Chapter 7

The Mesilla Basin Aquifer System of New Mexico, West Texas, and Chihuahua—An Overview of Its Hydrogeologic Framework and Related Aspects of Groundwater Flow and Chemistry

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Introduction

Our brief overview of the hydrogeology and geohydrology of basin-fill aquifers in the Mesilla Basin (Bolson) covers a large area of south-central New Mexico and adjacent parts of western Texas and northern Chihuahua (figs. 7-1, 7-2). Emphasis is on the hydrogeologic framework of this major intermontane basin and the controls exerted by basin-fill stratigraphy and structure on the distribution of major aquifer zones, the groundwater-flow regime, and related aspects of water chemistry. The 1,100-mi^2 Mesilla Basin is near the southern end of the river-linked series of structural basins that form the Rio Grande rift (RGR) tectonic province (Keller and Cather, 1994). The RGR extends southward from the San Luis Basin, which is flanked by the southern Rocky Mountains, to at least as far south as the Hueco Bolson in the southeastern sector of the Basin and Range province (Hawley, 1978; 1986).

The broad structural depression that forms the Mesilla Basin is bounded on the east by the Organ-Franklin-Juarez Mountain chain, and its western border includes fault-block and volcanic uplands that extend northward from the East Potrillo Mountains and West Potrillo basalt field to the Aden and Sleeping Lady Hills (figs. 7-1, 7-2). The entrenched Mesilla Valley of the Rio Grande, which has a valley-floor area of about 215 mi^2, crosses the eastern part of the basin. The metropolitan areas of Las Cruces and northwestern El Paso-Ciudad Juarez are located, respectively, in the northern part and at the southern end of the Mesilla Valley. The Robledo and Doña Ana mountains bound the northern end of the valley, but the northeastern basin boundary is transitional with the Jornada del Muerto Basin (Seager and others, 1987). The southern basin-boundary with the Bolson de los Muertos in north-central Chihuahua has still not been studied in detail. Regional groundwater and surface flow is toward "El Paso del Norte," the topographic and structural gap between the Franklin Mountains and Sierra Juarez that separates the

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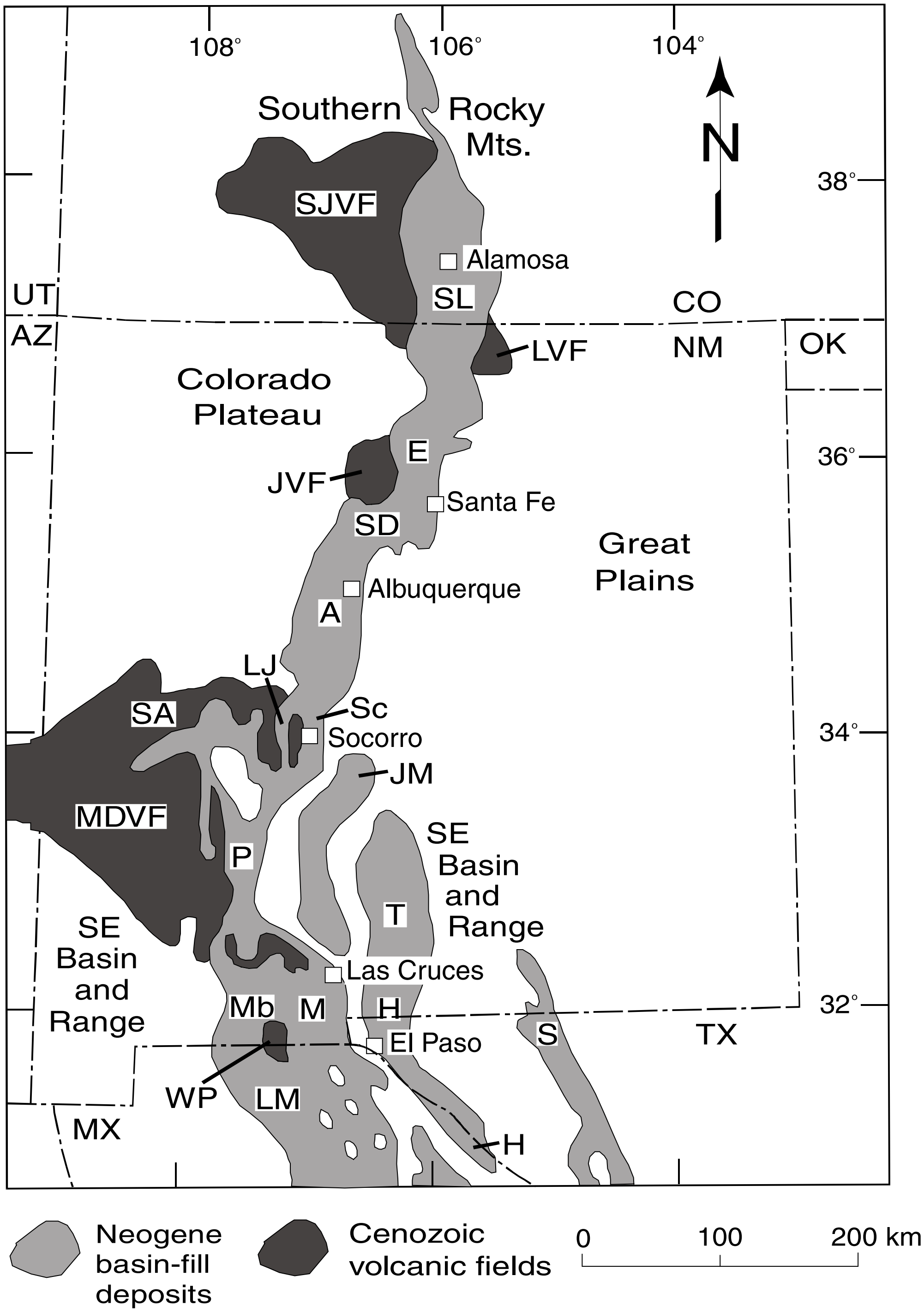

Figure 7-1: Index map showing location of the Mesilla Basin in the context of other basins and volcanic fields within the Rio Grande rift structural province. Basin abbreviations from north to south: San Luis (SL), Española (E), Santo Domingo (SD), Albuquerque (A), Socorro (Sc), La Jencia (LJ), San Agustin (SA), Jornada del Muerto (JM), Palomas (P), Tularosa (T), Mimbres (Mb), Mesilla (M), Los Muertos (LM), Hueco (H), and Salt (S). Cenozoic volcanic fields: San Juan (SJVF), Latir (LVF), Jemez (JVF), Mogollon-Datil (MDVF), and West Potrillo (WP) (modified from Keller and Cather, 1994).

