GROUND WATER
TEMPE QUADRANGLE, MARICOPA COUNTY, ARIZONA

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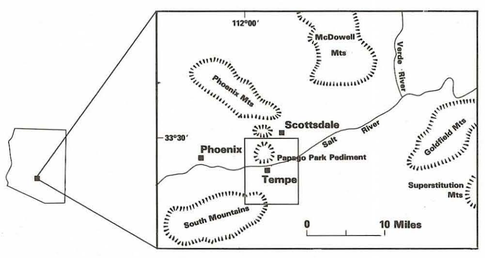

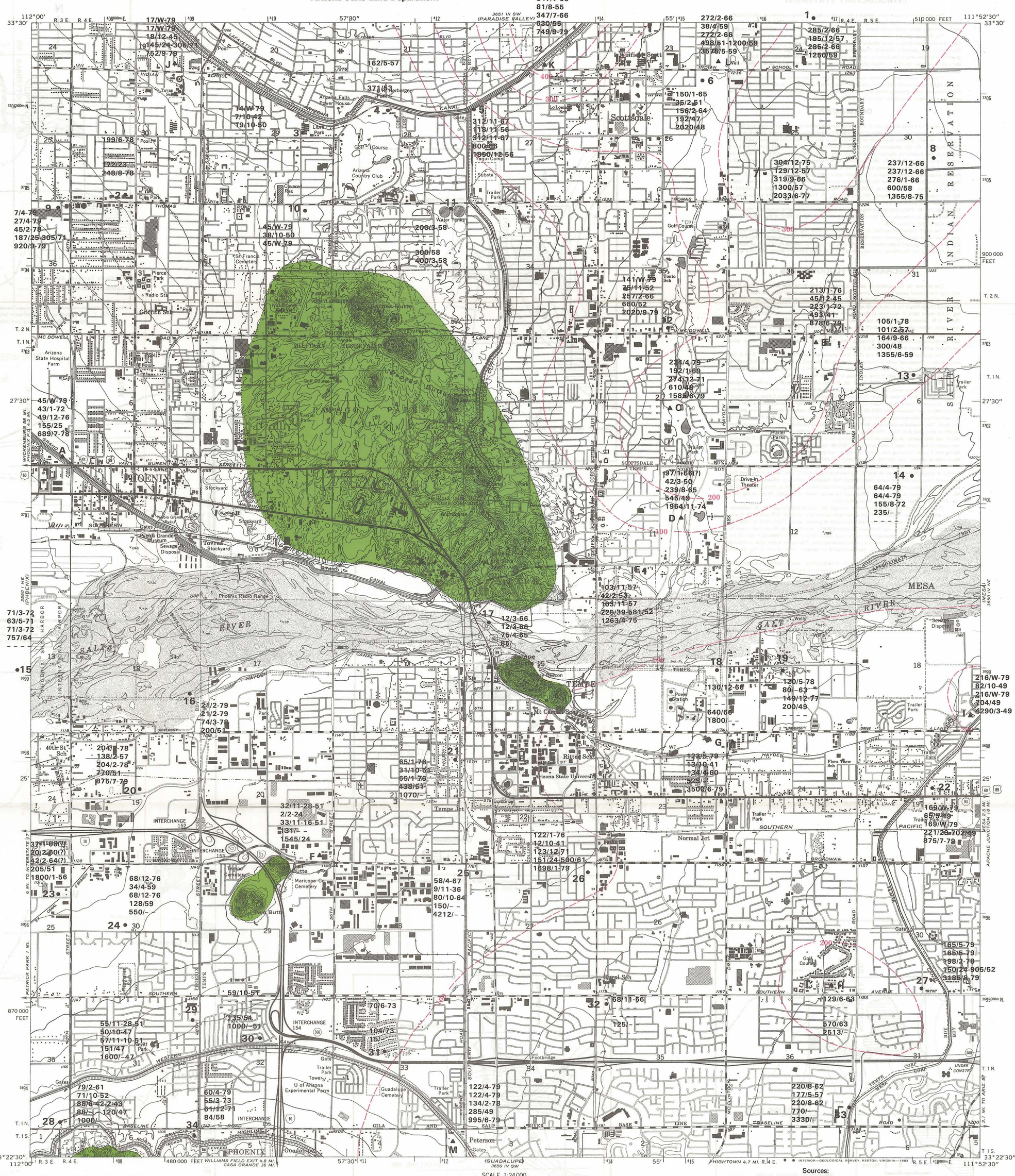

INTRODUCTORY STATEMENT

Those planning for land-use should consider the availability and utilization of both surface water and ground water, including the quality and quantity of those water resources, when making decisions to best meet the future domestic and industrial needs in the Tempe Quadrangle. Large quantities of good quality ground water are available within a few hundred feet of the surface. However, at the present rate of ground water usage, more water is being withdrawn than is being naturally recharged in the Salt River Valley, causing the water table to decline in most of the quadrangle. Surface water is presently available for use through arrangements with agencies which administrate and physically control any surface water into this area by permitting canal flow to facilities here. Surface water is also available sporadically during floodflows along the Salt River channel, or reservoir releases made to provide storage for potential floodflows from forecast storms.

Ground water is a major resource throughout Arizona; in 1983, about 66% of the water utilized was ground water (USGS, 1985). Therefore, an understanding of the ground water conditions is essential for the planning of future water supplies. Depth to the water table, ground water availability, and the probable quality of the water must be known. These factors are influenced by the geologic conditions of the area.

SUBSURFACE GEOLOGY

The Tempe Quadrangle is underlain by three alluvial units: the upper alluvium, the middle alluvium, and the lower alluvium (Arteaga and others, 1968; Laney, 1986). Alluvium is present in most areas of the Tempe Quadrangle and in the adjacent quadrangles of the eastern Salt River Valley. