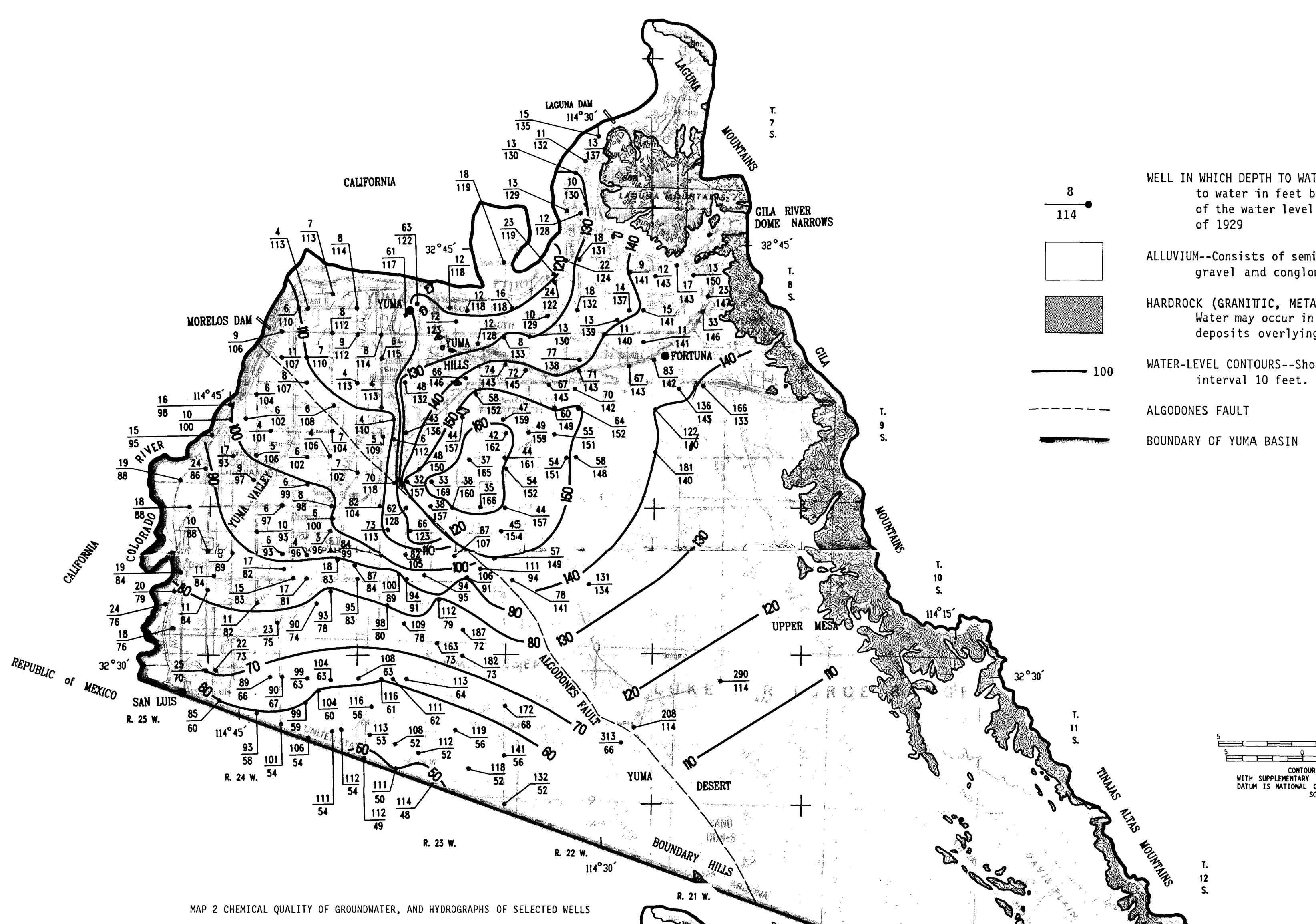
PREPARED IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

ARIZONA DEPARTMENT OF WATER RESOURCES

MAP 1 DEPTH TO WATER AND ALTITUDE OF THE WATER LEVEL



EXPLANATION

8 / 114 — WELL IN WHICH DEPTH TO WATER WAS MEASURED IN FALL 1992--Upper number, 8, is depth to water in feet below land surface. Lower number, 114, is the altitude of the water level in feet. Datum is the National Vertical Geodetic Datum of 1929