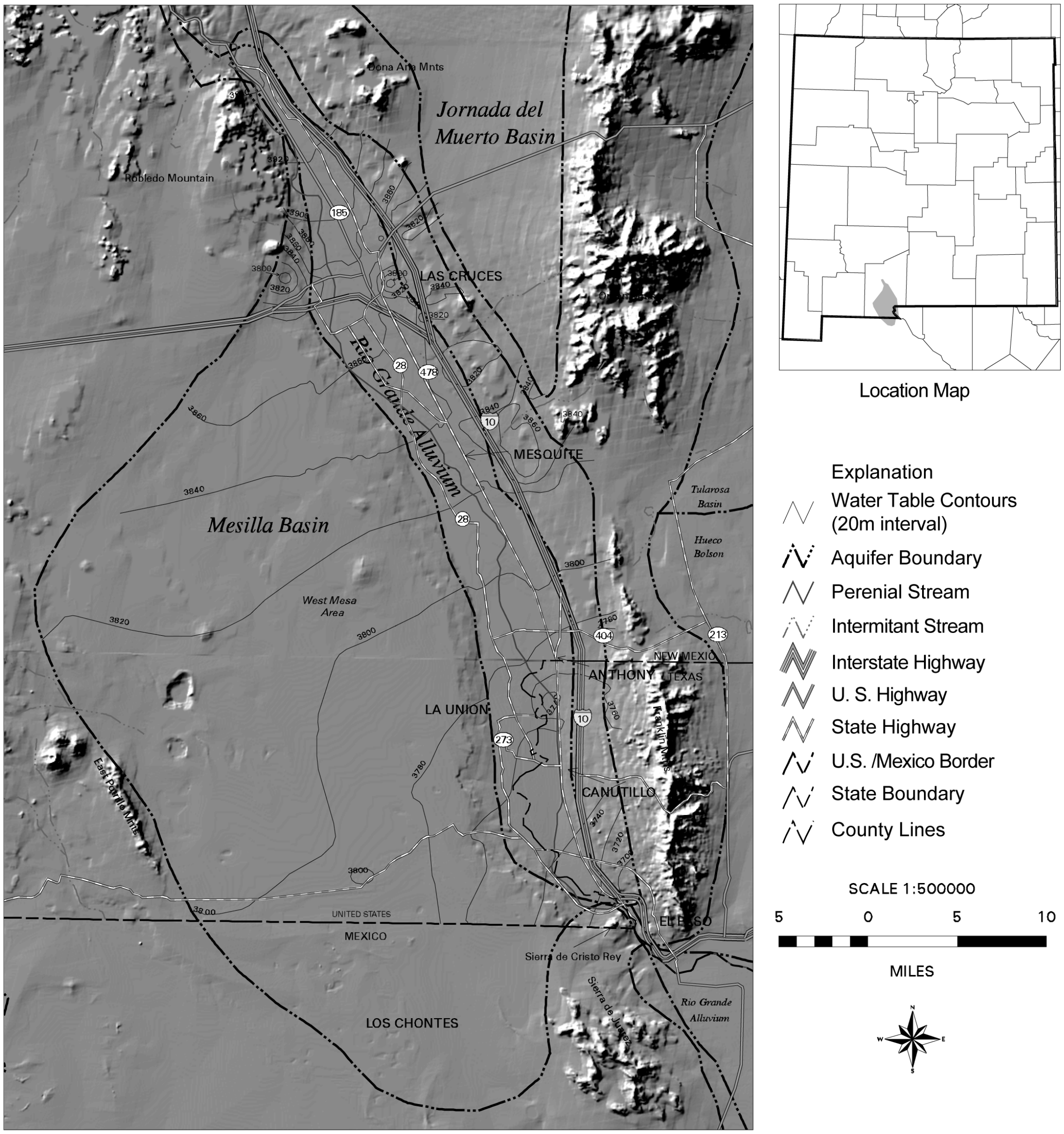

Figure 7-2: Shaded-relief index map of the Mesilla Basin area of southern New Mexico and adjacent parts of Texas and Chihuahua showing extent of modeled basin-fill (Santa Fe Gp) and Mesilla Valley aquifer systems. General water-table configuration and groundwater-flow direction in upper aquifer units are also illustrated (adapted from Hibbs and others [1997], with shaded relief from latest available U.S. Geological Survey DEM database).

Mesilla Basin from the Hueco Bolson (fig. 7-2). Underflow contribution from the Jornada Basin is restricted by a buried bedrock high between the Doña Ana and Tortugas Mountains east of Las Cruces (King and others, 1971; Wilson and others, 1981; Woodward and Myers, 1997).

Background—Development of Basic Hydrogeologic and Geohydrologic Models

We open this discussion with a brief review of how the present conceptual model of basin hydrogeology has developed over the past century. In terms of modern concepts of groundwater flow in basin-fill aquifers, W. T. Lee (1907) and Kirk Bryan (1938) are the two most important early workers to characterize the Rio Grande Valley and RGR region between Colorado and Trans-Pecos Texas. However, we must note here that the contributions of Lee and Bryan are just one product of the great amount of cross-fertilization of geological and hydrological concepts that occurred throughout the American Southwest during the late 19th and early 20th centuries. Very important contributions by contemporary workers include Hill (1896, 1900), Slichter (1905), Richardson (1909), Tolman (1909, 1937), Meinzer and Hare (1915), Darton (1916), Schwennesen (1918), Dunham (1935), Theis (1938), and Sayre and Livingston (1945).

Lee (1907) developed an early scenario for evolution of the Rio Grande Valley system in New Mexico and emphasized the potential for building a large dam at the Elephant Butte site for irrigation water storage. Bryan's (1938) most significant hydrogeologic contributions include development of the earliest synoptic models of the RGR structural province (his "Rio Grande depression") and evolution of the northern Rio Grande fluvial system. He observed that (1) the main body of sedimentary deposits of the Rio Grande depression, from the north end of the San Luis valley to and beyond El Paso, is considered to be the same general age and to belong to the Santa Fe Formation (p. 205); (2) in general, the basins appear to have been elongated into ovals and to be divisible into two major types— basins with a through-flowing river and basins with enclosed drainage (p. 205); and, (3) [Rio Grande depression basins] differ from other basins [in the Basin and Range province] principally in being strung like beads on a string along the line of the Rio Grande (p. 221).

On the basis of observations in adjacent parts of Mexico and the American Southwest, Tolman (1909, 1937) also made a major contribution in developing a better definition of the fundamental hydrogeologic distinction between depositional systems in aggrading intermontane basins with topographic closure (bolsons) and those that are open in terms of both surface and subsurface flow (semibolsons). Both Bryan and Tolman recognized three basic classes of lithofacies assemblages in this continuum of closed and open basin landforms. Piedmont-slope facies (e.g., alluvial-fan) are present along the margins of both basin types, while basin floors in closed systems include alluvial flats that grade to terminal, playa-lake plains. Floors of basins that are integrated with surface-flow systems, in marked contrast, include alluvial flats and fluvial plains that grade to basin outlets.

Figures 7-3 and 7-4 illustrate the Bryan-Tolman conceptual models of the hydrogeologic framework and groundwater-flow regimes in basin-fill aquifer systems of the Basin and Range province. Figure 7-3, adapted from Bryan (1938, his figs. 51, 52), clearly demonstrates his basic understanding of the integrated groundwater and surface-water flow system in basins of the “Rio Grande depression.” Figure 7-4, adapted from Eakin and others (1976), illustrates the Bryan-Tolman conceptual model in a more general hydrogeologic sense for the entire Basin and Range province, and it incorporates subsequent work in the Great Basin section (e.g., Mifflin, 1988), as well as the Trans-Pecos Texas and Chihuahua bolson region (Hibbs and others, 1998). The topographic terms *closed* and *open* are here used only in reference to the surface flow into, through, and from intermontane basins, whereas the terms *undrained*, *partly drained*, and *drained* designate classes of groundwater flow involving intrabasin and/or interbasin movement. *Phreatic* and *vadose*, respectively, indicate saturated and unsaturated subsurface conditions. *Phreatic playas* (with springs and seeps) are restricted to floors of *closed* basins (*bolsons, bolsones*) that are *undrained* or *partly drained;* and *vadose playas* occur in both *closed* and *open*, *drained* basins. In the Mesilla Basin region, as well as in most other intermontane basins of western North America, the intermediate basin class referred to as *partly drained* probably represents the major groundwater-flow regime. Few intermontane basins (*bolsons* and *semibolsons*) are truly *undrained* in terms of groundwater discharge, whether they are *closed* or *open* in terms of surface flow.

