GROUND-WATER RESOURCES OF THE BISBEE-NACO AREA, COCHISE COUNTY, ARIZONA

By G. R. Littin

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For readers who prefer to use the metric (International System) units, the conversion factors for the inch-pound units used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
ton (short)	0.0972	tonne (t)
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

<u>Sea level</u>: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

The Bisbee-Naco area is in southeastern Arizona and northeastern Sonora, Mexico. Annual rainfall averages about 17 inches. The basin fill is the principal aquifer and supplies about 95 percent of all water for domestic purposes. The total ground water pumped in 1985 was about 6,500 acre-feet. Of that amount, 2,200 acre-feet was used for domestic use and the rest was used for irrigation and livestock. Domestic use is expected to increase 20 percent by the year 2000. Water levels at the Bisbee well field have remained virtually unchanged since 1953, but water levels have declined about 25 feet in areas east and southeast of the well field.

The native ground water in the area is a calcium bicarbonate type and generally is suitable for domestic use. Ground water downgradient from a mine-tailings pond contains 650 to 850 milligrams per liter of sulfate. Recharge occurs naturally through direct infiltration of rainfall along the mountain fronts and through subsurface inflow from adjacent areas. Some water is recharged through direct infiltration from a mine-tailings pond, sewage ponds, septic systems, and urban runoff.

The potential for contamination exists from mine tailings, sewage, and urban runoff. No other sources of drinking water are readily available in the immediate area. Potential alternate sources of drinking water are the aquifers underlying Sulphur Spring Valley and San Pedro River valley.

SUMMARY OF FINDINGS

1. Population in the Bisbee-Naco area was about 12,300 in 1980. Projected growth is expected to reach 16,000 by the year 2000.

2. Climate is arid to semiarid with mild year-round temperatures. The average annual precipitation is about 17 in., of which about 36 percent occurs during July and August.

3. Land use is mainly cattle ranching and rural residential. Agriculture is limited to about 1,400 acres, of which about 90 percent is located in Mexico.

4. The basin fill is the principal aquifer and provides about 95 percent of the drinking water to the area.

5. Ground water generally moves in the same direction as the surface flow. Some flow may occur through fractured or faulted rocks in hydraulic connection with the aquifer. Flow velocity from the northeast ranges from about 0.5 to 0.8 ft/d.

6. Annual surface recharge from natural means is about 2,000 to 2,500 acre-ft. Recharge from mine tailings is about 400 to 500 acre-ft/yr and may have been much greater when mining activity was at its peak.

7. In 1985, about 6,500 acre-ft of ground water was used for irrigation, public-supply, mining, domestic, and stock purposes. About 3,600 to 4,200 acre-ft of water was used for agricultural purposes, and 2,200 acre-ft of water was used for public-supply and domestic purposes.

8. Water levels in the Bisbee well field have remained virtually unchanged since 1953. Declines of about 25 ft have been recorded east and southeast of the well field.

9. Well yields range from less than 2 gal/min in the sedimentary rocks to more than 1,400 gal/min in the basin fill.

10. Two types of water occur in the area—calcium bicarbonate water and calcium sulfate water. The calcium bicarbonate water occurs naturally and is the most widespread. The calcium sulfate water occurs in the sedimentary rocks northeast of Naco and deep within the mines near Warren.

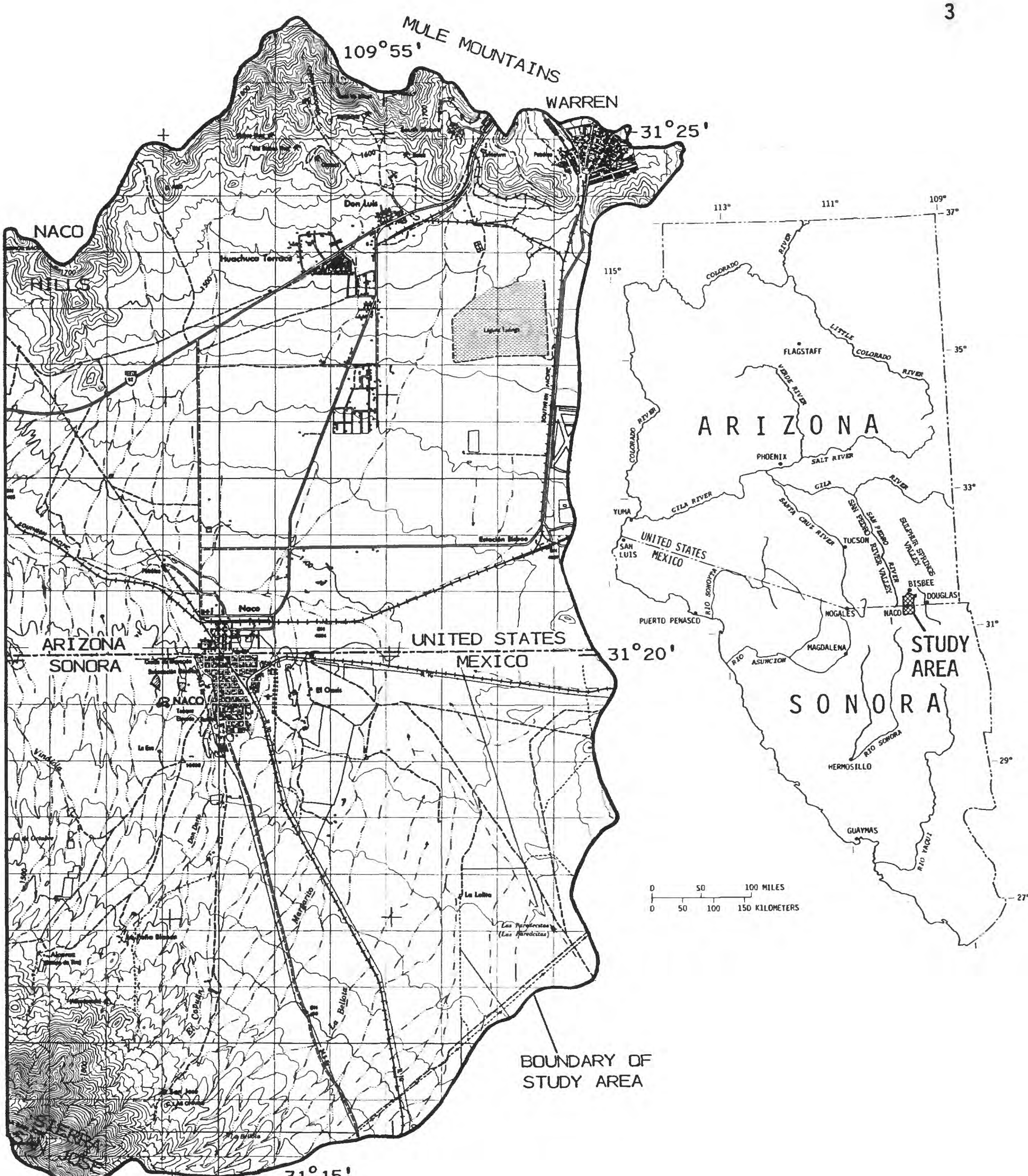
11. Dissolved-solids concentrations range from about 230 to 360 mg/L (milligrams per liter) in the basin fill. Dissolved-solids concentrations of as much as 1,650 mg/L and sulfate concentrations of between 650 and 850 mg/L were found in wells that penetrate the sedimentary rocks. Chemical analyses included most of the primary and secondary contaminants.

12. The potential for contamination of the aquifer exists from mine tailings, sewage, and urban runoff. Various soils throughout the study area have a relatively high infiltration potential and can provide conduits for contaminants during periods of runoff.

13. Alternate sources of water would be aquifers underlying Sulphur Spring Valley or San Pedro River valley; however, importation would be costly.

INTRODUCTION

The Bisbee-Naco area includes about 46,000 acres (72 mi^2) in southeastern Arizona and northeastern Sonora, Mexico (fig. 1). The basin fill is the principal aquifer and the main source of domestic, stock, and public water supplies in this area. Perennial streamflow is not known to exist in the area; therefore, future development will depend on ground water. Ground water is stored within the voids of the basin-fill deposits and in variable amounts in fractures and faults in the consolidated rocks that bound the area.



BASE FROM ESTADOS UNIDOS MEXICANOS 1:50,000,
CUAUHTEMOC, SONORA, MEXICO AND UNITED STATES

0 1/2 1 2 3 4 MILES

0 .5 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 20 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 1.--Area of report.

A petition was submitted to the U.S. Environmental Protection Agency by concerned citizens of Bisbee, Arizona, requesting that the local aquifer be declared a sole-source aquifer because of the existing potential for water-quality degradation. The U.S. Environmental Protection Agency, in turn, requested the U.S. Geological Survey to evaluate the hydrologic system of the area.

Purpose and Scope

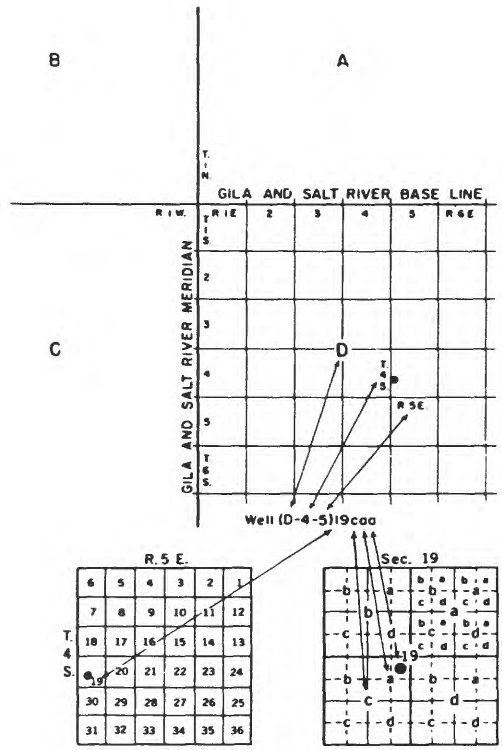
The investigation was done to determine (1) if the local aquifer is the sole source of drinking water for the area and (2) if the aquifer is susceptible to contamination and, if contaminated, will the water present a significant health hazard? Gravity surveys and geophysical logging were done to define the subsurface configuration and geology of the area. Aquifer tests and water-level and well-discharge measurements were made to define the ground-water flow system. Water samples from selected wells were analyzed to determine the quality of water, and soils data were collected and analyzed to define infiltration characteristics of sediments in the area. Pumpage records and water-use data were compiled to estimate the inflow and outflow components of the water budget for the basin. Existing drinking-water supplies were identified and possible alternative sources were discussed. Previous studies and field data provided background information for this investigation. In order to evaluate these characteristics, new geologic and hydrologic data were collected from November 1985 to April 1986; the data were analyzed and the results are discussed in this report.

Well-Numbering and Naming System

The records in tables 2 and 3 are identified by township, range, and section under the well-numbering system used in Arizona in accordance with the Bureau of Land Management's system of land subdivision (fig. 2). The base map used (fig. 3) does not have township and range lines but instead has a metric grid. Hence, local identifiers were used in figure 3 and in the column "Other identifiers" in tables 2 and 3. A three-letter identifier was used for incorporated wells and a one- or two-letter geographic identifier was used for private wells. Exceptions are the two-letter company identifier (PD) assigned to the mine sample, the two-letter identifier (PZ) assigned to the Gilos Agriculture Cooperative samples, and the two-letter identifier (NS) assigned to the Naco Water Company in Sonora, Mexico, samples. Many small domestic wells exist in some areas but only a few were inventoried for use in evaluating water resources of the area.

Previous Investigations

Several previous investigations were helpful in evaluating the geohydrologic relations in the area. Dumble (1899, 1901) published the first papers of any consequence on the geology in northeastern Sonora and



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (D-4-5)19caa designates the well as being in the NE¼NE¼SW¼ sec. 19, T. 4 S., R. 5 E. Where more than one well is within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 2.--Well-numbering system in Arizona.

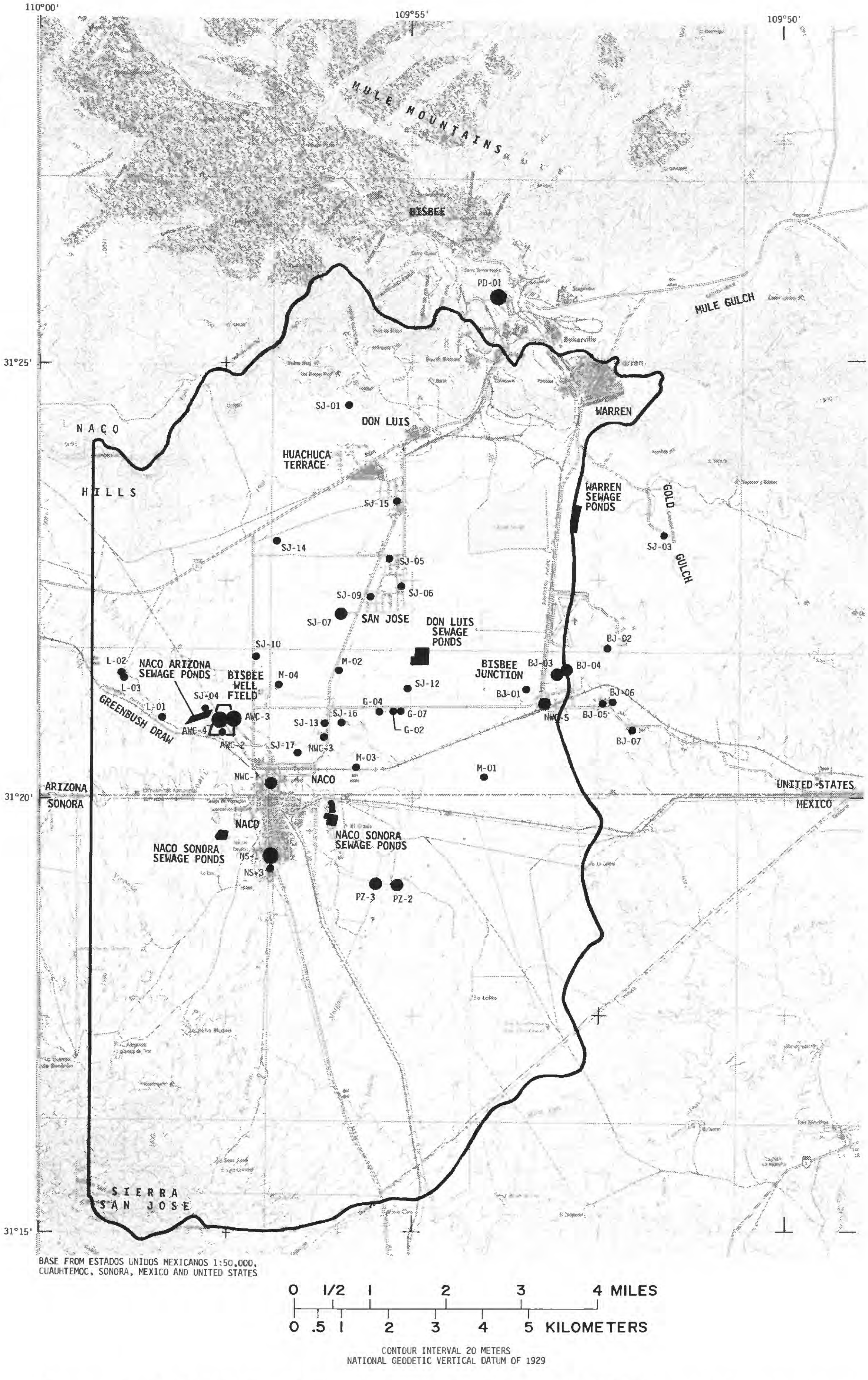


Figure 3.--Selected well locations, Bisbee well field, and sewage ponds.

EXPLANATION

● NWC-1 — WELL OR MINE SITE—NWC-1, is well or mine identifier

PRODUCTION, IN GALLONS PER MINUTE

● 0 to 100

● 100 to 500

● More than 500

——— BOUNDARY OF STUDY AREA

Figure 3.

southeastern Arizona, respectively. Ransome (1904) published a comprehensive report on the geology of the Bisbee quadrangle. Later investigations by Imlay (1939) and Hayes and Landis (1964, 1965) contributed further understanding of the geology throughout the area. With the exception of Imlay, only cursory mention was given to the post-Cretaceous sediments that make up the alluvial deposits in the area.

Previous hydrologic data are scarce. Parts of an unpublished report prepared in 1953 for the Arizona Public Service Company by Headman, Ferguson, and Carolla were made available by the Arizona Water Company and provided water-level, aquifer-test, water-use, and water-quality data for a small area near Naco, Arizona. Konieczki (1980) provided additional water-level data. Water-quality data were also provided by the Arizona Water Company and the Naco Water Company, Naco, Arizona.

Acknowledgments

This investigation was done in cooperation with the U.S. Environmental Protection Agency on behalf of the citizens of Bisbee. The author gratefully acknowledges the cooperation and assistance of the personnel of the Arizona Water Company; Cochise County Sanitation Department; Phelps Dodge Corporation; City of Bisbee Public Works Department; Naco Water Company; Naco Sanitation District; City of Naco, Sonora; the Gilos Agriculture Cooperative; U.S. Soil Conservation Service; and University of Arizona. Special thanks are due to Al D. Rand, Arizona Water Company; Arnold Nanez and Juan J. Alegria, Cochise County Sanitation Department; Joseph W. Durrenberger, Phelps Dodge Corporation; James A. Gillen, Bisbee Public Works; Lloyd Law, Jr., U.S. Soil Conservation Service; and countless others residing in the study area for their assistance and many helpful discussions in this investigation.

DESCRIPTION OF THE STUDY AREA

Location and Population

The Bisbee-Naco area is about 85 mi southeast of Tucson and straddles the international boundary between the United States and Mexico; part of the area is in Mexico (fig. 1). Once a mining boomtown with a population of more than 16,000, Bisbee's population today is estimated to be about 5,300 and is supported largely by public service and private wholesale and retail establishments. Recent interest by developers and artisans has revitalized the economy of the area.

In 1980 the population of the Bisbee-Naco area was about 12,300 according to figures provided by the cities of Bisbee, Arizona, and Naco, Sonora. Population in the area is expected to reach 16,000 by the year 2000 (Jesse B. Brown, Southeast Arizona Governments Organization (SEAGO), written commun., 1985). This figure represents an increase of about 33 percent over the 20-year period. Nearly 70 percent of this increase is expected to occur in the Naco area as a result of nonmining industrial development.

Physiographic Setting and Land Use

The area is characterized by steeply sloping mountains separated by broad, flat-lying alluvial plains. The area is bounded on the north and east by the Mule Mountains in Arizona and their unnamed southern extension in Sonora and on the south and southwest by Sierra San Jose. On the west, the boundary has been arbitrarily established along a line extending north from the summit of Sierra San Jose to the Naco Hills southwest of Bisbee. Beyond the mountains, to the east and west, respectively, are Sulphur Spring Valley and San Pedro River valley.

Land use is mainly cattle ranching and rural residential. Agriculture is limited, and only about 1,400 acres, mostly alfalfa, are cultivated in a single growing season. About 90 percent of all irrigable acreage in the study area is in Mexico. Recreational use includes outdoor activities such as hiking and hunting and a 9-hole municipal golf course near Naco. Copper mining, once the area's mainstay, is now limited to leaching operations near Warren (fig. 3). A large unused tailings pond on the plain northeast of Naco covers nearly 1,000 acres. The tailings pond is located on top of a huge mound of mine tailings, which by virtue of its height, is the most prominent landmark in the area. Several small mining claims, including a lime quarry in Mexico, are presently being worked in the surrounding mountains. Several sewage-treatment ponds are scattered throughout the plain and cover a combined area of about 50 acres.

Geologic Setting

The mountains in the study area are a complex assemblage of faulted igneous, metamorphic, and sedimentary rocks. Locally, the rocks are mineralized and have been extensively mined. The alluvial plain in this area lies between the Mule Mountains to the north and the mountains in Mexico to the south. The plain is the surface of Quaternary and Tertiary sedimentary deposits that fill a relatively shallow basin. These deposits are commonly referred to as basin fill and range in thickness from 0 to at least 270 ft. The basin fill consists of boulder to pebble conglomerate and interbedded gravel, sand, silt, and clay. To the north and east, these deposits form a thin veneer on flat, gently sloping, pedimentlike surfaces and become thicker to the south and west. Gravity data indicate a general deepening of the basin toward the southwest. To the south, the deposits form heavily dissected alluvial fans around the base of Sierra San Jose and slope northward and eastward toward Greenbush Draw.

Thick accumulations of consolidated sedimentary rocks ranging in age from Cambrian to Cretaceous make up much of the surrounding mountains and hills (fig. 4). These rocks consist of thick alternating deposits of limestone, sandstone, and shale. Borehole geophysical data, collected during this investigation at well sites SJ-14 and SJ-15, indicate that these rocks extend southward from the Mule Mountains and underlie the basin fill. On the basis of surface exposures (Ransome, 1904; Hayes, 1970), the rocks are estimated to range from 4,000 to 9,000 ft in thickness. Underlying the sedimentary rocks is a basement complex made up of Precambrian schist and granitic rocks of Jurassic age. Magnetic surveys by Phelps Dodge Corporation in the late 1960's indicate the presence of a dike (fig. 4), possibly andesite, trending north-south near the base of the basin fill beneath the Bisbee well field.

Precipitation

The climate throughout the area is arid to semiarid with mild year-round temperatures. Heavy rains, which occur in July and August, accounted for about 36 percent of the average annual precipitation for 1978-85 (table 1). A comparison of these data with earlier records for Bisbee (no data are available for Naco prior to 1978) indicates that the annual precipitation has been slightly greater in recent years and that July and August have been noticeably drier. The calculated average annual precipitation for the Bisbee-Naco area is 16.7 in. for 1978-85.

Table 1.--Monthly and annual average precipitation data for Bisbee and Naco, Arizona

[Values are in inches except where indicated]

	1978-85				1931-61	
	Bisbee	Naco	Monthly average	Percent of annual	Bisbee	Percent of annual
January	1.68	1.71	1.69	10	1.40	9
February	1.00	0.83	0.92	6	0.77	5
March	1.20	1.03	.40	6	.98	6
April	0.49	.31	.40	2	.49	3
May	.23	.22	.22	1	.15	1
June	.39	.40	.40	2	.76	5
July	2.55	2.69	2.62	16	3.70	23
August	3.44	3.11	3.28	20	4.21	26
September	1.77	1.99	1.88	11	1.45	9
October	1.42	1.21	1.32	8	.91	5
November	.91	.99	.95	6	.44	3
December	2.13	1.87	2.00	12	.95	5
Annual	17.21	16.19	16.71	100	16.21	100

Surface Drainage

Major drainage is from east to west through the middle of the study area, and tributary drainage is from the north and the south to the middle. About half of the drainage area is in Mexico. Drainage is well defined in the southern half of the area where many washes drain northward from Sierra San Jose into Greenbush Draw (fig. 5). Drainage in the northern half is less well defined, and during periods of intense rainfall, sheetflow is common. Runoff is confined to a few relatively shallow washes that drain southward into Greenbush Draw. Greenbush Draw discharges northwest into the adjacent San Pedro River valley.

Annual surface discharge from Greenbush Draw to the San Pedro River was estimated to be 2,600 acre-ft[1] (S. G. Brown and B. N. Aldridge, U.S. Geological Survey, written commun., 1973). The estimate was based on an equation developed by Moosburner (1970) for ungaged tributary inflow and represents the average total runoff from the watershed. The drainage area included an additional 33 mi^2 west of the study area. The annual surface discharge from the study area therefore is estimated to be about 1,800 acre-ft. Of this amount, about 50 percent or 900 acre-ft is from the drainage area south of the international boundary.

GROUND WATER

Occurrence

Ground water occurs in the basin fill, the consolidated sedimentary rocks, and the basement rocks. Well yields vary considerably from well to well and from consolidated rocks to basin fill. The principal aquifer is the basin fill, which provides about 95 percent of all water for domestic purposes. Wells in the basin fill equipped with large-capacity pumps commonly yield between 400 and 800 gal/min. Well AWC-4 yields more than 1,400 gal/min from a system of hand-dug drifts that penetrate the basin fill. Wells penetrating the consolidated sedimentary rocks yield from less than 2 to 180 gal/min. The sedimentary rocks are capable of yielding large quantities of water through fault and fracture zones. One such zone is in the Mule Mountains, where mine shafts penetrate to depths of between 1,800 and 3,100 ft below the land surface (site PD-01, fig. 3 and table 2) and pumping rates of more than 6,000 gal/min were used to maintain a stable water level in the mines (Phelps Dodge Corporation, oral commun., 1986). In the plains area between the Mule Mountains and Sierra San Jose, the sedimentary rocks yield relatively little water to wells. The basement rocks contain little space for the storage of water except where they are highly fractured or faulted. Several wells in and near Bisbee are reported to yield between 5 and 35 gal/min from schist and granite, according to the Arizona Department of Water Resources (ADWR) well-registry records.

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[1]An acre-foot is the quantity of water needed to cover 1 acre to a depth of 1 foot and is equal to 325,851 gallons or 43,560 cubic feet.

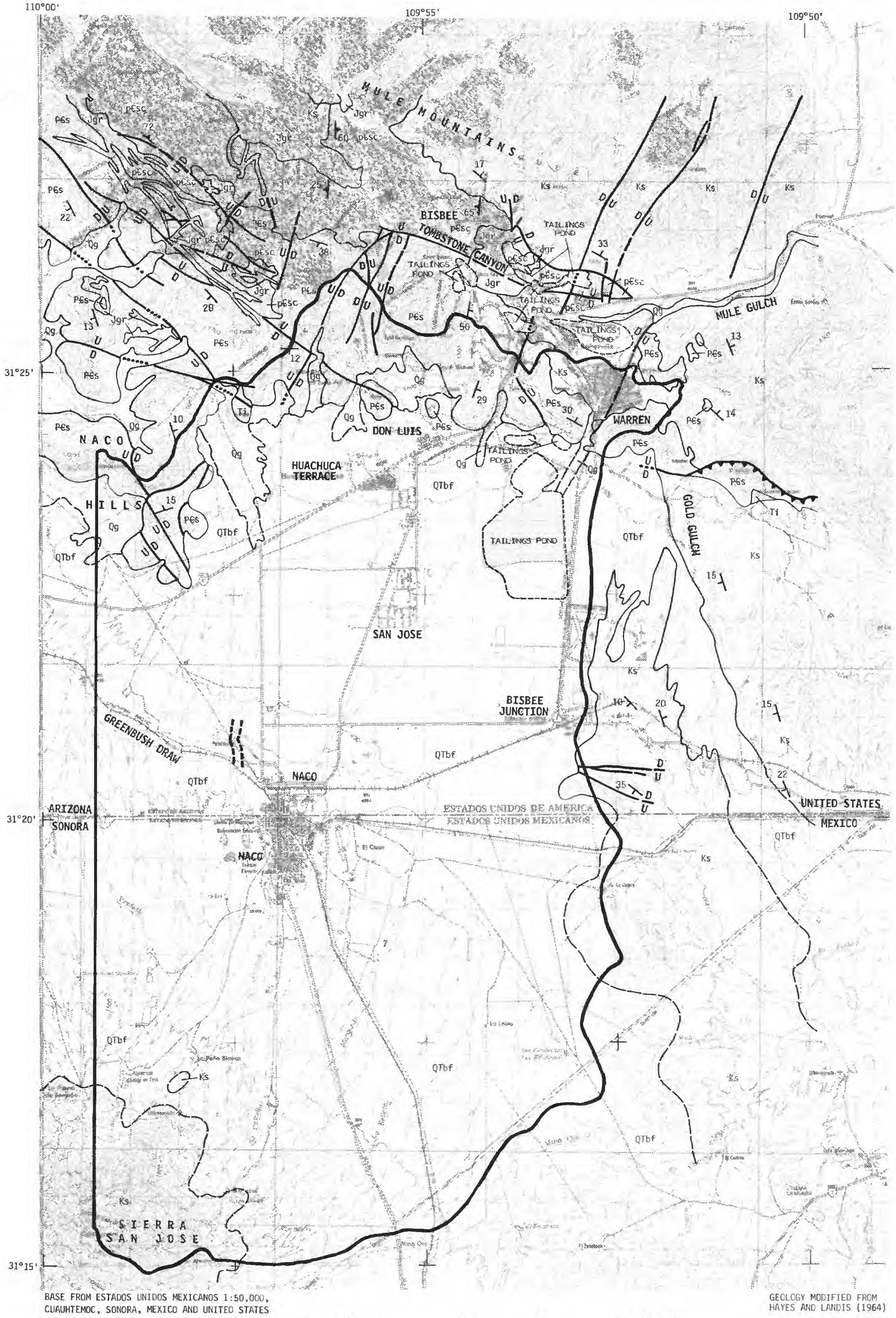

Figure 4.--Generalized geology.

E X P L A N A T I O N

Qg	PEDIMENT, TERRACE GRAVEL	QUATERNARY
QTbf	BASIN FILL, UNDIFFERENTIATED	QUATERNARY AND TERTIARY
	Unconformity	
Ti	INTRUSIVE ROCKS	TERTIARY
Ks	CONSOLIDATED SEDIMENTARY ROCKS, UNDIFFERENTIATED	CRETACEOUS
	Unconformity	
Jgr	GRANITE	JURASSIC
P€s	CONSOLIDATED SEDIMENTARY ROCKS, UNDIFFERENTIATED	PERMIAN-CAMBRIAN
	Unconformity	
p€sc	SCHIST	PRECAMBRIAN

	CONTACT—Dashed where approximately located
U D ?	FAULT—Dashed where approximately located; dotted where concealed; queried where uncertain. U, upthrown side; D, downthrown side
	THRUST FAULT—Dashed where approximately located. Sawteeth on upper plate
	BURIED DIKE
25	STRIKE AND DIP OF BEDS
65	STRIKE AND DIP OF FOLIATION
	BOUNDARY OF STUDY AREA

Figure 4

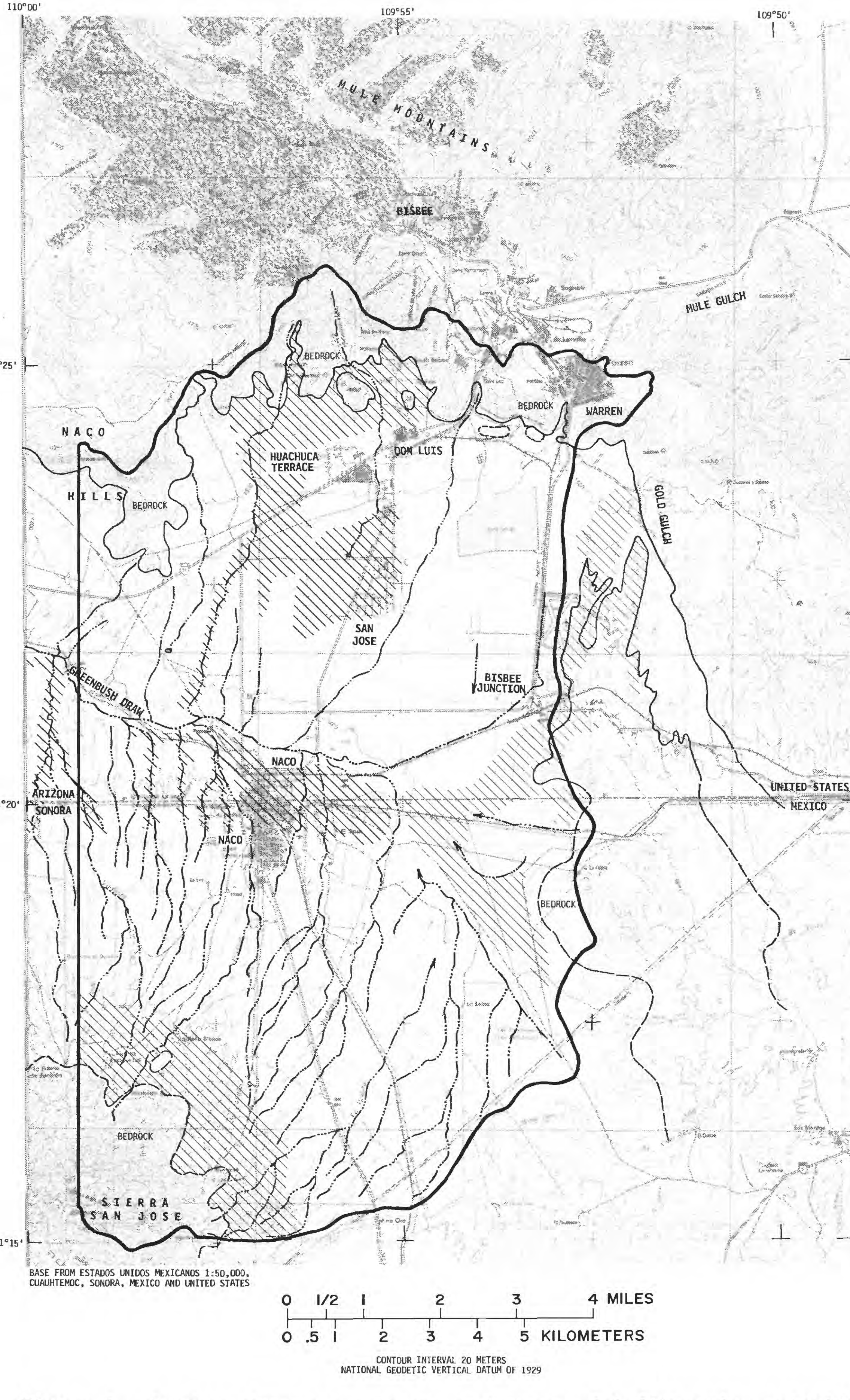

Figure 5.--Surface-drainage patterns and areas of infiltration potential.

EXPLANATION

AREA OF LOW INFILTRATION POTENTIAL

AREA OF MODERATE TO HIGH INFILTRATION POTENTIAL

BEDROCK — BEDROCK

SURFACE-DRAINAGE PATTERN AND DIRECTION OF FLOW

BOUNDARY OF STUDY AREA

Figure 5.

Hydraulic Characteristics of the Aquifer

The hydraulic characteristics of the basin fill in this area are poorly known. A transmissivity of about 4,700 ft^2/d (35,200 gal/day/ft) was calculated from an aquifer test at well AWC-3; the average discharge was 800 gal/min. This transmissivity reflects local conditions, which may not be typical of the aquifer as a whole. The average value may be much less. The specific capacity[2] for this well was 18 gal/min/ft (2.4 ft^2/min) of drawdown. The specific capacity of wells SJ-17 and NWC-1 was 11 and 14 gal/min/ft of drawdown, respectively (Arizona Public Service Company, written commun., 1953). The hydraulic gradient is relatively steep southwest of the mine tailings and becomes much flatter within the boundary of the main water-bearing unit (fig. 6). The change in gradient is indicative of a relative difference in hydraulic conductivity in the two areas; the greater conductivity is associated with the flatter gradient. On the basis of the hydraulic gradient, the basin-fill aquifer appears to be in hydraulic connection with the surrounding sedimentary rock. No data are available on the hydraulic characteristics of the sedimentary, igneous, and metamorphic rocks.

Movement

In general, the ground water moves in the same direction as the surface flow (fig. 6). From the north, ground water moves southward and westward to the topographic low along Greenbush Draw and converges with ground water from the south moving northward and westward. The rate of movement from the northeast ranges from about 0.5 to 0.8 ft/d (see section entitled "Water Quality"). The movement of ground water near the Bisbee well field may be affected by a north-south dike near the base of the basin fill. The effect of the dike, if any, on the ground-water system is unknown but probably is localized and small in relation to the regional system.

Water-Level Changes and Depth to Ground Water

Continuous long-term water-level records are not available for the study area. Water levels in the Bisbee well field, wells AWC-2, AWC-3, and AWC-4 (fig. 3, table 2), have remained virtually unchanged since 1953 on the basis of data from Arizona Public Service Company (written commun., 1953). Water levels in wells SJ-17, NWC-1, and NS-1 have declined about 25 ft; this decline may be due in part to agricultural development east and southeast of Naco.

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[2]Specific capacity, which commonly is reported in gallons per minute per foot of drawdown, converts to cubic foot per minute per foot or square foot per minute. One cubic foot equals 7.48 gallons.

Water levels in wells in the Bisbee Junction area show a rise of between 10 and 60 ft since 1977. This rise in water level is compatible with the development of a ground-water mound resulting from recharge at the mine-tailings pond northeast of Naco.

Water levels range from 14 ft below the land surface at well BJ-02 in the Bisbee Junction area east of Naco to more than 300 ft at well SJ-01 north of Huachuca Terrace at the base of the Mule Mountains. Exceptions include two wells (SJ-14 and SJ-15) recently drilled just south of Huachuca Terrace. Both wells appear to have penetrated formations that contain only a small amount of water. Water levels in the basin fill range from 83 ft below the land surface at AWC-1 in the Bisbee well field to about 220 ft at NS-3 in Naco, Sonora. (See table 2.)

Discharge

In the Bisbee-Naco area, virtually all the water used is ground water, although small amounts of precipitation may be used to supplement supplies for agriculture and livestock. In 1985, about 6,500 acre-ft of ground water was used for irrigation, public-supply, mining, domestic, and stock purposes; between 75 and 80 percent was from the basin fill. Most ground water is used for agricultural purposes. Annual usage for agriculture is estimated to be 3,600 to 4,200 acre-ft on the basis of estimated consumptive use by alfalfa of about 3.0 to 3.5 ft/acre/yr.

Water service in the area is provided by the Arizona Water Company (AWC) and the Naco Water Company in Arizona (NWC) and Naco Water Company in Sonora, Mexico (NS) (fig. 7, table 2). Two other purveyors are in Naco, Arizona, and service about 15 residents.

The total ground water pumped for public supply in 1985 was about 2,200 acre-ft (717 million gallons) and is expected to increase 20 percent by the year 2000. The Arizona Water Company is the largest supplier of water in the area. Since 1955, the company's annual production has fluctuated between 600 and 1,800 acre-ft. In the past 5 years, however, production has averaged about 1,100 acre-ft/yr. By the year 2000, production is expected to increase by 300 to 400 acre-ft/yr, if projected population figures are met.

About 60 wells are scattered throughout the area. The locations of selected wells are shown in figures 3, 6, and 8. In the study area, about 85 percent of the wells are north of the international boundary. Of those wells, about half are used for public-supply, irrigation, and livestock purposes and the other half primarily for domestic purposes. The annual discharge from private domestic and stock wells is estimated to range between 12 and 16 acre-ft owing to the general conservative use of domestic water supplies in the area. The quantity of water used for mining purposes is unknown but is believed to be negligible except for that pumped from the mine near Warren. Water from the mine is delivered to the unused tailings pond to keep the tailings from blowing (J. W. Durrenberger, oral commun., 1986).

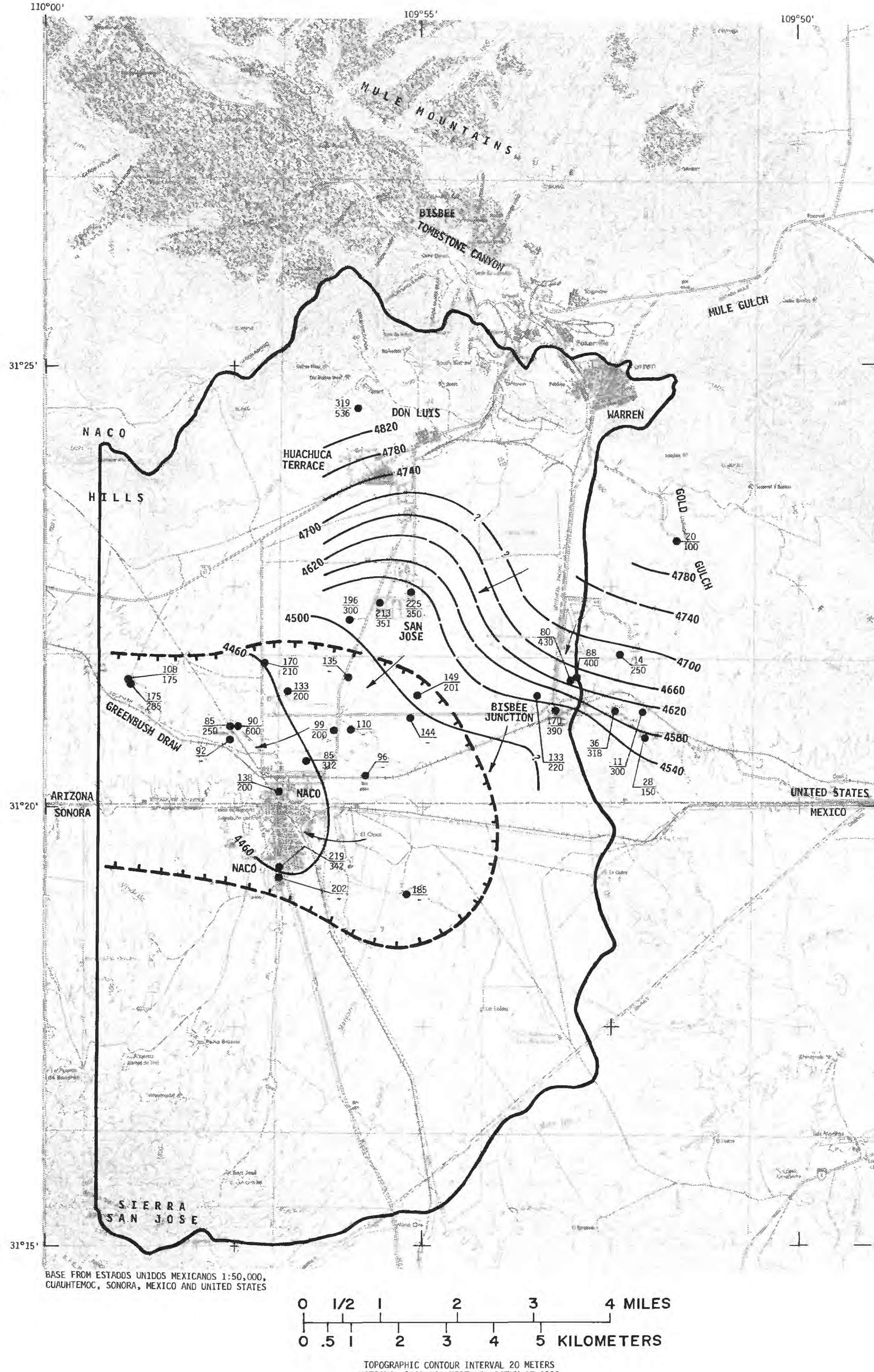


Figure 6.--Water-level altitude and direction of ground-water flow.

EXPLANATION

—— 4700 —?— WATER-LEVEL CONTOUR—Shows approximate altitude of the water level, 1985-86. Queried where uncertain. Contour interval 40 feet. National Geodetic Vertical Datum of 1929

● 99/200 WELL IN WHICH DEPTH TO WATER WAS MEASURED IN 1985-86—First entry, 99, is depth to water in feet below land surface. Second entry, 200, is depth of well in feet

APPROXIMATE BOUNDARY OF THE MAIN WATERBEARING UNIT

GENERALIZED DIRECTION OF GROUND-WATER FLOW

BOUNDARY OF STUDY AREA

Figure 6.

Table 2.--Well and water-level data

[Other identifier: PD-01, Phelps Dodge mine entrance. Primary use of water: D, dewater; H, domestic; I, irrigation; N, industrial; P, public supply; R, recreation; S, stock; U, unused]

OTHER IDENTI-FIER	LOCAL WELL NUMBER	SITE-ID	STATE	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	ALTITUDE OF LAND SURFACE (FEET)	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED
NS-1	NACO 1	311916109565601	80	P	---	4660	-----	--------
PZ-3	NACO 2	311903109531601	80	I	---	4660	-----	--------
NS-3	NACO 3	311907109565401	80	P	342	4680	219	04-29-86
PZ-2	NACO 4	311901109551101	80	I	---	4650	185	05-29-86
AWC-1	D-24-23 13ABC2	312053109573501	04	U	---	4520	83.0	- -53
AWC-2	D-24-23 13ACB	312049109573401	04	U	---	4540	91.6	11-21-85
AWC-3	D-24-23 13ABD	312052109572901	04	P	600	4540	89.8	02-19-86
AWC-4	D-24-23 13ABC1	312052109573501	04	P	250	4520	85.2	02-19-86
NWC-1	D-24-24 18CCD	312012109565601	04	P	200	4600	138	11-20-85
NWC-3	D-24-24 18ADD	312039109561001	04	P	178	4570	96.0	09-22-77
M-01	D-24-24 15CCC	312016109533601	04	S	---	4630	139	11-20-85
M-02	D-24-24 08CBA	312128109555701	04	S	---	4620	135	11-19-85
M-03	D-24-24 17CDA	312022109554201	04	S	---	4580	95.8	11-20-85
M-04	D-24-24 07CAC	312119109564701	04	H	200	4610	133	11-20-85
L-01	D-24-23 14AAB	312058109582101	04	S	85	4520	65.8	09-19-69
L-02	D-24-23 11CBA1	312124109585801	04	S	175	4520	108	11-21-85
L-03	D-24-23 11CBA2	312123109585701	04	H	285	4520	175	11-21-85
BJ-01	D-24-24 10DCB	312113109533301	04	D	220	4680	133	11-19-85
BJ-02	D-24-24 11ABD	312143109522601	04	H	250	4710	14.3	11-20-85
BJ-03	D-24-24 11CBC1	312126109530301	04	R	430	4720	79.8	11-19-85
BJ-04	D-24-24 11CBC2	312128109525701	04	H	400	4720	87.6	11-19-85
BJ-05	D-24-24 11DCC	312104109522801	04	H	318	4660	36.4	11-19-85
BJ-06	D-24-24 11DDD	312106109521601	04	H	300	4620	11.1	11-19-85
BJ-07	D-24-24 13BCB	312043109515701	04	H	150	4600	28.1	11-19-85
SJ-01	D-23-24 29BBA	312428109555401	04	H	536	5180	319	11-21-85
SJ-03	D-23-24 36CAD	312304109513601	04	H	100	4840	20.0	11-22-85
SJ-04	D-24-23 13BAA	312057109574601	04	U	261	4520	100	- -82
SJ-05	D-24-24 05AAA	312216109551401	04	S	---	4800	-----	--------
SJ-06	D-24-24 05ADD	312225109550901	04	H	350	4740	225	11-21-85
SJ-07	D-24-24 05CCA	312207109555801	04	H	300	4700	196	11-19-85
SJ-08	D-24-24 05DBB1	312220109553501	04	U	250	4730	221	11-21-85
SJ-09	D-24-24 05DBB2	312219109553301	04	H	351	4730	213	11-21-85
SJ-10	D-24-24 07BCB	312136109570701	04	H	210	4630	170	12-11-85
SJ-12	D-24-24 09CBC	312118109550501	04	U	201	4660	149	12-10-85
SJ-13	D-24-24 18ADA2	312047109560901	04	H	200	4580	99.3	12-12-85
SJ-14	D-23-24 31CDB	312259109564801	04	U	680	4820	-----	--------
SJ-15	D-23-24 32ADD	312320109551301	04	U	787	4880	-----	--------
PD-01	D-23-24 15CAC	312540109534401	04	N	---	4880	-----	--------
SJ-16	D-24-24 17BBD	312054109555301	04	S	---	4600	110	11-20-85
SJ-17	D-24-24 18DBB2	312034109563201	04	I	312	4540	85.0	05-06-85
NWC-5	D-24-24 10DDC2	312104109531501	04	P	390	4680	170	11-19-85
G-02	D-24-24 17AAB2	312058109552101	04	H	---	4630	-----	--------
G-04	D-24-24 17ABB	312101109552801	04	H	---	4620	-----	--------
G-07	D-24-24 17AAA	312059109551001	04	I	---	4640	144	11-20-85

Perennial streams or springs are not known to exist in the study area. A few springs are reported in Sierra San Jose (Arizona Public Service Company, written commun., 1953), but the magnitude and duration of the flow is not known. Studies done by S. G. Brown and B. N. Aldridge (written commun., 1973) indicate that the amount of underflow from the basin fill leaving the area may range from 220 to 650 acre-ft/yr. The total ground-water discharge from the area is estimated to range from 6,720 to 7,150 acre-ft/yr.

Discharge from the ground-water system through evapotranspiration probably is small, perhaps a few acre-feet per year. Phreatophytes are scarce because water levels are too far below the land surface in most areas.

Recharge

Ground-water recharge to the basin fill occurs by natural and artificial means. Natural recharge, which is the primary source of recharge in the study area, occurs largely from infiltration of surface runoff along the mountain fronts and through soils with high infiltration potential (fig. 5). Sierra San Jose probably is the largest contributor of mountain-front recharge in the area; however, a significant amount of recharge also may occur from greater distances through fractured and faulted rocks in the subsurface. The latter probably is the main contributing factor for recharge from north of Greenbush Draw. Natural recharge also occurs differentially throughout the alluvial plain. Relative infiltration potential for precipitation north of the international boundary (fig. 5) is based on recent soils analyses conducted by the U.S. Soil Conservation Service (Lloyd Law, Jr., written commun., 1986). Areas of low infiltration potential have a high potential for runoff during periods of heavy precipitation. Runoff along the east boundary of the study area probably is slight owing to the low relief of the hills in that area rather than the high permeability of the soils. Soils south of Greenbush Draw have a moderately high infiltration potential and may be indicative of the permeability of the alluvial deposits that cover the area south to Sierra San Jose. The bedrock of the mountains probably is relatively impermeable.

Artificial recharge occurs from infiltration of surface discharge through mine tailings and municipal sewage effluent and may occur from residential septic systems, urban runoff, and irrigation. An unused mine-tailings pond about 3 mi northeast of Greenbush Draw covers about 1,000 acres. The pond appears to be a significant contributing source of artificial recharge in the study area on the basis of the ground-water mounding that occurs in the area of and to the south of the mine-tailings pond. Five municipal sewage-treatment facilities are located in the study area. Four facilities are in use and have a combined inflow of about 500,000 gal/d. The fifth facility, west of Naco, Sonora, is expected to be operational later this year (1986). About half of the homes in the San Jose area of Bisbee use septic systems. The number of septic systems in Naco, Sonora, is unknown. Most recharge from irrigation occurs during the single growing season, but the quantity of recharge is unknown.

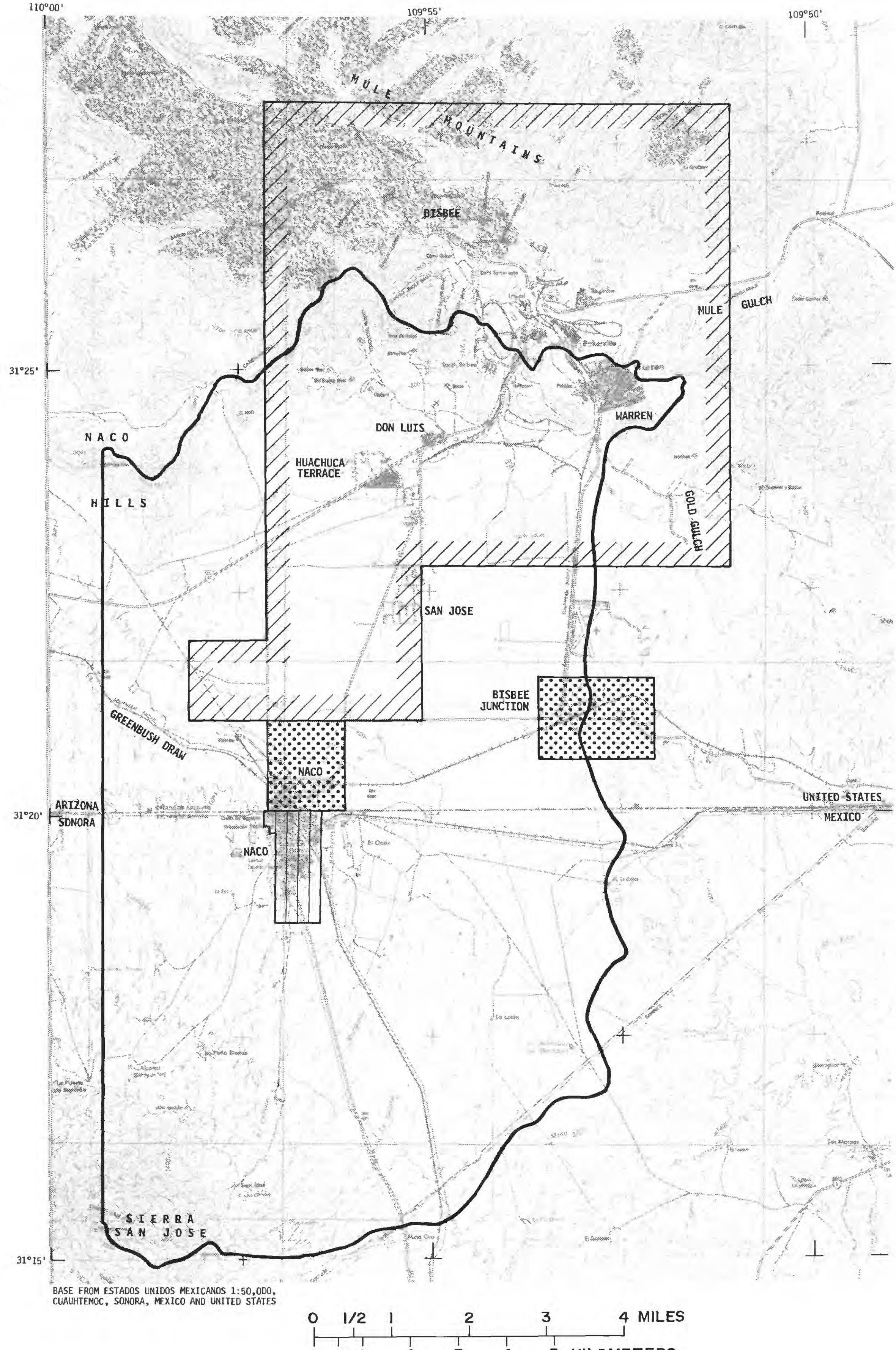


Figure 7.--Public water-supply service areas.

E X P L A N A T I O N

AREA SERVICED BY THE ARIZONA WATER COMPANY

AREA SERVICED BY THE NACO WATER COMPANY, ARIZONA

APPROXIMATE AREA SERVICED BY THE CITY OF NACO WATER COMPANY, SONORA, MEXICO

BOUNDARY OF STUDY AREA

Figure 7.

The surface recharge from natural means is estimated to range from 2,000 to 2,500 acre-ft/yr on the basis of previous studies (Anderson, 1972; B. N. Aldridge and S. G. Brown, written commun., 1971; S. G. Brown and B. N. Aldridge, written commun., 1973). The recharge from the mine-tailings pond is about 400 to 500 acre-ft/yr, assuming a permeability of about 0.4 to 0.5 ft/yr (Todd, 1959, p. 53). The recharge from sewage ponds is about 250 acre-ft/yr (5 ft/yr from 50 acres of ponds) as calculated from a water budget. Thus, the total recharge, not including subsurface inflow, is estimated to range from 2,650 to 3,250 acre-ft/yr.

