PRELIMINARY WORK FOR
A HYDROLOGIC REPORT ON
HIDALGO COUNTY, NEW MEXICO

by

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and

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PREFACE

This study grew out of three smaller Bureau studies in or including Hidalgo County. One was a Tech masters thesis on Quaternary Lake Animas (Fleischhauer, 1977). Another was a compilation of geological/geophysical information for alluvial basins in New Mexico (Stone and others, 1979). The other was a hydrogeologic study of Animas Valley done as part of the U.S. Geological Survey’s Southwest Alluvial Basins Regional Aquifer Systems Analysis (O’Brien and Stone, 1981, 1982a, b, 1983). Once these Animas Valley studies were completed, we reasoned (erroneously) that it should take relatively little more effort to compile information on the remaining valleys and thus prepare a county-wide report.

The hydrologic work on Animas Valley was conducted 1981 through 1982. Most data on the rest of the county were compiled in 1983. In June 1984, O'Brien left the Bureau but planned to complete the report. However, other demands on his time prohibited this and in January 1987 the responsibility for report preparation was transferred to me. Additional field work on Pyramid Mountain wells was done in 1990. As I too am leaving the Bureau without completing the study, this document is offered to 1) preserve work done to date, 2) provide a starting place should completion be undertaken by someone else and 3) serve as a source of water-resource information for the area in the meantime.

W. J. Stone
December 1990
CONTENTS

Preface 2

Abstract 6

Introduction 7
  Problem and Scope 9
  Approach and Data Sources 13
  Previous Works 14
  Acknowledgments 17

Using This Report 18
  Well Numbering System 18
  Elevations of Wells 19
  Finding Information 21
  Illustrations 22

Regional Setting 22
  Physiography 23
  Climate 25
  Soils and Vegetation 30

General Geology 31
  Mountains 31
  Valleys 34
  Subsurface Units 34
  History 41

Economy and Water Use 43
  Population 43
  Land Ownership 45
  Agriculture 48
  Mineral Extraction 51
  Other Activities 51
  Water Use 54

General Ground-Water Hydrology 54
  General Ground-Water Occurrence 57
  General Ground-Water Movement 59
  General Ground-Water Quality 61
CONTENTS (cont'd)

Animas Valley
   Ground-Water Occurrence 63
   Ground-Water Movement 63
   Ground-Water Movement 69
   Ground-Water Quality 71
   Alkali Flats 74
   Hydrologic Model 76
   Geothermal Resources 79

Other Areas 83
   Gila Valley 83
   Pyramid Mountains 85

Additional Work Needed 89

Conclusions 90
   Geologic Controls 91
   Water Supply 92

Glossary 94

References 102

TABLES

1. Locating water-resource information for Hidalgo County 16
2. Summary of climatic data 28
3. Distribution of vegetation 32
4. Subsurface Geology 39
5. Land ownership 47
6. Land use 47
7. Water use 56
8. Recharge values 60
9. Trace metals, Animas Valley groundwater 62
10. Well records (printout) 102
11. Chemical Analyses (printout) 102
12. Additional well records 87
13. Additional chemical analyses 88
FIGURES

1. Location map 8
2. Declared basins 10
3. State Engineer Office, Deming (photo) 11
4. Well numbering 20
5. Big Hatchet Mountains (photo) 24
6. Ephemeral stream (photo) 26
7. South Alkali Flat (photo) 27
8. Hydrogeologic column 33
9. Geologic map 35
10. Volcanic breccia, Pyramid Mountains (photo) 36
11. Gravity map 37
12. Tectonic map 42
13. Shoreline features, Lake Animas 44
14. Ghost town of Shakespeare (photo) 46
15. Stock well (photo) 49
16. Irrigated crops (photo) 50
17. Mining camp of Valedon (photo) 52
18. Hidalgo Smelter (photo) 53
19. Antelope Wells (photo) 55
20. Lithologic Log, Animas Valley 64
21. Texture, bolson aquifer 65
22. Hydrograph, Animas Valley well 67
23. Winter water levels 68
24. Water level decline, Animas Valley 70
25. SAR, Animas Valley 73
26. WATEQF results, Animas Valley 75
27. Model grid/transmissivity 77
28. Steady-state calibration 78
29. Transient calibration 80
30. Transient verification 81
31. Lightning Dock KGRA 82
32. Ground-water temperatures, KGRA 84

PLATES

1. Geologic Map
2. Cross sections
3. Water-well map
ABSTRACT

Hidalgo County, in extreme southwestern New Mexico, is characterized by typical arid-semiarid, basin-and-range terrain. The continental divide bisects area. Although the hydrology of each of the basins has been previously studied to some extent, most of these efforts are more than 25 years old and there is no comprehensive report on the county.

Ground water is recharged mainly in the mountain ranges. From there flow is toward the adjacent basins and then along their axes to discharge points, often outside the county boundaries. The main aquifer is bolson fill of Quaternary age. It consists of interbedded gravel, sand, silt, and clay. Thickness of water-yielding sediments may be as much as 2,600 ft. Average transmissivity is on the order of tens of thousands of gpd/ft. Depth to water ranges from <20 to >400 ft, but averages approximately 100 ft along the basin axes. In most areas, management of ground-water development (declaration of underground water basins) has reduced or stabilized water-level declines associated with earlier periods of excessive pumping.

Water chemistry varies with location. Major cations are calcium and sodium whereas major anions are bicarbonate, sulfate, and chloride. Sodium adsorption ratios are generally <10. Fluoride and boron concentrations are excessive in some areas.

Ground water is used mainly for irrigation, stock watering, copper smelting, and domestic or municipal supplies. Geothermal waters are used to heat greenhouses in Animas Valley.
INTRODUCTION

Hidalgo County occupies the southwesternmost corner of the state (Fig. 1). This sparsely populated area (1.8 persons/mi²) has had a colorful geologic and human history. Rocks of the area record ancient seas and volcanoes. The mountains and valleys attest to the past restlessness of the earth's crust. Several abandoned shorelines mark the extent of ice-age lakes. Fossilized bones in the lake deposits reveal that mammoths once roamed their shores. Since then, Apaches, soldiers, miners, railroaders, cowboys, farmers and vintners have called this land home.

Scarcity of water was a critical factor in the early human history of the area. Because of its aridity, it was long overlooked and avoided, except by the most hardy and adaptable souls. The Apaches, who were the native human inhabitants, survived through their nomadic way of life. If one mountain spring dried up, they simply moved camp to another. By contrast, the non-Indian activities (agriculture, mining, railroad settlements and ranching) were stationary and required reliable, permanent water supplies. The best supplies were found in the intermontane valleys. As mineral deposits in the mountains were depleted or railroad operations changed, activity centers shifted. In some cases only vague records or ghost towns (for example, Shakespeare and Steins) are all that mark their passing.

Today the area is a curious blend of this historic past and modern marvels. For example, the county boasts a major gas pipeline, geothermal greenhouses, a massive copper smelter, and tens of thousands of acres of irrigated agriculture on the desert valley floor. A main interstate highway and principal railway replace the Butterfield
Figure 1. Location of places and features of interest, Hidalgo County.
stage and horse trails as the main routes of ground travel.

PROBLEM AND PURPOSE

Water is just as important now as it was in the pioneering days. It sustains the various agricultural, industrial, and municipal endeavors of the county. However, because of the arid setting, water is scarce. Only in the northern panhandle is there a perennial stream: the Gila River (Fig. 1). Thus, most of the water used in the county comes from the ground. An understanding of the ground-water systems of the county is essential for their effective use and management.

Agricultural and industrial developments have induced stresses on the water resources of the county. For example, as a result of heavy pumping of ground water for various uses, water levels have dropped markedly. Reeder (1957) documented this in the Animas Valley. In response to this increased ground-water use, the State Engineer designated several areas as declared basins (Fig. 2). Ground-water withdrawal in such basins is subject to approval by the State Engineer Office, Deming (Fig. 3). Nonetheless, annual monitoring data show that water levels continue to decline (U.S. Geological Survey/Office of the State Engineer, annual water-level observation data). In an attempt to slow the rate of ground-water depletion, the Deming and Hidalgo Soil and Water Conservation Districts are studying irrigation efficiency in the region (Margo, 1989). New water uses include irrigation of vineyards and a winery supply. In addition to use for irrigation, water is also being withdrawn for geothermal energy (Animas Valley) and copper smelting (Playas Valley).
Figure 2. Declared underground water basins, Hidalgo County.

Explanation:
1. Gila–San Francisco
2. Virden Valley
3. San Simon
4. Animas
5. Lordsburg Valley
6. Playas Valley
Figure 3. State Engineer Office, Deming
As the more populated areas of the country run out of landfill sites, they look longingly at the wide-open spaces of the western states. Hidalgo County has already been targeted. In 1989 an eastern-based company looked into purchasing land for such a facility in Lordsburg Valley. Although the physical setting of the county permits disposal of a modest volume of locally generated waste, it could not survive a large influx of transported material. In areas where readily workable unconsolidated sediments lie at the surface, ground water is too shallow and too fresh to even consider exposing them to such a facility. Sites with deeper and/or more saline ground water are available elsewhere. Local protest eventually forced abandonment of this project. A compilation of available hydrogeologic information is needed to exclude future disposal-site projects.

A 321,703-ac property known as the Gray Ranch, was purchased by The Nature Conservancy in January 1990 for establishment of the Animas Mountain Wildlife Refuge (Thompson, 1990). The 500 mi² area, approximately centered on the Animas Mountains, straddles the continental divide. It extends from the Mexican border to just south of the town of Animas.

A wide variety of concerns have been raised by area residents regarding impact of these plans on the area. Some involve water-resource pressures. Grazing will reportedly be allowed to continue, but at a reduced capacity. Existing watering systems should suffice. However, the projected influx of 70,000 tourists per year would require additional supplies. Better understanding of both the regional and local hydrologic systems will be required.

Several excellent reports have been published on the individual basins in Hidalgo
County. The information they give is valid and useful. It is considered beyond the scope of this report to repeat the information they contain. However, as the most recent hydrologic study in the county, other than those in the Animas Valley (O'Brien and Stone, 1981, 1982, 1983), is more than twenty-five years old (Trauger and Herrick, 1962) and the last attempt to integrate the hydrology of the various basins is more than seventy years old (Schwennesen, 1918), it was felt that an overview, emphasizing new information, would be of use.

The purpose of this report is to present observations on the geology and hydrology of Hidalgo County and to offer interpretations of these observations as regards the water resources of the region. The geologic controls of the hydrologic phenomena and their implications for managing water quantity and quality will also be addressed. A particular goal of this document is to make such information available prior to the preparation of a formal Bureau Hydrologic Report.

**APPROACH AND DATA SOURCES**

The scale and focus has varied throughout the project. Work began with a study of Quaternary Lake Animas in the Animas Valley (Fleischhauer and Stone, 1982). Next came a compilation of available geologic and geophysical data for the entire county (Stone and others, 1979). Then a comprehensive hydrogeologic study was made of Animas Valley, the major basin in the county. This included compilation of available hydrogeologic information, as well as collection of supplementary data in the field (O'Brien and Stone, 1981, 1982). Based on the geologic, geophysical, and hydrologic
data, a conceptual model was formulated. This was used to construct two-dimensional, finite-difference flow models for both steady-state and transient conditions (O’Brien and Stone, 1983 and 1984). Finally, available hydrologic data were compiled and reconnaissance level hydrogeologic studies were made of the other basins in the county. Supplementary field measurements were obtained in these areas where possible.

Data sources include published geologic, geophysical, and hydrologic reports, unpublished U.S. Geological Survey seismic profiles, the files of the Deming Office of the New Mexico State Engineer, and field observations. Published sources are discussed under Previous Works below. Specific sources of well-records or water analyses are indicated on listings in the Tables at the end of this report.

PREVIOUS WORKS

This study was made easier by the various previous works on the geology and hydrology of the region. These are referenced where appropriate in the text. However, a summary of major works is useful at the outset.

Various geologic works cover most of the area. The only geologic maps of the entire county are the state geologic map by Dane and Bachman (1965) and the Highway Geologic Map (Clemons, 1983). The general geology of southwestern New Mexico was reviewed by Clemons and Mack (1988). Zeller (1959, 1962), Zeller and Alper (1965), Soule (1972) and Drewes (1986) addressed the geology of the Animas Mountains. Zeller (1958, 1966, 1970, and 1975) and Thompson and Jacka (1981) studied the Big Hatchet Mountains extensively. Zeller (1959) made a reconnaissance map of the Dog Mountains.

Hydrologic studies have been previously made to some extent of all the major valleys or basins (Table 1). The earliest known investigation is that by Schwennesen (1918). It covered the Animas, Hachita, Playas and San Luis basins. Another early Hidalgo County study is that by McClure (1938). Reeder (1957), Summers (1967), Arras (1979), Hawkins (1981), Hawkins and Stephens (1981) and O'Brien and Stone (1981,
Table 1. Locating water-resource information for Hidalgo County by area.

<table>
<thead>
<tr>
<th>Area</th>
<th>This Report</th>
<th>Previous Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text Tables 9,10</td>
<td>S¹ R² D³ T/H⁴ T⁵ O/S⁶ Other⁷</td>
</tr>
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<tr>
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</tr>
<tr>
<td>Animas Valley</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Apache Hills</td>
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<td>Guadalupe Mts</td>
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<td>Hachita Valley</td>
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</tr>
<tr>
<td>Peloncillo Mts</td>
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<td></td>
</tr>
<tr>
<td>Playas Valley</td>
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</tr>
<tr>
<td>Pyramid Mts</td>
<td>x</td>
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</tr>
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<td>Sierra Rica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whitewater Mts</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

¹Schwennesen (1918)
²Reeder (1957)
³Doty (1960)
⁴Trauger and Herrick (1962)
⁵Trauger (1972)
⁶Brien and Stone (1981, 1982a,b, 1983)
⁷a - Summers (1967)
  b - Arras (1979)
  c - Hawkins (1981)
  e - Turner and others (1941)
  f - Turner (1960)
  g - Loeltz and others (1962)
  h - United Geophysical Corp. (1956)
  i - Schwennesen (1919)
  j - Cushman and Jones (1946)
  k - DeCook (1952)
  l - White (1963)
  m - White and Hardt (1965)
  n - White and others (1965)
  o - Couse (1967)
  p - Wilson and White (1976)
  q - Freethey and others (1986)
1982a, b, and 1983) reported on various hydrologic aspects of the Animas Valley. Turner and others (1941) and Dinwiddie and others (1966) reported on water resources of the Gila River Valley. Trauger and Herrick (1962) studied central Hachita Valley. Loeltz and others (1942) and Turner (1960) studied the Lordsburg Valley. United Geophysical Corporation (1956) and Doty (1960) presented results of work on the Playas Valley. The San Simon Basin was first studied by Schwennesen (1918). More recent works there include those by Cushman and Jones (1946), DeCook (1952), White (1963), White and Hardt (1965), White and Smith (1965), Couse (1967) Freethey and others (1986) and Freethey and Anderson (1986).


ACKNOWLEDGMENTS

We wish to than John Hawley (Bureau), Dan Stephens (New Mexico Tech), Dave Hawkins (Hargis and Associates, Inc.), Kelly Summers (City of Albuquerque) and Dave Wilkins (U.S. Geological Survey) for helpful discussions of various stages of the work. Fred Trauger, John W. Hawley, and Sam Thompson III provided useful reviews, illustrations or discussions of this report. Work on the Animas Valley was funded under
contract with the U.S. Geological Survey (agreement no. 14-08-0001-18817) as part of their Southwest Alluvial Basins Regional Aquifer System Analysis project. The tremendous task of computerizing well and water chemistry data processing was carried out by Sharon Boyd and Lori Leser (while undergraduate student assistants, NM Tech). Water analyses were performed under the direction of Lynn Brandvold (Bureau). Robert Eveleth (Bureau) provided data on mineral production and the railroad in Hidalgo County. Lynne McNeil typed all versions of the report. Roger Ford, SCS-Albuquerque, kindly provided a draft of their report on the potential for improving irrigation practices in Hidalgo and Luna Counties. Finally, the cooperation of land owners, ranchers and ranch managers is gratefully acknowledged, especially that of Bob Hughes, Justin Kipp, Dan Puckett, Joe Rouse and Richard Searle.

USING THIS REPORT

The following comments on organization and contents are intended to help the reader make maximum use of this report. Specific information on the various maps and tables should clarify their preparation and facilitate their use. The glossary is offered to assist the layman in understanding the more technical aspects of the report.

WELL NUMBERING SYSTEM

The system of numbering wells in this report is that used by the New Mexico State Engineer. It is based on the Public Land Survey System (township, range, section). In this system, each well or spring has a unique location number consisting of four parts
The first part (on the left) refers to the township, the second designates the range, and the third identifies the section (Fig. 4). All wells and springs in the study area are south of the New Mexico base line and west of the New Mexico principal meridian but letters designating compass directions are given for clarity. The fourth part locates the well or spring within the section to the nearest 10-acre tract as follows: each section is divided into quarters which are assigned numbers such that the northwest quarter is number 1, the northeast quarter is number 2, the southwest quarter is number 3, and the southeast quarter is number 4. Each quarter section is then divided into quarters that are numbered in the same manner. Each quarter-quarter section is similarly divided and numbered. If the location of a well or spring cannot be determined to one of the sub-section designations, zero is entered in the appropriate position in the right-hand or fourth part of the number. A well designated 23.18.20.213 is located in the SW1/4 NW1/4 NE1/4 sec. 20, T. 23 S., R. 18 W. (Fig. 3). A spring located in the NW1/4 sec. 31, T. 24 S., R. 19 W. would be numbered 24.19.31.100.

ELEVATIONS OF WELLS

Ground-surface elevation is critical to determining water-level elevation. For various reasons, ground elevations are sometimes not reported or reported incorrectly. Reasons include improper well location, nonavailability of detailed topographic maps, reliance on an uncalibrated or otherwise faulty altimeter, incorrect measurement from bench marks or even typographical errors.

In an attempt to correct or standardize ground-surface elevations used in this
Figure 4. Method of numbering wells used in New Mexico.
report, the following procedures were adopted whenever elevation was suspect or not assigned. Wells located only to the nearest quarter-section were plotted at the center of that quarter-section. Wells located to the nearest section were assigned to the center of a quarter-section based on the well location map in the source, if available. The assignment of an elevation to a well within a quarter-section depended on the amount of relief in the quarter-section. If there was less than 20 ft of relief in a quarter-section then the elevation of the nearest contour line or spot elevation was assigned. If the well location was equidistant between either two contour lines or a contour line and a spot elevation then the mean value of these known elevations was used. In cases where the relief in a quarter-section exceeded 20 ft, the well location was refined by reference to the well location map in the source and the well was assigned an elevation following the criteria stated above. If the relief in a quarter-section exceeded 50 ft, then a well elevation was not assigned.

FINDING INFORMATION

For discussion purposes, the county may be subdivided into areas (Table 1). Most human activity is restricted to the intermontane valleys of the county. Consequently, hydrologic data are fairly abundant for those areas, but almost lacking for the bordering mountains.

There are several ways to quickly find information on a specific locality. If township/range/section are known, go to Table 10 and look for entries on other wells with a similar location. If only general area of interest is known, check Table 1 to see if
it is covered in this report. If the area is not known, the reader may determine this from
the location map (Fig. 1), using township and range of the area of interest. To learn the
water level or water chemistry in a given area, search the appropriate table (10 or 11)
using the location (legal description) in well-number format (Fig. 4). The table of
contents shows the overall organization of the report and location of general topics.

ILLUSTRATIONS

The geologic map (Plate 1) is a basic illustration. It shows the distribution of
rocks and unconsolidated sediments at the earth’s surface in Hidalgo County. The
legend describes the nature of the material in each unit. See the glossary for the
meaning of the various rock types or ranks employed and Fig. 8 for water-yielding
characteristics.

The water-well map (Plate 3) shows location of wells in Table 10, which should be
consulted for water depth, etc. As flow is generally from areas of higher elevation to
those of lower elevation, the map can be used to learn general ground-water flow
direction.

A chart for converting inch-pound units into the metric system is given on the last
page.

REGIONAL SETTING

Hidalgo County is unique in two respects. It embodies the southernmost extent of
the state and is the only place where old Mexico lies not only to the south, but also to
the east (Fig. 1). Arizona bounds Hidalgo County on the west and Grant County bounds
it on the north and all but a small portion of the eastern margin, where it abuts against
Luna County.

PHYSIOGRAPHY

Hidalgo County lies entirely in the Mexican Highlands section of the Basin and
Range physiographic province. The region is characterized by rugged mountain ranges
and nearly flat intermontane basins with playas (Fig. 1). Elevation ranges from
approximately 3,700 ft, where the Gila River crosses the state line into Arizona, to 8,531
ft atop Animas Peak. Maximum relief in the county is 4,831 ft. Most mountains rise
above 5,000 ft. Valley floors slope, but generally lie below 4,200-4,500 ft.

Major peaks include Animas Peak (8,531 ft), Center Peak (7,020 ft), and Gillespie
Mountain (7,309 ft), in the Animas Mountains, Big Hatchet Peak (8,441 ft) in the Big
Hatchet Mountains (Fig. 5), Pierce Peak (6,159 ft) in the Alamo Hueco Mountains, and
North Pyramid Peak (6,008 ft) and South Pyramid Peak (5,910 ft) in the Pyramid
Mountains. Minor uplands include Black Mountain, Lordsburg Mesa, Tabletop
Mountain, and Tank Mountain.

Major basins include the Animas Valley, Gila Valley, Hachita Valley, Lordsburg
Valley, Playas Valley, and San Simon Valley.

The continental divide splits Hidalgo County into unequal parts. The western part is
drained by the Lower Colorado River and accounts for 64% of the area. The remaining
Figure 5. Big Hatchet Peak (frontispiece, Zeller, 1965).
36% of the area east of the divide is drained by the Rio Grande (State Engineer Office, 1974). Drainage does not necessarily reach these rivers. Except for the northern panhandle, which is crossed by the Gila River, drainage is by ephemeral streams into closed basins (Fig. 6). Large playas occupy the lowest portions of the valley floors. North and South Alkali Flats in the Animas Valley are characterized by alkaline soils and salt-loving plants as a result of salt buildup from ponded runoff (Fig. 7).

CLIMATE

Hidalgo County lies in a northern extension of the Chihuahuan Desert (Mueller, 1988). It has a continental, arid to semiarid climate (Maker and others, 1970). Available climatic data show that precipitation varies with elevation across the county (Table 2). Mean annual precipitation ranges from 6.92 to 23.45 in/yr. According to Gabin and Lesperance (1977), rainiest months are July, August, and September with monthly means ranging from 1.01 in (Sept., Playas) to 5.96 in (August, Skeleton Canyon). During this time, brief but often intense showers and thunderstorms occur as a result of a northward flow of moist air from the Gulf of Mexico. Precipitation is low in the spring and in the month of November. Lowest monthly precipitation for stations with more than 1 yr of record is 0.03 in (May, Playas; Gabin and Lesperance, 1977). Annual snowfall averages 4-6 in in the northern two-thirds of the county and 16 in or more in the southern mountain areas (Maker and others, 1970).

Pan evaporation data are available only for Animas. Based on 3 yrs of record, it averages 101.60 in/yr, or nearly ten times mean annual precipitation (Table 2). For other
Figure 6. Typical ephemeral stream draining Little Hatchet Mountains, east of Granite Pass; near Twelvemile Wells, SE sec. 20, T29S, R15W.
Figure 7. Typical playa: South Alkali Flat in lower Animas Valley, north of Interstate 10.
Table 2. Summary of climatic data, Hidalgo County (Gabin and Lesperance, 1977, except Butler Ranch which is from written comm. Marx Brook, 1979); Lat = latitude, Long = longitude, Elev = elevation, P = mean annual precipitation, YR = years of record, T = mean annual temperature, ET = evapotranspiration calculated as by Blaney and Criddle (1962), ND = no data. Years of record are not concurrent, nor do they necessarily extend to the date of compilation.

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<th>Station</th>
<th>Lat</th>
<th>Long</th>
<th>Elev (ft)</th>
<th>P (inches)</th>
<th>YR</th>
<th>T (°F)</th>
<th>YR</th>
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<td>45</td>
<td>60.1</td>
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¹ Gabin and Lesperance did not give temperature ranges.
² A pan evaporation value of 101.6 inches was also reported for this station.
stations Gabin and Lesperance (1977) calculated potential evapotranspiration using the procedure given by Blaney and Criddle (1962). These range from 41.36 in/yr at Gray Ranch to 52.59 in/yr at Rodeo (Table 2). Although less than the rate indicated by the limited pan-evaporation data, these values represent four to five times the annual precipitation.

By subtracting the potential evapotranspiration value from the mean annual precipitation value, water surplus or deficit may be obtained. All stations in the region show a net deficit; that is, potential evapotranspiration is greater than available precipitation. Winter months may, however, be characterized by temporary surpluses of water, due to lower temperatures and evapotranspiration at these times.

Mean annual temperature is fairly uniform across the county, hovering around 60°F. Based on data from Lordsburg for 1946-1960, lowest temperature is 2°F (reached in both Jan. and Dec.) and the highest temperature is 100°F (reached in July). Last time of freezing temperatures is in April and first time of freezing temperatures is in late October/early November (Maker and others, 1970). The length of the growing season ranges from approximately 170 days at higher elevations to more than 200 days at lower elevations.