ALLUVIUM--Consists of semi-consolidated to poorly consolidated sand, silt, clay, gravel and conglomerate

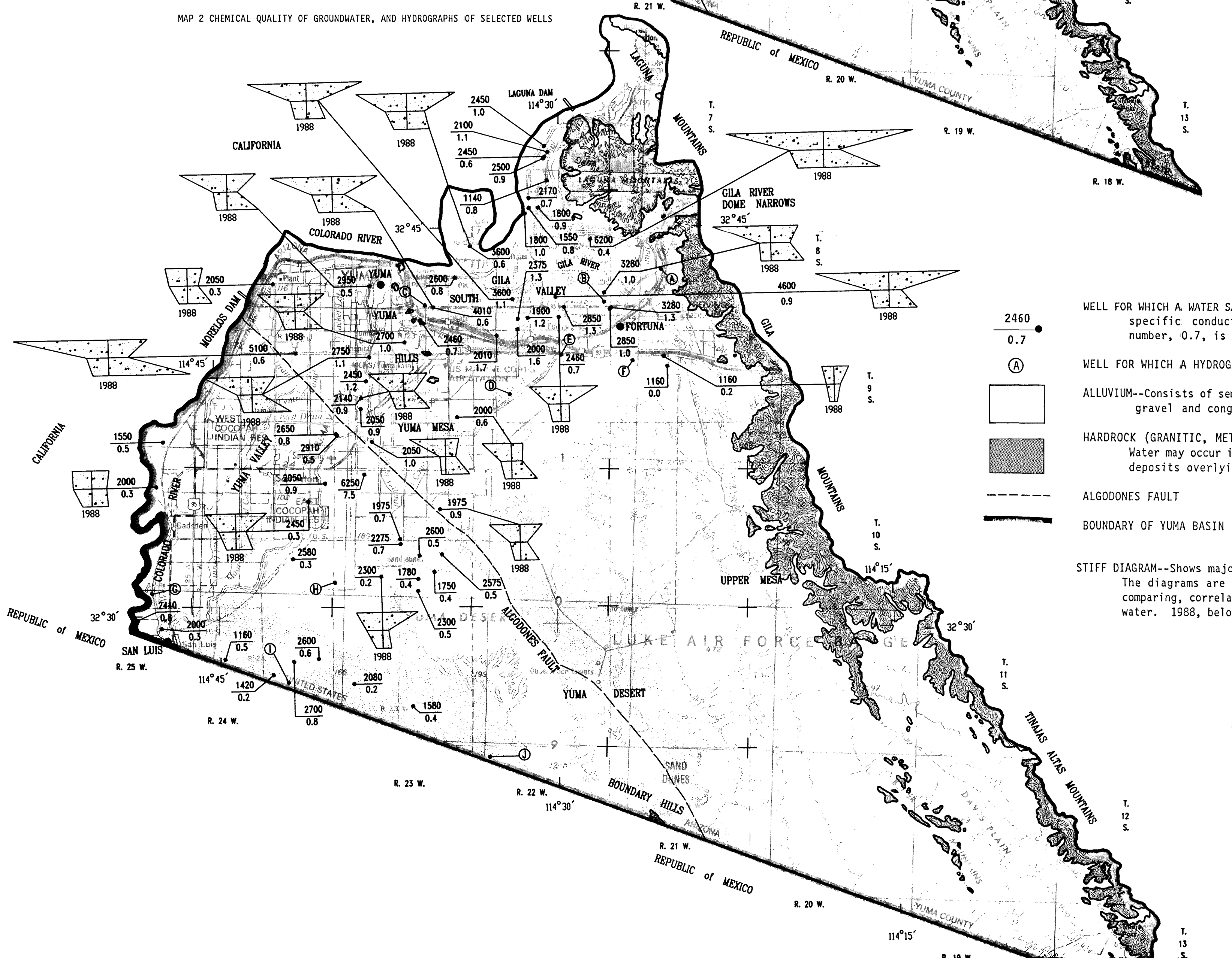
HARDROCK (GRANITIC, METAMORPHIC, VOLCANIC OR CONSOLIDATED SEDIMENTARY ROCK)--Water may occur in weathered or fractured zones, joint systems, or fluvial deposits overlying bedrock