Under predevelopment conditions, groundwater discharge in the region occurred mainly through subsurface leakage from one basin system into another, discharge into the gaining reaches of perennial or intermittent streams, discharge from springs, or by evapotranspiration from *phreatic playas* and cienegas (valley-floor wetlands). Most recharge to basin-fill aquifers occurs by two mechanisms, (1) “mountain front,” where some precipitation falling on bedrock highlands contributes to the groundwater reservoir along basin margins, and (2) “tributary,” where the reservoir is replenished along losing reaches of larger intrabasin streams (Hearne and Dewey, 1988; Kernodle, 1992; Wasiolek 1995; Anderholm, 2000). Recharge estimates in this paper are based on the assumption that (1) less than 2 percent of average annual precipitation contributes to recharge and (2) this contribution is distributed very unevenly over higher watersheds and in major stream valleys.

Developments Since 1945

Scientific and technological breakthroughs since 1945 include development of modern geophysical-survey and deep-drilling methods and advances in geochemistry. These breakthroughs contributed to much better characterization of basin-fill aquifers and groundwater-flow systems in the southern New Mexico–Trans-Pecos Texas region by the U.S. Geological Survey, Texas Water Commission, City of El Paso, U.S. Soil Conservation Service, and New Mexico State University (e.g., Conover, 1954; Knowles and Kennedy 1958; Leggat and others, 1962; Cliett 1969; Hawley, 1969; Hawley and

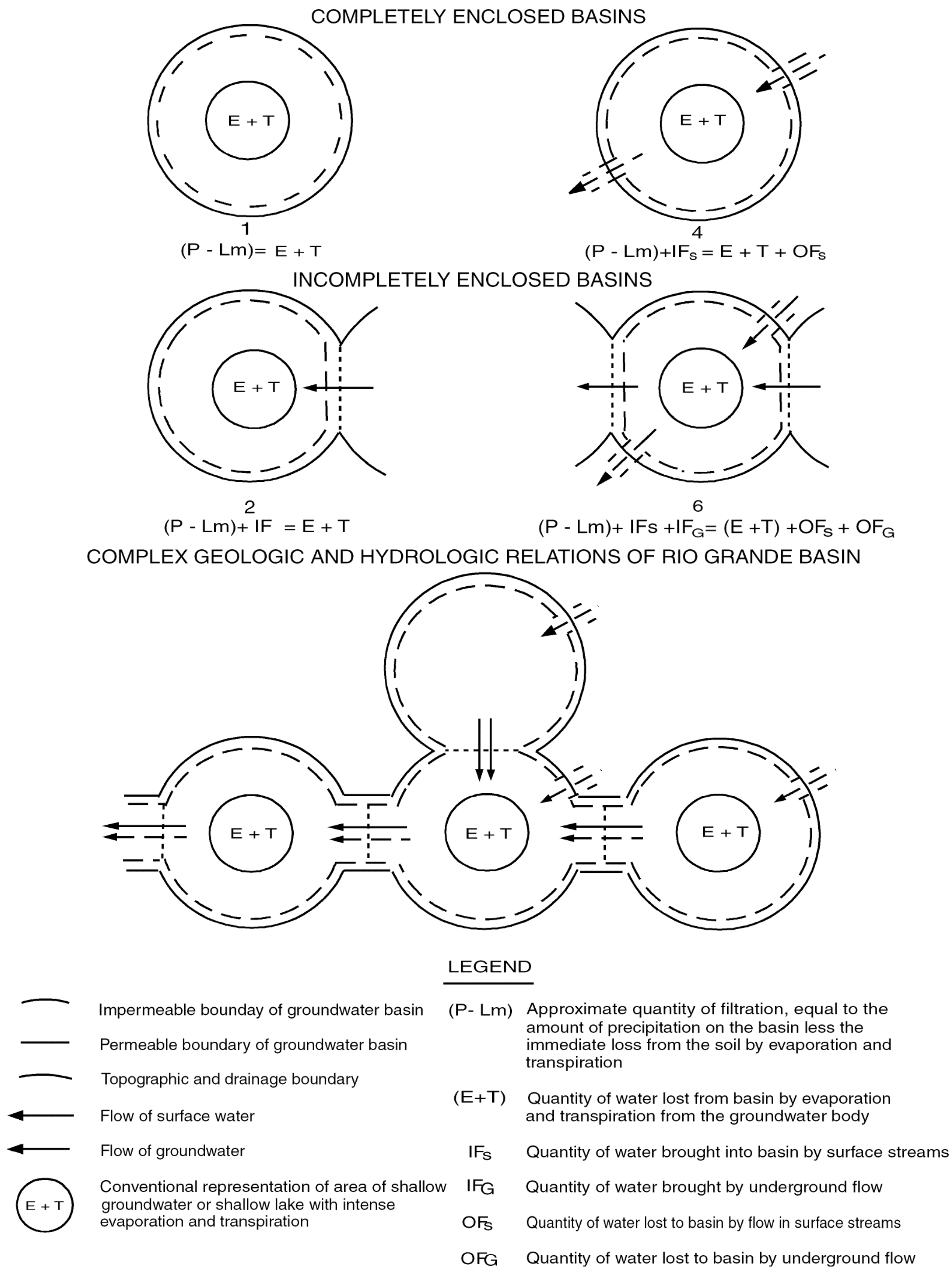

Figure 7-3: Kirk Bryan's conceptual models of "hydraulic regimes" in groundwater reservoirs of the "Rio Grande depression" (modified from Bryan, 1938, his figs. 51 and 52).

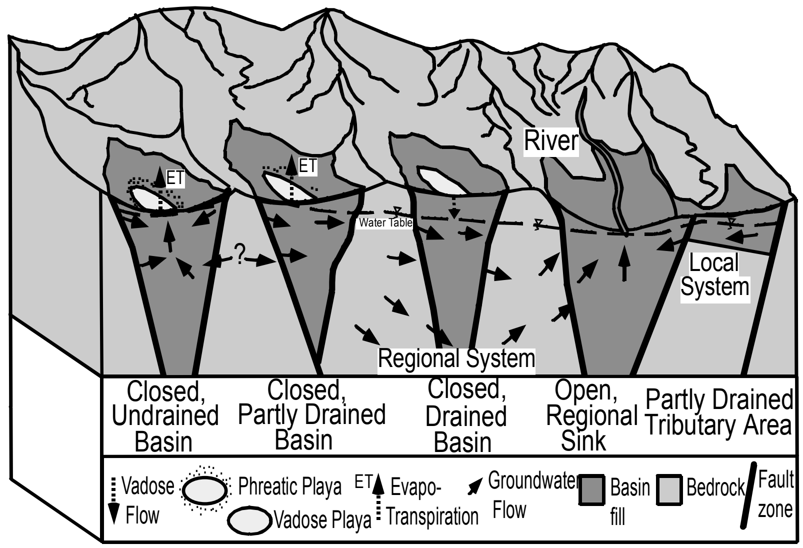

Figure 7-4: Schematic diagram showing hydrogeologic framework and groundwater-flow system in interconnected group of *closed* and *open, undrained, partly drained, and drained* intermontane basins (modified from Eakin and others, 1976, and Hibbs and others, 1998).

others, 1969; King and others, 1971; Gile and others, 1981; Wilson and others, 1981; Wilson and White, 1984).

