CHAPTER 5 – HACHITA-MOSCOS BASIN

INTRODUCTION

Emphasis in this chapter is on the relationship between groundwater flow and the hydrogeologic framework of basin-fill aquifers in the Hachita-Moscos Basin system. Most of the basic concepts and interpretations of how groundwater-flow systems function in the intermontane basins of the study area have already been discussed in considerable detail (Chapters 3 and 4). Discussions here will, therefore, primarily focus on aspects of basin-fill hydrogeology and groundwater-flow systems that distinguish the Hachita-Moscos area from contiguous basins of the International Boundary region. The chapter concludes with an overview of groundwater quality in the context of hydrogeologic controls on the basin's groundwater-flow system.

LOCATION AND PHYSIOGRAPHIC SETTING

Overview

The Hachita-Moscos Basin system is an interconnected group of geohydrologic subbasins that covers an area of about 2,700 km^2 (1,040 mi^2), and comprises parts of the United States and the Republic of Mexico. Approximately, 1,600 km^2 (620 mi^2) of the basin system is in southwestern New Mexico, including parts of Hidalgo, Grant, and Luna counties.

All of the Hachita-Moscos Basin system (Figure 5-1) is in the Mexican Highland section of the Basin and Range physiographic province (Hawley 1986), which is here characterized by north to northwest-trending mountain ranges and intermontane basins. Structural basins are relatively narrow compared to the broad bolson plains of the Mimbres Basin system, and except for the bolson-floor surrounding Laguna los Moscos (Figure 3-1), these basins are *semibolsons* characterized by axial drainageways (following the basin classification scheme of Tolman 1909, 1937). One of the best sources of supplemental information on physiographic features in the Chihuahua part of the study area is Morrison's (1969) interpretation of photographs taken from the Gemini and Apollo spacecrafts, which was supplemented by limited field reconnaissance in the Ascención - Laguna los Moscos area. Another source is the report by Hawley (1969) that is based on a reconnaissance soil survey and geomorphic investigation of northwestern Chihuahua conducted by the Secretaria de Recursos Hidraulicos in cooperation with the U.S. Soil Conservation Service (Flores 1970). The basin system includes the Upper Hachita and Wamel-Moscos (*open* and *drained*) subbasins in New Mexico, and the *closed* and *partly drained* Lower Hachita Subbasin in Mexico. The latter area receives surface runoff and subsurface drainage from the Upper Hachita and Wamel-Moscos subbasins. Much of the southeastern part of the basin system is a broad bolson floor occupied by the ephemeral-lake plain of Laguna los Moscos, relict lacustrine features of pluvial Lake Hachita, and an abandoned fan-delta complex of the Rio Casas Grandes (Figures 3-1, 3-2; Table 3-1; Hawley 1993).

Except for its southeastern (underflow-discharge) boundary with the Ascención-Boca Grande segment of the lower Rio Casas Grandes basin, almost all surface-water and groundwater flow boundaries of the Hachita-Moscos Basin system coincide. However, it has long been recognized that the Upper Hachita Subbasin system receives at least a small amount of surface runoff and groundwater underflow from the Lower Playas Subbasin system (Chapter 6). This contribution enters the Hachita Valley through a narrow saddle in the buried bedrock high connecting the Big Hatchet and Little Hatchet uplifts at Hatchet Gap (Schwennesen 1918, Doty 1960, Trauger and Herrick 1962).

The entire western margin of the Hachita-Moscos Basin system has a common boundary with the Playas Basin. From south to north the western border generally follows the crests of the Dog, Alamo Hueco, Big Hatchet, and Little Hatchet mountains, with the (above mentioned) major topographic and geohydrologic break between the latter two ranges at Hatchet Gap. The Big Hatchet range is the only high mountain mass (Big Hatchet Peak elev. 2,573 m, 8,441 ft) along the basin system's perimeter.

A short, very low segment of the Continental Divide forms the northern boundary of the basin system, with the southeastern Lordsburg Subbasin of the Animas Basin system located to the north. To the northeast, the basin system shares a common boundary with the southwestern Mimbres Basin system along the crest of the Cedar Mountain Range. The eastern border is also along the drainage divide between these two basin systems, crossing the Carrizalillo Hills north of the International Boundary and following the crest of Sierra Alta to the south.

The entire southeastern boundary of the Hachita-Moscos system (from Sierra Alta to the area of low hills about 20 km (12 mi) northwest of Ascención) is poorly defined in terms of both surface- and subsurface-flow regimes. Most of the Upper Hachita, Wamel-Moscos, and Lower Hachita (Figures 3-1, 3-2) subbasins are *open* and *drained.* They contribute surface runoff (and groundwater flow) to the playa-lake plain of Laguna los Moscos, which exhibits both *vadose* and *phreatic* characteristics. The southern area (Lower Hachita Subbasin, Figure 3-1) includes a relict fan-delta complex of the ancestral Rio Casas Grandes that occupies much of the basin floor area west of the present river valley and upstream from the Boca Grande bedrock construction. A very low (about 10 m) topographic divide presently separates Rio Casas Grandes Valley from the *closed* Laguna los Moscos depression. This area appears to be part of a local *partly drained* geohydrologic system that can contribute underflow to the Rio Casas Grandes depending on the extent of flooding of Laguna los Moscos.

There are no perennial streams in the Hachita-Moscos Basin system. Major arroyos are not formally named in most topographic maps of the area, but following local usage, they are here named for the subbasins ("Valleys") in which they occur. The longest drainageway, Hachita Draw, extends from near the Continental Divide (about 8 km, 5 mi north of Hachita) down the axis of the "Hachita Valley" to a zone of fan-delta distributaries near the International Boundary. This fan-delta complex in turn grades southeastward toward Laguna los Moscos. The area drained by Hachita Draw is here designated the Upper Hachita Subbasin and is equivalent to the Hachita Valley of Schwennesen (1918) and Trauger and Herrick (1962). It occupies the structural basin (semi-bolson) between the (Little and Big) Hatchet uplift to the west and southwest, and the Apache Hills-Sierra Rica uplift to the northeast. The Upper Hachita Subbasin also receives storm runoff through the topographic saddle at Hatchet Gap from the axial system of draws that head in the Upper (southern) Playas "Valley" (Chapter 6).

The other major axial drainageway is Wamel's Draw, which heads in the northwest-trending structural basin between the Cedar Mountain Range (to the northeast) and the Apache Hills - Sierra Rica uplifts (to the southwest). South of the International Boundary, Wamel's Draw makes an abrupt bend to the south-southwest and continues southward in the "Moscos" structural basin segment between Sierra Rica (west) and Sierra Alta (east). Cerro el Picacho (elev. 2,106m, 6,909 ft) on the crest of Sierra Alta is the second highest peak in the basin system. The combined Wamel "valley" and "Moscos" basin segments form the Wamel-Moscos Subbasin of this report (Figure 3-1).

Larger ephemeral streams in the southwestern part of the basin system include arroyos heading in the Dog, Alamo Hueco, and southern Big Hatchet mountains (e.g., Horse, Sycamore, Cottonwood, Emory, and South Sheridan canyons). The two major canyons in the northeastern Big Hatchet Mountains, Thompson and Sheridan, are the source areas for large alluvial fans that comprise much of the Gila Group basin fill in the southern part of the Upper Hachita Subbasin (southwestern part of the "central Hachita Valley" of Trauger and Herrick 1962).

Land Use

Land use/landcover in the Hachita-Moscos Basin system is predominantly rangeland with some barren and playa areas (Figure 5-1). The only urban area is the village of Hachita, and there is no cropland in the basin. Water use is not reported for the area, but consists primarily of domestic wells and livestock water supplied by windmills (see Table 3-3).

Climate

The only climate station in the Hachita-Moscos Basin is located at Hachita in the northern portion, which is representative of the basin. This basin is arid with mostly clear skies and limited rainfall and humidity. Average annual precipitation is reported at 25.2 cm (9.93 in), with most occurring as thunderstorms from July through September. Snow depths average 11.5 cm (4.54 in) (NCDC 1999).

Large diurnal changes in temperature are common with the average mean air temperature at Hachita for the period 1948-1995 reported at 15.6° C (60.1° F). Average minimum temperatures were 6.3° C (43.4° F) and average maximum temperatures were 25° C (77° F).

Pan evaporation records are not available for the Hachita station, but comparable information is available from nearby stations in the Mimbres (Chapter 4) and Animas (Chapter 7) Basin systems.

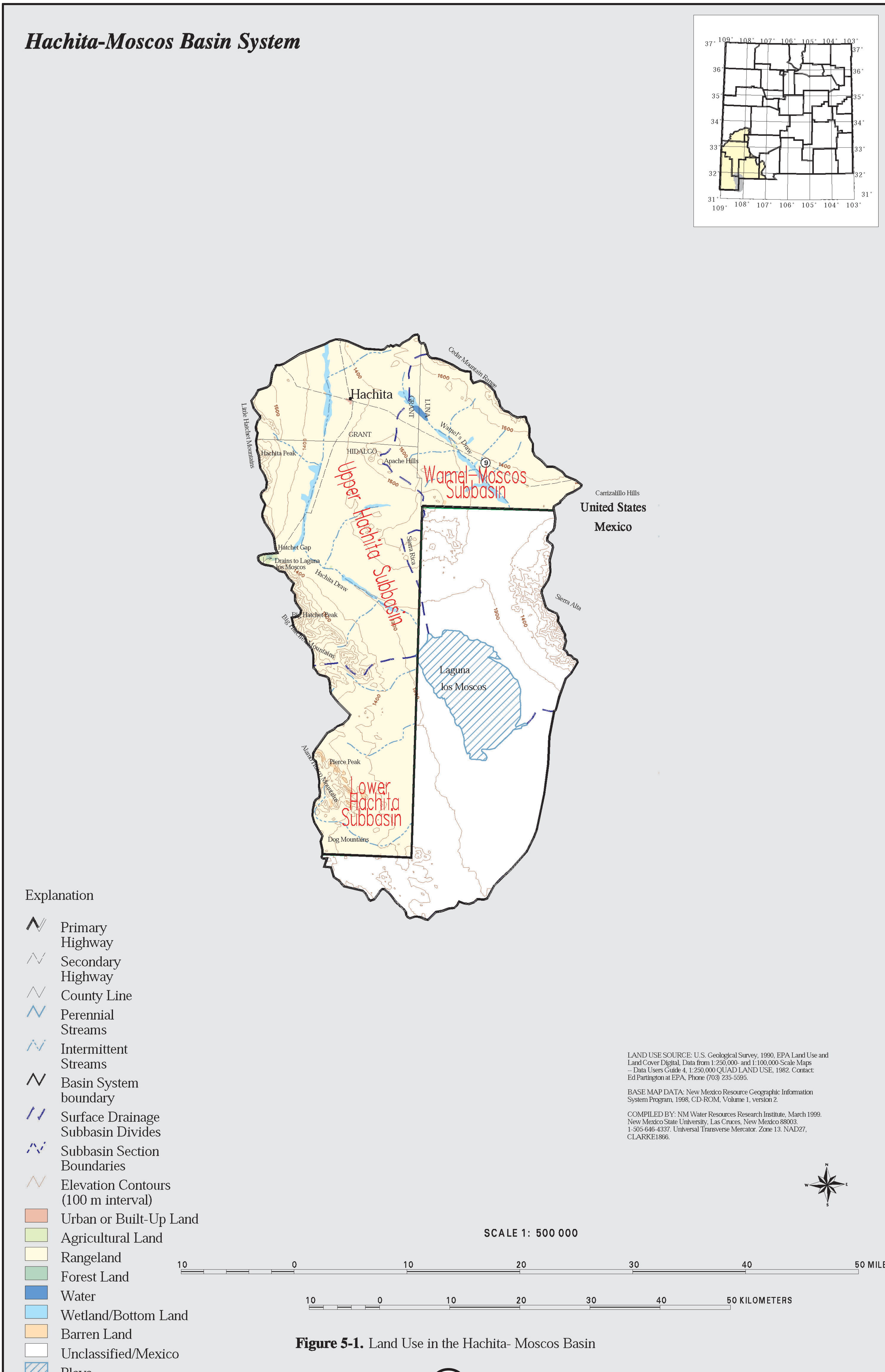


Figure 5-1. Land Use in the Hachita- Moscos Basin

HYDROGEOLOGIC FRAMEWORK

Introduction

In terms of deep crustal structure, the entire Hachita-Moscos Basin system is in the southern Basin and Range tectonic province. As noted in Chapter 4, however, province-scale tectonic features have little effect on the groundwater-flow system that is the primary focus of this report. Emphasis here will be on the hydrogeologic setting of individual basins and ranges at relatively shallow depths (above mean sea level) and how geologic features at this scale influence flow in the basin-fill aquifer system. This approach requires proper identification of (1) structural and (bedrock) lithologic boundaries and (2) hydrostratigraphic and lithofacies composition in order to provide a sound basis for compiling the basic hydrogeologic framework of individual basin systems and their subbasin components.

The major published sources of geologic information on the setting of the Hachita-Moscos Basin system are a series of maps and reports by Bromfield and Wrucke (1961) and Zeller (1958, 1959, 1970, 1975), with supplemental geological and geophysical interpretations of deep-subsurface conditions by Thompson (1982), Corbitt (1988), DeAngelo and Keller (1988), and Klein (1995). Geologic and geohydrologic information on the basin-system area in Mexico was compiled from DGGTN (nd, a, b) maps of the Agua Prieta and Ciudad Juárez (1° x 2°sheets). In addition, the reconnaissance work on basin-fill deposits in the Hachita-Moscos area by Schwennesen (1918), Doty (1960), Trauger and Doty (1965), Morrison (1969), and Trauger (1972) has provided an excellent base for development of the conceptual models of basin-fill aquifers and groundwater-flow systems presented here (Figure 5-2; Plate 9, Sections EE' and FF). However, most of the synthesis and interpretation of information on the Late Cenozoic history and hydrogeologic setting has been done specifically for this study by J.W. Hawley.

Structural Boundary and Bedrock Components

The major geologic features of the Hachita-Moscos basin system are first considered in terms of basin-boundary conditions and partitioning effects in intra-basin areas. The longitudinal profile on Figure 5-2 illustrates the relationship between structure and hydrostratigraphy along the dominant groundwater-flow path down the central part of the system (from the Continental Divide to Laguna los Moscos). The combination of hydrogeologic cross sections (EE', FF', and GG') and the surface distribution patterns of faults and basin-fill units (Plate 1), allow placement of reasonable limits on estimates of aquifer (hydraulic) characteristics and models of groundwater-flow behavior.

As already noted, there are three major subbasins that form the Hachita-Moscos Basin system (Figure 3-1): (1) the Upper Hachita Subbasin; (2) the Wamel-Moscos Subbasin; and (3) the Lower Hachita Subbasin. All three converge at the local *sink* formed by the *partly drained*, *closed* depression occupied by Laguna los Moscos (a partly ? *phreatic playa*).

The mountain uplifts bordering and separating the three subbasins are structurally and lithologically very complex. Interpretations of fundamental structural style vary significantly among the geologists who have worked in the area during the past few decades (cf. Corbitt 1988, Clemons and Mack 1988). The schematic cross sections of basin-bounding bedrock terranes compiled for this report (Plate 1, Figure 5-2) are definitely not designed to portray accurately aspects of structural geology that predate the Neogene interval of crustal extension, which produced the present regional Basin and Range tectonic features. The distribution of major rock types, however, is accurately presented for most upland areas of the basin system in the New Mexico part of the study area. Basic information on bedrock composition of upland areas in Chihuahua (DGGTN, nd, Ciudad Juárez and Agua Prieta 1° x 2° sheets) also appears to be adequate, since the primary emphasis of this report is on basin-fill aquifer systems in New Mexico.

The Alamo Hueco and Dog mountains along the southwestern boundary of the basin system (sections FF' and GG', Plate 1) are mainly composed of Tertiary silicic to basaltic volcanics, lower Tertiary conglomerates, and a variety of Cretaceous sedimentary rocks. East to northeast-tilted fault blocks are the major Basin and Range structures. Dominant rock types in the Big Hatchet Mountains are Upper Paleozoic limestone, shale and sandstone, with local exposures of lower Paleozoic carbonate rocks and sandstone, and underlying Precambrian granite at the northern end of the range. The Big Hatchet Mountains is a high-standing horst block that forms the footwall of a major (buried) fault zone at the southwestern margin of the Upper Hachita Subbasin. The asymmetrical (southwest- to west-tilted) Hachita half-graben depression ascends northeastward to form the southwestern flank of Sierra Rica and Apache Hills uplift (Trauger and Herrick 1962, Figure 2). These highlands are composed of Paleozoic and Mesozoic sedimentary rocks (limestone, sandstone, and shale), and a variety of silicic to intermediate igneous intrusive and volcanic rocks of Early to Middle Tertiary age (section EE').

North of Hatchet Gap, the Little Hatchet Mountains are a continuation of the Big Hatchet structural high. These ranges form a tectonic feature that is here referred to as the Hatchet uplift. The Hachita Valley fault (Lawton and Harrington 1998, Machette et al.1998, no. 2141) forms the western boundary of the Upper Hachita Subbasin (section EE'). This fault, which off-sets Lower to Middle Pleistocene piedmont deposits, is here mapped as a continuation of the Big Hatchet boundary zone originally recognized by Schwennesen (1918, Figure 17). Mudstone, limestone, and volcanic rocks of Cretaceous age, and Lower to Middle Tertiary igneous-intrusive rocks are major lithologic units exposed in this range. The eastern margin of the subbasin north of Sierra Rica includes the Apache Hills, a major Middle Tertiary Volcanic center composed of silicic to intermediate tuffs and flows, and the western end of Wamel-Moscos Subbasin and the Cedar Mountain Range (Figure 5-1, 5-2).

About 5 km (3 mi) east of the village of Hachita, an Upper Miocene basalt flow caps conglomeratic sandstone and mudstone of the Lower to Middle Gila Group in a broad saddle connecting the Upper Hachita Subbasin and Wamel "Valley" area of the Wamel-Moscos Subbasin. The latter structural depression is a southeast-trending half-graben that is downfaulted against (and tilted northeastward toward) the Cedar Mountain Range (Bromfield and Wrucke 1961). The Cedar Mountain uplift is capped by Middle Tertiary basaltic andesite flows that overlap a variety of intermediate to silicic volcanics, including both lava and pyroclastic (tuff) units.

In the International Boundary "corner" area southeast of the Apache Hills, Cretaceous and Paleozoic sedimentary rocks are exposed in the bedrock uplands that merge southward with the Sierra Rica uplift (section EE'). To the east of Sierra Rica, the southern Wamel-Moscos Subbasin has a north-south trend. Sierra Alta forms the eastern boundary of the subbasin and is primarily composed of Upper (?) Paleozoic sedimentary rocks (sandstone, shale, and limestone). A small fan delta at the southern end of the Wamel-Moscos Subbasin merges with the ephemeral-lake plain of Laguna los Moscos and the fan-delta complex at the end of Hachita Draw.

Basin-Fill Aquifer System

Major Hydrostratigraphic Subdivisions

Lithostratigraphic units in the Hachita-Moscos Basin system range in age from Precambrian to Quaternary (Plate 1, Figure 5-2). However, Neogene basin fill forms the only important aquifer system. Neogene and Quaternary deposits are here subdivided into the major hydrostratigraphic-unit classes defined in Chapter 3 (Figure 3-5, Tables 3-2, 3-3). Previous workers have lumped much of this material into an undivided "older alluvium and valley fill" unit or Gila "conglomerate." In this basin system, the terms "valley fill" and "basin fill" are commonly used interchangeably, and "younger alluvium and valley fill" usually refers to Upper Quaternary deposits in major draws and arroyo channels.

In the Hachita-Moscos Basin system, all intermontane basin fills of Early Miocene to Middle Pleistocene age are included in the Gila Group lithostratigraphic unit. Informal "upper" and "lower" formation-rank subdivisions are recognized that have the same basic lithologic characteristics as the (primarily unconsolidated and undeformed) "upper" and (partly indurated and structurally deformed) "lower" Gila lithostratigraphic units described in Chapter 4. Maximum estimated thickness of basin-fill "alluvium" reported by Trauger and Herrick (1962, Figure 2) in the southern part of the Upper Hachita Subbasin (hanging-wall side of half-graben adjacent to the Big Hatchet Mountains) is about 520 m (1,700 ft). Preliminary interpretations of geophysical data in transects along the International Boundary that cross the middle part of the Wamel-Moscos Subbasin (Heywood 1992, Klein 1995) suggest that maximum basin fill thickness may be about 900 m (2,950 ft) in that area (Section EE', Plate 9). It should be noted here, however, that almost all of this fill comprises Middle and Lower Gila Hydrostratigraphic Units (discussed below) that are partly indurated, commonly medium to coarse-grained, and (at least locally) structurally deformed.

As has been previously emphasized, the hydrostratigraphic-unit (HSU) classification introduced in this report (including HSUs: LG, MLG, MG, UG) provides a logical mechanism for subdividing the basin fill into mappable units that are primarily defined in terms of stratigraphic position, depositional environment, and lithologic properties (cf. lithofacies assemblages) that directly relate to aquifer behavior. Since subbasins (Upper Hachita and Wamel-Moscos) in the New Mexico part of the study area are half grabens with through-going axial drainage (*open* and *drained* groundwater-flow systems, Figure 3-2) basin-floor hydrostratigraphic units UG2 and MG2 mainly consist of medium to coarse-grained fluvial sediments.

The second important class of hydrostratigraphic units in the basin system comprises (1) surficial alluvium in major drainageways (draws, arroyos, canyon floors) and (2) finer grained sediments on basin and valley floors characterized by restricted surface-flow regimes (playa, lake, alluvial-flat, and cienega deposits). Where saturated, these deposits are important components of the geohydrologic system in terms of groundwater recharge, movement and discharge (units AA, BA, LL and LP).

Major Lithofacies Assemblages

Lithofacies assemblages described in Chapter 3 (Figure 3-6, Tables 3-4 to 3-6) are the basic building blocks of the individual hydrostratigraphic units (HSUs) that form the framework of the basin-fill aquifer system. The explanation of Plate 1 provides a key to the lithofacies composition of the major hydrostratigraphic units that are schematically depicted on hydrogeologic maps and sections in this report (Plate 1 and Figure 5-2, sections EE' - HH'). For example, the dominant lithofacies assemblages (*7* and *8*) of the Upper Hachita and Wamel-Moscos basin-fill subbasins are conglomeratic sandstones and mudstones (older piedmont facies) that are the major components of HSUs: MGl, MGlc, MLG, and LG. Considering the probabilities that these subbasins have had axial drainage for much of Neogene time, there should also be a significant amount of conglomeratic sandstone (coarse-grained subfacies of assemblage *4*) and interbedded (partly indurated) sand and silt-clay (facies *3*) of hydrostratigraphic units MG2 and MLG. Where present, these units would have been deposited by ancient fluvial systems that flowed into the Lower Hachita Subbasin. Overlying Upper Gila piedmont deposits (HSUs: UGl, UGlc; primarily facies *5* and *6*), are here a very minor component of the aquifer system, because they are usually above the water table. However, axial stream deposits (facies *1-3*) in unit UG2 may be present near the top of the saturated zone.

Basin-floor and distal piedmont-slope facies assemblages (*1-4, 5, 7, 9, 10*) appear to dominate most of the Gila Group sequence in the Lower Hachita Subbasin, and as well in the southernmost parts of the Upper Hachita and Wamel-Moscos subbasins. Major hydrostratigraphic units in this area include: UG-2 and MG2, and parts of units UGl, MGl, MLG and LG. Fluvial sand and interbedded silt and clay deposited by the ancestral Rio Casas Grandes system south of Laguna los Moscos (units UG2 and MG2, facies *1-4*), and fine-grained lake and playa sediments (units UG2 and MG2, facies *8* and *9*) are probably the major basin-fill component in the basin-floor area of the Lower Hachita Subbasin. Eolian sand and silt (facies *2-4*) may or may not be a significant component of the basin-fill aquifer system in that area. In any case, the water-quality data presented in the final section of this chapter indicate that fresh water resources may be limited in the east-central part of the basin system.