100 — WATER-LEVEL CONTOURS--Shows the approximate altitude of the water-level contour interval 10 feet. Datum is the National Vertical Geodetic Datum of 1929

ALGODONES FAULT

BOUNDARY OF YUMA BASIN

MAP 2 CHEMICAL QUALITY OF GROUNDWATER, AND HYDROGRAPHS OF SELECTED WELLS



EXPLANATION

2460 / 0.7 — WELL FOR WHICH A WATER SAMPLE WAS COLLECTED IN 1988-1994--Upper number, 2460, is specific conductance in microsiemens per centimeter at 25°C. Lower number, 0.7, is the fluoride concentration in milligrams per liter

(A) — WELL FOR WHICH A HYDROGRAPH DEPICTING CHANGES IN DEPTH TO WATER IS SHOWN

ALLUVIUM--Consists of semi-consolidated to poorly consolidated sand, silt, clay, gravel and conglomerate

HARDROCK (GRANITIC, METAMORPHIC, VOLCANIC OR CONSOLIDATED SEDIMENTARY ROCK)--Water may occur in weathered or fractured zones, joint systems, or fluvial deposits overlying bedrock

ALGODONES FAULT

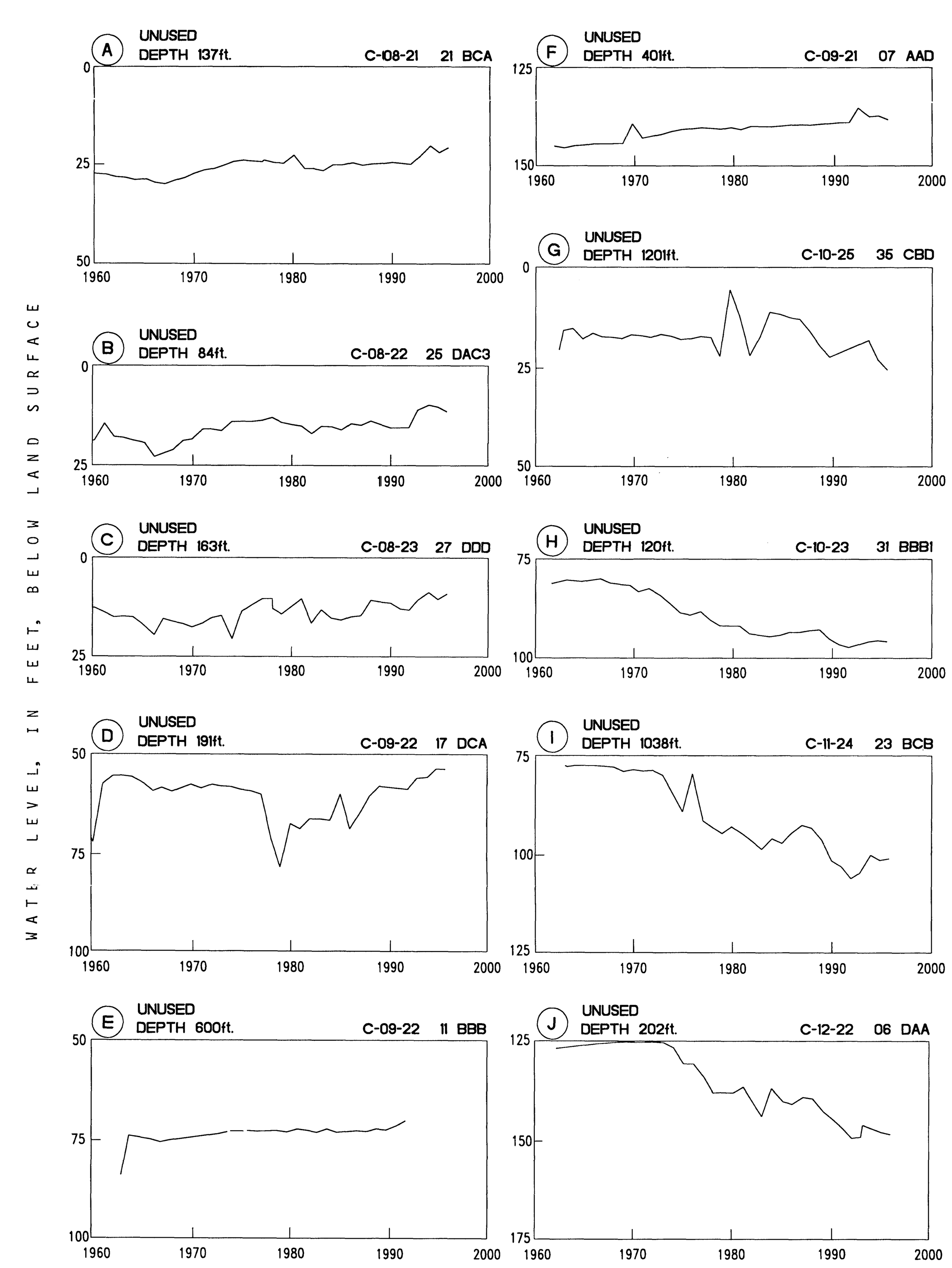
BOUNDARY OF YUMA BASIN

STIFF DIAGRAM--Shows major chemical constituents in milliequivalents per liter. The diagrams are in a variety of shapes and sizes, providing a means of comparing, correlating, and characterizing similar or dissimilar types of water. 1988, below diagram, indicates year in which sample was collected

MILLIEQUIVALENTS PER LITER

CATIONS — ANIONS
SODIUM — CHLORIDE
CALCIUM — TOTAL ALKALINITY
MAGNESIUM — SULFATE
1988

HYDROGRAPHS OF THE WATER LEVEL IN SELECTED WELLS
(Dashed lines indicate inferred water level)



For readers who prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
acre	0.4047	square hectometer
acre-foot	0.001233	cubic hectometer
gallons per minute	0.06309	liters per second

INTRODUCTION

This report is a summary of general groundwater conditions in the Yuma basin in late 1992. It is based on data collected and compiled by the Basic Data Section of the Arizona Department of Water Resources during the course of several ongoing activities. These activities include a well inventory and water-level measurement collection and analysis of general quality of groundwater and annual monitoring of water levels and quality of groundwater in selected wells.