Recent investigations are characterized by the increased availability of high-quality geophysical and geochemical data and deep borehole sample and core logs. We are now in an era dominated by the exponentially increasing power of computers and the evolution of numerical modeling and GIS technology. In the Mesilla Basin region, as elsewhere, the bridge between the early-20th-century conceptual world and the present will continue to be *hydrogeologic ground truth*. Our surface and underground view of geohydrologic systems must now be expressed in units that modelers of groundwater-flow systems can understand and computers can process. The rapid improvements in our understanding of subsurface geophysical and geochemical systems, geochronology, and the definition of the hydrogeologic units described herein now allow modelers to join forces effectively with hydrogeologists, geophysicists, and geochemists in meeting the incredible water-resource challenges that face Third Millennium society in this and other arid and semiarid regions.

Recent and ongoing studies in the Mesilla Basin area that have provided much of the background material for our paper are reviewed or described in detail in the following reports and maps: Peterson and others (1984), Seager and others (1987), Hawley and Lozinsky (1992), Wade and Reiter (1994), Heywood (1995), Seager (1995), Gile and others (1996), Hibbs and others (1997; 1998; 1999), Hibbs (1999), Collins and Raney (2000), Hawley and others (2000), and Kennedy and others (2000). Discussion of a large geothermal system located near Tortugas Mountain, east of Las Cruces, is beyond the scope of this paper. The system results from very deep circulation of meteoric-source groundwater in a high heat-flow environment. Research on this complex (regional and local) groundwater-flow regime is in progress (e.g., Ross and Witcher, 1998).

Recent Developments in Groundwater-Flow Models

Models of groundwater flow in the Mesilla Basin aquifer system (e.g., Peterson and others, 1984; Frenzel and Kaehler, 1990; West, 1996; Balleau, 1999;) must be examined in terms of the hydrogeologic constraints placed on flow regimes by lithofacies, stratigraphic, and structural-boundary conditions that are either well documented or reasonably inferred. The critique of "U.S. Geological Survey Ground-Water-Flow Models of Basin-Fill Aquifers in the Southwestern Alluvial Basins Region" (Kernodle, 1992) relates directly to this concern. "As a rule identifiable geologic features that affect groundwater-flow paths, including geologic structure and lithology of beds, need to be represented in the model," (p. 65) and major categories of geohydrologic boundaries in alluvial basins include "(1) internal boundaries that alter flow paths, including small-permeability beds, fissure-flow volcanics and faults; (2) recharge boundaries, primarily around the perimeter of basins (mountain-front recharge), and along the channels of intermittent streams, arroyos, and washes (tributary recharge); [and] (3) recharge and discharge boundaries associated with semipermanent surface-water systems in the flood plains of major streams." (p. 66) Finally, "although two-dimensional models may successfully reproduce selected responses of the aquifer, they fail to accurately mimic the function of the system." (p. 59) In comparison, "three-dimensional models more accurately portray the flow system in basin-fill [aquifers] by simulating the vertical component of flow. However, the worth of the model is still a function of the accuracy of the hydrologist's concept of the workings of the aquifer system." (p. 59)

We must also emphasize that short- and long-term climatic changes have significant impacts on all water resources. This observation is well documented by both modern meteorological data and the historic and prehistoric tree-ring record (Thomas, 1962; Schmidt, 1986; D'Arrigo and Jacoby, 1992; U.S. Dept. of Commerce, 1999; and Hawley and others, 2000). For example, the region experienced prolonged droughts from the late 1940's until the late 1970's, and the following two decades were abnormally wet.

Conceptual Hydrogeologic-Framework Model

The hydrogeologic framework of basin-fill aquifers in the RGR region, with special emphasis on features related to environmental concerns, is described here in terms of three basic conceptual building blocks: lithofacies assemblages (LFA's), hydrostratigraphic units (HSU's), and structural-boundary conditions. A conceptual hydrogeologic model of an interconnected, shallow, valley-fill/basin-fill and deep-basin aquifer system was initially developed for use in groundwater-flow models of the Mesilla and Albuquerque basins (Peterson and others, 1984; Frenzel and Kaehler, 1990; Hawley and Haase, 1992; Hawley and Lozinsky, 1992; Kernodle, 1992, 1998; Thorn and others, 1993; Hawley and others, 1995; Kernodle and others, 1995). However, basic design of the conceptual model is flexible enough to allow it to be modified for use in other basins of the Rio Grande rift and adjacent parts of the southeastern Basin and Range province (Hawley and others, 2000).

Hydrogeologic models of this type are simply qualitative to semiquantitative descriptions (graphical, numerical, and verbal) of how a given geohydrologic system is influenced by (1) bedrock-boundary conditions, (2) internal-basin structure, and (3) lithofacies characteristics of various basin-fill stratigraphic units. They provide a mechanism for systematically organizing a large amount of relevant hydrogeologic information of widely varying quality and scale (from very general drillers' observations to detailed borehole logs and water-quality data). Model elements can then be graphically displayed in combined map and cross-section (GIS) formats so that basic information and inferences on geohydrologic attributes (e.g., hydraulic conductivity, transmissivity, anisotropy, and general patterns of unit distribution) may be transferred to basin-scale, three-dimensional numerical models of groundwater-flow systems. As emphasized by Hawley and Kernodle (2000), however, this scheme of data presentation and interpretation is normally not designed for site-specific groundwater investigations.

Lithofacies Assemblages

Lithofacies assemblages (LFA's) are the basic building blocks of the hydrogeologic model (fig. 7-5, table 1), and they are the primary components of the hydrostratigraphic units (HSU's) discussed below. These sedimentary-facies classes are defined primarily on the basis of grain-size distribution, mineralogy, sedimentary structures, and degree of postdepositional alteration. The secondary basis for facies-assemblage definitions is according to inferred environments of deposition. LFA's have distinctive geophysical, geochemical and hydrologic attributes, and they provide a mechanism for showing distribution patterns of major aquifers and confining units in hydrogeologic cross sections. In this study, basin and valley fills are subdivided into 13 major assemblages that are ranked in decreasing order of aquifer potential (tables 1 to 3; LFA's *1-10, a-c*). Figure 7-5 is a schematic illustration of the distribution pattern LFA's observed in the New Mexico Basin and Range Region. Lithofacies properties that influence groundwater flow and production potential in this region are summarized in tables 2 and 3. Note that *Roman numeral* notations (I–X) originally used in previous hydrogeologic framework models (Hawley and Lozinsky, 1992; Hawley and others, 1995) have been changed to *Arabic* style in order to facilitate the development of alphanumeric attribute codes that can be used in both conceptual and numerical models of basin-fill aquifer systems.

Hydrostratigraphic Units

As already noted, most of the RGR basin fill in the south-central New Mexico border region have been subdivided into formation-rank, lithostratigraphic units of the Santa Fe Group (e.g., Hawley and others, 1969; Hawley, 1978; Gile and others, 1981), Seager and