Average relative humidity normally ranges from nearly 65% in the early morning to only 35% in the afternoon (Maker and others, 1970). Cooler temperatures result in higher humidity in the mountains. Lowest values occur in the Spring. Morning values at Rodeo average approximately 40% and afternoon values average approximately 20% (Maker and others, 1970).
Table 3. Distribution of vegetation in Hidalgo County by soil type (compiled from Maker and others, 1970).

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Hondale-Playas Association is a deep, moderately fine to fine textured soil on nearly level to gently sloping alkali flats in the lowest portions of Animas, Lordsburg, Playas, and Hachita Valleys. The Sonoita-Yturbi-Hap Association is a deep, coarse and moderately fine textured gravelly soil on gentle to moderately sloping old alluvial fan surfaces in a small area northeast of Lordsburg.

Vegetation is typical of the arid Southwest. Although plant cover varies across the county, similar landscape settings have similar vegetation. Maker and others (1970) summarized the characteristic vegetation for each soil association, which is also a reflection of setting. This information has been tabulated to show distribution of vegetation by soil type (Table 3). No plants occur in all soil associations but some occur in several. Other plants are unique to a given soil on setting.

GENERAL GEOLOGY

Although the age of rocks and unconsolidated sediments at or near the surface in Hidalgo County ranges from Precambrian to Quaternary, the geologic record is incomplete (Fig. 8). Deposits of Silurian, Triassic, Jurassic, and Eocene age are missing (Thompson and others, 1978). These intervals were apparently characterized by nondeposition or were followed by periods of erosion that removed all trace of their rock record.

MOUNTAINS

The mountain ranges consist of Precambrian granodiorite, Paleozoic carbonates,
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<th>Age</th>
<th>Symbol</th>
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<th>Description (thickness, ft)</th>
<th>Hydrogeologic Unit</th>
<th>Water-Resource Potential</th>
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<td>bolson fill; alluvial, eolian, lacustrine deposits</td>
<td>gvl, sd, st, cly (&lt;1000)</td>
<td>Bolson Aquifer</td>
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<td>gen. above water table</td>
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<td>QTb</td>
<td>flows, plugs, cinders</td>
<td>basalt (&lt;100?)</td>
<td>Gila Conglomerate</td>
<td>locally useful, poorly known</td>
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<td>Gila Conglomerate</td>
<td>uncons/cons gvl, sd, sit, cly (to 2000?)</td>
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<td>felsic tuff (to 6500)</td>
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<td>Ti</td>
<td>dikes, stocks</td>
<td>rhyolite (&lt;100?)</td>
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* Various units prefixed Tw are mapped in Hidalgo County.

Figure 8. Hydrogeologic column for Hidalgo County. Geology modified from Thompson and others (1978); thicknesses from Lasky (1938), Zeller (1965), Deal and others (1978), and O'Brien and Stone (1982).
Figure 9. General geologic map of Hidalgo County as compiled from Dane and Bachman (1965), Clemons (1983), Drewes and Thorman (1980a, b) by O'Brien and Stone (1984).
Mesozoic sedimentary rocks, and Cretaceous and Tertiary volcanic, plutonic and sedimentary rocks (Fig. 9 and Plate 1). Tertiary intrusive rocks include a 34.9 m.y. old stock in the Animas Mountains, a 30-33 m.y. old quartz-monzonite-porphyry stock in the Peloncillo Mountains, and a 56 m.y. old granodiorite stock in the northern Pyramid Mountains. Tertiary volcanic rocks have been dated in the Peloncillo Mountains near Road Forks at 41.7 m.y. and in the northern Pyramid Mountains southwest of Lordsburg at 67 m.y. The Pyramid Mountains are chiefly composed of Oligocene rhyolitic to andesitic rocks (Fig. 10). Two Quaternary/Tertiary basalt flows west of the town of Animas have been dated at 4.4 m.y. and 0.14 m.y.

VALLEYS

By contrast, the valleys are filled with Quaternary/Tertiary sedimentary rocks and Quaternary sediments. These include alluvial fan deposits as well as fluvial, eolian and lacustrine facies. Older bedrock units underlie this basin fill material (Fig. 8). The Gila Conglomerate, reported in oil tests, represents an earlier phase of valley filling. A gravity-anomaly map (Fig. 11) indicates concentrations of thickest fill.

SUBSURFACE UNITS

Oil and gas wells are an excellent source of information on subsurface geology, depth to bedrock and water-producing zones. Some unsuccessful petroleum wells are even converted to ranch wells, if they encounter significant fresh-water flows. Data on petroleum wells may be obtained from published reports, the files of the Oil
Figure 10. Outcrop of volcanic breccia along Bluebird Draw, east side of Pyramid Mountains, NW sec. 30, T23S, R18W.
Figure 11. General Bouguer gravity anomaly map of Hidalgo County as modified from Lance and others (1982) by O'Brien and Stone (1984). Gravity highs generally correspond to shallow bedrock, whereas lows equate to deep bedrock or thick basin fill.
Conservation Division or the Bureau of Mines and correspondence with the operators involved.

Several published reports, reviewing results of petroleum exploration in the region, give valuable subsurface information. Zeller (1969) compiled descriptions and interpretations of strata tapped by deep oil tests in the Big Hatchet Mountains area. A more regional summary by Kottlowski and others (1969) includes findings in key Hidalgo County wells. Thompson and others (1978) focused on the Pedregosa Basin but gave subsurface geology for other parts of the county as well.

Bureau Petroleum Exploration Map No. 23 shows 30 wells in Hidalgo County. However, less information than this would indicate is actually available as records for very early wells, tight holes and stratigraphic tests are sketchy. Table 4 summarizes available subsurface data for other wells.

Of special interest are oil tests that make water. Such wells provide insight into the water potential of bedrock units not normally penetrated by water wells. An example is Iverson Estate State No. 1-36 in Hachita Valley (NW, sec 36, T29S, R15W). This well, drilled by Phillips Petroleum in 1984, encountered fresh water (chloride content 200-500 ppm) in highly fractured Horquilla Limestone, between 1107 and 1450 ft (Tom Earley, Phillips Petroleum, oral communication, 19 April 1984). Maximum flow rate was 100+ bbl/hr or 70 gpm (1 bbl = 42 gal). The zone was plugged and drilling continued to 8,000 ft. As this was a stratigraphic test, no logs or reports are required by the state and further information is not available at this time.
Table 4. Subsurface geology from petroleum wells, Hidalgo County. Not all formation tops may be reported; KB = Kelly bushing, DF = drill floor; GL = ground level.

<table>
<thead>
<tr>
<th>Location, Name, Date</th>
<th>Elevation (ft)</th>
<th>Depth to top (ft)</th>
<th>TD (ft)</th>
<th>Source*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec 35, T22S, R20W</td>
<td>--</td>
<td>0 - clay and gravel</td>
<td>700</td>
<td>1</td>
</tr>
<tr>
<td>Buffalo Oil and Gas No. 1</td>
<td></td>
<td>340 - black muck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>344 - blue clay, gravel, cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE Sec 31, T24S, R19W Cockrell No. 1</td>
<td>4244 KB</td>
<td>0 - Quaternary deposits</td>
<td>7404</td>
<td>2</td>
</tr>
<tr>
<td>Federal Pyramid 9-30-69</td>
<td></td>
<td>305 - Gila Conglomerate(?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1890 - Tertiary volc. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5795 - Mississippian sed. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7340 - Precambrian rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Sec 4, T26S, R17W Powers Operating Co. No. 1 State 12-3-72</td>
<td>4372 GL</td>
<td>0 - volcanic wash</td>
<td>4005</td>
<td>1,3</td>
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<td></td>
<td></td>
<td>920 - Tertiary volc. rocks</td>
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<td></td>
<td></td>
<td>1180 - Cretaceous sed. rocks</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>3930 - Tertiary intr. rocks</td>
<td></td>
<td></td>
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<tr>
<td>SE Sec 25, T27S, R17W Arthur B. Ramsey 1 Ramsey 25 State 7-2-89</td>
<td>4513 GL</td>
<td>0 - Quaternary deposits</td>
<td>1854</td>
<td>4</td>
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<td></td>
<td></td>
<td>1021 - Tertiary volc. rocks</td>
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<tr>
<td>NW Sec 36, T29S, R15W Phillips Iverson Estate State No. 1-36 1983</td>
<td>3628 GL</td>
<td>1107-1450 - highly fractured zone in Horquilla Ls. (Pennsylvanian) produced 70 gpm; cased over and drilled on</td>
<td>13,000</td>
<td>1,4</td>
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<tr>
<td></td>
<td></td>
<td>14 - Mississippian sed. rocks</td>
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<td></td>
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<tr>
<td>SW Sec 28, T29S, R15W Beal No. 1 Fed 4-28-54</td>
<td>4356 GL</td>
<td>0 - Quaternary deposits</td>
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<td>1</td>
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<td></td>
<td></td>
<td>310 - Permian sed. rocks</td>
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<td></td>
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<tr>
<td>SE Sec 16, T30S, R14W Exploration Funds Norman Jones 1 State A 7-1-70</td>
<td>4460 GL</td>
<td>0 - Quaternary deposits</td>
<td>2350</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 - Tertiary volc. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plugged back to 1000 ft for water well.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW Sec 12, T30S, R15W Nachita Dome No. 1 Tidball-Berry Federal 5-23-57</td>
<td>4349 DF</td>
<td>0 - Quaternary deposits</td>
<td>2726</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 - Mississippian sed. rocks</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2723 - Precambrian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW Sec 12, T30S, R15W Bill J. Graham 1 Hatchet Fed 11-22-78</td>
<td>4331 GL</td>
<td>1410 - Ordovician sed. rocks</td>
<td>2455</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ordovician</td>
<td></td>
</tr>
<tr>
<td>NE Sec 14, T30S, R17W Cockrell No. 1 Playas 6-11-70</td>
<td>4455 KB</td>
<td>0 - Quaternary deposits</td>
<td>7086</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 - Gila Conglomerate</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>2480 - Permian sed. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7030 - Precambrian(?)</td>
<td></td>
<td></td>
</tr>
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Table 4 cont'd.

<table>
<thead>
<tr>
<th>Location, Name, Date</th>
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<th>Depth to top (ft)</th>
<th>TD (ft)</th>
<th>Source*</th>
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<tr>
<td>NE Sec 12, T31S, R17W Cockrell No. 1</td>
<td>4480 KB</td>
<td>0 - Quaternary deposits</td>
<td>4005</td>
<td>2</td>
</tr>
<tr>
<td>State - 1225</td>
<td></td>
<td>150 - Gila Conglomerate</td>
<td></td>
<td>Permian</td>
</tr>
<tr>
<td>11-24-70</td>
<td></td>
<td>2465 - Tertiary volc./sed.(?) rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2595 - Permian sed. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE Sec 3, T31S, R18W KCM Co. No. 1 Forest Fed.</td>
<td>5156 KB</td>
<td>0 - Permian sed. rocks</td>
<td>4464</td>
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<tr>
<td>1-22-70</td>
<td></td>
<td></td>
<td></td>
<td>meta.</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td>Pennsylvanian</td>
</tr>
<tr>
<td>NE Sec 25, T32S, R16W Humble No. 1 State BA</td>
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<td>12-24-58</td>
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<td>230 - Cretaceous sed. rocks</td>
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<td>Ordovician</td>
</tr>
<tr>
<td></td>
<td></td>
<td>995 - Permian sed. rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE Sec 16, T33S, R14W Midwest Refining</td>
<td>4535 DF</td>
<td>100 - Malpais</td>
<td>14585</td>
<td>1</td>
</tr>
<tr>
<td>No. 1 State</td>
<td></td>
<td></td>
<td></td>
<td>Ordovician</td>
</tr>
<tr>
<td>11-8-61</td>
<td>Water at 122 ft (20 gpm) and 135 ft; converted to water well.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW Sec 10, T33S, R20W Arco</td>
<td>5165 GL</td>
<td>690-4508 - Tertiary volc. rocks</td>
<td>10793</td>
<td>1</td>
</tr>
<tr>
<td>1 Fitzpatrick</td>
<td></td>
<td>5582 - pre Tertiary</td>
<td></td>
<td>?</td>
</tr>
</tbody>
</table>

* 1 = scout card, Bureau Petroleum Section
  2 = Thompson and others (1978)
  3 = Thorman (1977)
  4 = phone call to operator
HISTORY

The deeper units (Paleozoic and Mesozoic) record a complex depositional history (Thompson and others, 1978). Paleozoic strata consist mainly of carbonate rock (limestone and dolostone) and occasional sandstone or mudstone intervals. These represent deposition under alternating shallow marine and nonmarine conditions. Cretaceous rocks include conglomerate, much sandstone, mudstone and minor limestone. These too reflect alternating shallow marine and nonmarine environments in the county.