Hydraulic Properties of Major Aquifer System Components

Published information on hydraulic properties of the basin-fill aquifer units in the Hachita-Moscos Basin system is very limited, however, general overviews of aquifer performance with some specific data on individual wells are provided in reports by Schwennesen (1918), Trauger and Doty (1965), and Wilkins (1986). Information in Table 1 of Trauger and Herrick (1962) allows very approximate calculations of specific capacity values for three test holes in the southern part of the Upper Hachita Subbasin. These values of about 3.6 x 10^3 $m^3/d/m$ (0.2 gpm/ft), 18 $m^3/d/m$ (1 gpm/ft), and 180 $m^3/d/m$ (10 gpm/ft), are based solely on data from short-term pumping tests of wells that only penetrated the upper part of the saturated zone. The well with the highest specific capacity is located in the lower valley of Hachita Draw and penetrates about 120 m (400 ft) of saturated basin-fill (probably HSU: UG2, facies *3*). The other two test-well sites (T-1 and T-2, Figure 2, Trauger and Herrick 1962) are on the alluvial fan of Thompson Canyon in a piedmont area that overlies the deepest part of the Upper Hachita Subbasin half graben. These wells penetrate less than 45 m (150 ft) of saturated piedmont-slope deposits that are partly cemented with secondary carbonate (pedogenic and/or nonpedogenic calcrete), and they are probably completed in HSU: MGlc (facies *6* and *8*).

General observations made in Chapter 4 on basin-fill hydraulic properties also pertain to this basin system, but upper parts of the basin-fill sequence present in the central Mimbres Basin system (e.g., UG2 units represented in the upper part of Figure 4-3) are thin or absent in most of the Hachita-Moscos Basin system in New Mexico. Moreover, in the Wamel-Moscos Subbasin (Plate 9, EE'), most of the basin fill comprises conglomerate sandstones and mudstones of the Lower and Middle Gila hydrostratigraphic units (MG1, MLG, LG). Upper Gila hydrostratigraphic units are present in the Lower Hachita Subbasin, but here they are mostly represented by fine-grained basin-floor facies (*3, 9, 10*) except in the area between Ascención and Laguna los Moscos where coarser grained fan-delta deposits (facies *1-3*) of the ancestral Rio Casas Grandes may be present. One part of the Lower Hachita Subbasin in New Mexico that does deserve more attention is the southeastern piedmont slope of the Alamo Hueco Mountains. This area may have some potential for future groundwater development because of local presence of coarse-grained facies assemblages (*5-7*) and increased chance for mountain-front recharge.

Water quality problems (see water quality section) and general absence of high yield aquifers will probably limit any pumping stress on the Hachita-Moscos Basin aquifer system that could produce significant amounts of basin-fill consolidation and land-surface subsidence.

With respect to hydraulic properties of bedrock units, cavernous zones are locally present in carbonate rocks of Cretaceous and Late Paleozoic age that are well exposed in highlands of the Hachita-Moscos Basin system. There is no evidence, however, that these features form important bedrock-aquifer zones either in uplands or beneath basin fills. In other basin systems of the study area, porous and/or fractured volcanic rocks such as basaltic andesite flows, silicic lavas, and ash-flow tuffs (welded to poorly welded) are also reported to be important local groundwater reservoirs. However, in this basin system, bedrock units and basin-bounding structures (mainly faults) primarily act as barriers to, rather than conduits, for groundwater flow.

MAJOR COMPONENTS OF THE GROUND-WATER FLOW SYSTEM

Surface-Water Components

Surface flow in the Hachita-Moscos Basin system has two components that directly interface with groundwater flow: (1) ephemeral streams in arroyos and draws, and (2) widely scattered springs and seeps in higher upland areas. The major draws and arroyos are briefly described in the section on physiographic setting. The two major axial drainage ways in the basin system are Hachita Draw in the Upper Hachita Subbasin and Wamel's Draw in the Wamel-Moscos Subbasin. These streams are clearly ephemeral because reported depths to groundwater in the immediate vicinity of axial drainageways commonly range from 15 to 91 m (50-300 ft.) (Schwennesen 1918, Trauger and Herrick 1962, Table 2; Trauger and Doty 1965, p. 215).

Topographic maps and other historical documents covering parts of the Hachita-Moscos Basin system show a number of springs (seeps?) in mountain valleys of the area. However, these surface-water features have not been described in terms of detailed flow or water-quality measurements. The following comment by Hanson and others (1994, p. 20) related to the Mimbres Basin system also applies to this area: "Most springs discharge from fractured bedrock in the mountainous areas of the basin, or represent underflow in alluvial channels that is forced to the surface by shallow bedrock . . ." In the context of basin-fill groundwater-flow, nearly all springs and seeps in the upland parts of the basin system are here considered to be components of "mountain-front-recharge" because at least some of their discharge ultimately contributes to the basin-fill groundwater reservoir (cf. Figure 3-3). Any springs that might act as drains to this reservoir would be restricted to the lowest parts of the groundwater flow system in the Laguna los Moscos and Rio Casas Grandes Valley area.

Recharge

As is the case for all basin-fill aquifers in this arid to semiarid region, only a small percentage of basinwide precipitation and surface runoff contributes to groundwater recharge. Considering the absence of extensive mountain areas above 1,800 m (6,000 ft) in the Hachita-Moscos Basin system, and the widespread cover of desert scrub and semiarid grassland, most of the average annual precipitation of about 30 cm (12 in) is lost to evapotranspiration. It is here assumed that (1) higher parts of the basin system that drain to the broad bolson plain surrounding Laguna los Moscos (primarily a discharge area) have a surface area of about 2,000 km^2 (770 mi^2); (2) this area receives 6 x 10^8 m^3 (486,000 ac-ft) of unevenly distributed annual precipitation of about 30 cm (12 in); and (3) one percent of this precipitation (6 x 10^6 m^3; 4,860 ac-ft) contributes to groundwater recharge. This is clearly an "estimate," but the values are supported by geohydrologic investigations in all the other basins of the study area (cf Chapters 4, 6-9).

The mountain-front-recharge component would, of course, vary considerably from place to place. However, it should be a significant contributor to the groundwater reservoir in basins adjacent to the major fault-block uplifts with substantial watershed areas above 1,800 m (6,000 ft). These areas include parts of the Big and Little Hatchet ranges, Sierra Alta, and the Alamo Hueco Mountains. Extensive limestone terranes of the Hatchet uplift, with higher than normal occurrence of solution-enlarged fracture zones (including local cavernous porosity), may effectively capture runoff from intense-precipitation events. These fracture zones could then directly transfer water through the mountain mass to the buried part of the range front where recharge to the contiguous basin-fill aquifer system could take place (cf Figure 3-3). In direct contrast, highlands primarily composed of igneous intrusive and volcanic rocks would provide a relatively impermeable "floor" to mountain-valley fills. This barrier would in turn reject much of the downward percolating snow-melt in storm-runoff water and force it back to the surface as seeps and springs. The Alamo Hueco-Dog Mountain uplift is an example of this type of local recharge system. These uplands also appear to be an area where much of the surface and shallow subsurface flow is directly consumed by riparian vegetation (as suggested by the place names: Cottonwood Canyon and Sycamore Canyon).

The other significant source of recharge in the Hachita-Moscos Basin system is water percolating through thinner parts of the vadose zone beneath the empheral-stream channels of the system's two major axial drainageways: Hachita Draw and Wamel's Draw. This component is termed "tributary recharge" by Kernodle (1992a) as distinct from "mountain-front-recharge." Since the lower reach of the Hachita Draw receives some floodwater runoff from the Upper Playas "Valley" through Hatchet Gap (Schwennesen 1918), this may be a particularly important recharge area.

The broad piedmont slopes separating range fronts from axial stream valleys and alluvial flats are not considered to be significant places for recharge (Trauger and Herrick 1962). The water table in these areas is commonly very deep, locally exceeding 90 m (300 ft); the component coalescent alluvial-fan deposits (Gila Group: UGl/MGl/MLG; facies assemblages *5-9*) are very poorly sorted and partly indurated (mostly carbonate cements); and vegetative cover of desert scrub and semiarid-zone grasses are very effective in capturing most of the annual precipitation. However, major flood runoff events from the Thompson and Sheridan canyon watersheds in the Big Hatchet Mountains could occasionally also contribute surface flow to the lower reach of Hachita Draw.

As already noted, previous investigations (Schwennesen 1918, Doty 1960, Trauger and Herrick 1962) have documented the presence of a narrow topographic saddle and shallowly buried bedrock "sill" between the Big Hatchet and Little Hatchet mountains that allows small amounts of surface flow and groundwater underflow from the Upper (southern) Playas Subbasin system to "spill" through Hatchet Gap into the Upper Hachita Subbasin (Schwennesen 1918, Figure 17). This feature is located about 1 km (0.6 mi) south of the pass between the Hachita and Playas subbasins crossed by NM Highway 81 (Figure 5-1). A rough (D'Arcy-Law-based) calculation suggests that no more than 8,500 m^3/yr (7 ac-ft/yr) of underflow from the Upper Playas Subbasin aquifer recharges to the groundwater reservoir in the Upper Hachita Subbasin. This calculation assumes that (1) the width of saturated valley fill (facies *6*) in the bedrock constriction is about 750 m (2,500 ft), (2) its thickness is about 10 m (33 ft), (3) hydraulic conductivity is about 3 m/day (10 ft/day), and (4) the hydraulic gradient is about 0.001. Even if this amount is doubled or tripled, it is a tiny recharge contribution to the groundwater-flow system in the Upper Hachita Subbasin.

Movement and Discharge

Since there has never been any significant effort to develop groundwater resources in this basin system, groundwater movement and discharge have remained essentially at a "predevelopment" state. However, the local history of attempts to locate water supplies for a variety of uses (including mining operations, irrigation agriculture, ranch operations, and the former route of the Southern Pacific Railroad through Wamel Valley and Hachita) all suggest that substantial supplies of economically recoverable groundwater are simply not present (cf. Darton 1916, 1933, Schwennesen 1918, Trauger and Doty 1965, Trauger 1972, Wilkins 1986).

Groundwater-flow direction in the Hachita-Moscos Basin system has been described by Trauger and Herrick (1962) and Schwennesen (1918). Flow is generally from the northern and western highlands and through the Upper Hachita and Wamel-Moscos subbasins, which in turn discharge southward toward the Mexico border (Figure 5-3). In a very subdued manner, the shape of the potentiometric surface (water table approximation) mimics the surface topography and shows that the regional sink for groundwater flow is in the Laguna los Moscos-Rio Casas Grandes Valley area. Isolated interior mountains and buried structural features locally modify the regional flow pattern by adding minor amounts of recharge and altering the width and depth of the basin-fill aquifer system.

CONCEPTUAL MODEL OF GROUNDWATER FLOW

The conceptual model of groundwater flow in the Hachita-Moscos Basin aquifer system is here examined in the context of the hydrogeologic constraints placed on the flow regime by structural-boundary, hydrostratigraphic, and lithofacies conditions, which are either well documented or reasonably inferred. The interpretations of relevant information presented in this section are graphically illustrated or tabulated on Plate 1, Figures 5-2 and 5-3, and Tables 3-2 to 3-6. Kernodle's (1992a) basic guidelines for development of "U.S. Geological Survey Ground-Water-Flow Models of Basin-Fill Aquifers in the Southwestern Alluvial Basin Region . . . " provide a template for the conceptual model of groundwater flow described in this section and have been discussed at length in Chapter 4.