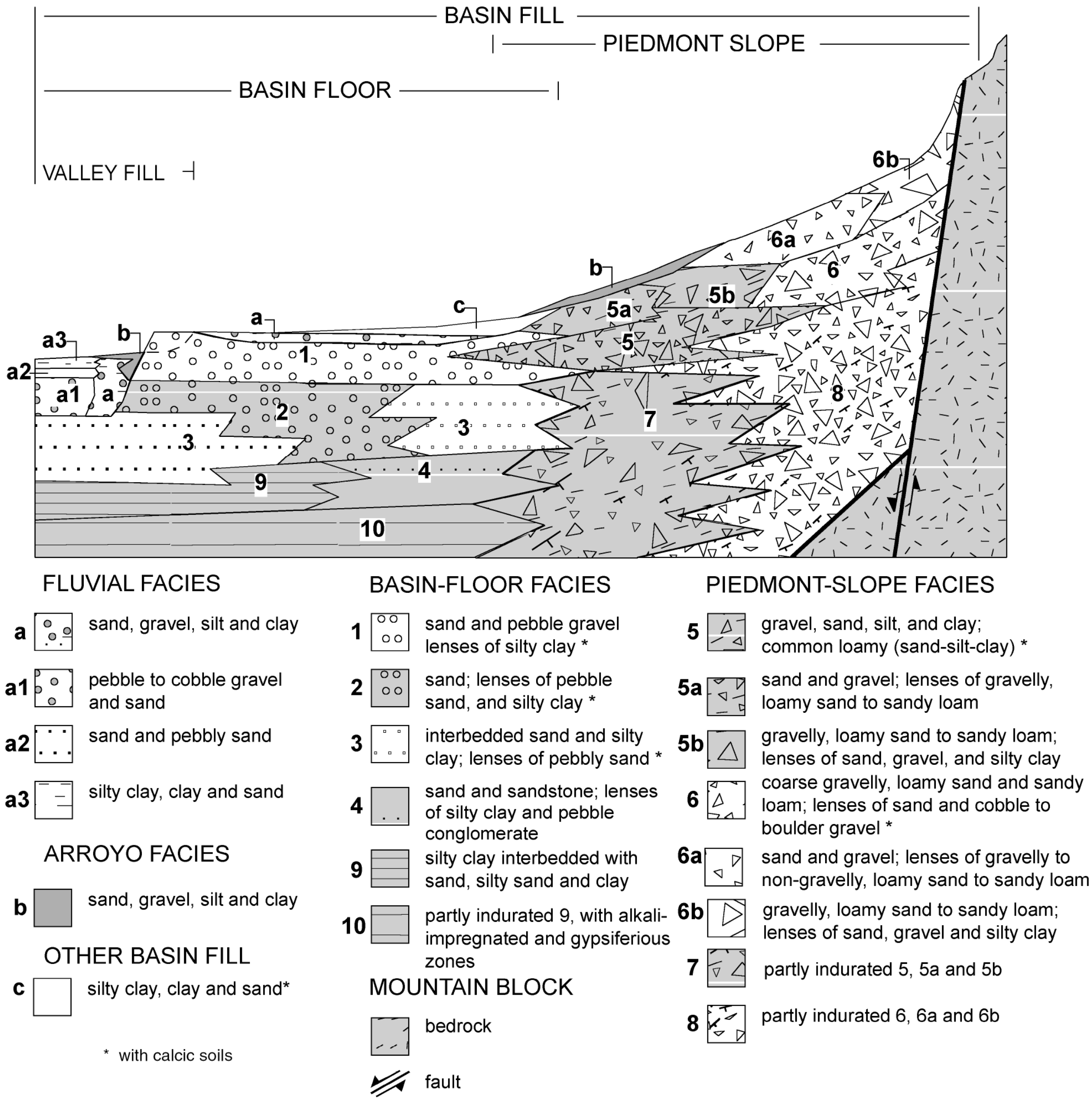

Figure 7-5: Schematic distribution pattern of major lithofacies assemblages (tables 1 through 3) in basin and valley fills of the Rio Grande rift region (from Hawley and others, 2000).

others, 1987; Mack and others, 1998b; Keller and Cather, 1994; Collins and Raney, 2000; Hawley and others, 2000). However, a clear distinction has rarely been made between deposits simply classed as "bolson" or "basin" fill and contiguous Santa Fe Group subdivisions. As a first step in organizing available information on basin-fill stratigraphy with emphasis on aquifer characteristics, a provisional hydrostratigraphic classification system has been developed during the past 20 yr that is applicable to all basins of the southeastern Basin and Range province.

Table 7-1: Stratigraphic units that comprise the aquifers of Loving, Pecos, Reeves, Ward and Winkler Counties.

Lithofacies		Dominant depositional settings and process	Dominant textural classes
1		Basin-floor fluvial plain	Sand and pebble gravel, lenses of silty clay
2		Basin-floor fluvial, locally eolian	Sand; lenses of pebble sand, and silty clay
3		Basin-floor, fluvial-overbank fluvial-deltaic and playa-lake;eolian	Interbedded sand and silty clay; lenses of pebbly sand
4		Eolian, basin-floor alluvial	Sand and sandstone; lenses of silty sand to clay
5		Distal to medial piedmont-slope, alluvial fan	Gravel, sand, silt, and clay; common loamy (sand-silt-clay)
	5a	Distal to medial piedmont-slope, alluvial fan; associated with large watersheds; alluvial-fan distributary-channel primary, sheet-flood and debris-flow, secondary	Sand and gravel; lenses of gravelly, loamy sand to sandy loam
	5b	Distal to medial piedmont-slope, alluvial-fan; associated with small steep watersheds; debris-flow, sheet-flood and distributary-channel	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
6		Proximal to medial piedmont-slope, alluvial-fan	Coarse gravelly, loamy sand and sandy loam; lenses of sand and cobble to boulder gravel
	6a	Like 5a	Sand and gravel; lenses of gravelly to non-gravelly, loamy sand to sandy loam
	6b	Like 5b	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
7		Like 5	Partly indurated 5
8		Like 6	Partly indurated 6
9		Basin-floor --alluvial flat, playa, lake, and fluvial-lacustrine; distal-piedmaont alluvial	Silty clay interbedded with sand, silty sand and clay
10		Like 9, with evaporite processes (paleophreatic)	Partly indurated 9, with gypsiferous and alkali-impregnated zones
a		River-valley, fluvial	Sand, gravel, silt and clay
	a1	Basal channel	Pebble to cobble gravel and sand (like 1)
	a2	Braided plain, channel	Sand and pebbly sand (like 2)
	a3	Overbank, meander-belt, oxbow	Silty clay, clay, and sand (like 3)
b		Arroyo channel and valley-border alluvial-fan	Sand, gravel, silt, and clay (like 5)
c		Basin floor, alluvial flat, cienega, playa, and fluvial-fan to lacustrine plain	Silty clay, clay and sand (like 3,5, and 9)

Hydrostratigraphic units defined in the RGR region are mappable bodies of basin fill and valley fill that are grouped on the basis of origin and position in both lithostratigraphic and chronostratigraphic sequences. The informal upper, middle, and lower Santa Fe hydrostratigraphic units (HSU's: USF, MSF, LSF) form the major basin-fill aquifer zones, and they correspond roughly to the (formal and informal) upper, middle, and lower lithostratigraphic subdivisions of the Santa Fe Group used in local and regional geologic mapping (fig. 7-6). Dominant lithofacies assemblages in the upper Santa Fe HSU are *LFA's 1-3, 5 and 6*. The middle Santa Fe HSU is characterized by *LFA's 3, 4, 7-9*, and the lower Santa Fe commonly comprises *LFA's 7-10*. Basin-floor facies assemblages *3* and *9* are normally present throughout the Santa Fe Group section in closed-basin (bolson) areas.

Table 7-2: Summary of properties that influence groundwater production potential of Gila and Santa Fe Group (modified from Haase and Lozinsky 1992) [>, greater than, <, less than].

Lithofacies	Ratio of sand plus gravel to silt plus clay [1]	Bedding thickness (meters)	Bedding configuration [2]	Bedding continuity (meters) [3]	Bedding connectivity [4]	Hydraulic conductivity (K)[5]	Groundwater production potential
1	High	> 1.5	Elongate to planar	> 300	High	High	High
2	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
3	Moderate	> 1.5	Planar	150 to 300	Moderate to high	Moderate	Moderate
4	Moderate to low*	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate	Moderate
5	Moderate to high	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate to low	Moderate to low
5a	High to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate	Moderate
5b	Moderate	0.3 to 1.5	Lobate	30 to 150	Moderate to low	Moderate to low	Moderate to low
6	Moderate to low	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate to low	Moderate to low	Low to moderate
6a	Moderate	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate	Moderate to low	Moderate to low
6b	Moderate to low	0.3 to 1.5	Lobate	< 30	Low to moderate	Low to moderate	Low
7	Moderate*	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Low	Low
8	Moderate to low *	> 1.5	Lobate	< 30	Low to moderate	Low	Low
9	Low	> 3.0	Planar	> 150	Low	Very low	Very low
10	Low*	> 3.0	Planar	> 150	Low	Very low	Very low

[1] High >2; moderate 0.5-2; low < 0.5

[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).