Most structural features in Hidalgo County formed in response to one of two separate tectonic events: the Laramide Orogeny and Basin-and-Range faulting. The main phase of Laramide deformation occurred in Late Cretaceous time (approximately 75 m yrs ago) and consisted of compressional deformation with extensive thrust faulting, originally along northwest trending basement faults (Drewes, 1982). This thrusting was followed by widespread magmatism. The northwest-southeast trending exposure of Precambrian, Paleozoic, and Mesozoic rocks corresponds roughly to the thrust zone shown on Figure 9 and the northwest-southeast trend of gravity highs shown on Figure 8. After the Laramide, tensional conditions dominated. The region was topographically high during Eocene time and detritus of the accompanying deep erosion was carried out of the region. Basin-and-Range tectonism (mid to late Tertiary) was characterized by east-west tensional stress. This produced block faulting, emplacement of granitic plutons, and renewed volcanism with formation of cauldron complexes. Elston et al. (1979) delineated approximate limits of cauldron-outter-ring-fracture zones associated with Tertiary volcanics in Hidalgo County (Fig. 12). Delineation of the major faults in Figure
9 is based on published geologic maps, Landsat imagery, complete and residual Bouguer gravity anomalies, and seismic refraction profiles. High-angle normal faulting characterized the latest stages of this tectonic event. The interval since the Pleistocene has been one of minor faulting and erosion.

In response to wetter conditions in the Quaternary, lakes developed in the valleys. Such pluvial lakes have been recognized mainly in the Animas and San Luis Valleys. Lake Animas, which occupied the Animas and western Lordsburg Valleys, had three major stands, based on shoreline features (Fig. 13). At its highest stage (Late Pleistocene) this lake was 17 mi long, 8 mi wide, 50 ft deep, and covered an area of 150 mi² (Fleischhauer and Stone, 1982). The middle and lower shorelines represent Holocene phases of the lake (6,000-3,000 yrs BP). A large delta formed where Animas Creek entered the south end of the lake. San Luis Valley was the site of a smaller ancient lake (Schwennesen, 1918). Some striking shoreline features are well displayed there.

Such lakes may have existed in the other basins but the evidence is less obvious and they have been little studied. Schwennesen (1918) suggested the area of ephemeral lakes in Playas Valley was the site of an ancient lake and reported a possible abandoned shoreline along the southern margin of Hachita Valley as well.

ECONOMY AND WATER USE

POPULATION

The 1980 census (U.S. Department of Commerce, 1982) shows that the population
Figure 13. Shoreline features of ancient Lake Animas (modified from Fleischhauer and Stone, 1982); Qd = dune deposits, Qps = plays shore ridge deposits, Qvf = valley flat deposits (over lake deposits), Qs = shore ridge deposits of Lake Animas, Qf = alluvial fan deposits.
of Hidalgo County has varied with the economy. In 1960 the population was 4,961. The 1970 figure was down 5% from this or 4,734. But by 1980, the county experienced a population increase of 28% to 6,049. This is attributed to the construction of the new Hidalgo copper smelter (and creation of local jobs) at Playas in 1976. The 1980 population was divided nearly equally between urban and rural residents.

Most of the population is centered in Lordsburg, the county seat and only incorporated municipality. Lordsburg was founded in 1880 when the Southern Pacific—the nation’s second transcontinental railroad—reached that point. In fact, it was named for the engineer in charge of the construction crew (Pearce, 1975). The population of Lordsburg has decreased slightly, but steadily, over the past 20 years: 3,436 in 1960, 3,429 in 1970, and 3,195 in 1980.

Other communities include Animas, Antelope Wells, Cotton City, Playas, Road Forks, Rodeo, and Virden. Populations of most of these surviving towns were not counted in the census. However, data for the farming village of Virden show that its population has steadily increased over the past 20 yrs: 135 in 1960, 151 in 1970, and 246 in 1980. Cloverdale, Shakespeare, Steins, and Summit are essentially ghost towns (Fig. 14).

LAND OWNERSHIP

The economy of an area is reflected to a large extent by its land ownership and administration. Five ownership categories are recognized in Hidalgo County (Table 5). Private land is the largest category (957,970 ac). Federal land (BLM and Forest Service)
Figure 14. Shakespeare: ghost town of mining activity in 1880's, in northern Pyramid Mountains (NW sec. 7, T23S, R18W).
is a close second, totaling 882,679 ac. The next largest category covers less than half this area (state land with 354,431 ac).

AGRICULTURE

Agriculture is by far the largest single land use in Hidalgo County (Table 6). During years of adequate precipitation, and under good management, a fair to high amount of forage is available for livestock and wildlife in most areas (Maker and others, 1970). Grazing accounts for 96% of the total acreage in the county. Water is generally pumped for stock by windmills (Fig. 15).

Irrigation is practiced on only a small percentage (1.5%) of the land, but provides much of the income (Fig. 16). This involves more than 40,000 ac (Lansford and others, 1990). Largest areas of irrigation occur in the Animas and Virden Valleys. Major irrigated crops include cotton, grain, sorghum, and alfalfa. Irrigation also produces minor amounts of small grains, corn, beans, sugar beets, and vegetable crops. Newest crops are Christmas trees and grapes. Two vineyards (approximately 100 acres total) have operated in the Cotton City area for the past 5-6 yrs. A winery located on the eastern edge of the county processes grapes from a vineyard in adjacent Grant County. Some irrigation water is also devoted to maintaining pasture.

Geothermal resources and technology have given rise to a new hot-house industry in Hidalgo County (Gerard, 1987). As of August 1987, three separate greenhouses heated by geothermal energy were operating in the county. These are all located in the Animas Valley, where an extensive reservoir of geothermal fluids exists (see Animas
Table 5. Land ownership by river basin in Hidalgo County, 1966-67 (NMISC/SEO, 1974).

<table>
<thead>
<tr>
<th>Category</th>
<th>Lower Colorado</th>
<th>Rio Grande</th>
<th>Total</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>582,920</td>
<td>375,050</td>
<td>957,970</td>
<td>43</td>
</tr>
<tr>
<td>BLM</td>
<td>515,749</td>
<td>300,710</td>
<td>816,459</td>
<td>37</td>
</tr>
<tr>
<td>State</td>
<td>232,751</td>
<td>121,680</td>
<td>354,431</td>
<td>16</td>
</tr>
<tr>
<td>Forest Service</td>
<td>77,220</td>
<td>0</td>
<td>77,220</td>
<td>3</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>1,408,640</strong></td>
<td><strong>794,400</strong></td>
<td>2,206,080</td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 6. Land use by river basin in Hidalgo County, 1968-70 (NMISC/SEO, 1974).

<table>
<thead>
<tr>
<th>Category</th>
<th>Lower Colorado</th>
<th>Rio Grande</th>
<th>Total</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>1,338,476</td>
<td>783,707</td>
<td>2,122,383</td>
<td>96</td>
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<tr>
<td>Irrigated cropland</td>
<td>29,190</td>
<td>6,040</td>
<td>35,230</td>
<td>1.5</td>
</tr>
<tr>
<td>Inland waters</td>
<td>11,648</td>
<td>4,426</td>
<td>16,074</td>
<td>1</td>
</tr>
<tr>
<td>Commercial timber</td>
<td>11,666</td>
<td>0</td>
<td>11,666</td>
<td>0.5</td>
</tr>
<tr>
<td>Urbanized</td>
<td>10,470</td>
<td>0</td>
<td>10,470</td>
<td>0.5</td>
</tr>
<tr>
<td>Roads and Recreation</td>
<td>7,190</td>
<td>3,067</td>
<td>10,251</td>
<td>0.5</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td><strong>1,408,640</strong></td>
<td><strong>797,440</strong></td>
<td>2,206,080</td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Figure 15. Typical livestock water supply well: Negrohead Well, SE sec. 24, T24S, R19W, west side Pyramid Mountains, Joe Rouse Ranch.
Figure 16. Irrigated crops in Gila River valley east of Virden.
Figure 17. Mining camp of Valedon, just southwest of Lordsburg at northeast edge of Pyramid Mountains ca. 1930 (from postcard provided by R. W. Eveleth).
MINERAL EXTRACTION

Although mining is not represented in the land-use figures above, it has long been an important part of the economy (Fig. 17). The acreage devoted to mineral extraction is small, but the value of resources produced is significant. In 1974, probably the peak of production in recent years, $4,342,000 worth of copper, stone, sand and gravel, silver, clay, zinc, and lead (in order of value) were produced in Hidalgo County (U.S. Bureau of Mines, 1977). Mining activity declined sharply in 1975 and has continued to be depressed to the present (1988). For comparison, only $164,000 worth of silver, gold, stone, clay, lead, and copper (in order of value) were produced in 1984 (U.S. Bureau of Mines, 1986).

In addition to mining, Hidalgo County is also the site of a major copper smelter. Phelps Dodge Corporation's Hidalgo Smelter is located in the Playas Valley, approximately 42 miles southeast of Lordsburg (Fig. 18). In 1978, daily production included approximately 500 t of fine refined copper, 2,200 t of sulfuric acid, and 1,350 t of slag (Kotovsky, 1978). The smelter is also site of a new town, Playas, constructed for the approximately 400 Phelps-Dodge employees. It includes a commercial center with a store, medical clinic, bank, and post office.

OTHER ACTIVITIES

Several other activities contribute to the economy. The main line of the Southern
Figure 18. Hidalgo copper smelter of Phelps-Dodge Corporation, in Playas Valley.
Pacific Railroad, a major east-west line, crosses the northern part of the county, passing through Lordsburg. Numerous motels, campgrounds, and restaurants cater to the travelers on Interstate 10, which generally parallels the railroad across southern New Mexico. Various state and federal government agencies maintain offices in Lordsburg as well. Antelope Wells, 73 miles southeast of Lordsburg in Playas Valley, is an international border crossing (Fig. 19).

WATER USE

Ground water is the main source of supply for these various activities. In 1985, groundwater withdrawals totalled 40,732 af as compared to 1301 af for surface water (Table 7). Depletions are high: 22,859 af for ground water and 1213 af for surface water. Put another way, approximately 50% of the ground water pumped is depleted whereas nearly 100% of the surface water diverted is depleted.

Specific amounts devoted to various uses are shown in Table 6. Most (80%) of the water withdrawn goes to irrigation. The next largest category (14%) is mineral extraction. According to Wilson (1986) per capita water consumption in Lordsburg for 1985 was 242 gpd, that in Rodeo was 112 gpd (46% of the Lordsburg rate) and that in rural areas was only 60 gpd (25% of the Lordsburg rate).

GENERAL GROUND-WATER HYDROLOGY

Ground water occurs beneath the water table throughout the county. However, the water table is usually shallower, and yields are better in the intermontane basins and
Figure 19. International border crossing, Antelope Wells, New Mexico.
Table 7 - Water use in Hidalgo County, 1985 (modified from Wilson, 1986); W = withdrawals, TW = total withdrawals; D = depletions; TD = total depletions; < less than

<table>
<thead>
<tr>
<th>USE</th>
<th>GROUND WATER</th>
<th>SURFACE WATER</th>
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<tr>
<td></td>
<td>W (af)</td>
<td>% of TW</td>
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<tr>
<td>Urban</td>
<td>836</td>
<td>2</td>
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<tr>
<td>Rural</td>
<td>199</td>
<td>&lt;1</td>
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<tr>
<td>Irrigated Agriculture</td>
<td>33,351</td>
<td>82</td>
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<tr>
<td>Livestock</td>
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<td>Stockpond Evaporation</td>
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<td>0</td>
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<tr>
<td>Commercial</td>
<td>153</td>
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<td>Fish &amp; Wildlife</td>
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<td>&lt;1</td>
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<tr>
<td>Reservoir Evaporation</td>
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<td>0</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td>40,732</td>
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stream valleys than in the mountain ranges. Thus most wells are drilled in the valleys. As most valleys are declared basins and reports are required for wells drilled in declared basins, data are fairly abundant for those areas. By contrast, information for wells in the mountains is essentially nonexistent. A field inventory of wells in the Pyramid Mountains affords some appreciation of ground-water resources of such areas.

GENERAL GROUND-WATER OCCURRENCE

A hydrogeologic column for Hidalgo County is given in Figure 8. Only two materials are classified as aquifers, based on available information: the bolson fill of the major basins and the alluvium of the Gila River Valley. Distribution of these aquifers is shown on Plate 1.

The major aquifer is the basin-fill material of Quaternary age, concentrated in the valleys (bolson aquifer of Fig. 8). The bolson aquifer consists of alluvial, fluvial, and lacustrine deposits. More specifically, it includes interbedded gravel, sand, silt and clay. Geologic and geophysical data suggest the total thickness of the fill may be as much as 6,000 ft. Thickness of water-yielding sediments may be as much as 2,600 ft.

As might be expected of basin-fill deposits, the aquifer lithology is quite variable. Schwennesen (1918) noted that it is difficult to correlate units between even relatively closely spaced wells. The reason is that sediment type varies with depositional environment. Lateral shifting of environments is common and thus a horizontally and vertically variable stratigraphic record is produced.

The Gila Valley aquifer is restricted to the channel and floodplain of the Gila
River in the northern or panhandle region of the county. It consists of gravel, sand and silt. Additional information is given in the section on the Gila Valley below.

The stratigraphic column includes other potentially water-bearing units as well (Fig. 8). The Gila Conglomerate, immediately underlying the basin fill, consists of better indurated tuffaceous conglomerate and sandstone. Thickness and hydrologic properties of the Gila and other younger bedrock units in Hidalgo County are unknown. The older bedrock of Fig. 8 includes the entire Paleozoic section. These units are lumped together because, except for the occasional oil test, nothing is known of their water-yielding characteristics.

As wells encounter water before reaching bedrock in the valleys and few wells have been drilled into bedrock in the mountains, and even fewer tested, little is known of the water-yielding characteristics of the pre-Quaternary materials. However, based on the general rock types involved, they are not believed to be conducive to good wells (Figure 8). The Paleozoic carbonate rocks, Cretaceous clastic rocks, and Tertiary volcanics are fairly tight, having significant porosity/permeability only where fractured.

Geologic mapping provides the nature and distribution of these materials at the surface (Plate 1). The main source of geologic information for these units in the subsurface is oil tests. Zeller (1965), Kottlowski and others (1969), and Thompson and others (1978) summarized exploration activity and reported the depth to tops of rock units involved. Additional information is also available in the Petroleum Records section of the Bureau. Water-yielding oil tests are discussed above.

Aquifer properties are not well documented. Average transmissivity values are on
the order of tens of thousands of gpd/ft. Available information is discussed by area below.

Water-level data presented in this report (Tables 10, 12) were selected so as to represent conditions since those reported by previous workers. In some basins new data were gathered in the field or compiled from agency files. In others, only older published data were available. Water depth varies with location relative to recharge areas (mountain fronts) and discharge areas (irrigation pumping centers). Although well records show depth to water ranges from <20 to >400 ft, it is commonly near the 100-ft mark.

GENERAL GROUND-WATER MOVEMENT

Ground-water movement includes recharge, flow, and discharge. More specifically, flow is from recharge areas toward discharge areas.

The aquifers are recharged by seepage from ephemeral streams and overland flow along the mountain fronts, seepage from perennial streams, precipitation on the valley floors, irrigation return flow, and possibly underflow from adjacent basins. Recharge rates are largely unquantified. Table 8 gives reported values for the region.

Ground-water movement is topographically controlled. In Hidalgo County ground water moves from recharge areas in the mountain ranges, toward valleys, thence along their area and finally to discharge areas. Flow direction varies from basin to basin (Plate 1).

Some of the valleys extend beyond the county boundary and discharge areas lie
Table 8. Reported recharge values for basins and mountains adjacent to the Animas Valley.

<table>
<thead>
<tr>
<th>Location</th>
<th>Drainage Area (mi²)</th>
<th>Mean Annual Precipitation (in/yr)</th>
<th>Ground-water Recharge (ac-ft/yr)</th>
<th>Percent of Precipitation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Simon, AZ</td>
<td>309</td>
<td>9</td>
<td>15,000</td>
<td>10</td>
<td>White, Hardt (1965)</td>
</tr>
<tr>
<td>Willcox, AZ</td>
<td>550</td>
<td>11</td>
<td>75,000</td>
<td>23</td>
<td>Brown, Schumann (1969)</td>
</tr>
<tr>
<td>Cienega, AZ</td>
<td>113</td>
<td>20</td>
<td>6,900</td>
<td>6</td>
<td>Geraghty and Miller (1970)</td>
</tr>
<tr>
<td>Cienega, AZ</td>
<td>113</td>
<td>20</td>
<td>4,800</td>
<td>4</td>
<td>Nuzman (1970)</td>
</tr>
<tr>
<td>Cienega, AZ</td>
<td>113</td>
<td>20</td>
<td>19,558</td>
<td>16</td>
<td>Kafri et al. (1976)</td>
</tr>
<tr>
<td>Cienega, AZ</td>
<td>113</td>
<td>20</td>
<td>15,700</td>
<td>13</td>
<td>Kafri et al. (1976)</td>
</tr>
<tr>
<td>Animas, NM</td>
<td>112</td>
<td>11</td>
<td>1,180</td>
<td>2</td>
<td>Hawkins (1981)</td>
</tr>
<tr>
<td><strong>Mountains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peloncillo Mtns</td>
<td>34</td>
<td>9</td>
<td>2,500</td>
<td>16</td>
<td>O'Brien and Stone (198_)</td>
</tr>
<tr>
<td>Pyramid Mtns</td>
<td>65</td>
<td>11</td>
<td>3,000</td>
<td>8</td>
<td>O'Brien and Stone (198_)</td>
</tr>
</tbody>
</table>
elsewhere. Others lie wholly within the county and discharge is to adjacent basins. Such interbasin is difficult to assess due to lack of piezometers in intervening saddle areas. Flow direction in such areas no doubt reverses periodically with fluctuations in precipitation and recharge.

GENERAL GROUND-WATER QUALITY

We think of water chemistry as water quality when considering suitability for an intended use. Major uses include irrigation, stock watering, copper smelting, and domestic/municipal supply. The various dissolved constituents in a ground water make up its chemistry. Water quality varies considerably throughout the county (Tables 11, 13). Water quality can also vary within a basin, depending on aquifer composition, distance from recharge area (time in contact with aquifer), and mixing with other ground waters (fresh or mineralized). Some new analyses for major dissolved constituents were made (Table 13). No organic, bacterial or trace-element analyses were made. A trace-element study for Animas Valley is summarized (Table 9).

Hot water has been reported at various places in the county (Elston and others, 1983). Potential was great enough in Animas Valley for designation of a Known Geothermal Resource Area (KGRA). More information is given on this in the following section. Hot water was also encountered in a well on the Muir Ranch (NE, NE, sec 10, T23S, R17W) in the Playas Valley. Water with a temperature of 120° F was reported from a depth of 1200 ft in a well on the Cooke farm near Lordsburg. Other favorable geothermal targets in Hidalgo County include areas south of the KGRA and the San
<table>
<thead>
<tr>
<th>Element</th>
<th>Concentrations (mg/Kg)</th>
<th>Standards (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ag (silver)</td>
<td>&lt;0.03</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>Al (aluminum)</td>
<td>&lt;1.0</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>As (arsenic)</td>
<td>0.002</td>
<td>0.031</td>
</tr>
<tr>
<td>B (boron)</td>
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<td>0.78</td>
</tr>
<tr>
<td>Ba (barium)</td>
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<td>&lt;0.70</td>
</tr>
<tr>
<td>Br (bromine)</td>
<td>0.12</td>
<td>1.52</td>
</tr>
<tr>
<td>Cd (cadmium)</td>
<td>&lt;0.01</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Co (cobalt)</td>
<td>&lt;0.14</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Cr (chromium)</td>
<td>&lt;0.1</td>
<td>&lt;0.14</td>
</tr>
<tr>
<td>Cu (copper)</td>
<td>&lt;0.10</td>
<td>0.69</td>
</tr>
<tr>
<td>Fe (iron)</td>
<td>&lt;0.10</td>
<td>74.58</td>
</tr>
<tr>
<td>Hg (mercury)</td>
<td>&lt;0.0002</td>
<td>0.0009</td>
</tr>
<tr>
<td>Li (lithium)</td>
<td>&lt;0.1</td>
<td>0.11</td>
</tr>
<tr>
<td>Mn (manganese)</td>
<td>&lt;0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Mo (molybdenum)</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Ni (nickel)</td>
<td>&lt;0.03</td>
<td>&lt;0.16</td>
</tr>
<tr>
<td>P (phosphorus)</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>Pb (lead)</td>
<td>0.001</td>
<td>867.5</td>
</tr>
<tr>
<td>Sb (tin)</td>
<td>&lt;0.5</td>
<td>3.19</td>
</tr>
<tr>
<td>Se (selenium)</td>
<td>&lt;0.002</td>
<td>0.016</td>
</tr>
<tr>
<td>SiO₂ (silica)</td>
<td>0.95</td>
<td>149.7</td>
</tr>
<tr>
<td>Sr (strontium)</td>
<td>&lt;0.02</td>
<td>0.47</td>
</tr>
<tr>
<td>Zn (zinc)</td>
<td>&lt;0.02</td>
<td>2.68</td>
</tr>
</tbody>
</table>

2 EPA (1976) unless indicated
3 Hem (1970)
Simon Valley near Rodeo.

ANIMAS VALLEY

The Animas Valley lies between the Peloncillo Mountains on the west and the Pyramid and Animas Mountain ranges on the east (Fig. 1). Drainage is toward the valley axis then northerly by means of Animas Creek, which soaks into the ground south of the town of Animas. Runoff from the mountain flanks accumulates in the low areas at the north end of the valley to form North and South Alkali Flats (Fig. 1).

GROUND-WATER OCCURRENCE

In terms of ground-water use the Animas Valley is probably the most developed area in the county. The main aquifer is the bolson fill deposits. These consist of interbedded gravel, sand, silt, and clay (Plate 1). A 415-ft deep test hole in SW, NE, NE, sec 6, T22S, R20W shows a typical sequence of basin-fill sediments (Fig. 20). The hole penetrated (in descending order) 60 ft of silt-coarse sand, 65 ft of predominantly clay, 95 ft of sand and gravel, 20 ft of pebbly clay, and 175 ft of silty clay (O'Brien and Stone, 1982, hole T-1). Fragments of volcanic rock are abundant in samples from this hole. The source was presumably the Pyramid and/or Peloncillo Mountains as both include outcrops of flows and pyroclastics.

Sieve analysis of samples from this and another test hole 50 ft away by O'Brien and Stone (1982) show typical textures of the bolson aquifer (Fig. 21). Median grain sizes are in the fine or coarse sand range. The coarse sands are better sorted than the
Figure 21. Texture of bolson aquifer, test well T-2, NE sec. 6, T22S, R20W (modified from O'Brien and Stone, 1982b).
Figure 20. Lithologic log of test well T-1, NE sec. 6, T22S, R20W (modified from O'Brien and Stone, 1982b, Appendix A).
fine sands. Grain shape varies from angular to rounded; most are intermediate (subangular-subrounded).

Because suitable aquifer material is found in one area does not mean it will be in another, owing to the shifting environments of deposition. O'Brien and Stone (1982) found that even clay horizons, which presumably represent stable periods of lacustrine deposition over broad regions of the valley, could not be correlated across the basin (Plate 2).

Although hydraulic parameters of the bolson aquifer are poorly known, previous workers have reported some values. Reeder (1957) gave transmissivities for the Animas Valley ranging from 2,940 to 32,890 ft²/day and averaging 6,685 ft²/d. Arras (1979) reported a pumping test from which a T of 3,560 ft²/d was calculated. Summers (1967) determined an average T of 8,250 ft²/d for the irrigated part of the Animas Valley.

Reeder (1957) calculated storage coefficients for the Animas Valley ranging from 0.07 to 0.14 and averaging 0.11. Summers (1967) computed storage coefficient to be 0.06-0.07.

The best record of pre-development water-table conditions is that reported by Schwennesen (1918). Extensive pumping of water for irrigation resulted in water-level declines, especially in the Animas Valley. Water level dropped at least 20 ft over an area extending from the southern part of T27S to the northern part of T24S (Reeder, 1955). Greatest decline was in sec 35, T25S, R20W. Current management of ground-water development has reduced or stabilized water-level declines (Figs. 22 and 23). More recent water levels are given in Tables 10 and 12.
Figure 22. Comparison of five annual hydrographs for well 24.20.01.444, Animas Valley; dashed lines indicate projections through missing measurements (data from USGS/SEO annual observation well network).
Figure 23. Comparison of winter water levels for selected wells in Hidalgo County basins, 1960-1983; dashed lines indicate projections through missing measurements (data from USGS/SEO annual observation well network).
GROUND-WATER MOVEMENT

Ground water movement generally follows topography. Most water flows from mountain and valley recharge areas toward the Gila River Valley, where it discharges. Locally, ground water flow is diverted toward artificial discharge areas or pumping centers. The significant zones of depression shown in Figure 24 capture ground-water flow in those areas.

Recharge measurements were not made. However, in modeling the hydrologic system of the Animas Valley, O'Brien and Stone (1983) used mountain-front recharge values of 2,500 ac-ft/yr (16% of the 9 in. annual precipitation) for the Peloncillo Mountains and 3,000 ac-ft/yr (8% of the 11 in. annual precipitation) for the Pyramid Mountains. These were based on an equation derived by the USGS (Jack Dewey, written communication, 1982).

These values are within the ranges of recharge values reported for nearby areas (Table 8). The reported values represent 2-23% of average annual precipitation. For comparison, recharge based on a chloride mass-balance approach, in other parts of the state represents <1-3% of average annual precipitation (Stone, 1986).

Water levels are so similar in the Animas and Playas Valleys that interbasin flow is difficult to determine (Plate 3). The lack of specially constructed piezometers or even wells in the saddle area between the basins hinders analysis. If flow does occur, it is probably minor and the direction probably changes with differences in precipitation and recharge events in the two basins.
Figure 24. Water-level decline in lower Animas Valley, April 1948-January 1955 (modified from Reeder, 1957).
GROUND-WATER QUALITY

A general indication of ground-water quality is salinity or dissolved constituents. The two measures of salinity are total dissolved solids (TDS), determined in the laboratory, and specific conductance (SC), determined in both the field and the lab. The relationship between the two was determined for Animas Valley: TDS = 0.717 SC - 14.2 (O'Brien and Stone, 1982). In Animas Valley, Sc ranges from 204 to 7,672 μhmhos/cm (Plate 4; Table 11). Values >750 μhmhos represent a salinity hazard. Freshest water occurs in southern (upgradient) and basin-center locations: 300-500 μhmhos. Downgradient and central areas of the Animas Valley are characterized by SC values of 1800-3000 μhmhos. Highest values are associated with the KGRA: 442-7672 μhmhos.

The specific ions present or the concentration of those ions varies along flowpaths. For example, the major cation in Animas Valley waters is calcium or sodium, depending on location. Calcium comes from weathering of carbonate sedimentary rocks (limestone and dolostone). Sodium comes from clays. Calcium dominates in the recharge areas, whereas sodium dominates in downgradient areas, as a result of cation exchange. Similarly, the major anion in Animas Valley waters is bicarbonate, sulfate, or chloride, depending on location. Bicarbonate comes from the atmosphere, soil, and weathering of carbonate rocks. Sulfate results from the weathering of sulfate minerals followed by oxidation. Chloride comes mainly from recharging precipitation, dust, or solution of evaporite deposits. Bicarbonate characterizes recharge waters, sulfate joins bicarbonate in middle valley areas, and chloride is added in the lower (northern) part of the valley.

Cations and anions can be used to classify water chemistry. Ground water in the
upper (southern) part of the valley would be classified as mainly calcium-bicarbonate water. That of the middle valley (excluding the KGRA) is sodium/bicarbonate-sulfate water. In the KGRA the water is of the sodium-sulfate type. The lower (northern) part of the Animas Valley is characterized by sodium/sulfate-chloride ground water.

The potential for water to participate in cation exchange with clay minerals is indicated by the sodium-adsorption ratio (SAR):

\[ \text{SAR} = \frac{\text{Na}^+}{(\text{Ca}^{2+} + \text{Mg}^{2+}/2)}, \]

where ion concentrations are expressed as milliequivalents/liter. SAR has been determined for the Animas (O'Brien and Stone, 1982). It varies with location within a valley (Fig. 25). Values were generally <10; only values >18 indicate a salinity hazard.

Various other constituents or parameters must be considered in determining the usefulness of a ground water. For example, fluoride exceeds the standard of 1.5 ppm for public supplies in some areas (Table 11). This can lead to mottling of tooth enamel, especially in children. Hardness is also a problem with many waters. Values in the moderately hard (75-150) to hard (150-300) categories have been reported (O'Brien and Stone, 1982). Fortunately, it is the temporary or carbonate type of hardness and can be treated. Trace-metal data were available only for the KGRA (Logsdon, 1981). Table 9 summarizes ranges of concentrations and compares them with standards. Most concentrations are within standards but maximum values reported exceed limits in the case of chromium, iron and lead.

Deposition of minerals in pore space by circulating ground water (cementation) can reduce porosity and permeability. WATEQF, a computer program developed by
Figure 25. Sodium adsorption ratio for ground water samples from Animas Valley (O'Brien and Stone, 1982b).
Plummer and others (1978) to calculate the inorganic chemical equilibrium of waters, was applied to ground waters in the Animas Valley to learn of potential cementation problems (O’Brien and Stone, 1982a). Results are shown in Figure 26. This showed that upper Animas Valley ground water is saturated or supersaturated with respect to silica and thus quartz should be a common cement in the aquifer there. In the middle and lower parts of the valley, waters are saturated or supersaturated with respect to both silica and calcium carbonate. Quartz and calcite should be cementing the aquifer in those areas. Such cements not only reduce yields of the aquifer, they also make drilling more difficult. Furthermore, the same chemical conditions that lead to cementation might result in scale formation in well screens and casing. Available data did not allow for analysis of the potential for zeolite, iron oxide or hydroxide cements in Animas Valley aquifers.

ALKALI FLATS

The alkali flats in the lower (northern) Animas Valley are typical playas, that is, periodically flooded low-lying areas on the floor of an arid valley (Fig. 7). As playas occur at the lowest elevations in the basins, they may develop under either of two different hydrologic regimes. Flooding may be due to the accumulation of discharged ground water or merely the ponding of surface runoff.

In 1985 these areas were the subject of exploration for underground brine. Economic accumulations of brine or evaporites are most likely beneath playas developed under a discharge regime. This follows from the fact that, even before evaporation,
Figure 26. Results of evaluating Animas Valley ground-water samples with WATEQF, a computer program that determines what mineral species the water is saturated or supersaturated with (O'Brien and Stone, 1982b).
ground water generally contains more dissolved solids than runoff.

Predictably the exploration was unsuccessful. The company was surprised that holes were dry even to 100 ft or more and that they encountered evaporites, not even gypsum. The reason is that these playas formed under a runoff regime, discharge being via the subsurface the Gila River outside the valley to the north. Use of available data (O'Brien and Stone, 1981, 1982a, b, and 1983) could have saved these drilling costs.

HYDROLOGIC MODEL

Computer models test conceptual hydrologic models and presumed aquifer properties. The two-dimensional, finite-difference ground-water flow code developed by the USGS (Trescott and others, 1976) was applied to the Animas Valley for this purpose (O'Brien and Stone, 1983). Aquifer parameters were assigned based on all available geological and geophysical data (O'Brien and Stone, 1984). More specifically, transmissivity values were adjusted in view of apparent gravity data/aquifer thickness relationships (Fig. 27).

Steady-state conditions were simulated first using water levels from Reeder (1957). Model calibration was considered complete when simulated water levels were within 25 ft of observed water levels. The model matched steady-state water levels fairly well (Fig. 28).

Next the model was applied to transient conditions using drawdown data for April 1948 to January 1955 (Reeder, 1957). Calibration was considered done when simulated drawdown contours were within 10 ft of observed contours. A reasonable match was
Figure 27. Grid and assigned transmissivity values (based in part on gravity data shown) for two-dimensional, finite-difference computer model of the hydrologic system in Animas Valley (O’Brien and Stone, 1984).
Figure 28. Results of calibrating steady-state model for Animas Valley (O'Brien and Stone, 1984).
Figure 29. Results of calibrating transient model for Animas Valley, April 1948-January 1955 data (O'Brien and Stone, 1984).
achieved (Fig. 29).

For verification of the transient model, drawdown data for the period April 1948 to April 1981 were used. These came from Reeder (1957) and the USGS/SEO annual water-level monitoring network. The model did better for drawdowns in the center of pumpage than for outlying areas (Fig. 30).

GEOTHERMAL RESOURCES

Various aspects of the geothermal phenomena in the Animas Valley have been well covered by previous workers and no attempt will be made to repeat their findings here (see Previous Works above). However, a brief description of the resource, taken largely from Elston and others (1983), is presented for completeness.

In 1948, while drilling for water in NE, sec 7, T25S, R19W, boiling water was encountered in rhyolite at a depth of 87 ft. Kintzinger (1956) mapped temperature 1 m below the surface adjacent to the hot well and was the first to show the broad extent of the hot spot (approximately 2 mi²). Since then other hot wells have been drilled and the area appears to be even larger (Lansford and others, 1981). The anomaly has been designated as the Lightning Dock Known Geothermal Resource Area or KGRA (Fig. 31).

The hot wells seem to lie at the northeast end of a deep, fault zone along which hot water flows. The water is apparently heated (to nearly 485°F) by deep basaltic magma. Near the hot wells, the hot water rises along a conduit formed by the intersection of the fault and the ring-fracture zone of the Muir cauldron. By mixing with
Figure 30. Results of running transient model for April 1948-April 1981 data (O'Brien and Stone, 1984).
Figure 31. Location of Lightning Dock KGRA and geothermal area near Hot Wells, Animas Valley.
normal ground water the hot water is cooled (330°F). Geochemical modeling has suggested the hot water is a blend of 25% deep geothermal fluid and 75% cold ground water (Elston and others, 1983). Ground-water temperatures in the KGRA are shown in Figure 32.

Owing to the relatively low temperature and small volume of hot water, the principal use is space-heating, especially of greenhouses. There were 5 ac of greenhouses in 1981 (Elston and others, 1983). One of these began to use geothermal energy as early as 1968 (Scanlon, 1981). In this operation the 215°F water produced from a depth of 60 ft has to be constantly blended with cold water to prevent the formation of steam. There are now three geothermal greenhouses in the county (Gerard, 1987). The new industry has boosted the economy by providing 20 new jobs and capital investments of nearly $1 million (Wood, 1986).

OTHER AREAS

Some new information was obtained or compiled for most other areas. In some cases this only supplemented a substantial data base. In others, it was the first available information. Those valleys or basins for which there are published reports and few or no new data to present are not included here. Information for such areas should, however, be summarized in the final Hydrologic Report.

GILA VALLEY

The Gila Valley lies north of the Animas Valley, in the northern tip or panhandle
Figure 32. Ground-water temperatures (°F) in the Lightning Dock KGRA, Animas Valley (Lansford and others, 1981).
of the county. It is drained by the Gila River that flows northwesterly into Arizona. Trauger (1972) covered the Grant County portion of the valley. An older Arizona publication (Turner and others, 1941) is the only report on the Hidalgo County part of the valley.

The main aquifer is the alluvium underlying the floodplain of the Gila River. It consists of gravel, sand, and silt. According to Morrison (1965), the upper part of this unit is mainly silt and sand with thin stringers of gravel, whereas the lower part is more gravelly. Thickness is several feet along the valley margins, approximately 75 ft in the center of the floodplain, and 100 ft or more where the channel scoured deep into the underlying Gila Formation (Morrison, 1965). The Gila Valley aquifer can be expected to be lithologically variable for the same reasons given under general hydrology above. Terraces above the valley consist of similar material but are probably above the water table in most places.

The Gila Conglomerate (Tertiary/Quaternary) crops out in the valley walls (Fig. 35) and underlies the alluvium on the floodplain. Where saturated this unit is also an aquifer. Table 7 shows only one well tapping this unit. Wells may be completed in both it and the Gila valley aquifer, where the saturated thickness of the overlying alluvium is small.

PYRAMID MOUNTAINS

The Pyramid Mountains lie south of Lordsburg and separate the northern (lower) part of Animas Valley from Lordsburg Valley (Fig. 1). The continental divide cuts across
their southern tip at South Pyramid Peak. This range is the only mountain area where wells were extensively inventoried.

A field survey of 20 some wells on both sides of the range shows most are used for stock watering. Yields are low but sufficient for pumping by windmills. The main material tapped is fractured bedrock. As shown on the geologic map (Plate 1), most of this is volcanic rock of Cretaceous to Tertiary age. Welded tuff or volcanic breccia was evident near most of the wells (Fig. 10).

Table 12 shows well and water-level depths in the area. Depth was difficult to determine because most well heads were tightly sealed and there was no access for a water-level probe. Based on meager measurements and interviews with ranchers, values range from 25 ft or less (often hand dug) to 800 ft. Depth of most wells is near the 100 ft mark.

Not all areas yield water. It was reported that several wells in this fractured medium (some in abandoned mine shafts or prospect pits) only make water shortly after precipitation events, presumably in response to rapid infiltration along cracks. At the Linn Wells (sec 33, T24S, R18W) there was evidence of three dry holes and drilling underway of a fourth was reportedly unsuccessful. The reason is probably that some of the volcanic units are less permeable (less brittle and fractured) than others.

Flow is from mountain slopes toward ephemeral stream valleys or major valleys and from higher slopes toward lower slopes. Too few data were obtained to accurately plot water-level contours in this area (Plate 3).

Quality of water from these mountain wells is generally excellent (Table 13).
Table 12. Records for miscellaneous wells not in Table 10 (mostly Pyramid Mountains area). Column heads/abbreviations as in Table 10.