As is the case in all of the basin systems described in this report, with the exception of the two completely *open* systems (Upper Gila and San Bernardino) that ultimately drain to the Gulf of California, the Hachita-Moscos Basin is part of a *closed* and *partly drained* groundwater-flow system (Figure 3-2). Basin-fill hydrostratigraphic units in the saturated (phreatic) zone include (1) older fan alluvium on piedmont slopes of upper basin areas, (2) fluvial deposits of through flowing ancestral streams that occupied the floors of the Upper Hachita and Wamel-Moscos subbasins, and (3) widespread basin-floor deposits at the lower end of the system (Lower Hachita Subbasin and Laguna los Moscos depression) that generally comprise a complex of fan-delta, lake, playa, and eolian sediments. Except for the latter area, Upper Gila Hydrostratigraphic Units (UG1-2) are only partly saturated, and the dominant aquifer system comprises Middle to Lower Gila Group hydrostratigraphic units (MG1-2, MLG). As already noted, the few specific reports on aquifer properties indicate that most basin-fill units have limited capacity for groundwater production, and estimates of the available water of good quality are speculative at best.

Even though saturated thickness of the basin-fill aquifer system is as much as 900 m (3,000 ft) in a few areas (based on geophysical-survey interpretations), the thickness of productive aquifer zones rarely exceeds 100 m (330 ft). Much of the basin-fill is partly indurated and very well consolidated. This material has low porosity and permeability and comprises Neogene subdivisions of the Middle to Lower Gila Group. A very "liberal" estimate of available groundwater stored in the upper part of the basin-fill sequence that forms the most productive portion of the aquifer system is about 6 x 10^9 m^3 (6 km^3; 4.86 x 10^6 ac-ft.). This estimate assumes an aquifer surface area of about 6 x 10^8 m^2 (6 x 10^2 km^2; 1.48 x 10^5 acres), an average saturated thickness of 100 m (330 ft), and a specific yield of 0.1.

Even though site-specific information is lacking on subsurface geologic and hydrologic conditions in most of the Hachita-Moscos Basin system, a reasonable conceptual model of groundwater flow in the basin-fill aquifer system can be constructed on the basis of (1) hydrogeologic maps and cross sections (Plate 1, Figure 5-2), and (2) supporting interpretations of hydrostratigraphic units and lithofacies assemblages in terms of their geohydrologic behavior (Plate 1 explanation, Tables 3-4 to 3-6). East-west sections EE', FF' and GG' that are roughly normal to the axes of the three subbasin components of the system. Sections EE' and FF' cross the major axial drainageways (Hachita and Wamel's Draw) of the Upper Hachita and Wamel-Moscos subbasins and illustrate the half-graben and semibolson (structural and physiographic) framework of these *open* and *drained* subbasins (Figure 3-2).

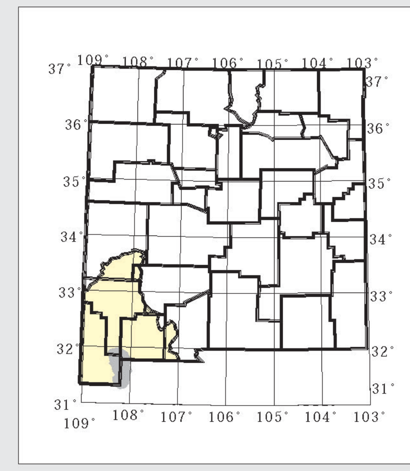
Longitudinal section HH'(Figure 5-2) closely follows the course of Hachita Draw from the Continental Divide to Laguna los Moscos, and it approximates the principle line of groundwater flow in the Upper Hatchita Subbasin. Since this section parallels the dominant (N-S, NW-SE) structural grain of the arcuate (hanging wall) half graben that is tilted toward the Hatchet (footwall) uplift, no major faults are crossed except in the Hachita area. There, an inferred northwest-trending, down-to-the-south fault crosses the subbasin about 5 km (3 mi) south of Hachita. Upper Gila Group deposits are thin or absent north of this fault in the northern parts of the Hachita and Wamel-Moscos subbasins (Plate 1, Figure 5-2). To the south, total thickness of Gila Group Hydrostratigraphic Units (UG and MLG) along the line of section HH' ranges from 200 to 300 m (660-1,000 ft), with no more than 100 m (330 ft) of Upper Gila Hydrostratigraphic Units (UG1 and UG2) being present. The unsaturated valley fill alluvium of Middle (?) to Late Quaternary age that caps the Gila Group near Hachita Draw (HSUs: AA, facies *a* and *b*) is probably no more than 20 m (65 ft) thick.

The thinning of basin-fill units near the section HH' – EE' junction is an artifact of section (HH') placement near the position of Hachita Draw, which rarely coincides with the deepest part of the Upper Hachita half-graben system. As previously mentioned, maximum basin-fill thickness, probably exceeding 500 m (1,650 ft), is inferred to be near the frontal-fault zone of the Hatchet uplift. This major Basin and Range structure separates the (hanging wall) Upper Hachita Subbasin block from the (footwall) Big Hatchet Mountains block (Plate 1, Section EE'; and Trauger and Herrick 1962, Figure 3).

In the general area that is crossed by the north-south segment of the International Boundary, the potentiometric surface approaches the land surface (Figure 5-3). This area is near the lower end of the Upper Hachita Subbasin where it merges with the floor of the Los Moscos *closed* depression, and several flowing wells and springs are reported on both sides of the border (Schwennesen 1918, Trauger and Herrick 1962). Characteristics of basin boundaries and aquifer (geohydrologic) components across a basin-fill section between the (Big) Hatchet and Sierra Rica uplifts place the following limits on a very preliminary estimate of about 1.1 x 10^6 m^3 / yr (890 ac-ft/yr) for transboundary-groundwater flow at the lower end of the Upper Hachita Subbasin:

1. Cross-section area of saturated basin fill is about 3 x 10^6 m^2 (3.3 x 10^7 ft^2), assuming a width of 10 km (33,000 ft)

Hachita-Moscos Basin System



GEOLOGY SOURCE:

Geologic data for the United States were transcribed from:

Seager, 1995; Seager, et al, 1982; Clemons, 1976; Clemons, 1977; Clemons, 1979; Clemons, 1981; Clemons and Seager, 1973; Elston, 1967; Hedlund, 1977; Drewes, et al, 1985; Broomfield and Wrucke, 1961; Zeller, 1971.

Geologic, hydrogeologic, and topographic data for Mexico were transcribed from the following published maps:

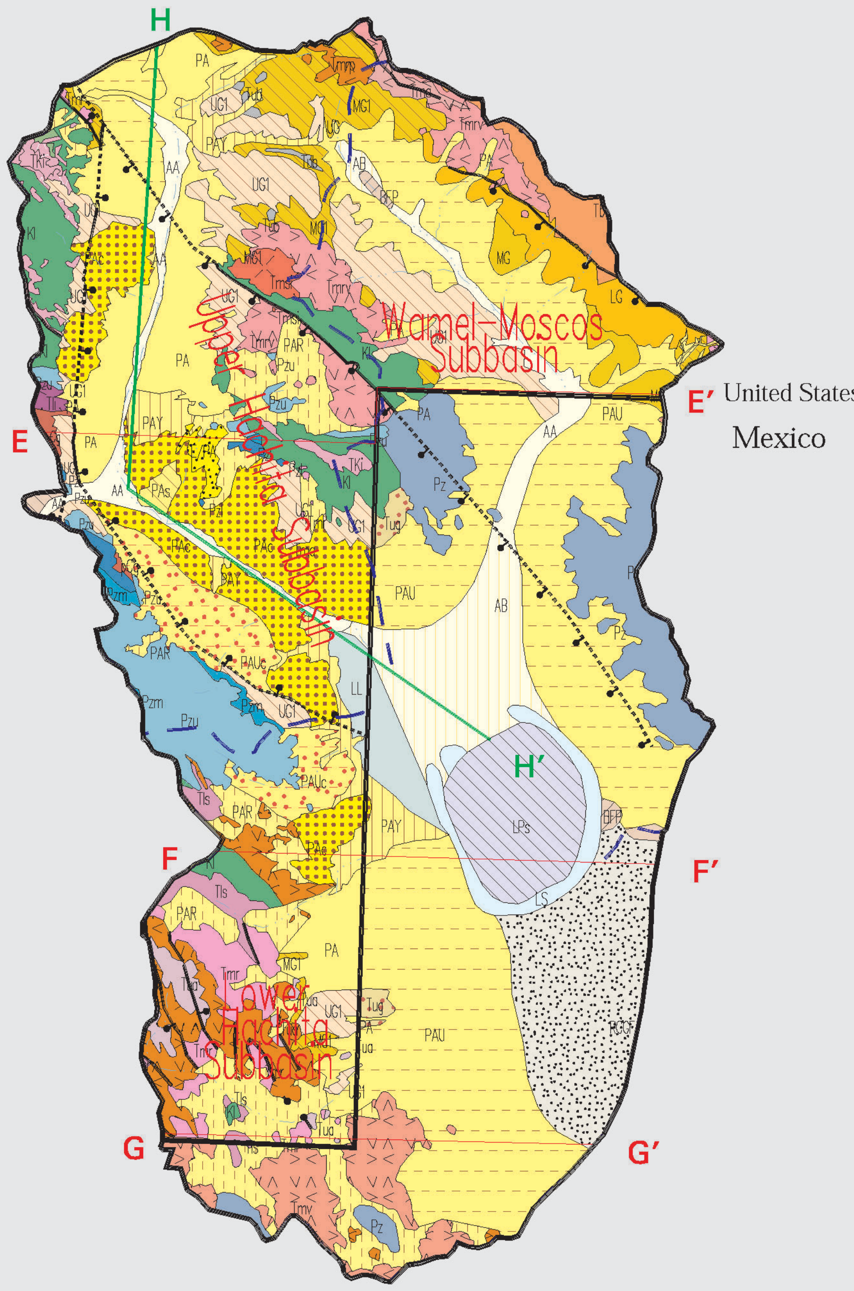
Carta Topografica, Carta Geologica, Carta Hidrologica de Auguas Superficiales, Carta Hidrologica de Auguas Subterraneas.
- Cuidad Juarez H13-1 1:250K
- Agua Prieta H13-4 1:250K

NOTE: Published Mexico data was used in order to improve interpertation of Trans-boundary Aquifers of the United States.

BASE MAP DATA: New Mexico Resource Geographic Information System Program, 1998, CD-ROM, Volume 1, version 2.

COMPILED BY: NM Water Resources Research Institute, March 1999. New Mexico State University, Las Cruces, New Mexico.

DATUM: Universal Transverse Mercator. Zone 13. NAD27, CLARKE1866.



Explanation

Post Gila and Santa Fe Group deposits

Alluvial deposits

AA
AB
AR
AP
AU
VAO
VAY
VA

Eolian deposits

E

Fluvial deposits

RG
RCG
RCG
RCGd
RSB
RMr
RM
RMF
RMFc
RMFf
RA
RAc
RAf
CA
TA

Basin Floor deposits

BF
BFs
BFP
BFY
BFO
LB
LS
LP
LPs
LL
BFU

Piedmont Slope deposits

PA
PAs
PAc
PAY
PAR
PAO
PAU
PAUc

Gila and Santa Fe Group Hydrostratigraphic Units

Upper Gila Group

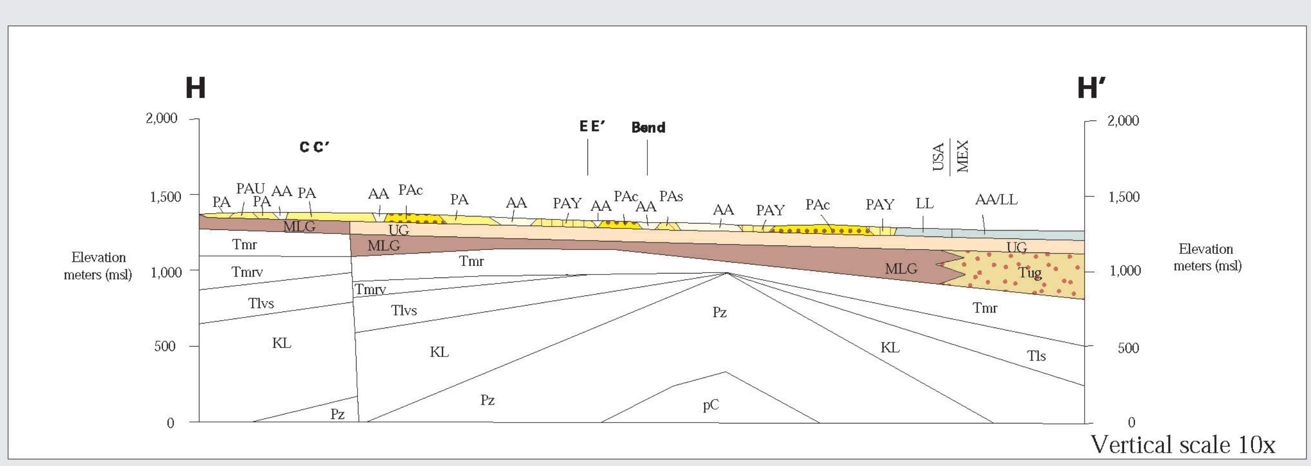
UGL
UG
UG1
UG1c
UG2
UG2r
UG2s
MG
MG2
MG
LG