[3] Measure of the lateral extent of an individual bed of given thickness and configuration.

[4] Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt+ clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal the greater the bedding, connectivity, the greater the groundwater production potential of a sedimentary unit (Hawley and Haase 1992, VI).

[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.

* Significant amounts of cementation of coarse-grained beds (as much as 30%)

The other major hydrostratigraphic units comprise channel and floodplain deposits of the Rio Grande (HSU–RG) and its major tributaries. These valley fills of Late Quaternary age (<130 ka) form the upper part of the region's most productive shallow-aquifer system. Surficial lake and playa deposits, fills of larger arroyo valleys, and piedmont-slope alluvium are primarily in the *vadose* zone. However, they locally form important groundwater discharge and recharge sites. Historical *phreatic* conditions exist, or have recently existed, in a few playa remnants of large pluvial lakes of Late Quaternary age (Hawley, 1993). Notable examples are gypsum or alkali flats in the Tularosa, Jornada del Muerto, and Los Muertos Basins, which are contiguous to but outside the area of discussion.

Table 7-3: Summary of properties that influence groundwater production potential of Gila and Santa Fe Group [>, greater than, <, less than].

Lithofacies	Ratio of sand plus gravel to silt plus clay [1]	Bedding thickness (meters) [3]	Bedding configuration [2]	Bedding continuity (meters) [3]	Bedding connectivity [4]	Hydraulic conductivity (K) [5]	Groundwater production potential
a	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
a1	High	> 1.5	Elongate to planar	> 300	High	High	High
a2	High to moderate	> 1.5	Planar to elongate	150 to 300	Moderate to high	Moderate	Moderate
a3	Moderate to low	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate to low	Moderate to low
b	Moderate to low	0.3 to 1.5	Elongate to lobate	<100	Moderate	Moderate to low	Moderate to low
c	Low to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Low	Low	Low

[1] High >2; moderate 0.5-2; low < 0.5

[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).

[3] Measure of the lateral extent of an individual bed of given thickness and configuration.

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[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.

Bedrock and Structural Boundary Components

Structural and bedrock features that influence aquifer composition and behavior include basin-boundary mountain uplifts, bedrock units beneath the basin fill, fault zones and flexures within and at the edges of basins, and igneous-intrusive and extrusive rocks that penetrate or are interbedded with basin fill. Tectonic evolution of the fault-block basins and ranges of the Mesilla Basin area (many with a half-graben structure and accommodation-zone terminations) has had a profound effect on the distribution of lithofacies assemblages and the timing and style of emplacement of all major hydrostratigraphic units (figs. 7-5, 7-6). Discussion of this topic is beyond the scope of this paper, however, and the reader is referred to particularly pertinent reviews in Seager and Morgan (1979), Keller and Cather (1994), Faulds and Varga (1998), and Mack and others (1998a). Moreover, most of the significant bedrock- and structural-boundary features in the area are well documented on geologic maps and sections by Seager and others (1987), Seager (1995), Woodward and Myers (1997), and Collins and Raney (2000).

Mesilla Basin Aquifer Systems

Figure 7-7 is a schematic hydrogeologic cross section of the south-central Mesilla Basin, which is approximately aligned along the 32nd parallel. The section is based on (1) geologic mapping, primarily by Seager and others (1987) and Seager (1995), and (2) subsurface geophysical, hydrogeologic, and water-quality information compiled by Hawley and Lozinsky (1992). Major contributors to the hydrogeologic interpretations shown in figure 7-6 include Leggat and others (1962), Cliett (1969), Hawley and others (1969), King and others (1971), Wilson and others (1981), Peterson and others (1984),

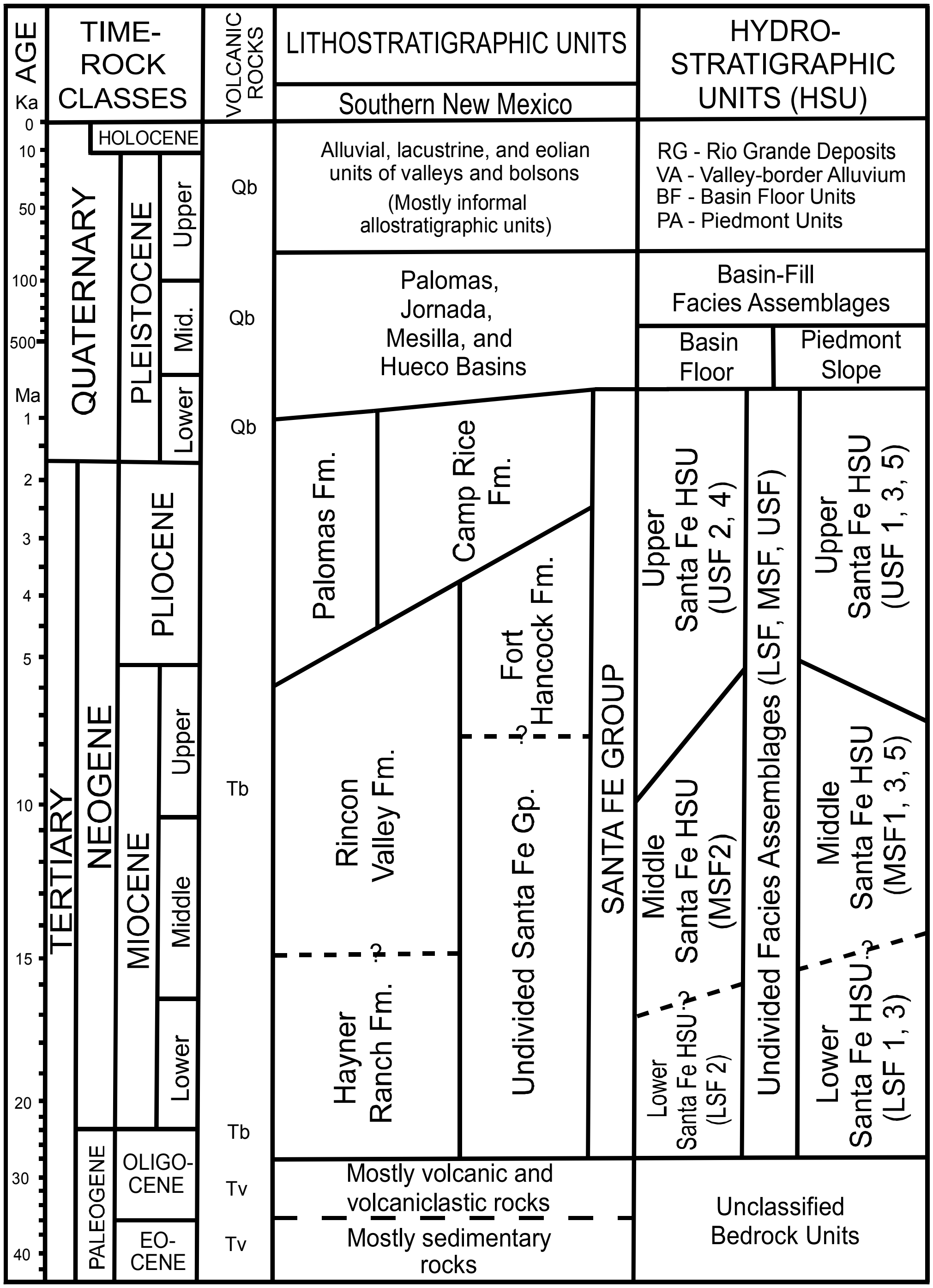

Figure 7-6: Regional summary and correlation of major chronlogic, lithostratigraphic, and basin-fill hydrostratigraphic units in the Messilla Basin-Hueco Bolson region of southern New Mexico and Trans-Pecos Texas. Igneous rock symbols: Qb-Quarternary basalt, Tb-Tertiary mafic volcanics, and Tv-older Tertiary intermediate and silcic volcanics and associated plutonic and sedimentary rocks (modified from Hawley and Kernodle, 2000).