The Yuma basin is located in the southwest corner of Arizona and encompasses an area of about 790 square miles. Portions of the basin extend structurally into California and the Republic of Mexico. In Arizona the Yuma basin is roughly triangular in shape and is bounded on the east by the Laguna, Gila and Tinajas Altas Mountains, on the west by the Colorado River and on the south by the International Boundary with the Republic of Mexico. The Yuma basin lies at the southwestern edge of the Sonoran Desert and the northeastern edge of the Salton Trough sections of the Basin and Range physiographic province. The Algodones Fault is the structural feature that separates the two sections in the study area (Olmsted, Loeltz and Irelan, 1973,fig.1-2, p.7-8).

The Yuma basin is characterized by alluvial valley floors adjacent to the Gila and Colorado River channels,and the river terrace which rises sharply from 60 to 80 feet above the river valley to form Yuma Mesa. The City of Yuma is situated on and around the northwestern finger of this terrace. Farther to the east and southeast of Yuma Mesa and west of the Gila and Tinajas Altas Mountains is a second terrace, the Upper Mesa. This terrace is characterized by sand dunes and dry washes formed by runoff from the adjacent Gila and Tinajas Altas Mountains and in places is almost barren of vegetation.

Land-surface altitudes range from about 75 feet where the Colorado River enters the Republic of Mexico,to over 3,100 feet atop Sheep Mountain in the Gila Mountains. Between these two extremes, altitudes on the valley floors range from about 90 to 130 feet in the Yuma Valley and about 130 to 165 feet in the Gila Valley. Altitudes on Yuma Mesa range from about 130 to 200 feet at the top of the escarpment to 200 to 250 feet at the foot of the Upper Mesa. On the Upper Mesa, altitudes range from about 250 to 300 feet atop the western front to roughly 400 to 800 feet along the foot of the Gila and Tinajas Altas Mountains.

