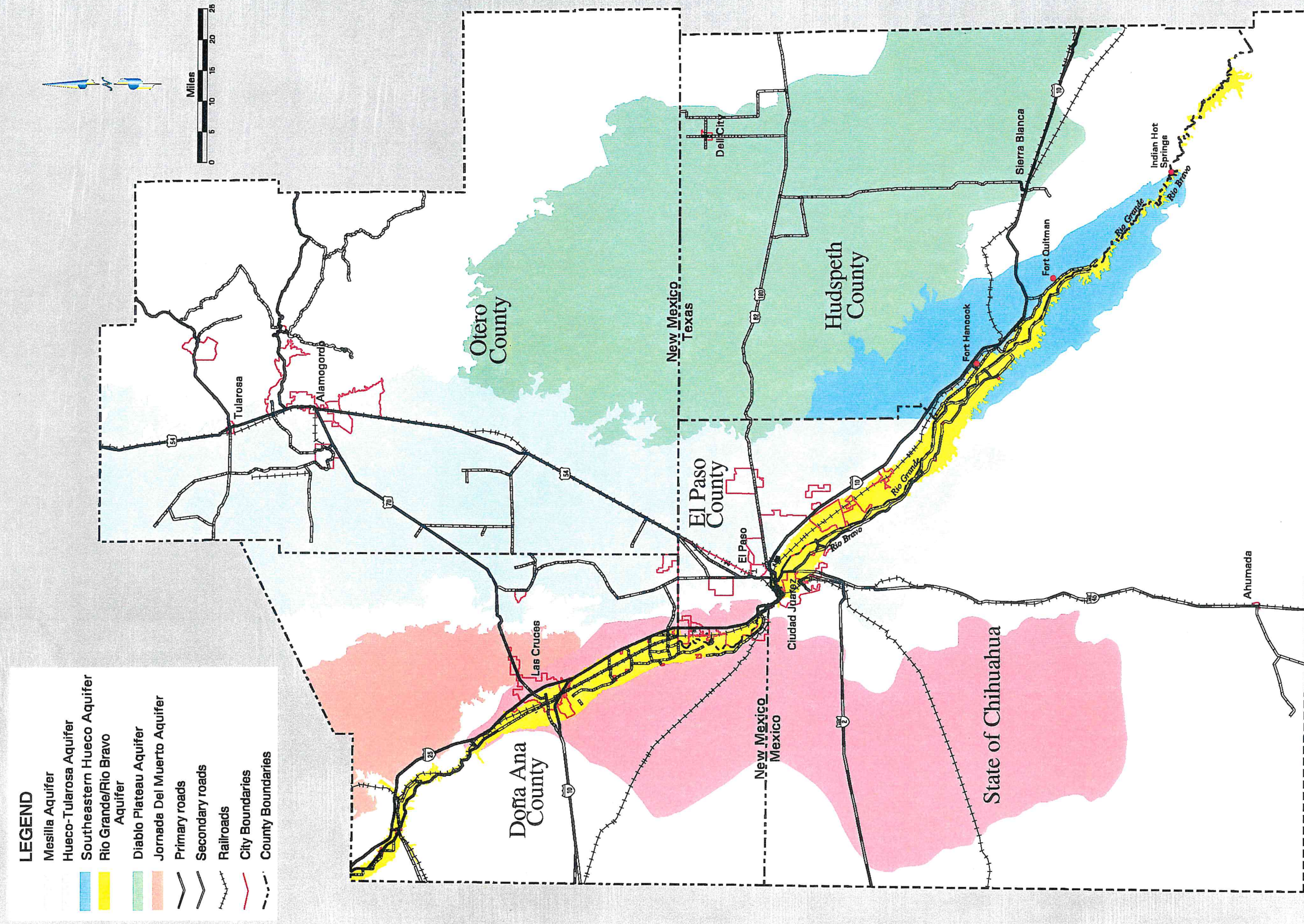


Figure 1.1. Location of study area.