<table>
<thead>
<tr>
<th>WELL NO.</th>
<th>QUAD</th>
<th>WELL NAME</th>
<th>C DATE</th>
<th>TYPE</th>
<th>TD (ft)</th>
<th>GSE</th>
<th>WL DEP(ft)</th>
<th>WL DATE</th>
<th>WL ELEV</th>
<th>AQIFER(^1)</th>
<th>ML</th>
<th>PS</th>
<th>USE(^2)</th>
<th>SC (mhos)(^3)</th>
<th>YIELD (gpm)</th>
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<tbody>
<tr>
<td>23S.18W.20.442</td>
<td>LORD</td>
<td>(unnamed)</td>
<td>1980</td>
<td>Dug</td>
<td>500 R</td>
<td>4448</td>
<td>22</td>
<td>3/90</td>
<td>4426</td>
<td>Qal/Tv</td>
<td>P</td>
<td>W</td>
<td>S</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>23S.18W.21.314</td>
<td>LORD</td>
<td>Kennedy</td>
<td>1950's</td>
<td>Druil</td>
<td>(pump at 120 R)</td>
<td>4570</td>
<td>70 R</td>
<td>3/90</td>
<td>4500</td>
<td>Qal/Tv</td>
<td>P</td>
<td>W</td>
<td>S</td>
<td>2-3 R</td>
<td></td>
</tr>
<tr>
<td>23S.18W.30.332b</td>
<td>LORD</td>
<td>R. Searle (new)</td>
<td>1980</td>
<td>Druil</td>
<td>230 R</td>
<td>4610</td>
<td>56 R</td>
<td>3/90</td>
<td>4554</td>
<td>Tv</td>
<td>(P)</td>
<td>(W)</td>
<td>($)</td>
<td>1600*</td>
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</tr>
<tr>
<td>23S.18W.30.111</td>
<td>LORD</td>
<td>Green King</td>
<td>1920</td>
<td>Dug</td>
<td>4191</td>
<td>31</td>
<td>3/78</td>
<td>4160</td>
<td>Qal</td>
<td>P</td>
<td>W</td>
<td>S</td>
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<tr>
<td>23S.19W.07.224</td>
<td>GARY</td>
<td>Fox</td>
<td>1920</td>
<td>Dug-shaft (pump at 80 R)</td>
<td>4690</td>
<td>-40 R</td>
<td>3/90</td>
<td>4650</td>
<td>Tv</td>
<td>S</td>
<td></td>
<td></td>
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<tr>
<td>24S.17W.26.111</td>
<td>MUIR</td>
<td>Muir Ranch</td>
<td>1882</td>
<td>Dug</td>
<td>140 R</td>
<td>4253</td>
<td>117 R</td>
<td>10/90</td>
<td>4136</td>
<td>Qal</td>
<td>S</td>
<td>E</td>
<td>D</td>
<td>S</td>
<td>470*</td>
</tr>
<tr>
<td>24S.18W.07.233</td>
<td>PYRA</td>
<td>Pyramid</td>
<td>1920</td>
<td>Druil</td>
<td>(pump at 120 R)</td>
<td>4775</td>
<td>-70 R</td>
<td>3/90</td>
<td>4715</td>
<td>Qal/Tv</td>
<td>W</td>
<td>M</td>
<td>W</td>
<td>S</td>
<td>5 R</td>
</tr>
<tr>
<td>24S.18W.18.114</td>
<td>PYRA</td>
<td>Mansfield Seep</td>
<td>1920</td>
<td>Druil</td>
<td>-20 R</td>
<td>4661</td>
<td>&lt;20 R</td>
<td>3/90</td>
<td>&gt;4641</td>
<td>Qal</td>
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<td>24S.18W.33.411</td>
<td>PYRA</td>
<td>Linn</td>
<td>1920</td>
<td>Druil</td>
<td>-200 R</td>
<td>4555</td>
<td>150 R</td>
<td>10/90</td>
<td>4405</td>
<td>Qal/Tv</td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>24S.18W.35.232</td>
<td>GARY</td>
<td>Robt. E. Lee Mine</td>
<td>1920</td>
<td>Druil</td>
<td>(pipe to 110 R)</td>
<td>4555</td>
<td>150 R</td>
<td>10/90</td>
<td>4405</td>
<td>Qal/Tv</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>24S.18W.35.232</td>
<td>GARY</td>
<td>Robt. E. Lee Mine</td>
<td>1920</td>
<td>Druil</td>
<td>(pipe to 150 R)</td>
<td>4555</td>
<td>150 R</td>
<td>10/90</td>
<td>4405</td>
<td>Qal/Tv</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>24S.18W.13.332</td>
<td>SWAL</td>
<td>Joe Rouse Ranch</td>
<td>1932</td>
<td>Druil</td>
<td>210 R</td>
<td>(pump at 110 R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24S.18W.24.442</td>
<td>PYRA</td>
<td>Negrohead</td>
<td>1920</td>
<td>Druil</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24S.19W.24.442</td>
<td>PYRA</td>
<td>South</td>
<td>1920</td>
<td>Druil</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
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<tr>
<td>24S.18W.06.211</td>
<td>PYRA</td>
<td>Goat Camp</td>
<td>1920</td>
<td>Druil</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24S.18W.07.421</td>
<td>PYRA</td>
<td>Graham</td>
<td>1920</td>
<td>Druil</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
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<tr>
<td>24S.18W.11.122</td>
<td>PYRA</td>
<td>Uhl</td>
<td>1920</td>
<td>Dug</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24S.18W.17.232</td>
<td>PYRA</td>
<td>Red</td>
<td>1920</td>
<td>Dug</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24S.19W.04.213</td>
<td>HACH</td>
<td>Eightmile</td>
<td>1920</td>
<td>Dug</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
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<tr>
<td>24S.19W.15.2431</td>
<td>HACH</td>
<td>Twelvemile</td>
<td>1920</td>
<td>Dug</td>
<td>206 R</td>
<td>4684</td>
<td>117 R</td>
<td>10/90</td>
<td>4567</td>
<td>Qal/Tv</td>
<td>S</td>
<td></td>
<td>500*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) Qal = alluvium (Quaternary), Tv = volcanic rocks (Tertiary)

\(^{2}\) parentheses indicate use before abandonment

\(^{3}\) asterisk indicates analysis available (Table 13)
Table 13. Analyses of waters not in Table 11 (mostly Pyramid Mountains area). Column heads same as in Table 11. Values are in Mg/L unless specified; pH units are dimensionless.

<table>
<thead>
<tr>
<th>WELL NO.</th>
<th>WELL NAME</th>
<th>DATE</th>
<th>CA</th>
<th>MG</th>
<th>NA</th>
<th>K</th>
<th>HCO₃</th>
<th>SO₄</th>
<th>CL</th>
<th>F</th>
<th>NO₃</th>
<th>TDS</th>
<th>SC (μhos)</th>
<th>HARD (ppm CaCO₃)</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>24S.18W.30.332b</td>
<td>R. Searle (new)</td>
<td>10/90</td>
<td>148</td>
<td>60</td>
<td>43</td>
<td>4.5</td>
<td>258</td>
<td>436</td>
<td>39</td>
<td>0.7</td>
<td>56</td>
<td>919</td>
<td>170</td>
<td>617</td>
<td>7.1</td>
</tr>
<tr>
<td>24S.17W.26.111</td>
<td>Muir Ranch</td>
<td>10/90</td>
<td>32</td>
<td>3.4</td>
<td>80</td>
<td>5.9</td>
<td>182</td>
<td>78</td>
<td>26</td>
<td>0.2</td>
<td>9</td>
<td>326</td>
<td>480</td>
<td>94</td>
<td>7.7</td>
</tr>
<tr>
<td>24S.18W.35.231</td>
<td>Bass</td>
<td>10/90</td>
<td>44</td>
<td>8.7</td>
<td>72</td>
<td>6.3</td>
<td>289</td>
<td>26</td>
<td>21</td>
<td>0.4</td>
<td>18</td>
<td>341</td>
<td>520</td>
<td>520</td>
<td>7.2</td>
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<tr>
<td>24S.19W.13.332</td>
<td>J. Rouse Ranch</td>
<td>6/90</td>
<td>49</td>
<td>6.0</td>
<td>77</td>
<td>6.0</td>
<td>285</td>
<td>28</td>
<td>21</td>
<td>0.6</td>
<td>42</td>
<td>369</td>
<td>580</td>
<td>147</td>
<td>6.8</td>
</tr>
<tr>
<td>24S.19W.24.442</td>
<td>Negrohead</td>
<td>6/90</td>
<td>42</td>
<td>5.2</td>
<td>76</td>
<td>2.2</td>
<td>280</td>
<td>18</td>
<td>17</td>
<td>0.8</td>
<td>12</td>
<td>313</td>
<td>460</td>
<td>126</td>
<td>6.8</td>
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<tr>
<td>24S.19W.24.333</td>
<td>South</td>
<td>6/90</td>
<td>19</td>
<td>7.5</td>
<td>101</td>
<td>2.6</td>
<td>297</td>
<td>25</td>
<td>21</td>
<td>0.8</td>
<td>5</td>
<td>330</td>
<td>650</td>
<td>78</td>
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<tr>
<td>25S.18W.07.421</td>
<td>Graham</td>
<td>10/90</td>
<td>124</td>
<td>28</td>
<td>75</td>
<td>6.8</td>
<td>316</td>
<td>126</td>
<td>101</td>
<td>&gt;0.2</td>
<td>47</td>
<td>666</td>
<td>1020</td>
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<tr>
<td>25S.18W.11.123</td>
<td>Uhl</td>
<td>10/90</td>
<td>65</td>
<td>17</td>
<td>41</td>
<td>2.3</td>
<td>265</td>
<td>36</td>
<td>34</td>
<td>0.4</td>
<td>25</td>
<td>353</td>
<td>580</td>
<td>252</td>
<td>7.1</td>
</tr>
<tr>
<td>25S.18W.17.232</td>
<td>Red</td>
<td>10/90</td>
<td>52</td>
<td>22</td>
<td>55</td>
<td>3.3</td>
<td>256</td>
<td>63</td>
<td>40</td>
<td>&lt;0.2</td>
<td>9</td>
<td>372</td>
<td>600</td>
<td>220</td>
<td>7.4</td>
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<tr>
<td>34S.16W.18.341</td>
<td>Antelope Wells</td>
<td>8/88</td>
<td>26.3</td>
<td>4.1</td>
<td>52.2</td>
<td>2.1</td>
<td>139</td>
<td>60</td>
<td>6.7</td>
<td>2.0</td>
<td>&lt;0.1</td>
<td>196</td>
<td>290</td>
<td>83</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Field measurements of specific conductance range from 470-1600 μmhos/cm. Total dissolved solids range from 313.919 mg/L.

Lab analyses show few wells exceed public health standards. Main water-quality problems are elevated total dissolved solids content, hardness and, in a few cases, elevated nitrate or sulfate. Most of these waters were used for stock consumption and were within limits for that. In the one case of elevated nitrate where humans were the main consumers, they were advised of the danger of methemoglobinemia ("blue-baby" syndrome). Well-head pollution or percolation from septic-tank or feed-lot effluent was the likely source of the elevated nitrate.

ADDITIONAL WORK NEEDED

Various parts of the Hidalgo County study are complete and pertinent sections of this report could be transferred directly to a Hydrologic Report (HR) with little or no modification. These include Introduction, Using This Report, Regional Setting, Economy/Water Use, General Hydrology, Animas Valley, and Pyramid Mountains and Glossary. Some up-dating, based on the 1990 census or water-use results data may be required. Also, figures prepared for this document should be suitable for the HR. Plates would require the addition of color. A base map, showing some topographic contours would help in plotting water-level contours. Such a map could be produced from separates for existing USGS 7.5' topo sheets. Plates 1 and 3 should be revised to incorporate the new base, if produced.

A continuation of the field inventory of mountain wells initiated in this study
would provide the water-level information needed to check suspected ground-water-flow patterns. Ideally this should include all mountain areas: the Alamo Hueco, ANimas, Big Hatchet, Dog, Guadalupe, Little Hatchet, Peloncillo and San Luis Mountains, as well as Apache Hills and Sierra Rica. However, the step-up in air-traffic surveillance along the international border has led to an increase in overland drug smuggling, making such field work increasingly dangerous, especially in the more remote or southern ranges. Fortunately there is little population growth or demand for new ground water in that portion of the area and existing data (for the valleys) may suffice.

Modeling the hydrology of other basins in the study area may also be instructive. It could provide insight as to interbasin connections. The weakest part of previous modelign efforts was input for recharge. A chloride mass-balance study of recharge in major Hidalgo County settings, as done elsewhere by Sonte (1986), would provide realistic values for this parameter.

Ground-water quality concerns now extend beyond normal dissolved constituents. Contamination by pesticides and leaking underground storage tanks is an increasing possibility. Thus, some samples should be submitted for analysis of organic content. Also, trace-metal content of waters should be evaluated in the vicinity of some of the various mines and mills in the county (active and abandoned).

CONCLUSIONS

Although incomplete, the information gathered for this report affords a better understanding of the water resources of this arid landscape. Several conclusions
regarding the geologic controls of the hydrologic systems and water supply in Hidalgo County may be drawn.