The climate of the Yuma basin is very arid. Precipitation averages less than 3 inches per year. In July the mean daily maximum temperature is 105.9°F and the mean daily minimum is 76.5°F. In January the mean daily maximum temperature is 67.0°F and the mean daily minimum is 42.4°F (Sellers and others, 1985, p.90 and 93).

The dominant types of natural vegetation in the desert areas of the Yuma basin are creosote bush and mesquite (Sellers and Hill, 1974, p.588). Low-lying strips of land covered with riparian vegetation are common along the river channels. Phreatophytes occupy areas between cultivated land in the flood plain where depth to groundwater is sufficiently shallow (Loeltz and Leake, 1983 p.13). Adjacent to stream channels where moisture is more abundant, paloverde, ironwood and mesquite trees are common. Saguaro, ocotillo, cholla and other less common cacti grow abundantly on the higher fan slopes near the mountains (Harper, Poulson and Foulger, 1941, p.3). Agriculture is the primary industry in the Yuma basin and the principal crops are vegetables, wheat, cotton and citrus.

Except for very limited agriculture by the Indians and Spanish before about 1850, irrigation with Colorado River water began in the late 19th century. By 1966, about 100,000 acres, located principally on the flood plains of the Colorado and Gila River valleys and on Yuma Mesa was being irrigated. Groundwater is a source of irrigation water only in the South Gila Valley and in small areas outside the established irrigation districts in the other river valleys and on Yuma Mesa (Olmsted and others, 1973, p.1). In 1991, about 105,500 acres was being irrigated (Croxen and Kandl, 1996, p.9).

In 1916,the first gravity-drainage ditches were constructed to alleviate the consequent water-logging problems caused by continued irrigation and leakage from unlined canals. The system was expanded to meet problems as they arose. Between the 1920's and the 1960's Colorado River water was imported for irrigation on Yuma Mesa which raised the water table under the mesa. This resulted in the formation of a groundwater mound and induced groundwater movement into the valleys west and north of Yuma Mesa. Beginning in the 1960's, drainage wells were constructed in Yuma Valley and South Gila Valley to control the waterlogging effects caused by the groundwater mound (Olmsted and others, 1973, p.7, 9 and 10). There were 62 operating drainage wells and over 90 miles of gravity drainage ditches serving the Yuma basin in 1991 (Croxen and Kandl, 1996, p.12).

GEOLOGY AND GROUNDWATER OCCURRENCE

Structurally, the Yuma basin occupies parts of two sections of the Basin and Range province-- the Sonoran Desert and the Salton Trough. In the Yuma basin, the Sonoran Desert begins with the rugged north-northwest trending Gila and Tinajas Altas Mountains on the eastern flank of the basin. The mountains are probably the result, at least in part, of block faulting. West of the mountains extends a broad desert of Cenozoic basin fill. Farther to the west on the edge of the Salton Trough,mountain masses lie buried or nearly buried under the desert. These nearly buried mountains, which rise from roughly 40 to 100 feet above the surrounding land surface, have been informally named the Yuma Hills and the Boundary Hills. The mountains and the basin evolved into their approximate present configuration by mid-Tertiary times. Subsequent deformation has involved only broad-scale warping and minor faulting, probably associated with regional subsidence along the southwest margin of the Sonoran Desert (Olmsted and others, 1973, p.23 and 57).

The Salton Trough is separated from the Sonoran Desert by an extensive fault system. The major fault of this system, in the Yuma basin, is known as the Algodones Fault. Minor faults lie en echelon on either side of this fault. The Algodones Fault is important hydrologically in that it creates a barrier to groundwater flow. This is evidenced by the offset in groundwater elevations on Yuma Mesa where water levels are approximately 50 feet higher on the northeast side of the fault than on the southwest side as shown on map 1 and Wilkins (1975, sht. 1). The Salton Trough is tectonically active to the present time, especially west of the Yuma area, where movement on faults is still ongoing. The Salton Trough has accumulated more than 16,000 feet of fill, and mostly consists of alluvial and deltaic deposits of the Colorado River (Olmsted and others, 1973, p.57).