Upper Santa Fe Group

USL
US1
US1c
US2
US2r
MSF
LSF

Bedrock Units are listed on Plate 1

Profile



UG - Early Pleistocene to late Miocene, Upper Gila HSUs, undivided basin-floor to medial piedmont slope deposits (includes Mimbres Formation); includes facies ***1, 2, 3 and 5*** : upper part in vadose zone

MLG - Middle and Lower Gila undivided HSUs, only on cross-sections

Tug - Upper Tertiary: Gila Group, correlatives mapped only in Mexico

SCALE 1: 500 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 KILOMETERS

Figure 5- 2. Hydrogeologic map and profile of the Hachita- Moscos Basin

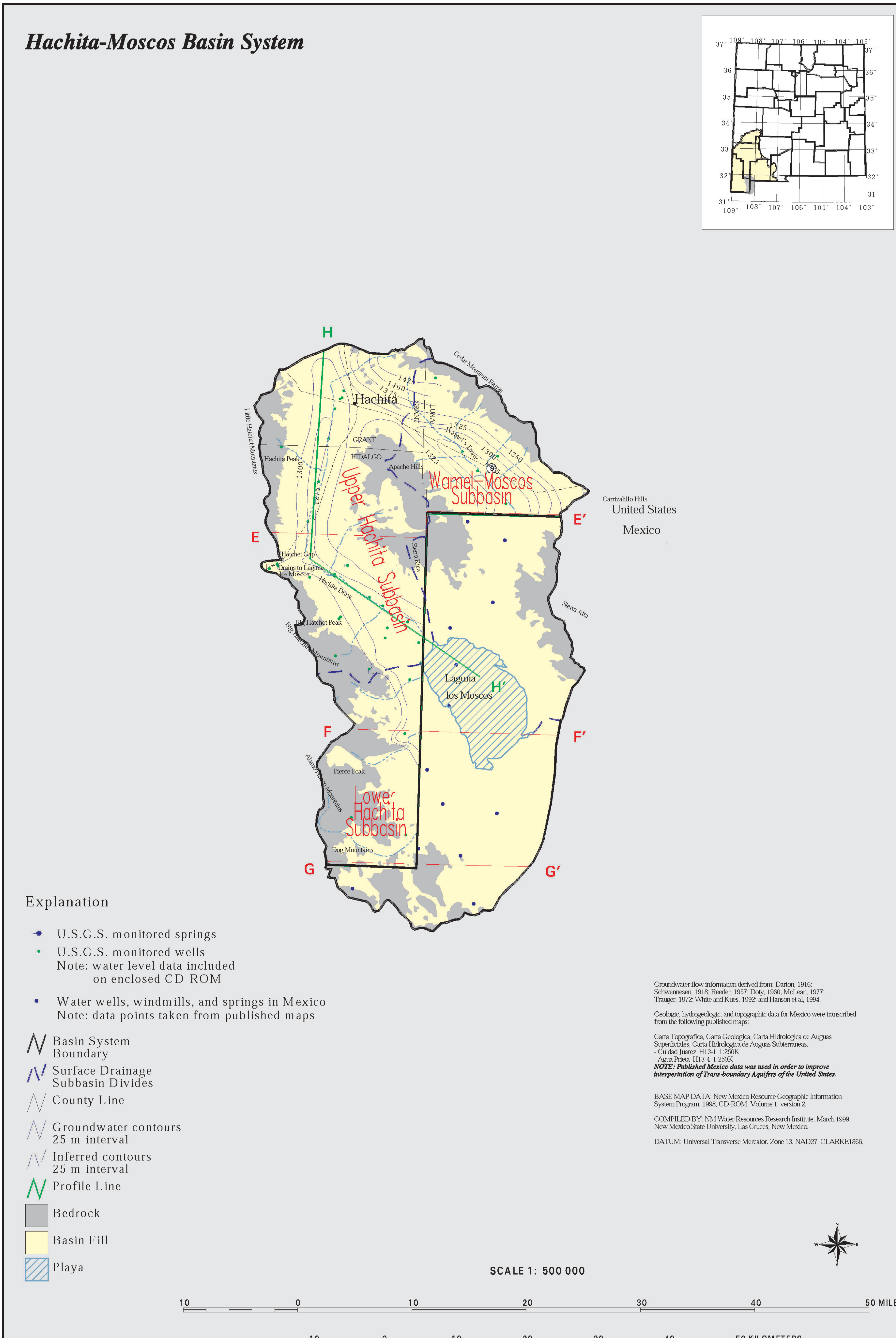


Figure 5-3. Hachita- Moscos groundwater contours, flow direction, and steam- aquifer relationships

and thickness of 300 m (1,000 ft).

2. The hydraulic gradient is 0.001.
3. Average horizontal hydraulic conductivity of combined hydrostratigraphic units UG1 and 2 (<100 m), and MGL (>200 m) is 1 m/day (3.3 ft/day).

The latter assumption derived from information on Plate 1 and Figure 5-2.

In the upstream part of the Upper Hachita Subbasin, where section EE' (Plate 1) crosses longitudinal section HH' (Figure 5-2), rough calculations of the amount of groundwater flowing down the central part of the subbasin provide a check on the flow estimates made at the International Boundary. Limiting assumptions made here are:

1. Width and thickness of saturated fill are 8,000 m (26,250 ft), and 200 m (660 ft), respectively, giving a cross-section area of 1.6 x 10^6 m^2 (1.7 x 10^7 ft^2).
2. Hydraulic gradient is 0.001.
3. Average hydraulic conductivity is 2 m/day (6.6 ft/day) for combined hydrostratigraphic units UG1-2, and MLG (with each being about 100 m; [330 ft] thick).

The calculated flow across section EE' is about 1.2 x 10^6 m^3/yr (970 ac-ft/yr), which is in close agreement with estimated annual transboundary flow of about 1.1 x 10^6 m^3 (890 ac-ft) at the southern end of the Upper Hachita Subbasin.

If annual groundwater-flow across the U.S./Mexico border through the lower part of the Wamel-Moscos Subbasin (also Section EE', Plate 9) is in the same general discharge range as calculated for the Upper Hachita Subbasin, combined transboundary flow through these two (cross-section) areas could reasonably be assumed to be less than 2.5 x 10^6 m^3/yr (2,000 ac-ft/year). However, hydraulic conductivity values for the conglomeratic sandstone and mudstone units (Middle and Lower Gila Group) that form the basin-fill aquifer in Upper Wamel-Moscos Subbasin are probably very low, and this area probably is not a major transboundary contributor even though Gila Group basin fill is very thick. Recalling that total estimated annual recharge for the entire Hachita Basin groundwater system is about 6 x 10^6 m^3 (4,860 ac-ft), all these inflow/outflow estimates appear to be reasonable for a real-world geohydrologic system.

Reports of flowing wells and springs at the western edge of the Los Moscos depression (where it merges with the Upper Hachita Subbasin) support the premise that the floor of Laguna los Moscos could be a *phreatic playa* (Figure 3-2) and that both surface and subsurface flow in the Hachita-Moscos Basin system ultimately discharge to a *closed* and *undrained* basin. Water-quality information, discussed in the next section, also indicates *undrained* conditions in at least part of the playa-lake depression. However, the proximity to the entrenched valley of the Rio Casas Grandes less than 10 km (6 mi) to the east and the lack prominent spring-discharge points along the playa margin indicates that at least some underflow from the regional groundwater-flow system leaves the Lower Hachita-Moscos Basin and contributes to both surface and subsurface flow in the lower Rio Casas Grandes Valley. For this reason, the basin system is classified as *closed* and *partly drained* in this report.

GROUNDWATER QUALITY

General Hydrochemistry

The general water quality information for the Hachita-Moscos Basin system is presented in the regional stiff map (Figure 5-4). Groundwaters in the Upper Hachita Subbasin vary from 250 to 1,000 mg/L TDS. Groundwaters in the U.S. part of the Wamel-Moscos Subbasin are all less than 500 mg/L TDS, with several samples present in concentrations that do not exceed 250 mg/L TDS. Groundwaters in the Mexican part of the Wamel-Moscos Subbasin mostly vary from 250 to 500 mg/L TDS, except for the slightly saline sample represented by the red stiff pattern at the Laguna los Moscos playa (Figure 5-4). Groundwaters in the Lower Hachita Subbasin are highly variable with respect to TDS, ranging from 250 mg/L to over 1,000 mg/L TDS.

Hydrochemical facies in the groundwaters of the Hachita-Moscos Basin are quite variable (Figure 5-4 and 5-5). Groundwaters in the Upper Hachita Subbasin vary from Ca-HCO_3 and Ca-HCO_3-SO_4 type waters to Na-HCO_3 and Na-HCO_3-SO_4 type waters. Groundwaters in the Wamel-Moscos Subbasin are mostly Na-HCO_3 to Na-Ca-HCO_3 type waters. Several groundwaters in the Mexican part of the Wamel-Moscos Subbasin are Na-HCO_3 to Na-Ca-HCO_3 type waters, however, a few samples are of the Na-HCO_3-SO_4 type. Groundwaters in the Lower Hachita Subbasin are the most variable and include Ca-Mg-SO_4, Na-SO_4, Na-HCO_3, Na-HCO_3-SO_4, and Na-Mg-HCO_3 type waters. There are no apparent correlations between hydrochemical facies and TDS in these basins (Figure 5-4).

The anion maps show concentrations of chloride and sulfate in groundwaters in the Hachita-Moscos Basin system (Figures 5-6 and 5-7). Only one analysis exceeds the recommended USEPA drinking water standard of 250 mg/L for chloride (Figure 5-6). Chloride concentrations vary from 25 to 60 mg/L Cl in most of the analyses in the middle and northern portions of the Upper Hachita Subbasin. A few samples that are clustered in the southern part of this basin are less than 25 mg/L Cl. All of the analyses in the U.S. part of the Wamel-Moscos Subbasin are less than 25 mg/L Cl. Most samples in the Mexican part of the Wamel-Moscos Subbasin vary from 25 to 50 mg/L Cl. One exception is the sample collected at the Laguna los Moscos playa, which is 383 mg/L Cl. All of the analyses in the Lower Hachita Subbasin are less than 100 mg/L Cl.

The sulfate map indicates that sulfate exceeds the recommended USEPA drinking water standard of 250 mg/L SO_4 in only 1 of the 23 analyses in the Upper Hachita Subbasin (Figure 5-7). Several analyses, especially in the central and northern portions of the Subbasin, vary from 100 to 250 mg/L SO_4. Most of the samples collected in the southern part of the Upper Hachita Subbasin range from 25 to 100 mg/L SO_4. Samples collected in the U.S. part of the Wamel-Moscos Subbasin are all less than 25 mg/L SO_4. Samples collected in the Mexican part of the Wamel-Moscos Subbasin are usually less than 150 mg/L SO_4, except for the sample collected at the Laguna los Moscos playa, which is 375 mg/L SO_4. Several samples collected in the southernmost part of the Lower Hachita Subbasin exceed 250 mg/L SO_4. Most of the other samples collected in this basin vary from 50 to 250 mg/L SO_4 (Figure 5-7).