1.2. Transboundary aquifers in the study area.

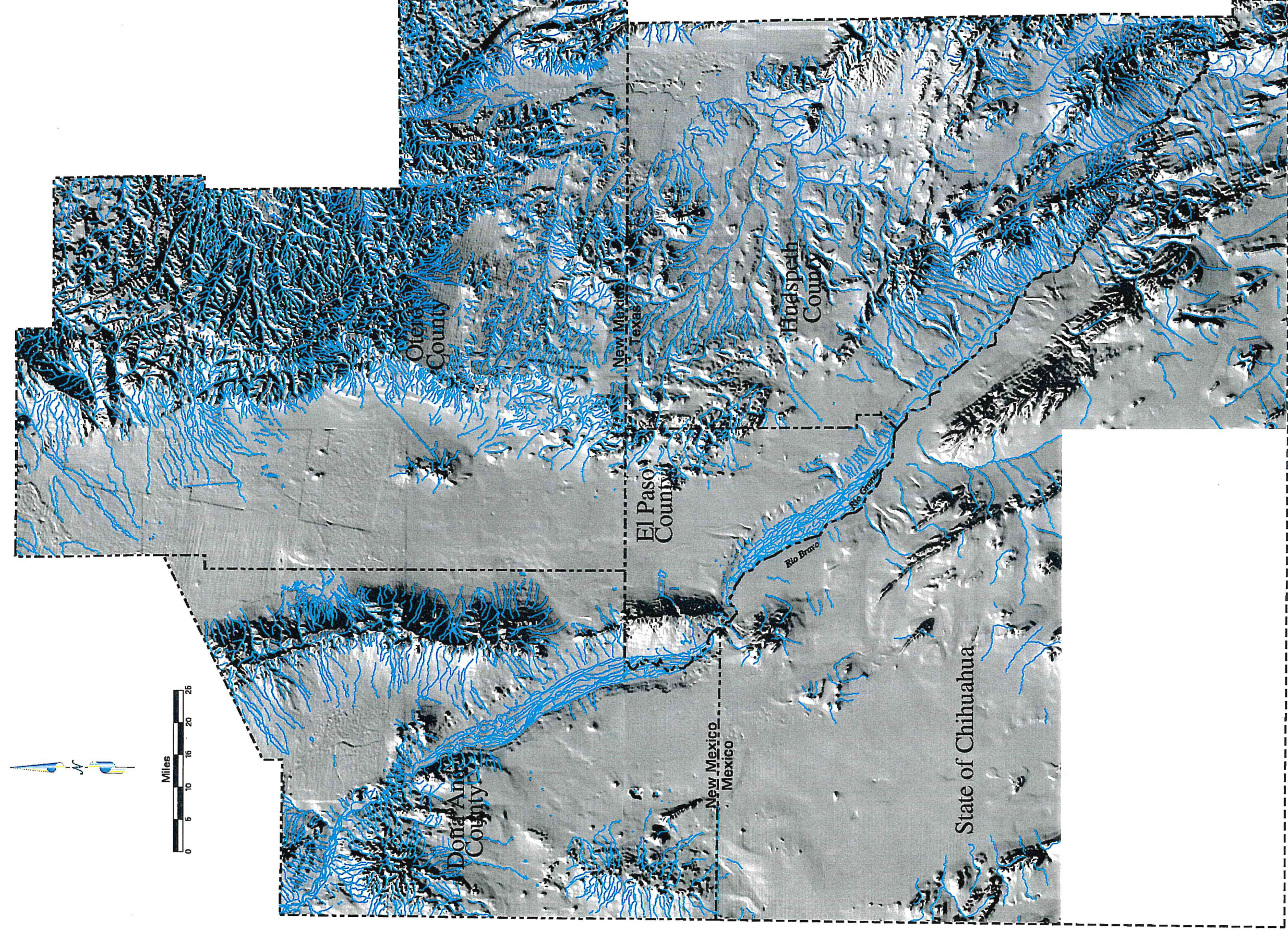


Figure 1.3. Three -dimensional depiction of surface topography and principal drainage in the transboundary study area.