The groundwater reservoir in the Yuma basin is composed of Cenozoic basin fill overlying bedrock. Although fill thicknesses exceed 16,000 feet in some areas, only the upper 2,000-2,500 feet is considered hydrologically important, because the upper layers are extremely transmissive and yield sufficient quantities of water to wells. The upper 2,000-2,500 feet is generally considered a single aquifer, but is subdivided into three hydrologically connected strata. In ascending order they are the wedge zone, the coarse-gravel zone and the upper fine-grained zone (Olmsted and others, 1973, p.63, 66; Hill, 1993, p.7).

The wedge zone constitutes the major part of the water-bearing deposits. Throughout most of the basin this zone overlies the Bouse Formation and underlies the coarse-gravel zone. The wedge zone is approximately 2,500 feet thick near San Luis and north of Fortuna, and generally pinches out laterally beneath the coarse-gravel zone against the Laguna and Gila Mountains to the northeast and against the Yuma Hills. According to geologic logs, the wedge zone consists of interbedded sands, gravel and cobbles up to 3 inches in diameter. Clay and silts appear to be more abundant below depths of 1,000 to 1,500 feet. The top of the wedge zone ranges from about 160 feet below land surface near Laguna Dam to nearly 300 feet below land surface in the southern Yuma Valley. In some areas the contact between the wedge zone and the overlying coarse-gravel zone is vague and arbitrary (Olmsted and others, 1973, p.66-67).

The coarse-gravel zone is the principal production zone in the Yuma basin and consists of fine to coarse gravels with cobbles up to 10 inches in diameter deposited by the Colorado and Gila Rivers. These fluvial deposits range in thickness from 0 to 100 feet. Depths to the top of the coarse-gravel zone range from approximately 100 feet below land surface in the river valleys to approximately 180 feet below land surface beneath the Yuma Mesa (Olmsted and others, 1973, p.68).

The upper fine-grained zone includes most of the younger alluvium, the uppermost deposits of older alluvium and relatively minor deposits of windblown sand located beneath the river valleys and Yuma Mesa. Although little water is pumped from this zone it is hydrologically significant because most of the groundwater recharge and discharge takes place through it and because the water table beneath the irrigated areas lies within it. This zone ranges from about 70 to 240 feet thick and averages about 100 feet beneath the Yuma and Gila Valleys and 170 to 180 feet beneath Yuma Mesa. Sand and silt are the most abundant materials in this zone, although beds of silty and sandy clay and sandy gravel are extensive in places (Olmsted and others, 1973, p.68-69).

In general, groundwater movement in the Yuma basin is from north and northeast to south and southwest, except under Yuma Mesa where groundwater flows radially away from the groundwater mound. Groundwater enters the Yuma basin in Arizona as underflow in two locations, beneath Laguna Dam on the Colorado River and at Dome Narrows on the Gila River. Groundwater exits the basin as underflow into Mexico to the southwest under the Colorado River and south toward the Alta Desert in Mexico. In the eastern portion of the basin, from the groundwater mound and southeast thereof, groundwater moves from northwest to southeast across the Yuma Desert, and exits east of the Algodones Fault into Mexico. Prior to the late 19th century, the volume of recoverable groundwater stored in the saturated zone to 1,200 feet below land surface was estimated to be 49 million acre-feet (Freethey and Anderson, 1986, sht.1).

Water from the Colorado River is the source of almost all groundwater recharge in the Yuma basin. In 1991, approximately 706,700 acre-feet of water was used for irrigation in the Yuma basin (Croxen and Kandl, 1996, p.9). Irrigation water is applied in excess of crop requirements to reduce salt accumulation in the root zone and to compensate for the naturally low water-holding capacity of the sandy soil of the upper fine-grained zone. Much of this irrigation water easily reaches the water table. Also, much of the seepage from the unlined canals of the irrigation distribution system reaches the water table. In 1991, 69,830 acre feet of canal water was reported lost to seepage (Croxen and Kandl, 1996, p.18-20).

In the Yuma basin, as in most desert regions, precipitation is too scant to allow for more than a very minor amount to penetrate beyond the upper soil zone. Even during wet years and periods of intensive rainfall, precipitation is a negligible source of groundwater recharge. A minor exception occurs along the front of the eastern mountains where a small amount of local runoff has reached the water table and also formed lenses of perched or semi-perched water (Olmsted and others, 1973, p.72).