Saturation Indices

Saturation indices were computed for a number of groundwater analyses in the U.S. portion of the Hachita-Moscos Basin system (Figure 5-8). These were the only analyses which included both temperature and pH measurements, the index parameters required for computation of saturation indices with the geochemical reaction path model PHREEQC (Parkhurst 1995). The absence of temperature data precluded the use of Mexican data for computation of saturation indices.

PHREEQC analyses indicate that groundwater is typically at equilibrium with respect to calcite in these basins. Groundwater is close to equilibrium with respect to dolomite, although there is a wide range of values for dolomite saturation (Figure 5-8). All groundwaters are moderately undersaturated with respect to gypsum. Waters are greatly undersaturated with respect to halite.

Origin of Solutes

Examination of the Piper diagrams (Figure 5-5) seems to indicate that groundwaters may evolve from mixed-cation rich compositions to sodium rich compositions, and from bicarbonate rich compositions to sulfate rich compositions as groundwater flows from the upper segments of the Upper and Lower Hachita and Wamel-Moscos Subbasins to the discharge areas at the Laguna los Moscos playa. These are not a correct set of evolutionary processes because these processes would require minerals to dissolve along flowpaths to produce more concentrated solutions. The hydrochemical data indicate that groundwaters become more dilute as they flow *toward* the discharge playa in Mexico, except in the immediate vicinity of the playa (compare Figures 5-4, 5-6, and 5-7).

Dilution of solutes along flowpaths is probably caused by inflows of meteoric waters that are recharged along the Big Hatchet and Sierra Rica mountains. Additional factors that control the origin and concentrations of solutes are more difficult to determine with the limited data. Some indicators, such as the presence of bicarbonate dominated waters and calcite and dolomite saturation imply that carbonate minerals dissolve in some areas. Carbonate rocks are very common in the surrounding mountains and are important cements in the alluvial basin-fill (Trauger and Herrick 1962). The presence of Na-HCO_3, Ca-SO_4, and Na-SO_4 waters suggest the influence of monovalent-divalent cation exchange, and dissolution of gypsum at other locations in the basins. Weathering of carbonate, granitic, and volcanic rocks provides the clays that act as exchange sites for Na-Ca and Na-Mg cation exchange. Gypsum is present in some of the basin-fill units and provides the source of SO_4. The summary hydrochemical processes in the Hachita-Moscos Basin system include: (1) dissolution of carbonate and other minerals at some locations, and cation exchange; (2) dilution by meteoric recharge waters along flowpaths; and (3) dissolution of gypsum and other evaporite minerals at the playa discharge area. Other analyses on the origin of solutes are not provided due to limited data.

Irrigation Water Quality

Most of the groundwater samples collected from the Upper Hachita Subbasin have a low alkali hazard and medium salinity hazard (Figure 5-9). A few samples in this Subbasin have a high salinity hazard and high alkali hazard. All but one of the groundwater samples collected in the Wamel-Moscos Subbasin have a low alkali hazard and medium salinity hazard. The exception is the sample that was collected at the Laguna los Moscos playa, which has a very high alkali hazard and a very high salinity hazard (Figure 5-9). Groundwater in the Lower Hachita Subbasin has irrigation water quality that varies from a low alkali hazard and medium salinity hazard to very high alkali hazard and very high salinity hazard (Figure 5-9). These data suggest that irrigation water quality is usually good for most varieties of crops in Upper Hachita and Wamel-

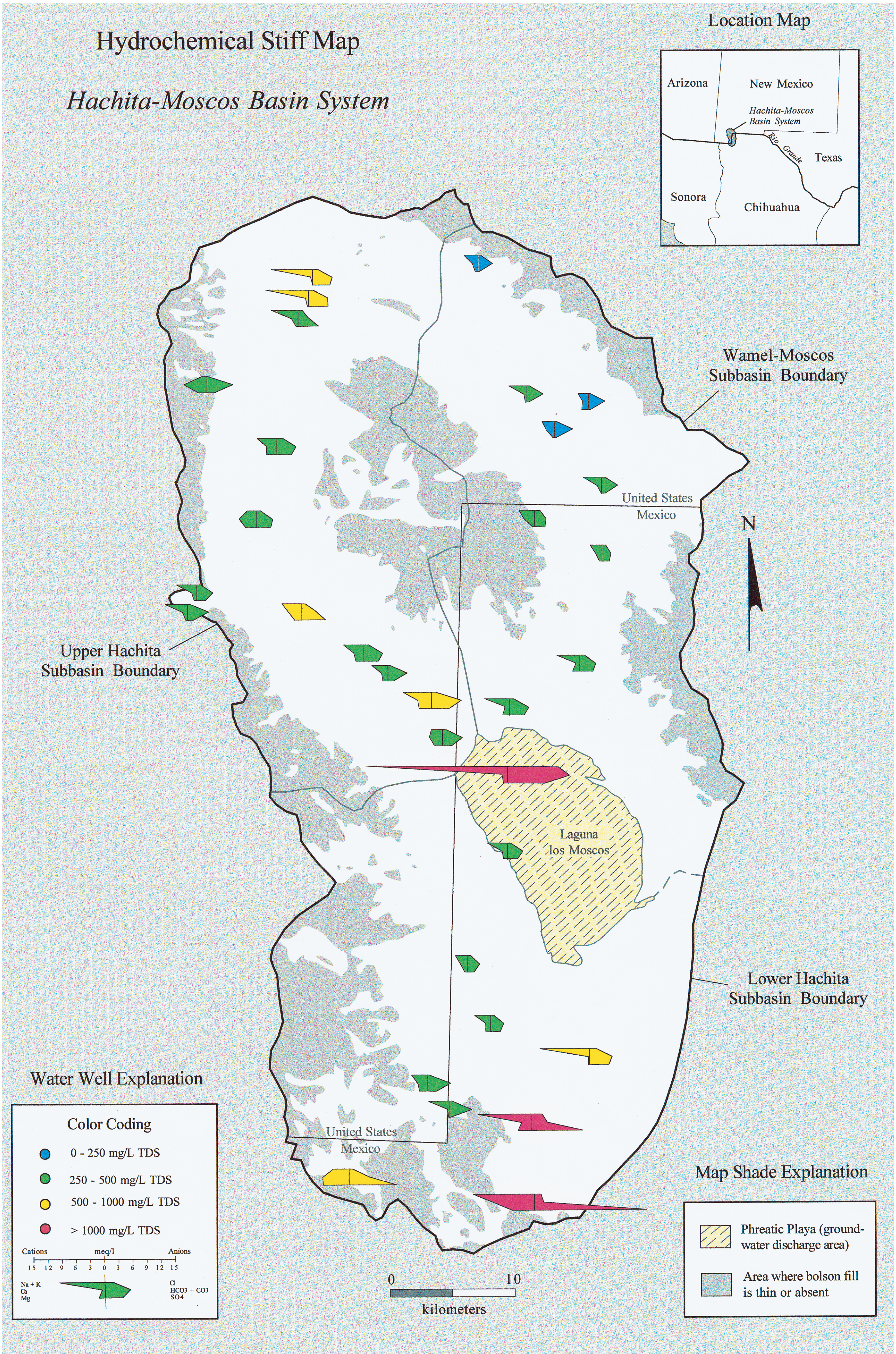


Figure 5-4. Hydrochemical stiff map for the Hachita-Moscos Basin System, showing stiff diagrams color coded by TDS ranges (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).

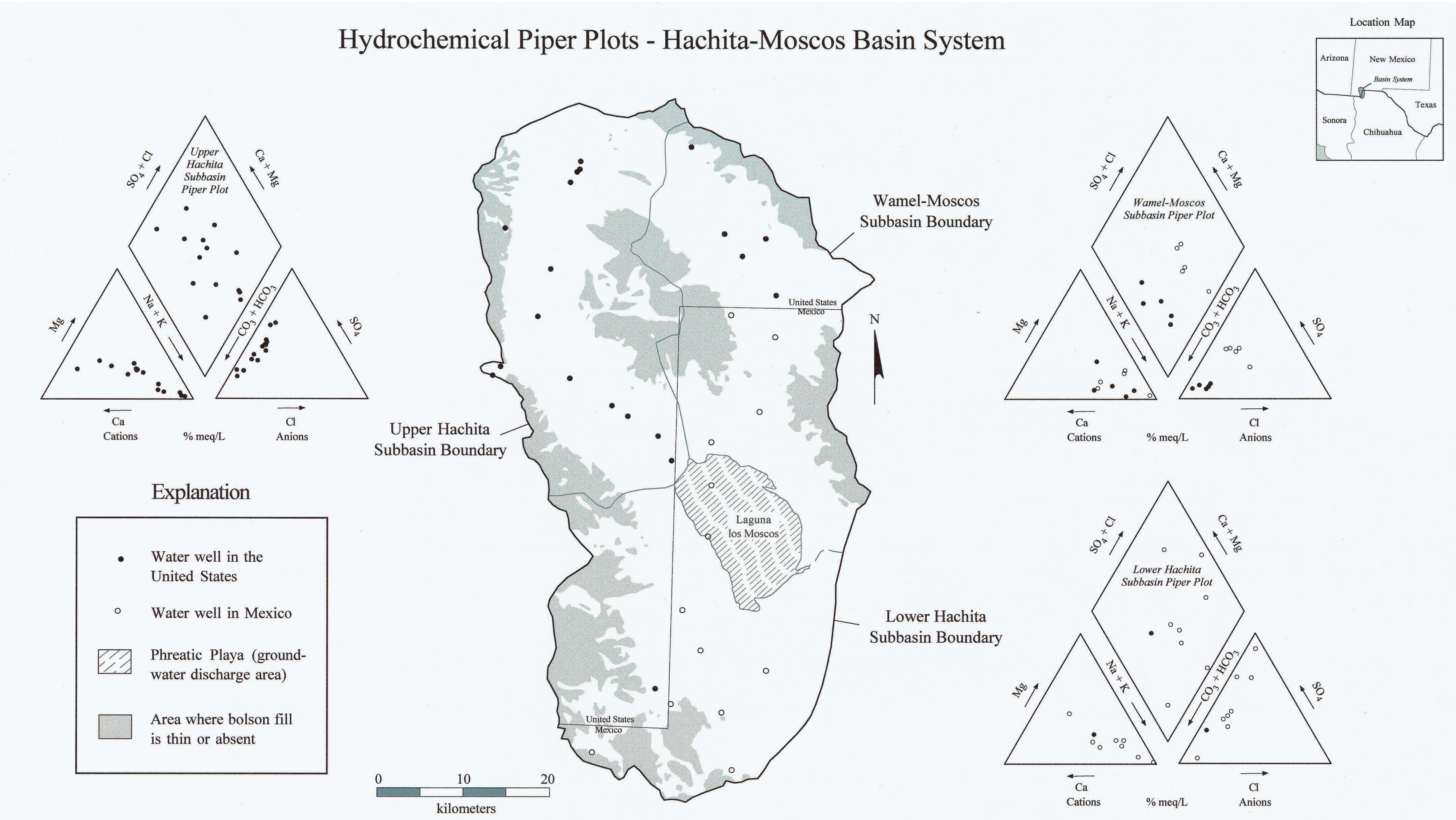


Figure 5-5. Hydrochemical Piper plots for ground water in the Upper Hachita Subbasin, Lower Hachita Subbasin, and Wamel-Moscos Subbasin. These indicate variable hydrochemical facies and evolution from calcium, magnesium, and bicarbonate rich waters to sodium and sulfate rich waters (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).