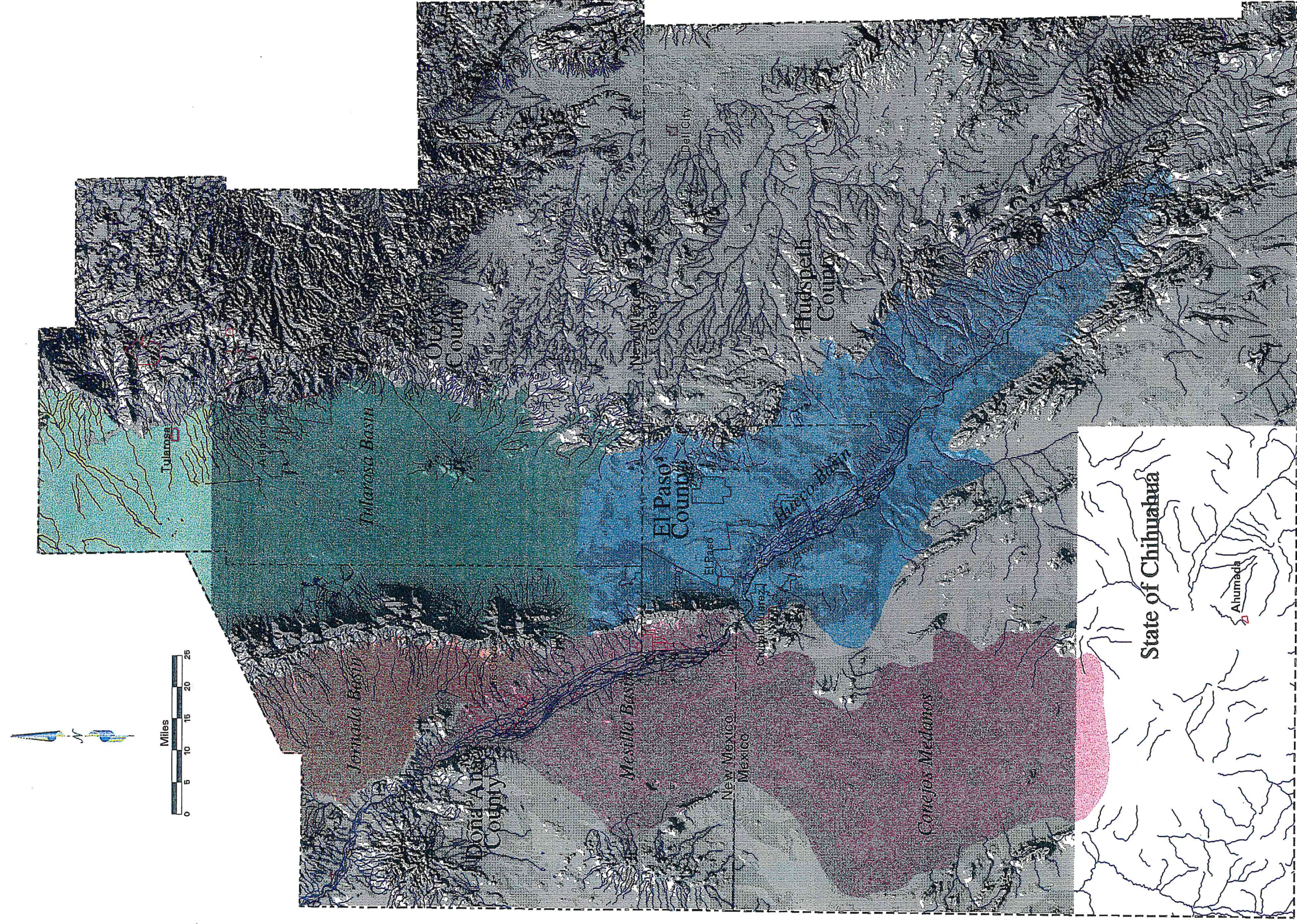


Figure 1.4. Surface drainage basins in the study area. These are defined by surface drainage characteristics and not by intrabasin and interbasin ground-water flow.

partly to the Rio Grande to the south along a drainage divide (Figure 1.3).

Climate

The study area is typical of the arid southwest, with mostly clear skies and limited rainfall and humidity. Average annual precipitation varies from as little as 6 in/yr in low lying basins to as much as 30 in/yr in the pine covered pinnacles in the Sacramento Mountains (USBR, 1984). Average annual rainfall over most of the study area is less than 12 in/yr.

Climatological data have been collected for decades at and near the major metropolitan areas. The climate at Las Cruces is arid in low-lying areas and semiarid in mountainous region. Average annual precipitation at Las Cruces, mostly in the form of rain, is 8.39 in (Frenzel and others, 1992). Nearly one-half of precipitation is from thunderstorms that occur from July through September. Large diurnal changes in temperature up to 30°F are common, especially during the summer months (Frenzel and others, 1992). Mean annual temperature is 60°F in Las Cruces.

The climate is arid to semiarid in the El Paso/Ciudad Juarez area (IBWC, 1989). Precipitation is mostly from thunderstorms that occur sporadically during the summer months. Precipitation records at several meteorological stations indicate that average annual rainfall along the El Paso/Ciudad Juarez corridor is about 10 in (IBWC, 1989). Temperatures during the summer may reach 100°F for several days. Normal night time temperatures during the summer vary from high 60°F to mid 70°F. Winter temperatures occasionally are below freezing and usually range from 40°F to 60°F (IBWC, 1989).

Toward the eastern part of the study area, near the City of Sierra Blanca, Texas, the subtropical-arid climate is characterized by high mean temperatures with large daily and annual fluctuations, and low mean precipitation with widely separated annual extremes (Larkin and Bomar, 1983). Average annual low tem-

peratures are nearly 48°F and average high temperatures are close to 80°F (Larkin and Bomar, 1983). Precipitation is mostly in the form of local and irregular summer showers (Nativ and Riggio, 1990). Winter rainfall accounts for less than one-third of total precipitation (Larkin and Bomar, 1983). Mean annual precipitation in Sierra Blanca is 12 inches.

Population and economy

The population of Doña Ana County was estimated to be 155,469 in 1994 up from the 1990 census of 135,510 (USDC, 1995 and 1991). This was an increase of 14.73%. The increase between 1980 and 1990 was 40.66%. The 1990 census indicates that there were 49,148 households in Doña Ana County with an average of 2.95 persons per household. Aside from the household figures for Las Cruces (22,509), Hatch (411), Mesilla (715), and Sunland Park (2,963), the unincorporated areas had a total of 22,550 households.