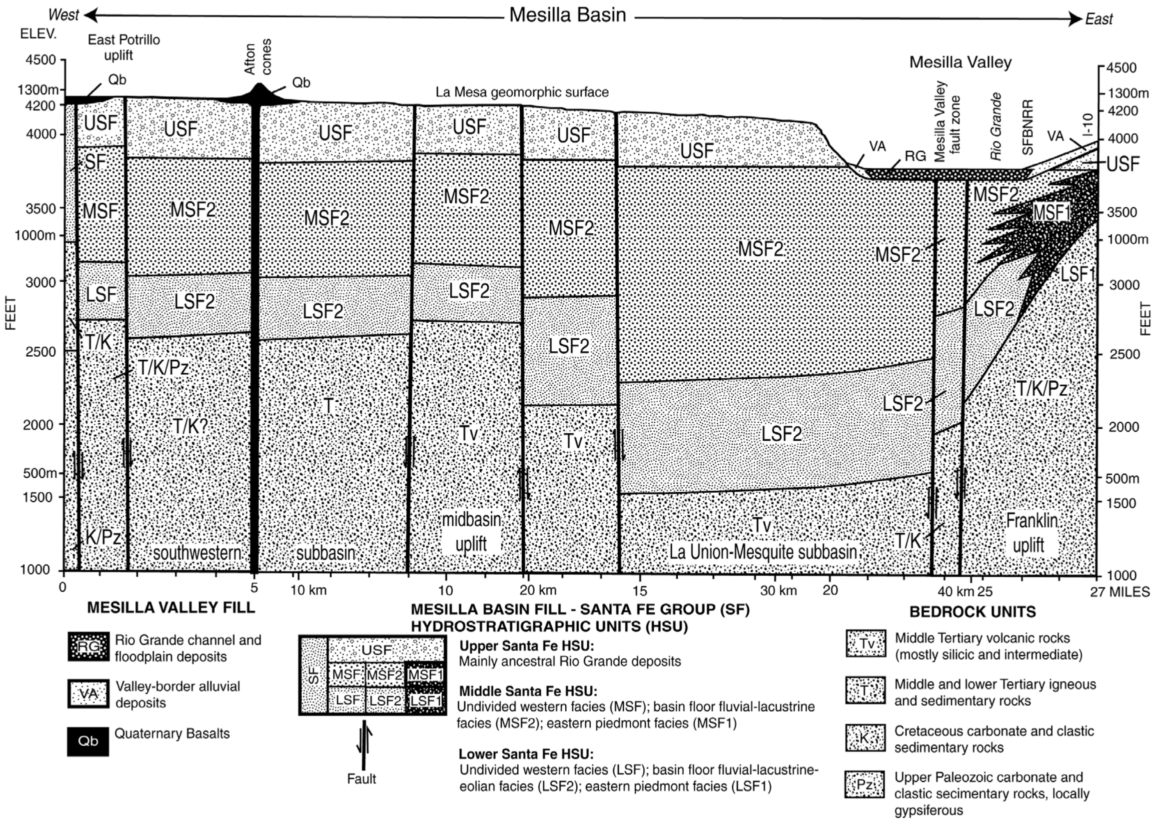

Figure 7-7: Schematic hydrogeologic cross section of the south-central Mesilla Basin near the 32nd Parallel in Doña Ana County, New Mexico, and El Paso County, Texas; with a vertical exaggeration of about 10× (modified from Hawley and Lozinsky, 1992).

Wilson and White (1984), Myers and Orr (1986), Seager and others (1987), Seager (1995), and Tom Cliett (EP-WUD) and Ken Stevens (USGS-WRD)—unpublished.

Major aquifers in the Mesilla Basin groundwater system occur in (1) Upper Quaternary alluvium of the inner river valley (valley-fill aquifer) and (2) poorly consolidated sedimentary deposits of the Santa Fe Group (basin-fill aquifer). The surface-water supply is derived from the Rio Grande, a few large tributary arroyo systems, and a network of canals, laterals, and drainage ditches that discharge to the river. The watershed of the Mesilla Basin covers approximately 11,000 mi^2.

Mesilla Valley Aquifer System

The Rio Grande "alluvial" aquifer (fig. 7-7, HSU-RG, *LFA's a & b*) underlies the Mesilla Valley floor between Leasburg Dam and the El Paso narrows. This hydrostratigraphic unit comprises river-channel and overbank facies ranging in texture from sand and gravel to silt and clay. The base of these fluvial deposits is about 60 to 80 ft below the inner-valley floor, which is locally as much as 5 mi wide. In many places, the fluvial facies extends laterally for hundreds of feet beyond the valley floor. The basal-channel gravel and sand layer, which is as much as 30 to 40 ft thick, was deposited during the interval of maximum valley incision near the end of the Late Pleistocene ice age (about 15 to 30 thousand yr ago). The valley-fill HSU extends continuously from Elephant Butte and Caballo reservoirs, through the Rincon and Mesilla Valleys, to the Fort Quitman area at the lower end of the Hueco Bolson.

Groundwater within the Mesilla Valley fill is generally unconfined and typically moves southward down the valley at an average gradient of about 4 to 6 ft per mile; however, local-flow direction is influenced by nearby hydraulic conditions, such as the river, drains, canals, well pumpage, and heavily irrigated fields. The water table is approximately 10 to 25 ft below the land surface in much of the valley-floor area. Recharge to the valley-fill aquifer occurs primarily as vertical flow from the surface water system (river, canals, laterals, and drains) and irrigated cropland fields except in times of extreme drought. The inner-valley aquifer zone is, in turn, the major source of recharge to underlying and laterally adjacent basin fill of the Santa Fe Group. Most of the discharge from the valley fill occurs through evapotranspiration of irrigated crops, flow to drain system, and irrigation and industrial pumping. Transmissivity values range from 10,000 to 30,000 ft^2/d, hydraulic conductivities vary from 100 to 350 ft/d, and estimated specific yield is 0.2. Specific capacities of large production wells range from 10 to 217 gpm/ft of drawdown, with an average value of 69 gpm/ft of drawdown. The quality of the water generally reflects the quality of the surface-water system, ranging from about 500 mg/L TDS to over 1,000 mg/L TDS. At the extreme southern end of the Mesilla Valley, however, TDS values locally exceed 10,000 mg/L.

Major Aquifer Zones in Santa Fe Group Basin Fill

A distinctive feature of Santa Fe Group basin fill in the Mesilla Basin is that it is relatively thin (maximum saturated thickness about 3,000 ft) in comparison to fills in adjacent parts of the Hueco-Tularosa and Mimbres Basin systems. Moreover, the major sources of fresh–to–slightly saline groundwater in the Mesilla Basin are from basin-floor facies assemblages in the middle to upper parts of the fill sequence. The dominant central-basin facies group comprises (1) thick sequences of fine-grained alluvial and lacustrine sediments that interfinger with and is overlapped by (2) coarser grained, ancestral-river deposits. Along basin margins both of these facies units are transitional with piedmont-slope alluvium (fig. 7-7).

The most-productive aquifer zones vary in thickness from about 300 ft in the northern and southernmost parts of the basin to over 2,000 ft in and near the eastern basin sector, which underlies the Mesilla Valley corridor from the Las Cruces metropolitan area to near Canutillo, Texas and La Union, New Mexico. Basic aquifer properties of the Mesilla Basin fill are very similar to properties of Hueco-Tularosa and Jornada Basin fills. The extent of these partly connected aquifer systems and the amount of interbasin groundwater flow is controlled in great part by the hydraulic properties of basin-boundary faults and lithofacies distribution patterns (depending, of course, on existing flow gradients). Fault zones and fine-grained facies commonly form effective barriers to interbasin flow. However, a small amount of flow may enter or leave the basin at low barrier points associated with zones of relatively high permeability.

The Mesilla Basin aquifer system comprises three major hydrostratigraphic subdivisions (HSU's) of the Santa Fe Group (Hawley and others, 1969; Hawley, 1978, charts 1 and 2). These units are ordered in upper to lower (younger to older) stratigraphic sequence (fig. 7-6). The upper Santa Fe unit (USF1,2) is generally correlative with the Camp Rice Formation (fig. 7-6), and its most productive aquifer zone consists of ancestral Rio Grande channel sand and gravel (HSU-USF2). However, the lower part of this unit is only saturated in the northeastern basin area near Las Cruces (Hawley and Lozinsky, 1992). The middle Santa Fe unit (MSF1,2) correlates with much of the Fort Hancock Formation in the Hueco Bolson, which is dominated by fine-grained, alluvial-flat, and playa-lake sediments. In the Mesilla Basin, however, the dominant facies assemblage (MSF2) includes extensive layers of clean sand that are interbedded with silty clay. The middle unit is less permeable than the upper unit because of a greater degree of cementation and the widespread presence of the fine-grained interbeds. HSU-MSF2, however, probably forms the major aquifer zone in the basin because it is almost entirely below the water table. The long-recognized "medial aquifer" zone of Leggat and others (1962) below the southern Mesilla Valley forms part of this unit (Cliett, 1969).

The lower Santa Fe unit (LSF) is primarily fine grained and party consolidated throughout much of the basin, and it only forms a significant part of the aquifer system in the lower Mesilla Valley area that extends from near Mesquite, New Mexico to Canutillo, Texas and La Union, New Mexico. This LSF unit was first identified in the El Paso Water Utilities-Canutillo well field by Leggat and others (1962) and was informally named the "deep aquifer" zone (HSU-LSF 2, fig. 7-6). The major component of the zone is a distinctive eolian-sand facies (LFA 4) that intertongues mountainward with piedmont fanglomerates (LFA's 7-8) and basinward with basin-floor facies assemblages (LFA's 3, 9 and 10?). The latter facies are here interpreted as fluvial-deltaic and playa-lake deposits (fig. 7-5, table 7-1). The sand facies is locally as much as 600 ft thick, and its base ranges from 1,000 to 1,500 ft below the Mesilla Valley floor. This extensive basin-floor to distal piedmont-slope deposit is interpreted as a buried dune field with an extent and thickness similar to that of *los Médanos de Samalayuca* dune complex in north-central Chihuahua (Cliett, 1969; Schmidt and Marston, 1981; Wilson and others, 1981; Hawley and Lozinsky, 1992).

Concluding Comments on Groundwater Flow and Quality Conditions

The near-surface components (general elevation and direction) of the groundwater-flow system are shown on figure 7-2. Hydraulic conditions range from unconfined to semiconfined to confined in most basin-fill aquifer zones. In the central part of the basin west of the Mesilla Valley, which is designated the West Mesa in many reports, a transmissivity of 5,900 ft^2/d was calculated for a well screened at selected depth intervals between 710 and 1,210 ft. In the northern part of the West Mesa area, aquifer transmissivity was estimated to be 10,000 ft^2/d, with a (confined) storage coefficient of 2×10^{-5}. According to aquifer tests, maximum values of transmissivity in the central Mesilla Basin ranged from 10,900 to 40,000 ft^2/d. The average horizontal hydraulic conductivity was 67 ft/d. This range in values, however, is probably only representative of the upper to middle parts of the Santa Fe Group aquifer system because these aquifer tests also provided evidence that the horizontal hydraulic conductivity decreases with depth. Vertical hydraulic conductivity values were found to range from 0.21 ft/d to 3.0 ft/d for the entire thickness of the confining layers at the aquifer-test sites.

Because of the limited scope of this paper, only a few comments on groundwater quality can be made. Water quality in the upper Santa Fe unit (HSU-USF2) in the eastern part of the basin generally reflects groundwater chemistry in the shallow valley-fill aquifer (HSU-RG) because this unit is the most significant recharge source for the upper part of the basin-fill aquifer system. Much of the groundwater pumped for irrigation is derived from the unconfined to semiconfined part of the (shallow) aquifer system that includes the river-valley fill (RG) and contiguous parts of HSU's USF2 and MSF2. A major influence on basinwide spatial variability in quality is due to irregular distribution patterns of fine-grained confining zones. Water in the middle Santa Fe unit (MSF2**)** is generally of better quality than in overlying valley-fill and basin-fill units, particularly in the northern part of the basin. Near the basin's southern end, however, available information indicates a significant deterioration in groundwater quality. The middle unit is the most heavily developed aquifer zone in terms of public and private drinking**-**water production. Water quality in the lower Santa Fe unit (LSF) is generally poorer than the middle unit except beneath the Mesilla Valley area between Mesquite and Canutillo. The majority of the discharge from the lower Santa Fe unit occurs as municipal and industrial pumping in the Anthony to Canutillo, Texas, area.

On the basis of review of data in the Frenzel and Kaehler (1992) groundwater-flow model, Balleau (1999, p. 46) estimated that about 14 million acre-ft of available water is stored in the upper 100 ft of saturated basin fill in the West Mesa area (~ 360,000 acres in New Mexico). This value is about twice our estimate, which assumes an effective aquifer porosity of 20 percent. Because saturated parts of HSU's USF2 and MSF2 in the West Mesa area range up to 1,000 ft in thickness, there is an enormous amount of potable to slightly saline groundwater stored in this part of the basin. Available fresh to slightly saline water stored in the upper 1,000 ft of Santa Fe Group hydrostratigraphic units, much of it very old, is probably no more than 100×10^6 acre-ft. Moreover, it has probably not been effectively recharged during the past 10,000 to 15,000 yr, except in areas contiguous to major streams.

The majority of recharge occurs through mountain**-**front mechanisms and through vertical groundwater flow from river-valley fill that forms the "shallow" alluvial aquifer. Except for a few perennial springs and seeps and short reaches of intermittent mountain streams, there are no permanent surface-water bodies in the small highland watersheds that flank the Mesilla Basin. Mountain-front recharge is, therefore, very low; and losing reaches of the Rio Grande channel and associated irrigation-canal systems are the major present sources of groundwater replenishment. Annual aquifer recharge in the 1,100-mi^2Mesilla Basin, exclusive of the 215-mi^2 Mesilla Valley area, is probably less than 10,000 acre-ft.

This estimate is based on the assumption that about 2 percent of the mean annual precipitation of 8 to 9 inches actually contributes to recharge outside the inner river valley. It must be noted in conclusion that present and projected basinwide groundwater use greatly exceeds this amount.

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