Water Budget

A water budget must account for all recharge, discharge, and changes in ground-water storage. Because the known water-level changes in the Bisbee-Naco area are small, changes in ground-water storage are considered to be small, and the recharge should be nearly equal to the discharge. The total surface recharge is about 2,650 to 3,250 acre-ft/yr, and the total discharge is about 6,720 to 7,150 acre-ft/yr. Estimates of discharge are based mainly on measured values that are thought to be reasonably accurate. The difference between recharge and discharge, which is about 4,000 acre-ft/yr, probably stems from errors in estimates of recharge or from unknown elements of recharge. Natural surface recharge may have been underestimated. Recharge from the mine-tailings pond may have been much greater than the calculated value when mining activity was at its peak and may be relatively insignificant now. Undetermined subsurface recharge may account for part of the difference between the recharge and discharge values.

Withdrawals of ground water have not affected water levels at the Bisbee well field. Thus, withdrawals could be increased by an amount equal to the natural discharge from the ground-water system without any measurable decline in water levels. The natural discharge is estimated to range from 220 to 650 acre-ft/yr.

Water Quality

Water-quality analyses were done on ground-water samples from 29 wells in and around the study area (fig. 8). Long-term water-quality data for wells in and around the Bisbee well field show no discernible change in water quality in the basin-fill aquifer since 1954 (table 3).

Native water is a calcium bicarbonate type. Large concentrations of sulfate were found in mine water taken from carbonate rock north of the Warren district in Bisbee (site PD-01, fig. 8 and table 3). Similar concentrations were found in water from three wells northeast of Naco. These data are consistent with significant recharge from the area of the mine-tailings pond and the direction of ground-water flow.

The total dissolved-solids concentrations in the Bisbee-Naco area range from about 200 to 1,650 mg/L. Water from wells in the saturated basin fill is a calcium bicarbonate type and contains total dissolved-solids concentrations that range from about 230 to 360 mg/L. These values probably reflect the range of values in the consolidated sedimentary rocks prior to the deposition of mine tailings northeast of Naco. Water from wells in the sedimentary rocks northeast of Naco is a calcium sulfate type and contains total dissolved-solids concentrations that range from about 500 to 1,650 mg/L (fig. 8). The total dissolved-solids values may be estimated by multiplying the specific conductance by a conversion factor. The conversion factors for specific conductance in this area ranged from 0.51 to 0.85. The samples of calcium sulfate water contained concentrations of sulfate between 650 and 850 mg/L. Fecal bacteria was found in stock well M-02, but no other samples contained bacterial contamination. Nitrate values ranged from 2.0 to 7.0 mg/L and show no evidence of change with time (table 3). Major ions are reported in milligrams per liter and trace elements in micrograms per liter (μg/L). One thousand micrograms per liter is equivalent to 1 milligram per liter.

The U.S. Environmental Protection Agency (1977a, b) has established national regulations and guidelines for the quality of water provided by public water systems in the United States. The regulations determine the maximum permissible amount of chemical constituents that are permitted in the drinking water to protect public health. These limits are expressed as "Maximum Contaminant Levels (MCL's)" where contaminant means any physical, chemical, biological, or radiological substance or matter in water. Primary drinking-water regulations govern constituents in drinking water that have been shown to affect human health, such as coliform bacteria, certain metals, and organic pesticides. Secondary drinking-water regulations govern constituents in drinking water that affect the esthetic quality of the water, such as chloride, iron, and total dissolved solids. Secondary drinking-water regulations therefore are unenforceable, although secondary MCL's represent reasonable goals for drinking-water quality.

The calcium bicarbonate water common to the area is suitable for domestic use. The calcium sulfate water found in the study area contains total dissolved-solids concentrations that range from about 500 to 1,650 mg/L. Dissolved sulfate levels ranged from 650 to 850 mg/L. Total dissolved solids and sulfates are secondary contaminants. The secondary MCL's or reasonable goals for drinking-water quality for total dissolved solids and sulfates are 500 mg/L and 250 mg/L, respectively.

Most of the water in the study area is suitable for domestic use. The infiltration of leachate from the tailings pond northeast of Naco appears to be contributing sulfate to the ground-water system upgradient from the basin-fill aquifer. Calculations of the rate of movement over the past 60 to 70 years indicate an advancement of about 0.5 to 0.8 ft/d. Chemical analyses done during this study did not include all primary and secondary contaminants, therefore additional sampling would be advisable. Also, some metals were detected for which no standards have been established.

The high infiltration rates of some soils (fig. 5) provide the potential for contamination from urban runoff. Sewage-treatment ponds and septic systems on or in these soils also pose a threat to the water

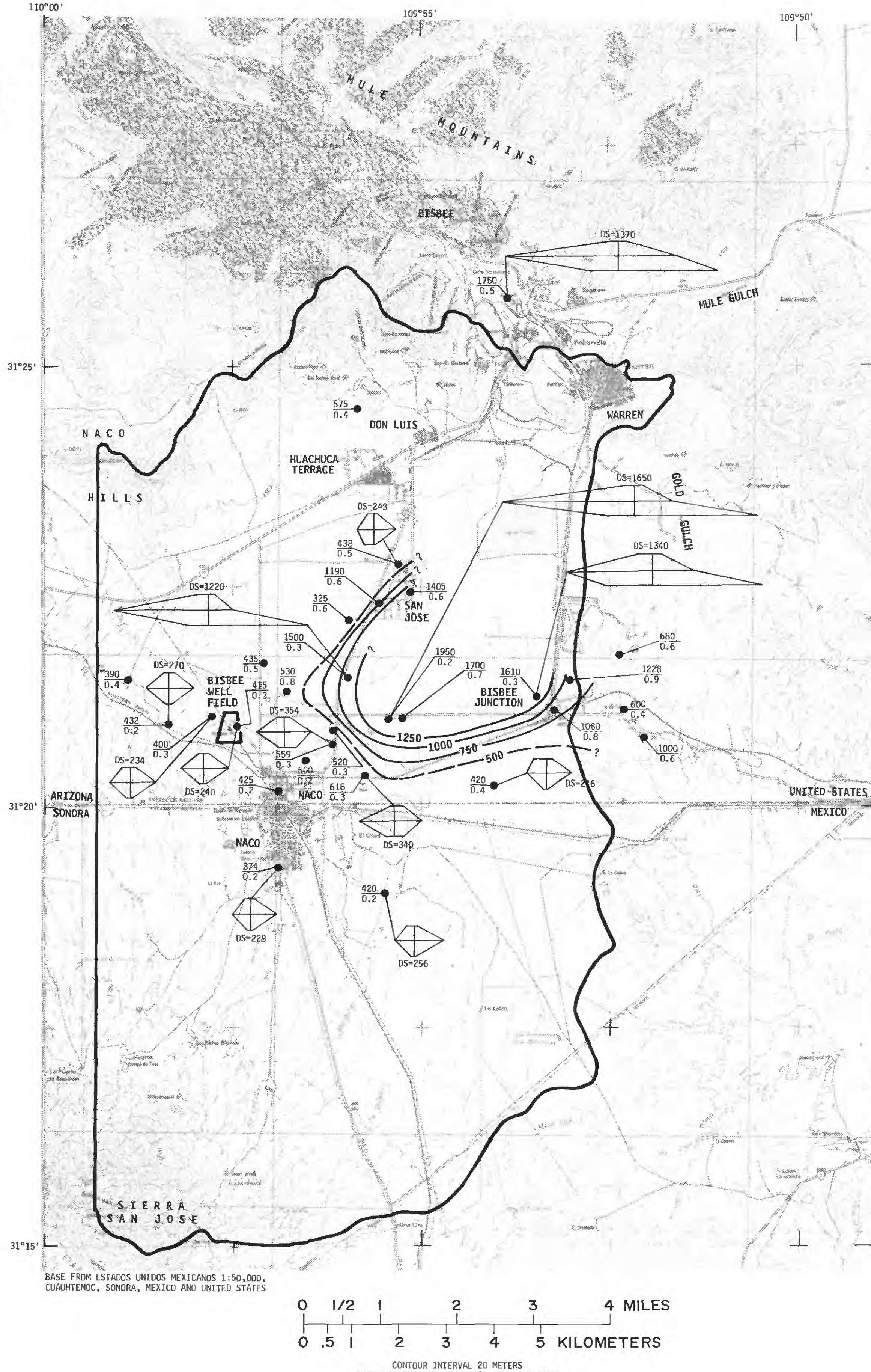
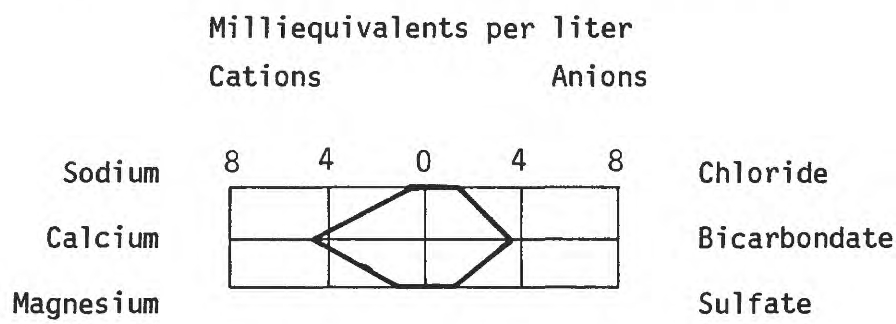


Figure 8.--Water quality and distribution of total dissolved solids.

E X P L A N A T I O N

620 / 0.3 — WELL OR MINE FROM WHICH A WATER SAMPLE WAS COLLECTED IN 1985-86—First entry, 620, is specific conductance in microsiemens per centimeter at 25 °C; specific conductance is an indication of the dissolved-solids concentration in milligrams per liter. Second entry, 0.3, is fluoride concentration in milligrams per liter

CHEMICAL-QUALITY DIAGRAM—Shows major chemical constituents in milliequivalents per liter. The diagrams are in a variety of shapes and sizes, and they provide a means of comparing, correlating, and characterizing types of water



DS=340 — DISSOLVED SOLIDS—Number, 340, is dissolved-solids concentrations in milligrams per liter

——500——?—— LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION, 1985-86—Approximately located. Queried where uncertain. Interval 250 milligrams per liter

———— BOUNDARY OF STUDY AREA

Figure 8.

Table 3.--Representative chemical analyses

[Other identifier: PD-01, Phelps Dodge mine entrance. °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter, mL, milliliters; dashes indicate no data; < indicates concentrations below detection limit for that analysis; K, based on non-ideal colony count]

OTHER IDENTI-FIER	LOCAL WELL NUMBER	STATION NUMBER	DATE	TIME	TEMPER-ATURE (°C)	TEMPER-ATURE, AIR (°C)	TUR-BID-ITY (NTU)	SPE-CIFIC CON-DUCT-ANCE (µS/cm)
PD-01	D-23-24 15CAC	312540109534401	01-16-86	09:30	27.0	27.0	0.3	1750
AWC-4	D-24-23 13ABC1	312052109573501	01-23-64	12:00	----	----	---	----
			04-17-85	12:00	----	----	---	----
AWC-1	D-24-23 13ABC2	312053109573501	12-13-56	12:00	----	----	---	----
			12-09-60	12:00	----	----	---	----
			01-23-64	12:00	----	----	---	----
AWC-3	D-24-23 13ABD	312052109572901	12-11-85	12:40	20.5	10.5	0.3	415
AWC-2	D-24-23 13ACB	312049109573401	10-13-54	12:00	----	----	---	----
			12-13-56	12:00	----	----	---	----
SJ-04	D-24-23 13BAA	312103109574701	12-11-85	09:35	21.0	4.5	0.5	400
L-01	D-24-23 14AAB	312058109582101	12-11-85	18:10	20.0	6.0	0.5	432
SJ-05	D-24-24 05AAA	312216109551401	01-06-86	14:00	21.0	17.0	5.1	438
M-02	D-24-24 08CBA	312128109555701	01-07-86	10:45	19.5	8.0	0.8	1,500
BJ-01	D-24-24 10DCB	312113109533301	12-09-85	15:30	19.0	----	0.3	1,610
M-01	D-24-24 15CCC	312016109533601	12-11-85	15:50	20.0	9.0	1.3	420
G-04	D-24-24 17ABB	312101109552801	01-07-86	17:30	20.0	4.5	4.9	1,950
M-03	D-24-24 17CDA	312022109554201	12-10-85	16:45	19.0	10.0	1.5	618
NWC-3	D-24-24 18ADD	312039109561001	01-08-86	13:05	21.0	10.0	1.5	559
SJ-17	D-24-24 18DBB2	312034109563201	12-10-85	12:30	18.5	10.0	0.3	497
NS-1	NACO 1	311916109565601	01-14-86	15:00	17.0	----	0.2	374
PZ-3	NACO 2	311903109531601	01-14-86	15:30	22.0	----	0.2	420

OTHER IDENTI-FIER	LOCAL WELL NUMBER	PH (STAN-ARD UNITS)	PH LAB (STAND-ARD UNITS)	CARBON DIOXIDE DIS-SOLVED (mg/L AS CO2)	ALKA-LINITY FIELD (mg/L AS CACO3)	NITRO-GEN, ORGANIC TOTAL (mg/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (mg/L AS N)	NITRO-GEN-AMMONIA TOTAL (mg/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (mg/L AS N)	NITRO-GEN, NITRATE DIS-SOLVED (mg/L AS N)
PD-01	D-23-24 15CAC	7.5	7.4	23	377	0.1	0.10	0.10	<0.01	----
AWC-4	D-24-23 13ABC1	---	---	----	176	----	----	----	----	7.00
		---	8.0	----	<180	----	----	----	----	2.20
AWC-1	D-24-23 13ABC2	---	---	----	184	----	----	----	----	6.00
		---	---	----	176	----	----	----	----	5.00
		---	---	----	172	----	----	----	----	2.00
AWC-3	D-24-23 13ABD	7.8	7.9	5.5	176	----	0.02	0.02	<0.01	----
AWC-2	D-24-23 13ACB	8.5	---	0.1	50	----	----	----	----	----
		---	---	----	135	----	----	----	----	7.00
SJ-04	D-24-23 13BAA	7.9	8.1	4.7	172	----	0.02	0.01	<0.01	----
L-01	D-24-23 14AAB	7.6	7.7	9.0	164	----	0.02	0.02	<0.01	----
SJ-05	D-24-24 05AAA	7.9	7.8	4.3	156	0.78	0.02	0.02	<0.01	----
M-02	D-24-24 08CBA	7.4	7.3	13	162	0.37	0.42	0.43	0.05	2.95
BJ-01	D-24-24 10DCB	7.2	7.2	32	256	0.18	0.12	0.12	<0.01	----
M-01	D-24-24 15CCC	7.6	7.7	8.2	167	0.28	0.02	0.02	<0.01	----
G-04	D-24-24 17ABB	7.1	7.1	43	246	0.37	0.09	0.13	<0.01	----
M-03	D-24-24 17CDA	7.4	7.5	14	183	0.36	0.03	0.04	<0.01	----
NWC-3	D-24-24 18ADD	7.6	7.7	8.2	171	0.69	0.01	0.01	<0.01	----
SJ-17	D-24-24 18DBB2	7.6	7.7	9.6	193	0.38	0.03	0.02	<0.01	----
NS-1	NACO 1	7.6	7.8	9.3	171	0.29	0.02	0.01	<0.01	----
PZ-3	NACO 2	7.6	7.7	9.0	192	0.39	0.02	0.01	<0.01	----

Table 3.--Representative chemical analyses--Continued

OTHER IDENTI- FIER	LOCAL WELL NUMBER	NITRO- GEN, AM- MONIA + ORGANIC TOTAL (mg/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (mg/L AS N)	PHOS- PHATE, ORTHO, DIS- SOLVED (mg/L AS PO4)	PHOS- PHORUS, TOTAL (mg/L AS P)	PHOS- PHORUS, DIS- SOLVED (mg/L AS P)	PHOS- PHORUS, ORTHO, DIS- SOLVED (mg/L AS P)	HARD- NESS (mg/L AS CACO3)	HARD- NESS, NONCAR- BONATE (mg/L CACO3)	CALCIUM DIS- SOLVED (mg/L AS CA)
PD-01	D-23-24 15CAC	0.2	2.20	0.03	<0.01	<0.01	0.01	1000	650	300
AWC-4	D-24-23 13ABC1	---	----	----	----	----	----	170	---	55
		---	----	----	----	----	----	180	---	59
AWC-1	D-24-23 13ABC2	---	----	----	----	----	----	160	---	58
		---	----	----	----	----	----	170	---	58
		---	----	----	----	----	----	170	---	50
AWC-3	D-24-23 13ABD	<0.2	2.50	----	0.01	<0.01	<0.01	180	---	58
AWC-2	D-24-23 13ACB	---	----	----	----	----	----	20	---	3.0
		---	----	----	----	----	----	110	---	35
SJ-04	D-24-23 13BAA	<0.2	2.10	0.03	0.02	<0.01	0.01	150	---	50
L-01	D-24-23 14AAB	<0.2	4.20	0.03	0.02	0.01	0.01	190	24	62
SJ-05	D-24-24 05AAA	0.8	8.10	0.03	<0.01	<0.01	0.01	180	19	44
M-02	D-24-24 08CBA	0.8	3.00	0.06	0.02	0.02	0.02	770	600	250
BJ-01	D-24-24 10DCB	0.3	6.50	0.03	0.01	0.02	0.01	890	630	230
M-01	D-24-24 15CCC	0.3	2.20	0.03	0.01	<0.01	0.01	160	---	53
G-04	D-24-24 17ABB	0.5	3.40	0.03	<0.01	<0.01	0.01	1100	820	350
M-03	D-24-24 17CDA	0.4	4.20	----	<0.01	<0.01	<0.01	280	98	92
NWC-3	D-24-24 18ADD	0.7	4.40	0.03	<0.01	<0.01	0.01	230	56	76
BJ-17	D-24-24 18DBB2	0.4	3.50	----	<0.01	<0.01	<0.01	210	16	70
NS-1	NACO 1	0.3	0.80	0.06	0.02	0.02	0.02	150	---	49
PZ-3	NACO 2	0.4	1.70	0.06	0.01	0.01	0.02	150	---	50

OTHER IDENTI- FIER	LOCAL WELL NUMBER	MAGNE- SIUM, DIS- SOLVED (mg/L AS MG)	SODIUM, DIS- SOLVED (mg/L AS NA)	SODIUM AD- SORP- TION RATIO	PERCENT SODIUM	POTAS- SIUM, DIS- SOLVED (mg/L AS K)	CHLO- RIDE, DIS- SOLVED (mg/L AS CL)	SULFATE DIS- SOLVED (mg/L AS SO4)	FLUO- RIDE, DIS- SOLVED (mg/L AS F)	SILICA, DIS- SOLVED (mg/L AS SIO2)
PD-01	D-23-24 15CAC	69	22	0.3	4	2.4	20	650	0.5	13
AWC-4	D-24-23 13ABC1	7.0	18	0.6	--	---	12	8.0	0.3	--
		9.0	19	0.6	--	---	12	7.0	0.3	--
AWC-1	D-24-23 13ABC2	3.0	16	0.6	--	---	8.0	11	0.2	--
		6.0	18	0.6	--	---	6.0	8.0	0.37	--
		10	12	0.4	--	---	6.0	6.0	0.1	--
AWC-3	D-24-23 13ABD	8.0	19	0.6	19	2.1	20	11	0.3	32
AWC-2	D-24-23 13ACB	3.0	38	4	--	---	12	50	0.4	19
		6.0	15	0.6	--	---	8.0	7.0	0.25	--
SJ-04	D-24-23 13BAA	7.0	25	0.9	26	1.9	15	12	0.3	30
L-01	D-24-23 14AAB	8.5	15	0.5	15	1.2	14	19	0.2	34
SJ-05	D-24-24 05AAA	16	20	0.7	20	2.2	18	11	0.5	22
M-02	D-24-24 08CBA	34	34	0.6	9	5.2	22	650	0.3	27
BJ-01	D-24-24 10DCB	77	40	0.6	9	19	30	710	0.3	31
M-01	D-24-24 15CCC	5.5	27	1	27	2.0	21	13	0.4	22
G-04	D-24-24 17ABB	45	36	0.5	7	4.7	30	850	0.2	30
M-03	D-24-24 17CDA	13	11	0.3	8	3.0	40	60	0.3	30
NWC-3	D-24-24 18ADD	10	21	0.6	16	2.7	21	71	0.3	31
SJ-17	D-24-24 18DBB2	9.3	21	0.7	17	2.1	30	13	0.2	33
NS-1	NACO 1	6.7	19	0.7	21	1.1	8.1	6.6	0.2	33
PZ-3	NACO 2	7.0	25	0.9	26	1.4	7.6	9.6	0.2	32

Table 3.--Representative chemical analyses--Continued

OTHER IDENTI- FIER	LOCAL WELL NUMBER	ARSENIC DIS- SOLVED (μg/L AS AS)	BARIUM, DIS- SOLVED (μg/L AS BA)	BERYL- LIUM, DIS- SOLVED (μg/L AS BE)	CADMIUM DIS- SOLVED (μg/L AS CD)	CHRO- MIUM, DIS- SOLVED (μg/L AS CR)	COBALT, DIS- SOLVED (μg/L AS CO)	COPPER, DIS- SOLVED (μg/L AS CU)	IRON, DIS- SOLVED (μg/L AS FE)	LEAD, DIS- SOLVED (μg/L AS PB)
PD-01	D-23-24 15CAC	--	---	---	--	----	--	--	---	--
AWC-4	D-24-23 13ABC1	--	---	---	--	<0.01	--	<0	<0	--
		<0	<1	---	<0	<0.01	--	<0	<0	<0
AWC-1	D-24-23 13ABC2	--	---	---	--	----	--	--	<0	--
		--	---	---	--	----	--	--	0	--
		--	---	---	--	<0.01	--	<0	<0	--
AWC-3	D-24-23 13ABD	--	---	---	--	----	--	--	---	--
AWC-2	D-24-23 13ACB	--	---	---	--	----	--	--	---	--
		--	---	---	--	----	--	--	0	--
SJ-04	D-24-23 13BAA	--	---	---	--	----	--	--	---	--
L-01	D-24-23 14AAB	--	---	---	--	----	--	--	---	--
SJ-05	D-24-24 05AAA	2	250	<0.5	<1	<1	<3	6	<3	2
M-02	D-24-24 08CBA	1	43	<0.5	1	<1	<3	1	120	1
BJ-01	D-24-24 10DCB	1	35	<0.5	<1	<1	<3	6	9	3
M-01	D-24-24 15CCC	--	---	---	--	----	--	--	--	--
G-04	D-24-24 17ABB	<1	26	<0.5	<1	<1	<3	6	4	3
M-03	D-24-24 17CDA	--	---	---	--	----	--	--	--	--
NWC-3	D-24-24 18ADD	--	---	---	--	----	--	--	--	--
SJ-17	D-24-24 18DBB2	--	---	---	--	----	--	--	--	--
NS-1	NACO 1	--	---	---	--	----	--	--	--	--
PZ-3	NACO 2	--	---	---	--	----	--	--	--	--

OTHER IDENTI- FIER	LOCAL WELL NUMBER	MANGA- NESE, DIS- SOLVED (μg/L AS MN)	THAL- LIUM, TOTAL (μg/L AS TL)	MOLYB- DENUM, DIS- SOLVED (μg/L AS MO)	NICKEL, DIS- SOLVED (μg/L AS NI)	SILVER, DIS- SOLVED (μg/L AS AG)	STRON- TIUM, DIS- SOLVED (μg/L AS SR)	VANA- DIUM, DIS- SOLVED (μg/L AS V)	ZINC, DIS- SOLVED (μg/L AS ZN)	ALUM- INUM, DIS- SOLVED (μg/L AS AL)
PD-01	D-23-24 15CAC	--	--	---	--	--	----	--	----	---
AWC-4	D-24-23 13ABC1	<0	--	---	--	--	----	--	----	---
		<0	--	---	--	<0	----	--	<0	---
AWC-1	D-24-23 13ABC2	--	<0	---	--	--	----	--	----	---
		<0	--	---	--	--	----	--	----	---
		<0	--	---	--	--	----	--	----	---
AWC-3	D-24-23 13ABD	--	--	---	--	--	----	--	----	---
AWC-2	D-24-23 13ACB	--	--	---	--	--	----	--	----	---
		<0	--	---	--	--	----	--	----	---
SJ-04	D-24-23 13BAA	--	--	---	--	--	----	--	----	---
L-01	D-24-23 14AAB	--	--	---	--	--	----	--	----	---
SJ-05	D-24-24 05AAA	4	--	<10	<1	<1	530	<6	1100	<10
M-02	D-24-24 08CBA	65	--	<10	3	<1	2300	<6	30	<10
BJ-01	D-24-24 10DCB	2	--	<10	<1	<1	1700	<6	840	<10
M-01	D-24-24 15CCC	--	--	---	--	--	----	--	----	---
G-04	D-24-24 17ABB	13	--	<10	2	<1	3300	<6	1000	<10
M-03	D-24-24 17CDA	--	--	---	--	--	----	--	----	---
NWC-3	D-24-24 18ADD	--	--	---	--	--	----	--	----	---
SJ-17	D-24-24 18DBB2	--	--	---	--	--	----	--	----	---
NS-1	NACO 1	--	--	---	--	--	----	--	----	---
PZ-3	NACO 2	--	--	---	--	--	----	--	----	---

Table 3.--Representative chemical analyses--Continued

OTHER IDENTI-FIER	LOCAL WELL NUMBER	LITHIUM DIS-SOLVED (µg/L AS LI)	SELE-NIUM, DIS-SOLVED (µg/L AS SE)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./ 100 mL)	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 mL)	SOLIDS, RESIDUE AT 180 °C DIS-SOLVED (mg/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (mg/L)	SOLIDS, DIS-SOLVED (TONS PER ACRE-FT)	NITRO-GEN, AMMONIA DIS-SOLVED (mg/L AS NH4)	NITRO-GEN, NITRATE DIS-SOLVED (mg/L AS NO3)
PD-01	D-23-24 15CAC	--	--	--	---	1370	1300	1.9	0.13	----
AWC-4	D-24-23 13ABC1	--	--	--	---	253	----	----	----	31
		--	<0	--	---	250	----	----	----	9.7
AWC-1	D-24-23 13ABC2	--	--	--	---	193	----	----	----	27
		--	--	--	---	256	----	----	----	22
		--	--	--	---	221	----	----	----	8.9
AWC-3	D-24-23 13ABD	--	--	<1	<1	240	260	0.33	0.03	----
AWC-2	D-24-23 13ACB	--	--	--	---	163	----	----	----	----
		--	--	--	---	145	----	----	----	31
SJ-04	D-24-23 13BAA	--	--	<1	<1	234	250	0.32	0.03	----
L-01	D-24-23 14AAB	--	--	<1	<1	270	250	0.37	0.03	----
SJ-05	D-24-24 05AAA	32	<1	<1	<1	243	230	0.33	0.03	----
M-02	D-24-24 08CBA	38	3	K1	K14	1220	1100	1.7	0.54	----
BJ-01	D-24-24 10DCB	34	3	<1	<1	1340	1300	1.8	0.15	----
M-01	D-24-24 15CCC	--	--	<1	<1	216	250	0.29	0.03	----
G-04	D-24-24 17ABB	46	2	<1	<1	1650	1500	2.2	0.12	----
M-03	D-24-24 17CDA	--	--	<1	<1	340	360	0.46	0.04	----
NWC-3	D-24-24 18ADD	--	--	<1	<1	354	340	0.48	0.01	----
SJ-17	D-24-24 18DBB2	--	--	<1	<1	276	300	0.38	0.04	----
NS-1	NACO 1	--	--	--	---	228	230	0.31	0.03	----
PZ-3	NACO 2	--	--	--	---	256	250	0.35	0.03	----

OTHER IDENTI-FIER	LOCAL WELL NUMBER	NITRO-GEN, NITRITE DIS-SOLVED (mg/L AS NO2)	MERCURY DIS-SOLVED (µg/L AS HG)	ELEV. OF LAND SURFACE DATUM (FEET ABOVE NGVD)	DEPTH OF WELL, TOTAL (FEET)	SPE-CIFIC CON-DUCT-ANCE LAB (µS/cm)	ALKA-LINITY LAB (mg/L AS CACO3)	ALKA-LINITY, CARBON-ATE IT-FLD (mg/L-CACO3)	BICAR-BONATE IT-FLD (mg/L AS HCO3)	CAR-BONATE IT-FLD (mg/L AS CO3)
PD-01	D-23-24 15CAC	----	---	4960	------	1730	384	379	462	0
AWC-4	D-24-23 13ABC1	----	---	4520	250.00	----	---	---	---	--
		----	<0	4520	250.00	----	---	---	---	--
AWC-1	D-24-23 13ABC2	----	---	4520	------	----	---	---	---	--
		----	---	4520	------	----	---	---	---	--
		----	---	4520	------	----	---	---	---	--
AWC-3	D-24-23 13ABD	----	---	4535	600.00	434	168	179	218	0
AWC-2	D-24-23 13ACB	----	---	4540	------	----	---	---	24	12
		----	---	4540	------	----	---	---	---	--
SJ-04	D-24-23 13BAA	----	---	4561	------	407	168	173	211	0
L-01	D-24-23 14AAB	----	---	4515	85.00	447	161	166	202	0
SJ-05	D-24-24 05AAA	----	<0.1	4795	------	445	151	158	193	0
M-02	D-24-24 08CBA	0.16	<0.1	4629	------	1460	152	165	201	0
BJ-01	D-24-24 10DCB	----	<0.1	4684	220.00	1820	249	259	316	0
M-01	D-24-24 15CCC	----	---	4625	------	429	164	169	206	0
G-04	D-24-24 17ABB	----	<0.1	4620	------	1920	247	248	303	0
M-03	D-24-24 17CDA	----	---	4581	------	609	180	185	226	0
NWC-3	D-24-24 18ADD	----	---	4570	178.00	564	160	175	214	0
SJ-17	D-24-24 18DBB2	----	---	4540	312.00	515	181	197	240	0
NS-1	NACO 1	----	---	4661	------	370	171	170	207	0
PZ-3	NACO 2	----	---	4663	------	419	193	194	237	0

quality. On several occasions, considerable amounts of raw sewage have spilled into washes in and around the town of Naco, Arizona, from sources in Naco, Sonora. About half the people in the San Jose area still use septic systems. Soils in that area have a high infiltration potential. Pesticides from agricultural areas are another potential source of contamination. Although the potential for contamination of the aquifer from urban runoff, sewage, and pesticides exists, the only evidence of contamination discovered during this investigation was the fecal bacteria in stock well M-02 and the elevated levels of sulfates in a number of the wells that were sampled.

OTHER SOURCES OF DRINKING WATER

The basin fill is the only readily available source of drinking water in the area. The sedimentary rocks underlying the basin fill may contain water, but the cost of exploratory drilling to locate an adequate supply and possibly pumping from great depths probably would be prohibitive. The basin fill and the sedimentary rocks are hydraulically connected. If equilibrium is to be maintained, additional production would be limited to an amount about equal to the natural outflow.

An alternative source would be the importation of drinking water from the aquifers underlying Sulphur Spring Valley near Double Adobe or San Pedro River valley near Palominas. The quantity and quality of water in these areas is suitable for most purposes (White and Childers, 1967; Mann and English, 1980; and Freethey, 1982). Double Adobe is about 20 mi from the Bisbee well field and about 500 ft lower in elevation; Palominas is about 10 mi from the well field and 300 ft lower. Importation of water from either of these areas would require the acquisition of water rights and the construction of a pipeline and pumping plant. The Arizona Ground-Water Management Act of 1980 may place some legal constraints on inter-basin transfer of water; however, discussion of these constraints is beyond the scope of this report.

SUMMARY AND CONCLUSIONS

Ground water is the only dependable source of water in the area and occurs in the basin fill and sedimentary rocks. In 1985, about 6,500 acre-ft of water was pumped from the aquifer and about 3,600 to 4,200 acre-ft was used for agricultural purposes. Well yields range from less than 2 gal/min in the sedimentary rocks to more than 1,400 gal/min in the basin fill. The basin fill is in hydraulic connection with the sedimentary rocks. Water levels in the Bisbee well field have remained virtually unchanged since 1953. Withdrawals could be increased by an amount equal to the natural discharge from the ground-water system without any measurable decline in water levels.

The native water is a calcium bicarbonate type and contains dissolved-solids concentrations that range from about 200 to 360 mg/L.

Water from a mine near Warren and from wells northeast of Naco is a calcium sulfate type and contains concentrations of sulfate that range from 650 to 850 mg/L and dissolved solids that range from about 1,100 to 1,650 mg/L.

The basin fill is the principal aquifer and is the only readily available source of drinking water. The aquifer is susceptible to contamination by leachate from mine tailings and sewage systems. The only evidence of contamination found during this study was fecal bacteria in one stock well and elevated levels of sulfates in a number of wells tested. Testing was not done for all primary and secondary contaminants in this study, and further testing of the calcium sulfate water would be advisable.

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