The economy of Doña Ana County is largely dependent upon government jobs. In 1988, state and local government work provided 11,100 jobs and \$167.4 million for county residents (USDC, 1990). This was the single largest category of earnings for the county, followed by private services with 10,900 jobs and \$119.2 million. Federal work provided 4300 jobs and \$105.1 million for the county in the same year. By 2020, the county earnings through private services are expected to reach \$277.0 million per year for 17,600 jobs and should represent the largest source of income for Doña Ana County (USDC, 1990). State and local government work should provide \$270.6 million through 12,700 jobs.

Doña Ana County has traditionally been an important producer of agricultural goods. In 1988 \$18.8 million was earned in Doña Ana County through its farms. This constituted one of the largest segments of income for the county (USDC, 1990).

Otero County, had a population of 54,307 in 1994. The largest municipality is Alamogordo, which had a 1994 population of 29,628. The economy of Otero County before 1940 was based primarily on crop agriculture, livestock, and some mining (USBR, 1984). The population at that time was about 10,000. Isolated and flat areas in the Tularosa Basin were selected by the military in the early 1940's as sites for explosive and missile testing and the population grew to its present number mostly to support military infrastructure. Sand, gravel, and building stone provide the only substantial mining base.

The City of El Paso is the largest city in El Paso County, Texas. Census information compiled in 1995 indicated that 583,431 people lived in the City of El Paso, or 87% of the county total (668,358). Fort Bliss (14,202) and smaller cities and rural areas accounted for the remaining county population of 84,927. Colonias populations are estimated to total 72,754 in El Paso County (TWDB, 1995).

El Paso is an important center of commerce and industry. Industries include smelting and metal refineries, gasoline refineries, meat packing and food processing facilities, and light manufacturing. Military installations in and adjacent to El Paso provide a substantial economic base. Rural areas, especially in the El Paso/Juarez Valley, host a number of agricultural industries, including irrigated agriculture, livestock, poultry, and dairy production.

Hudspeth County is the most rural county in the U.S. part of the study area. Total population in Hudspeth County was 3,422 in 1995. The largest cities in 1995 were Fort Hancock (1,993), Sierra Blanca (700), and Dell City (779). Irrigated agriculture is the principal activity in the Dell City and Fort Hancock areas. Dell City uses ground water for irrigation and Fort Hancock uses Rio Grande water mostly, and some ground water. The economy of Sierra Blanca is sustained by the ranching industry, interstate travel, and interstate sludge disposal facility. Rural areas not

adjacent to these cities are almost entirely ranching operations, except near the Rio Grande, where irrigated agriculture is common.

The population of Ciudad Juarez, northeastern Chihuahua Mexico was 850,000 in 1990 (USEPA, 1996). The population grew to 1,010,000 in 1995 (USEPA, 1996). We could not determine the number of residents in rural parts of the Mexican study area, but place the number at fewer than 50,000. Principal industries in Ciudad Juarez include industrial manufacturing, services, and tourism. Irrigated agriculture is common along the Rio Grande. Ranching operations are the principal activities in rural areas at distances from the river.

History of ground-water development

Mesilla Basin ground water has been a source of water for agriculture, municipal and industrial use since the early settlement in the area. Prior to 1950, non-agricultural withdrawals were negligible. It is estimated that non-agricultural ground-water withdrawals have increased from about 6 ft³/s in 1950 (Frenzel and others, 1992) to upwards of 60 ft³/s in the late 1980's (NMSEO, 1992). Ground water pumping for agriculture as a supplemental source of irrigation water constitutes a large volume of extraction from the Mesilla Basin. In the late 1940's, there were approximately 70 irrigation wells in both the Rincon and Mesilla Valleys combined. During the drought of 1951 - 57, several hundred wells were drilled in the Mesilla Valley. Many wells were also drilled during the shortage of surface water from 1963 to 1966. As of 1975 there were about 920 useable irrigation wells in the Mesilla Valley (Frenzel and others, 1992) most of which were drilled and completed in the floodplain alluvium.

The number of irrigated acres in the Mesilla Valley increased from about 25,000 acres near the turn of the century to about 77,000 acres during 1940 - 1975 which is about two-thirds of the area of the valley. In the Mesilla Valley after 1975, a large number of deep wells were drilled through the alluvium and completed

in the Mesilla Bolson deposits in order to obtain higher quality water than that available from shallow wells. The City of Las Cruces is currently pumping about 17,000 - 18,000 acre-ft of water per year for municipal use.

The first water supply wells in the City of El Paso/Ciudad Juarez area probably were dug by early Spanish missionaries. These shallow wells were used to augment surface water supplies, especially during droughty periods when there was little or no stream-flow in the Rio Grande (White, 1987). The first municipal water supply well for the City of El Paso was dug in 1892 (Sayre and Livingston, 1945). Subsequently other wells were installed and by 1918 the City of El Paso had about 150 wells screened in the Hueco Bolson (IBWC, 1989). Presently there are 142 city wells screened in Hueco Bolson sands and gravels. Hundreds of shallow irrigation wells have been drilled in the El Paso Valley, but many are active only during prolonged droughty spells. Estimates of the number of irrigation wells are not available because well inventories have not been conducted in sufficient detail to make accurate estimates.

Ciudad Juarez drilled its first water supply well in 1925 (IBWC, 1989). The number of wells drilled by the city peaked in the 1950's when there was a prolonged shortage of surface flows in the Rio Grande. Today, Ciudad Juarez maintains about 170 operational water wells; 100 or so of these are normally active. The drilling of an irrigation well is recorded in 1935 in Juarez Valley (de la O'Carreno, 1957), and by 1949 over 100 irrigation wells had been installed (IBWC, 1989). The number of irrigation wells in and adjacent to the Juarez Valley totaled 1,120 in 1980 (IBWC, 1989). Some of these draw water from deeper Hueco Bolson sands and gravels, although several are screened in the Rio Grande alluvium.

Regional Geologic Setting

Geologic characteristics

The southeastern Basin and Range province is defined by topographically high mountain ranges and plateaus separated by normal faults from adjacent basins. Geologic units in the study area range from Precambrian to recent (Figure 1.5). The ages of strata in outcrop are primarily Precambrian, Cretaceous, and Tertiary in mountainous areas, Cretaceous and Permian in plateaus, and Tertiary and Quaternary in bolson areas.

Major geologic features in the area formed in response to the Rio Grande rift, a fault bounded structural feature with uplifted blocks on the east/southeast and west/southwest. Uplifted blocks sometimes rise a few thousand feet above valley floors due to vertical displacement along normal faults. Many of the complex grabens have subsidiary grabens within the main basin (Wilkins, 1986; Collins and Raney, 1991). The basins are asymmetrical and structural relief, in general, is greater on the west and southwest sides of the basins (Chapin, 1971).

Basin fill of Cenozoic age was derived from erosion of rocks from flanking highlands, interbedded in some places with volcanic flows and tuffs. Basins include, from northwest to southeast, the Mesilla Basin, Tularosa Basin, and Hueco Basin (Figure 1.4). The Mesilla and Hueco Basins are "open" basins, and surface runoff in these basins is drained by the Rio Grande. The Tularosa Basin is a "closed" basin, having no exterior surface drainage. Open and closed basins are phrases sometimes used to describe interbasin ground-water flow, or lack thereof, to other basins or through-flowing streams in the basin-and-range province. The conventions used by Eakin and others (1976) are used in this report to describe ground-water flow (Figure 1.6). According to their convention (Eakin and others, 1976), the Mesilla and Hueco Basins are "regional sinks" and the Tularosa Basin is a "partly drained" basin (Figure 1.6). "Open" and

"closed" basins are used hereafter to describe surface runoff and surface drainage in basins (Figure 1.4), not ground-water flow.

Consolidated rock types are important to the makeup of the hydrostratigraphy of the study area. These include, from oldest to youngest, Precambrian metamorphic rocks that are weakly fractured; Paleozoic (especially Permian) carbonate and clastic rocks that are fractured and sometimes intensely karstified; Mesozoic (mostly Cretaceous) rocks that are fractured and occasionally karstified; and Tertiary and Quaternary volcanic intrusive and extrusive rocks that are usually fractured and jointed.

Semi-consolidated to unconsolidated sediments include Cenozoic basin fill, Quaternary Rio Grande alluvium, and recent alluvial deposits not associated with the Rio Grande (Figure 1.5). The Cenozoic basin-fill sediments consist largely of sand and gravel lenses interstratified with silt and clay. Significant amounts of interbedded volcanics are shown in some geologic logs, especially in the lower basin fill. Depositional environments included alluvial fans, riverine systems, and ephemeral lakes and saline playas. Vertical offset by Basin and Range faults and tabular and lenticular geometries of sand, silt, and clay deposits create significant intrastratigraphic discontinuities.

The Rio Grande alluvial deposits form a complex mosaic of braided and meandering river deposits. Formed during alternating periods of scour and fill in the late Quaternary Period, the river deposits consist of irregularly distributed gravels, sands, clay, and silt lenses and beds (USBR, 1973; Alvarez and Buckner, 1980). Lenses and beds are highly irregular in extent and thickness and correlations across short distances are difficult or impossible to make with available data. Recent alluvial deposits not formed by the Rio Grande are associated with arroyos that drain the mountains and flanking plateaus. Typically these deposits are poorly sorted sands, silts, and gravels.