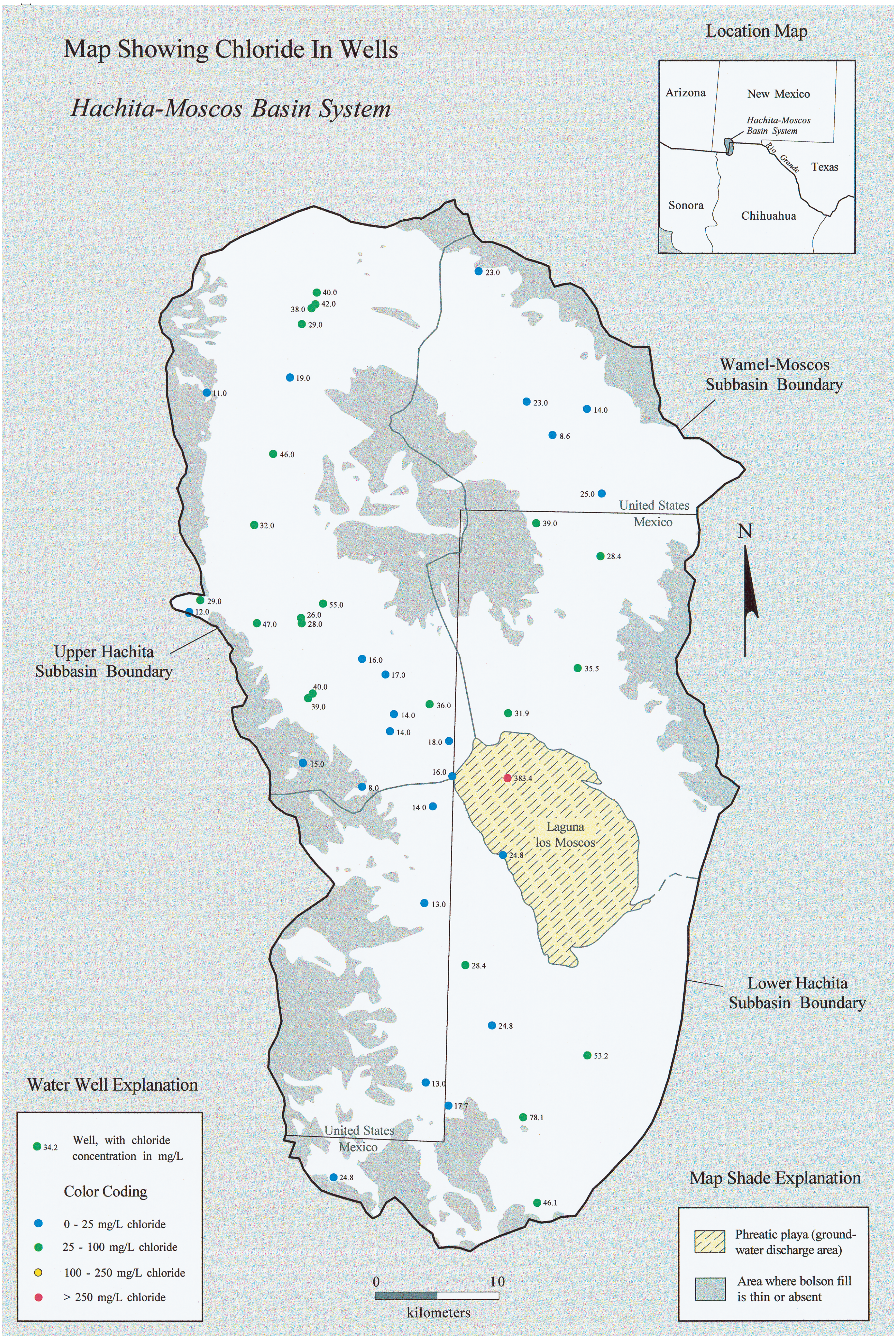


Figure 5-6. Map for the Hachita-Moscos Basin System, showing chloride concentrations in water wells color coded by range (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).

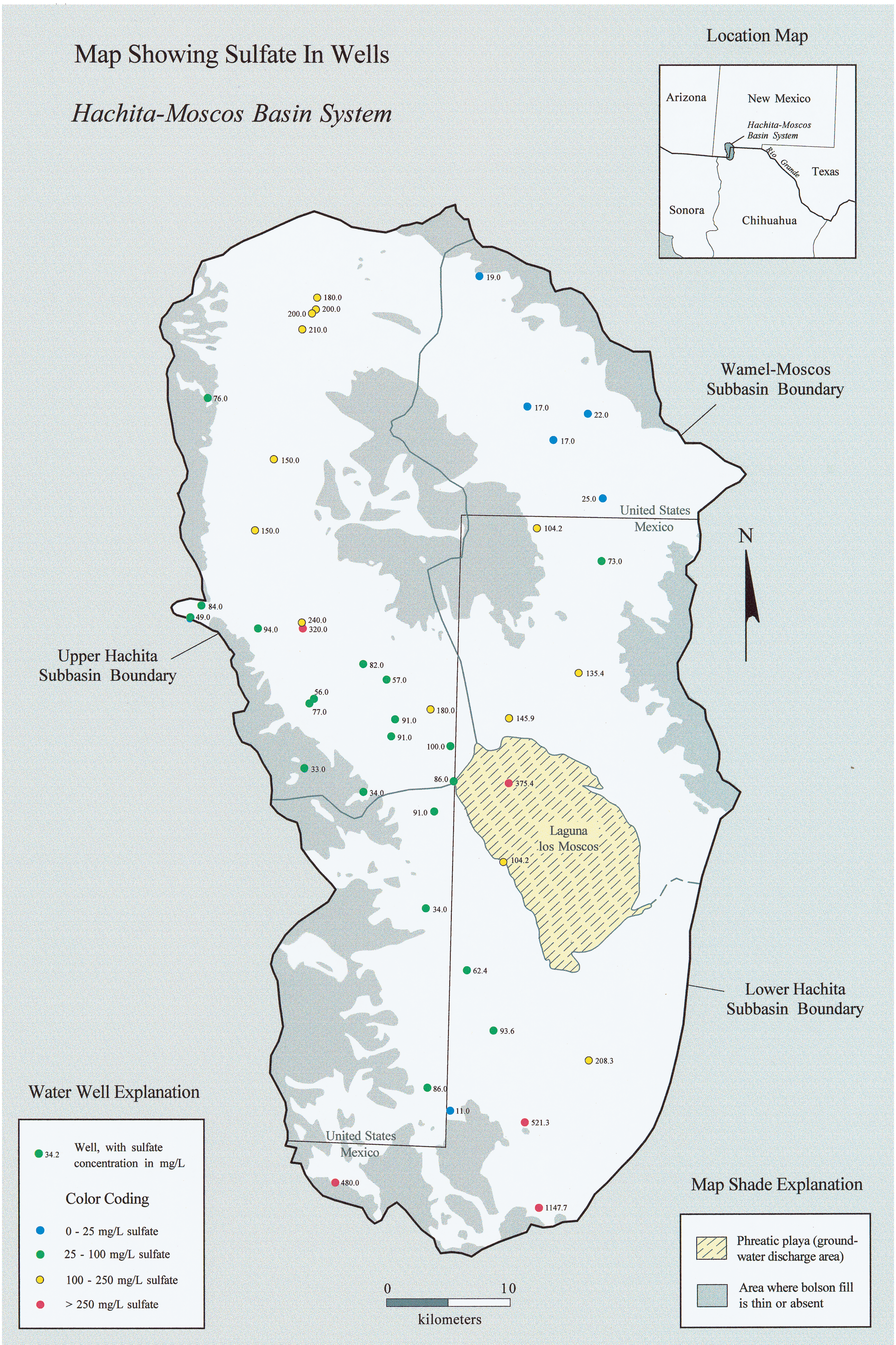


Figure 5-7. Map for the Hachita-Moscos Basin System, showing sulfate concentrations in water wells color coded by range (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).

Moscos Subbasins, but is fair to poor in the Lower Hachita Subbasin.

Nitrate in Groundwater

Nitrate is below the USEPA drinking water standard of 10 mg/L NO_3-N in the groundwater in the Hachita-Moscos Basin system (Figure 5-10). Most groundwater samples in Mexico have less than 2 mg/L NO_3-N. Most samples in the U.S. portion of the basin system have less than 4 mg/L NO_3-N. A single sample, located at the Upper Hachita Subbasin boundary, is greater than 5 mg/L NO_3-N. Nitrate data are very limited in the basin system. More data are needed to verify the potential health risks to residents in the U.S and Mexico.

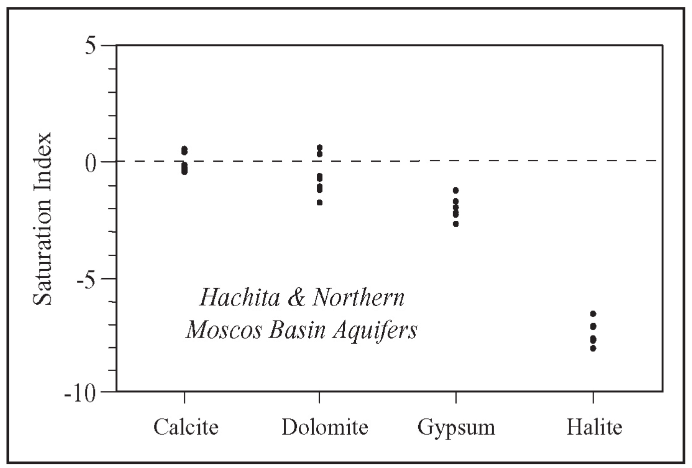


Figure 5-8. Range of saturation indices of calcite, dolomite, gypsum, and halite for the Hachita and Northern Moscos Basin aquifers.

SUMMARY

The Hachita-Moscos Basin system contains an important trans-international boundary aquifer component. The system is an interconnected group of geohydrologic subbasins that cover an area of about 2,700 km^2 (1,040 mi^2), and includes parts of the United States and the Republic of Mexico. Approximately 1,600 km^2 (620 mi^2) of the basin system is in southwestern New Mexico, including parts of Hidalgo, Grant and Luna counties. The entire area is in the Mexican Highland section of the Basin and Range physiographic province, and it comprises three major subbasins that are bounded by north-to northwest-trending mountain ranges. Bordering highlands, Sierra Alta and the Cedar Mountain Range to the east and northeast, and Big and Little Hachet ranges to the west, respectively, separate the Hachita-Moscos Basin system from the Mimbres and Playas and San Basilio Basin systems.

The Apache Hills-Sierra Rica uplift in the northcentral part of the basin system is located between the northern subbasin components, Upper Hachita and Wamel-Moscos. These half-graben structural basins are *semibolsons* with ephemeral axial streams (draws) that conduct surface flow to a *closed* depression in Chihuahua occupied by the ephemeral-lake plain (*phreatic playa*) of Laguna los Moscos. The Upper Hachita Subbasin also receives a small component of surface flow (and groundwater discharge) from the southern part of the Playas Basin system through Hachet Gap (between the Big and Little Hachet Mountains).

Emphemeral streams in the Lower Hachita Subbasin, which straddles the New Mexico-Chihuahua boundary, flow northeastward toward Laguna los Moscos. The eastern border of this half-graben structural basin is poorly defined in terms of both surface- and subsurface-flow regimes. The Hachita-Moscos Basin system in this area is transitional eastward with the Ascensión-Boca Grande reach of the lower Rio Casas Grandes and is part of a broad fluvial plain of the ancestral (Pleistocene) Casas Grandes system.

Land use/landcover categories in the Hachita-Moscos Basin system are predominantly rangeland, with extensive alkali flats in subbasin areas at and near Laguna los Moscos. There is no cropland and the small village of Hachita (in the Upper Hachita Subbasin) is the only urbanized part of the basin system. Groundwater use is primarily for livestock and very local domestic consumption. The climate of this intermontane basin is arid, with mostly clear skies, and limited rainfall and low humidity. Average annual precipitation at Hachita is reported at 25.2 cm (9.93 in), with most occurring as thunderstorms from July through September. Average mean air temperatures is 15.6 °C (60.1 °F).