The Colorado and Gila Rivers are also sources of short-term groundwater recharge during periods of flooding. At these times, the stages of the rivers are above the altitude of the water table. As a result, water infiltrates into and recharges the aquifer (Olmsted and others, 1973, p.70). This occurred during March-September 1983 when the stage of the Colorado River rose 17 feet in Yuma and 13 feet at the International Boundary (Mock and others, 1988, p.9).

Drainage channels provide one of the primary sources of groundwater discharge in the Yuma basin. In 1991, over 90 miles of gravity-drainage facilities discharged 150,496 acre-feet of groundwater from the basin. Approximately 2,800 acre-feet of gravity-drainage water was returned to irrigation canals for reuse. In 1991, 62 operating drainage wells pumped 153,093 acre-feet of groundwater. The total quantity of drainage water exported from the basin in 1991, was 256,130 acre-feet (Croxen and Kandl, 1996, p.12).

Another source of groundwater discharge comes from a well field located east of San Luis. This well field pumps groundwater and delivers it to Mexico. In 1991, 31,193 acre-feet was pumped and delivered to Mexico from this facility (International Boundary and Water Commission, 1992, p.29). Evaporation from water in the drainage channels and evapotranspiration from plants also constitute a source of groundwater discharge. Also, under normal conditions, the stage of the Colorado River is below the altitude of the adjacent water table. As a result, the river acts as a natural drain.

Approximately 600 water levels were measured by the Arizona Department of Water Resources and the U.S. Bureau of Reclamation in wells in the Yuma basin in November 1992 for this study. Water levels ranged from 4 feet below land surface in parts of the South Gila and Yuma Valleys to over 300 feet below land surface in the Yuma Desert. Generally, water levels ranged from 6 to 8 feet below land surface, to more than 20 feet below land surface in the valleys. On Yuma Mesa, water levels ranged from about 30 feet below land surface near the crest of the groundwater mound, to 40 to 70 feet below land surface over other parts of the groundwater mound.

Comparison of 1992 data and 1960 data show that water levels in the Yuma basin have changed very little except along the International Boundary where water levels have decreased approximately 20 to 25 feet (hydrographs H, I and J). Water levels in the remainder of the basin have fluctuated from year to year but regionally they are considered to be stable (hydrographs A-G). The dearth of change is primarily due to the extensive drainage channels and pumps which maintain groundwater levels below the root zone in the agricultural areas of the basin. The drainage pumps also provide a means of controlling groundwater movement from the groundwater mound along the northern and western faces of Yuma Mesa.

WATER QUALITY

Groundwater quality in the Yuma basin varies widely with location and depth. Most of the groundwater was originally similar in chemical composition to the source waters in the Colorado and Gila Rivers, and has been significantly altered by over 100 years of irrigation. While these conditions are not exclusively unique to the Yuma basin they have had a profound effect on irrigation in that special methods have been developed in order to use the groundwater effectively.

During the period 1988-94, a total of 90 water samples was collected and analyzed by the Arizona Department of Water Resources. Major ion and metal analyses were performed on 46 of the samples, while 44 samples were analyzed for specific conductance, fluoride, pH, and temperature only.

Specific conductance values in the Yuma basin ranged from 1,140 to 6,360 microsiemens per centimeter (μS/cm). Dissolved-solids concentration may be approximated by multiplying specific-conductance values by 0.6, which is the approximate ratio of dissolved solids in milligrams per liter (mg/L) to specific-conductance concentrations in μS/cm at 25°C. The U.S. Environmental Protection Agency (1988, p.14) has established the secondary maximum contaminate levels (SMCL) for total dissolved solids at 500 mg/L, which is approximately equivalent to 833 μS/cm. SMCL's are guidelines only and are not enforceable standards. SMCL's are based on aesthetic qualities of water such as taste, odor and color. Water with levels above the SMCL's are not necessarily a health risk. All of the 90 samples collected by the Arizona Department of Water Resources had specific-conductance values above 833 μS/cm.

Fluoride levels ranged from 0.2 to 1.7 mg/L except for a well in sec.5, T.10S., R23W., which had a level of 7.5 mg/L. Arizona has established a maximum contaminate level of 4.0 mg/L for fluoride (Arizona Department of Environmental Quality, 1991, p.26).