Geologic history

During much of the Paleozoic Era, the study area was covered over large areas by shallow seas (Wilkins, 1986). Carbonate and clastic rocks were deposited in and adjacent to the seas, especially during the Permian Period (Henry, 1979). Seas had regressed by the Triassic and Jurassic Periods and weathering and erosion of continental rock masses formed extensive red beds in northern parts of the Rio Grande rift. Triassic and Jurassic rocks were eroded or were not deposited prior to formation of Cretaceous rocks in the southern part of the rift.

Seas had transgressed by the Cretaceous Period and marine environments were the sites of deposition of thick sequences of limestone and clastic sediments (Henry, 1979; Wilkins, 1986). These and older rocks were deformed during the Late Cretaceous, Early Tertiary Laramide orogeny. Major thrust faults developed along the southeastern edge of the study area as a result of the orogeny, and deformation produced a series of north-northwest trending folds (Henry, 1979). Andesite intrusions and volcanic flow associated with Laramide faulting and volcanic activity continued through the Oligocene (Wilkins, 1986).

Rifting began at least 18 million years ago and took place along a north-northwest structural trend (Wilkins, 1986). The region was uplifted from elevations near sea level to several thousand feet above sea level during the late Tertiary. Block-faulting was superimposed on Laramide fault and fold structure, and thick sequences of bolson fill were deposited as a result of block faulting and uplift. Extension, along with uplift and erosion of flanking highlands formed the graben-type basins. Normal fault movement continues to the present in some parts of the study area (Belcher and Goetz, 1977).

The ancestral Rio Grande became a through-flowing river in the study area during the late Pliocene to early Pleistocene (Gustavson, 1990). Incision of the Rio Grande was affected by integration of the Upper Rio