The hydrogeologic framework of the Hachita-Moscos Basin system is dominated by half-graben structures that merge southward with the Ascensión-Boca Grande section of the lower Rio Casas Grandes basin. Maximum basin-fill thicknesses appear to be in the 600 to 900 m (2,000 to 3,000 ft) range based on geophysical (gravity and seismic) surveys. The primary aquifer system is formed by unconsolidated to partly indurated basin-fill deposits of the Gila Group, which here comprise basin-floor and piedmont-slope facies of the Upper and Middle Gila Hydrostratigraphic Units (HSUs: UG and MG). This aquifer system has unconfined, semiconfined and confined components. It is laterally extensive, but its thickness is quite variable. Results of short-term pumping and well-performance tests are only available for the southern part of the Upper Hachita Subbasin. The highest specific capacity reported (180 m^3/d/m, 10 gpm/ft of drawdown) is for a well near the lower end of Hachita Draw which penetrated 120 m (400 ft) of saturated basin fill. While the basin-fill aquifer system is as much as 900 m (3,000 ft) thick in deepest parts of the Hachita-Moscos Basin system, the maximum thickness of the primary groundwater production zone (HSUs: UG2-1/MG2-1) appears to be less than 200 m (660 ft). Underlying materials are here interpreted as partly indurated and well-consolidated deposits of undivided Middle and Lower Gila Hydrostratigraphic Units (HSU: MLG), which have very low hydraulic conductivities and storage coefficients indicative of semiconfined to confined hydraulic conditions. A very liberal estimate of available groundwater of good quality in storage is about 6 x 10^9 m^3 (6 km^3, 4.86 x 10^6 ac-ft).

The Hachita-Moscos Basin system is typical of most arid parts of the study area in that only a very small percentage (1 to 2%) of basinwide precipitation contributes to recharge. A provisional minimum estimate of annual recharge in this basin system is 6 x 10^6 m^3 (4,800 ac-ft). This estimate assumes that 1% of a mean annual precipitation of 30 cm (12 in) distributed (unevenly) over a watershed of 2,000 km^2 (770 mi^2) is available for recharge, and it excludes any spill or leakage into the Lower Hachita Subbasin from the southern Playas Basin system through Hachet Gap. Maximum groundwater discharge through the Gap appears to be less than 10,000 m^3/yr (8 ac-ft/yr).

Groundwater flow in Upper Hachita and Wamel-Moscos subbasins generally mimics surface topography and is southward along basin-axial trends toward the *closed* depression that is occupied by Laguna los Moscos. Groundwater flow in the Lower Hachita Subbasin is northeastward from the western mountain border zone toward Laguna los Moscos. The latter depression is here interpreted as a *partly drained*-partly *phreatic playa* complex that discharges an undetermined amount of underflow to the contiguous part of the lower Rio Casas Grandes basin.

A very preliminary estimate of potential transboundary groundwater flow from the United States into Mexico from the combined Upper Hachita and Wamel-Moscos International Boundary sectors is no more than 2.5 x 10^6 m^3/yr (2,000 ac-ft).

The total dissolved solids (TDS) content of sampled groundwater in the Upper Hachita Subbasin varies from 250 to 1,000 mg/L TDS. In the United States part of the Wamel-Moscos Subbasin, all groundwater has less than 500 mg/L TDS, and several sampled wells produced water with less than 250 mg/L TDS. Near and extending across the International Boundary in Lower Hachita Subbasin, as well as the two other subbasin areas proximal to Laguna los Moscos, water quality is highly variable with respect to TDS, with values ranging from 250 to over 1,000 mg/L.

Groundwater hydrochemical facies in the Upper Hachita Basin vary from Ca-HCO_3 and Ca-HCO_3-SO_4 to Na-HCO_3 and Na-HCO_3-SO_4 type waters. Samples from the Wamel-Moscos Subbasin are mostly Na-HCO_3 and Na-Ca-HCO_3 type waters, and a few samples of Na-HCO_3-SO_4 type groundwater have been collected in the Mexican part of the subbasin. Hydrochemical facies of groundwater in the Lower Hachita Subbasin include Ca-Mg-SO_4, Na-SO_4, Na-HCO_3, Na-HCO_3-SO_4 and Na-Mg-HCO_3. There are no apparent correlations between hydrochemical facies and TDS in any of these subbasins.

Most of the groundwater samples collected from the Upper Hachita and Wamel-Moscos subbasins have low alkali hazard and medium salinity hazard. Groundwater in the Lower Hachita Subbasin is quite variable in terms of alkali and salinity hazards. These hazards are very high only in the vicinity of Laguna los Moscos. No water samples had nitrate contents exceeding the recommended drinking-water limit of 10 mg/L NO_3-N, and only one sample (in the Upper Hachita Subbasin) had a value exceeding 5 mg/L NO_3-N.

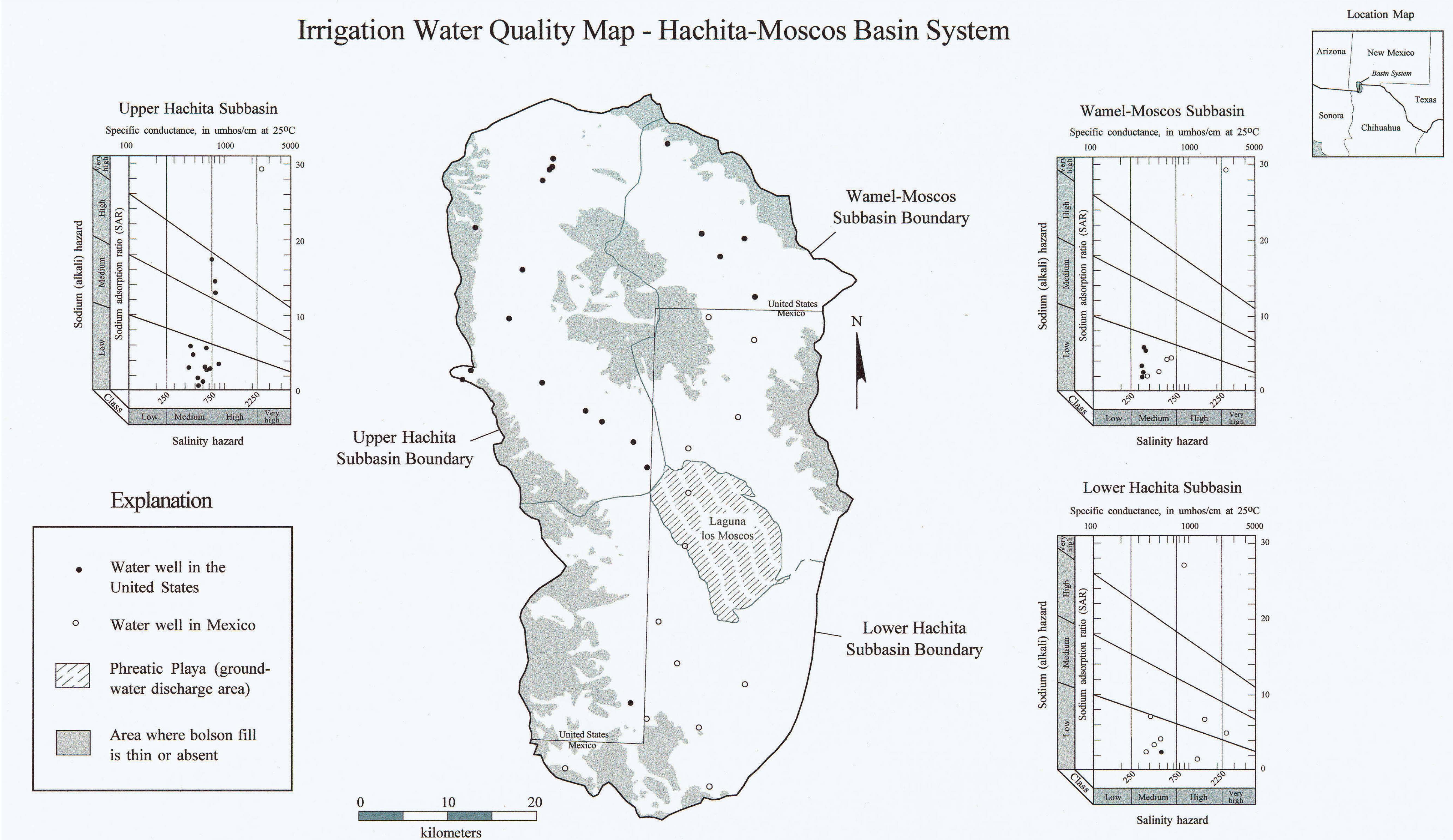


Figure 5-9. Irrigation water quality map for the Upper Hachita Subbasin, Lower Hachita Subbasin, and Wamel-Moscos Subbasin. These data indicate that water quality in these basins is generally suitable for most types of irrigation (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).

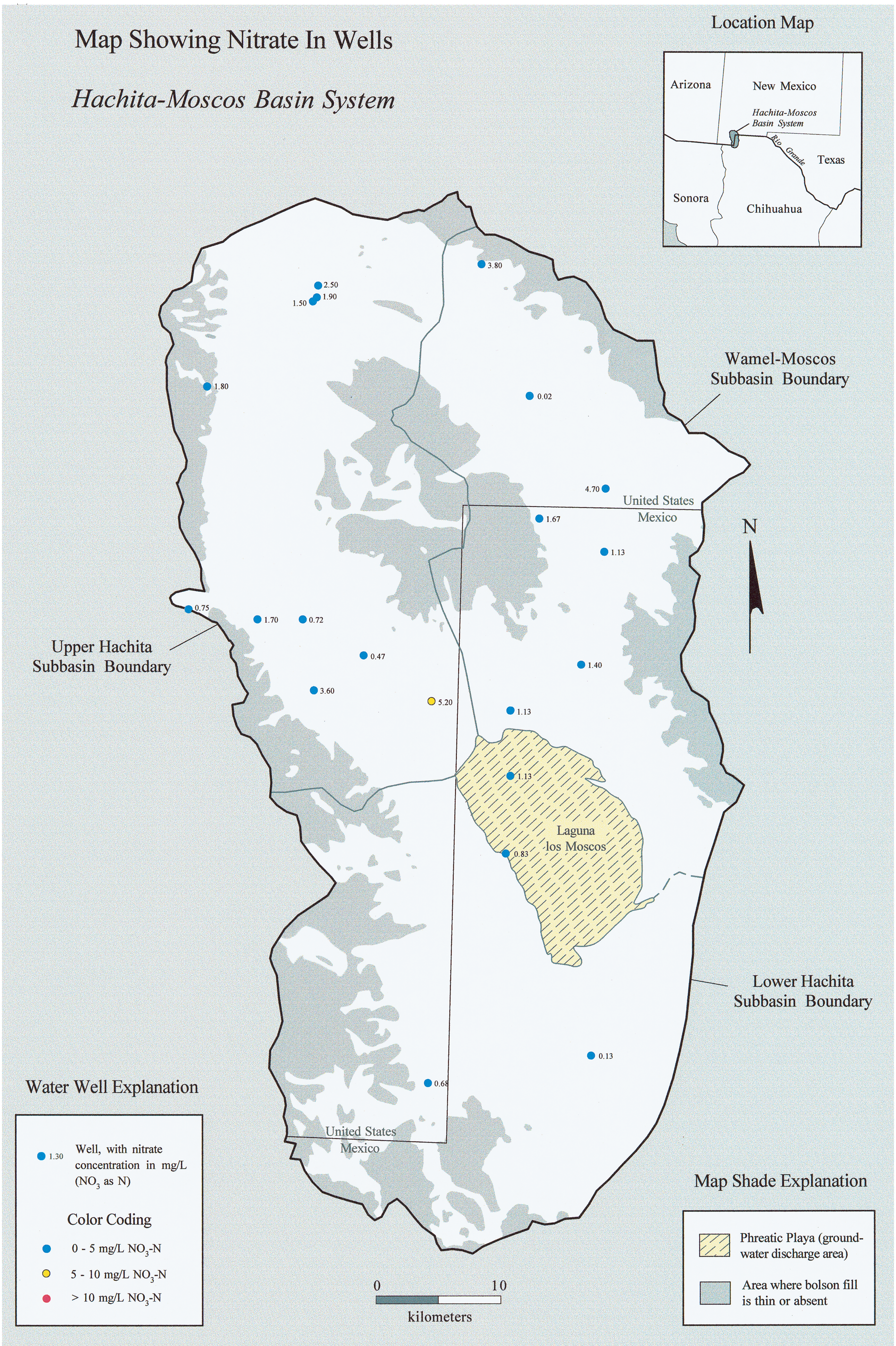


Figure 5-10. Map for the Hachita-Moscos Basin System, showing nitrate concentrations in water wells color coded by range (source of data: U.S. Geological Survey; Comision Nacional Del Agua; Instituto Nacional de Estadistica, Geografica e Informatica).