GEOLOGIC CONTROLS

The geologic setting significantly controls the hydrologic phenomena in Hidalgo County. More specifically, it influences the occurrence, movement, and quality of ground water in the region.

The physiography significantly controls ground-water occurrence, that is, where aquifers are located, their shape, texture, and extent. The basin-and-range setting dictates that consolidated rock and thus fairly high runoff will characterize the mountain ranges, that porous material and fairly high recharge will occur on alluvial fan surfaces, and that a fairly shallow ground-water reservoir will be maintained in the adjacent basins. Furthermore, the mountains and basins will be elongated essentially perpendicular to the direction of major storms. Variations in well yields are due in large part to natural variations in texture of the alluvial aquifers. Texture is in turn a result of the energy of the depositional environment that produced the sediment.

Geology also influences ground-water movement. Water flows from mountain recharge areas first toward basins and thence toward discharge areas, often a lower part of the basin or a cross-cutting river valley. Rate of movement depends not only on climate (as it controls the amount of water available for recharge) and pumping (artificial discharge) but also hydraulic conductivity of the aquifer (controlled by texture of the material). Interbasin movement is enhanced or hindered by the absence or presence of
rock barriers in otherwise suitable gaps in the mountain ranges.

Ground-water quality is also controlled in part by geologic parameters. The mineral make-up of the aquifer determines the dissolved species that will be present. Any factors controlling flow direction also control water chemistry. Fresher water is generally associated with upgradient areas, higher salinity with downgradient areas.

The tectonic framework of the area is responsible for the geothermal phenomena. Subsurface conditions are apparently favorable for the existence of magmatic heat sources. Faults and fractures serve as conduits for and direct the flow of the hot water.

WATER SUPPLY

Suitability of a supply involves both quantity and quality considerations. The bolson aquifer is extensive, thick, and characterized by good yields. Aside from some minor, treatable exceptions, water quality is quite good. Based on land ownership, water-use, and development trends, as well as the current regulatory framework, the aquifer should provide a reliable supply for many years to come.

If greater ground water volumes are required, deeper drilling could test the potential of buried bedrock units or recharge could be enhanced. In the case of deeper units, oil wells suggest there may be some potential. Regarding recharge enhancement, the playas that form in Animas Valley near the interstate could be drained so that the ultimate destiny of the runoff water is recharge not evapotranspiration. This might be accomplished by installation (during a dry period) of some perforated pipe, extending through the finer sediments that currently keep the runoff on the surface. Catchment
surfaces in the mountains and sediment filters might also be required.

Wet years, such as 1988, not only reduce pumping requirements, they almost certainly provide significant recharge. Whether the climate shifts experienced by broad regions of North America in 1988 are signals of the onset of permanent changes remains to be seen. Alternatively, wet or dry years may simply be natural excursions from the norm. Molles and DAhm (1990) showed strong correlation between increased spring flows of the Gila River and El Niño years (periods of elevated sea-surface temperature/reduced barometric pressure in the eastern tropical Pacific). Should southwestern New Mexico become more arid as zones shift northward, more ground water would be required, and the supply as defined here could become much more stressed than at present.
GLOSSARY

Hydrogeology has a language all its own. The following list includes terms most likely to be unfamiliar to the nonspecialist as well as terms having more than one meaning among specialists. Definitions of most geologic terms are modified from those given in the American Geological Institute glossary (Gary and others, 1974). Definitions of hydrologic terms are modified from Lohman and others (1972) or Freeze and Cherry (1979).

ALLUVIAL--deposited by running water on broad slopes or aprons, or in valleys adjacent to uplands.

ALLUVIUM--alluvial deposit; usually unconsolidated mixture of gravel, sand, silt, and clay.

ANDESITE--volcanic igneous rock with quartz, more calcium feldspar than any other type, and iron/magnesium minerals.

AQUIFER--consolidated or unconsolidated deposit having sufficient saturated permeable material to yield significant quantities of water to wells or springs; a material which both stores and transmits water.

AQUITARD--(also CONFINING BED) consolidated or unconsolidated material of low hydraulic conductivity which stores but doesn’t readily transmit water; overlying an aquifer and responsible for the confinement of water within it.

ARTESIAN (also CONFINED)--term applied to ground water under pressure so that it rises above the level at which it is encountered in drilling a well; also applied to
wells in which this rise occurs and to aquifers that produce it. The rise is not necessarily to the ground surface; if it is, well is said to be flowing artesian.

CALCITE--mineral consisting of calcium carbonate (CaCO₃); main mineral in limestone.

CARBONATE ROCK--chemical sedimentary rock composed of the carbonate radical \((\text{CO}_3^-)\), for example, limestone, \(\text{CaCO}_3\) and dolostone, \(\text{CaMg(CO}_3)_2\).

CAULDRON--volcanic subsidence crater.

CLAY--sediment composed of particles less than 0.00016 inch in diameter; finest textural class.

CONFINED--see ARTESIAN.

CONFINING BED--see AQUITARD.

CONTINENTAL DIVIDE--topographic boundary separating watersheds; in New Mexico, refers to boundary between Colorado River and Rio Grande drainage basins.

DECLARED BASIN--an area of specified boundaries within which well drilling and water extraction are regulated by the New Mexico State Engineer in order to protect the water rights of others.

DISCHARGE--loss of water from, or movement of water out of, an aquifer; the process by which ground water is depleted.

DRAWDOWN--lowering of the water table or potentiometric surface for an aquifer in response to pumpage or artesian flow from wells.

EOLIAN--deposited by the action of the wind.

EPHEMERAL--said of a stream or lake bed that carries or holds water only in direct response to precipitation events; also the flow of such streams.
EVAPOTRANSPIRATION--combined loss to the atmosphere of ground or soil water from an area through processes of evaporation from the soil and transpiration by plants.

EXTRUSIVE--same as VOLCANIC.

FELDSPAR--common mineral composed mainly of potassium, sodium, or calcium aluminum silicate.

FLUVIAL--deposited by running water in discrete channels as associated with rivers and streams.

FORMATION--fundamental unit used in the local stratigraphic classification of rocks, as on geologic maps.

FRESH--see TOTAL DISSOLVED SOLIDS.

GEOLOGY--study or science of the natural processes and products of the earth.

GEOTHERMAL--pertaining to the natural heat of the earth’s interior.

GRANODIORITE--plutonic igneous rock with more sodium feldspar and iron/magnesium minerals than quartz monzonite.

GRANITE--plutonic igneous rock in which quartz constitute 10-50% of the light minerals and potassium/sodium feldspar is 65-90% of total feldspar.

GRAVEL--sediment composed of particles greater than 0.08 inch in diameter; coarsest textural class.

GROUND WATER--subsurface water, especially water in saturated materials that exist below the water table.

GROUP--combination of two or more formations.
GYPSUM--common mineral composed of hydrous calcium sulfate (CaSO₄); may occur in layers with limestone, shale, or other evaporites.

HEAD----height (above a datum) of a column of water that can be supported by the static fluid pressure at a given point.

HOLOCENE--latest epoch of Quaternary Period (10,000 yrs ago-present).

HYDRAULIC CONDUCTIVITY--volume of water (at existing viscosity) that will move in unit time, under a unit hydraulic gradient, through a unit area of saturated material. Sometimes reported as gpd/sp ft; if gals are converted to cubic ft (ft³), unit become ft/day, as a result of algebraic cancellation.

HYDRAULIC GRADIENT--change in head per unit of distance in a given direction.

HYDROGEOLOGY--study or science of the geologic controls of hydrologic phenomena.

HYDROLOGY--study or science of the occurrence and behavior of water in nature.

IGNEOUS--formed by cooling from molten material.

INTERMITTENT--said of a stream along which perennial flow is restricted to certain reaches; also the flow of such a stream.

INTRUSIVE--same as PLUTONIC.

LACUSTRINE--deposited by settling out of standing water associated with temporary or permanent lakes.

LIMESTONE--sedimentary rock consisting of >50 percent calcite.

LITHOLOGY--physical character of a rock expressed in terms of texture, mineralogy, color, and structure.

MEMBER--subdivision of a formation.
METAMORPHIC--formed by metamorphism, that is, alternation of pre-existing rock through changes in temperature, pressure, and chemical conditions.

MINERAL--naturally occurring, inorganic substance, with a characteristic set of physical properties, and a fixed chemical composition or fixed range of composition.

PAN EVAPORATION--potential evaporation; amount of water (usually depth in inches) that could be lost to the atmosphere from a pan in which a fixed water level is maintained.

PERENNIAL--said of a stream that flows year round; also the flow of such a stream.

PERMEABILITY--measure of the relative ease with which a porous medium transmits a liquid.

PIEZOMETER--well constructed for measuring water level or hydraulic head at a specific horizon.

PLAYA--flat-floored, unvegetated, periodically flooded area in a desert region.

PLEISTOCENE--earliest epoch of Quaternary period; most recent episode of extensive glaciation in North America and Europe (1,000,000-10,000 yrs before present).

PLUTONIC--igneous rock formed at depth.

PLUVIAL LAKES--prehistoric lake formed in the period of heavy precipitation, such as the Pleistocene ice age; now largely extinct or greatly reduced.

PORPHYRY--texture of igneous rocks in which there are two or more sizes of crystals.

POROSITY--percent of total volume of a rock, soil, or unconsolidated sediment taken up by pores.

POTENTIOMETRIC SURFACE--surface that represents the static head for a given
aquifer.

PUMPING-TEST—test of a well to determine the hydrologic properties of the aquifer penetrated; involves pumping to remove (or injection to add) a known volume of water; accompanied (drawdown or pumping test) or followed (recovery test) by monitoring the water level at selected time intervals to determine the rate of the aquifer's response to the induced change.

QUARTZ—common mineral composed of crystalline silica (silicon dioxide, SiO₂).

QUATERNARY—latest period of geologic time scale (1,000,000 yrs ago-present).

QUARTZ-MONZONITE—plutonic igneous rock in which quartz constitutes 10-50% of the light minerals and potassium/sodium feldspar is 35-65% of total feldspar.

RECHARGE—addition of water to, or movement of water into, an aquifer; the process by which ground water is replenished.

RECOVERY TEST—see PUMPING TEST

RELIEF—difference in elevation between high and low points in an area.

RHYOLITE—extrusive igneous rock; volcanic equivalent of granite.

ROCK—naturally occurring aggregate of minerals.

SALINE—see TOTAL DISSOLVED SOLIDS.

SAND—sediment composed of particles 0.0025-0.08 inch in diameter; medium textural class.

SEDIMENTARY—formed by deposition of sediment.

SILT—sediment composed of particles 0.00016-0.0025 inch in diameter; textural class between clay and sand.
SOIL ASSOCIATION--basic mapping unit for soils.

SPECIFIC CAPACITY--relationship of discharge of a well and the drawdown of the water level in it. Measured as gpd/ft of drawdown; if gals are converted to ft³, unit becomes ft²/d.

SPECIFIC CONDUCTANCE--electrical measure of salinity (in microsiemens); the reciprocal of resistance. Specific conductance times 0.7 gives general approximation of the total dissolved solids in mg/L.

SPECIFIC STORAGE--volume of water released from or taken into storage per unit volume of porous medium, per unit change in head.

SPECIFIC YIELD--volume of water that will drain from a porous medium under the influence of gravity; equal to porosity minus specific retention.

STOCK--small body of plutonic igneous rock.

STORAGE COEFFICIENT--volume of water released from or taken into storage per unit surface area of porous medium, per unit change in hydraulic head.

THRUSTING--low angle (45° or less) faulting in which older rock mass is shoved up and over younger rock mass.

TOTAL DISSOLVED SOLIDS--physical measure of salinity; amount (mg/L) of residue obtained by oven drying a water sample. Water is often classified by this parameter:

- <1,000 mg/L = fresh
- 1,000-3,000 mg/L = slightly saline
- 3,000-10,000 mg/L = saline
10,000-35,000 mg/L = very saline

>35,000 mg/L = brine

TRANSMISSIVITY--rate at which water is transmitted through a cross section of material having the dimensions unit width and total thickness as height, under a unit hydraulic gradient; also hydraulic conductivity times the thickness of the material. Sometimes reported as gpd/ft of width; if gals are converted to ft³, unit becomes ft²/d.

UNCONFINED--term applied to ground water in a water-table aquifer or one not overlain by a confining bed; also applied to such an aquifer.

VOLCANIC--igneous rock formed at the surface.

WATER TABLE--that surface in an unconfined aquifer at which water stands in wells; roughly corresponds to the top of the saturated zone. Specifically, the surface formed by points at which water pressure equals atmospheric pressure.
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1. USGS MI I 1310-C
2. NM State Map
3. USGS MI 1686
4. Bureau Bull. 84
5. Bureau Circ. 146
6. USGS MF 1425-A
7. Bureau Geol. Map 17
8. Bureau Geol. Map 8
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