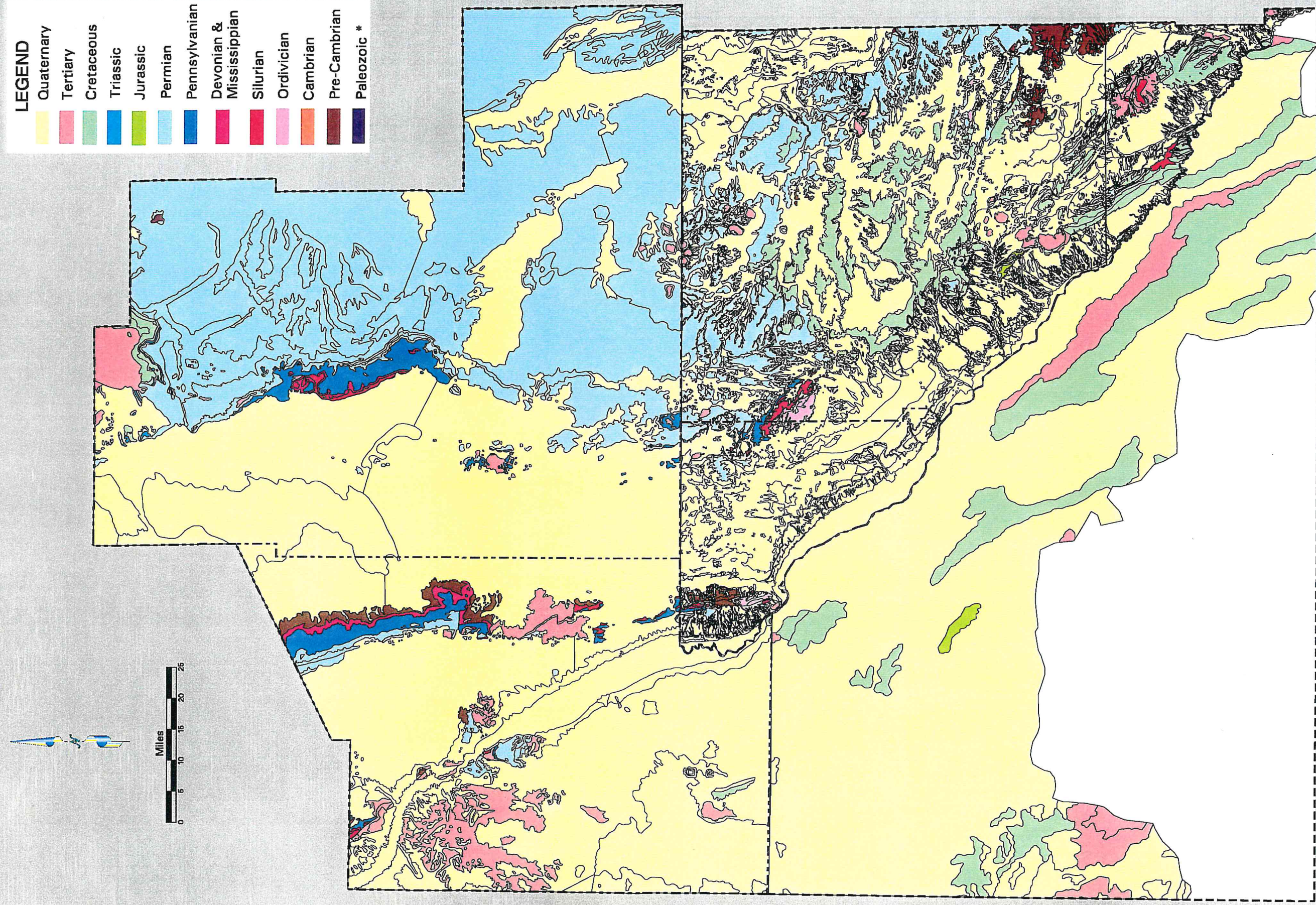


Figure 1.5. Geologic coverage map of the regional study area (source, Texas Bureau of Economic Geologic atlas sheets; Instituto Nacional de Estadística, Geografía e Informática geology sheets; New Mexico Geological Society highway geologic map).

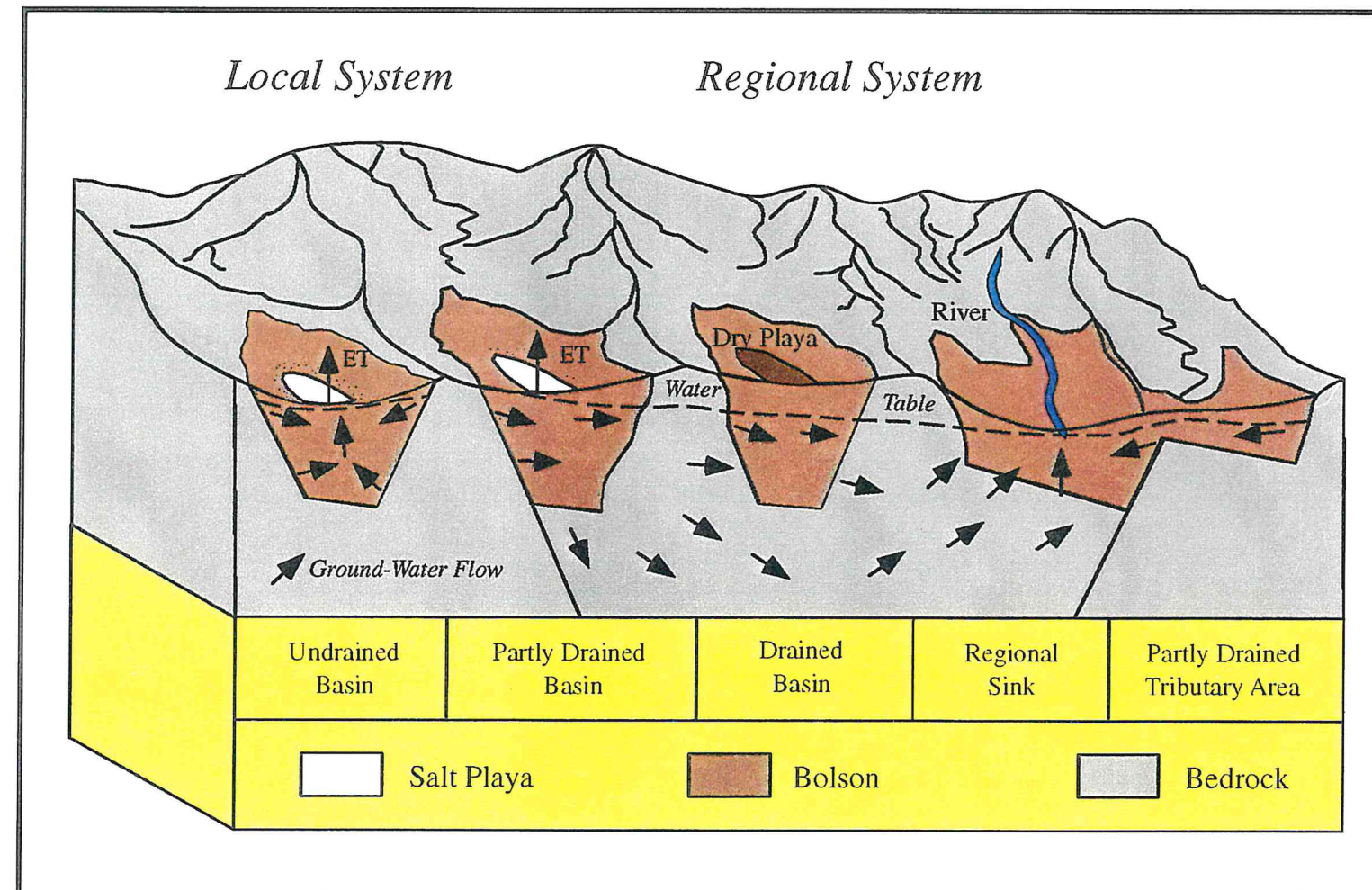


Figure 1.6. Conceptual hydrogeologic model showing undrained basins, partly drained basins, drained basins, and regional sinks (modified from Eakin and others, 1976).