Some of the detailed water analyses are shown on map 2 in the form of Stiff diagrams. These diagrams represent the ionic content of samples and can be used to compare and contrast water-quality analyses. They indicate the principal ions of sodium, chloride, calcium, bicarbonate (expressed as total alkalinity), magnesium and sulfate.

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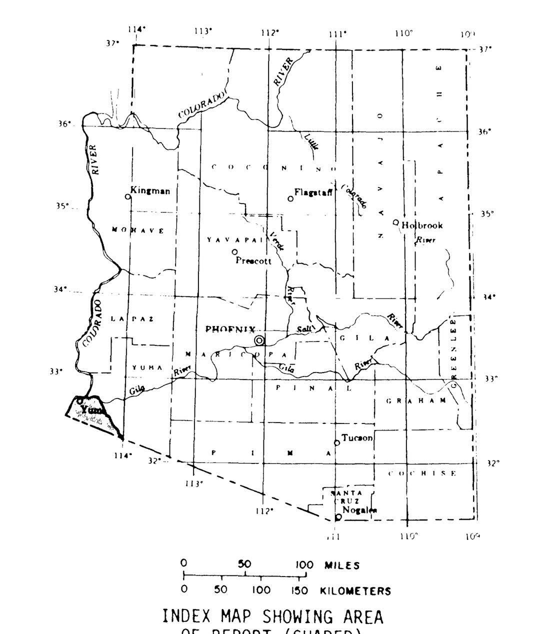
ESTIMATED GROUNDWATER PUMPAGE
IN THE YUMA AREA

[Numbers rounded to nearest thousand acre-feet. Numbers in parentheses indicate amount of pumpage for drainage of waterlogged land; the pumpage for drainage began in 1947 in Yuma Valley, in 1961 in South Gila Valley, and in 1970 on Yuma Mesa]

Year	Pumpage, in thousands of acre-feet	Year	Pumpage, in thousands of acre-feet
1915	2	1952	68 (8)
1916	2	1953	69 (9)
1917	2	1954	69 (11)
1918	3	1955	72 (17)
1919	4	1956	87 (27)
1920	4	1957	114 (55)
1921	4	1958	121 (62)
1922	4	1959	122 (62)
1923	4	1960	122 (62)
1924	4	1961	124 (74)
1925	5	1962	121 (118)
1926	6	1963	121 (116)
1927	7	1964	154 (103)
1928	8	1965	179 (131)
1929	9	1966	178 (131)
1930	10	1967	229 (151)
1931	11	1968	234 (148)
1932	12	1969	231 (143)
1933	13	1970	220 (137)
1934	14	1971	233 (140)
1935	15	1972	257 (162)
1936	16	1973	272 (166)
1937	17	1974	247 (159)
1938	18	1975	255 (158)
1939	19	1976	240 (148)
1940	19	1977	233 (141)
1941	20	1978	234 (132)
1942	21	1979	192 (117)
1943	22	1980	248 (132)
1944	20	1981	238 (152)
1945	22	1982	211 (143)
1946	32	1983	222 (129)
1947	39 (4)	1984	226 (132)
1948	62 (8)	1985	224 (123)
1949	65 (9)	1986	211 (140)
1950	64 (8)	1987	173 (123)
1951	70 (8)	1988	196 (129)
		1989	282 (158)
		1990	243 (141)
		TOTAL	7,941 (4,427)



INDEX MAP SHOWING AREA OF REPORT (SHADED)

Base from U.S. Geological Survey
1:250,000, EL CENTRO, 1977

MAPS SHOWING GROUNDWATER CONDITIONS IN THE YUMA BASIN
YUMA COUNTY, ARIZONA--1992
BY
ANDREW OVERBY

These hydrologic maps are available upon request from the Department of Water Resources, Basic Data Section, 2810 South 24th Street, Suite 322, Phoenix, Arizona, 85034. The hydrologic data on which these maps are based are available, for the most part, in computer-printout form and may be consulted at the Department of Water Resources and at the U.S. Geological Survey offices located at 520 North Park Avenue, Suite 221, Tucson, Arizona, 85719, and 1585 West University, Tempe, Arizona, 85281.