Grande system with the lower Rio Grande system and drainage into the Gulf of Mexico. Basins in the study area display arroyo dissection of basin fill that developed in response to new base level of the Rio Grande.

References

- Alvarez, H.J., and Buckner, A.W., 1980, Ground-water development in the El Paso region, Texas, with emphasis on the resources of the lower El Paso Valley: Texas Department of Water Resources Report 246, 346 p.
- Belcher, R.C., and Goetz, L.K., 1977, Eastern boundary of Late Quaternary faulting in Trans-Pecos Texas: Geological Society of America Abstracts with Programs, v. 9, no. 1, p. 5-6.
- Chapin, C.E., 1971, The Rio Grande Rift, part 1, Modifications and additions, in New Mexico Geological Society, 22nd Field Conference: p. 191-201.
- Collins, E.W., and Raney, J.A., 1991, Tertiary and Quaternary structure and paleotectonics of the Hueco Basin, Trans-Pecos Texas and Chihuahua, Mexico: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 91-2, 44 p.
- de la O'Carreno, Alfonso, 1957, Preliminary geohydrological study of the Juarez Valley and surrounding areas, State of Chihuahua: trans, Sergio Garza, Department of Water Resources Technical Advisory Memorandum No. 13.6 - 18, Mexico City, Fed. Dist. 106 p.
- Eakin, T.E., Price, D., and Harill, J.R., 1976, Summary appraisals of the nation's ground-water resources - Great Basin region: U.S. Geological Survey Professional Paper 813-G, 37 p.
- Frenzel, P.F., Kaehler, C.A., and Anderholm, S.K., 1992, Geohydrology and simulation of ground-water flow in the Mesilla Basin, Doña Ana County, New Mexico, and El Paso County, Texas, with a section on water quality and geochemistry: U.S. Geological Survey Professional Paper 1407-C, 105 p.
- Gustavson, T.C., 1990, Regional stratigraphy and geomorphic evolution of the southern Hueco Bolson, west Texas and Chihuahua, Mexico, in Hydrogeology of Trans-Pecos Texas: Bureau of Economic Geology Guidebook 25, p. 27 - 35.
- Henry, C.D., 1979, Geologic setting and geochemistry of thermal water and geothermal assessment, Trans-Pecos Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 96, 48 p.
- IBWC (International Boundary and Water Commission), 1989, Ground water conditions in El Paso/Juarez Valley: Hydraulics Branch, Planning Division, 43 p.
- Larkin, T.J., and Bomar, G.W., 1983, Climatic atlas of Texas: Texas Dept. Of Water Resources Publication LP-192, 151 p.
- Nativ, R., and Riggio, R., 1990, Precipitation in the southern High Plains: Meteorologic and Isotopic Features: Journal of Geophysical Research, v. 95, D13, p.22,559-22,564.
- NMSEO (New Mexico State Engineer Office), 1992, Las Cruces, NM, Municipal and industrial pumping totals for Mesilla Basin.
- Sayre, A.N., and Livingston, Penn, 1945, Ground-water resources of the El Paso area, Texas: U.S. Geological Survey Water-Supply Paper 919, 190 p.
- TWDB (Texas Water Development Board), 1995, Water and wastewater needs of Texas Colonias, 1995 update: internal open-file report, unpaginated.
- USBR (U.S. Bureau of Reclamation), 1973, Water Resources of El Paso County, Texas: Rio Grande Project, New Mexico - Texas Project Office, El Paso, Texas, 97 p.
- USBR (U.S. Bureau of Reclamation), 1984, Tularosa Basin Water and Energy Study, New Mexico, Appraisal Report: Southwest Regional Office, Amarillo, Texas, various pagination.
- USDC (U.S. Department of Commerce), 1990, BEA Regional Projections to 2040, Volume 2: Metropolitan Statistical Areas.
- USDC (U.S. Department of Commerce), 1991, 1990 Census Data.
- USDC (U.S. Department of Commerce), 1995, 1994 Population Estimates.
- USEPA (U.S. Environmental Protection Agency), 1996, US/Mexico Border XXI Program Draft Framework Document: EPA 160-D-96-001, various pagination.
- White, D.E., 1987, Summary of hydrologic information in the El Paso, Texas area, with emphasis on ground-water studies, 1908-1980: Texas Water Development Board Report 300, 75 p.
- Wilkins, D.W., 1986, Geohydrology of the southwest alluvial basins regional aquifer-systems analysis, parts of Colorado, New Mexico, and Texas: U.S. Geological Survey Water-Resources Investigations Report 84-4224, 61 p.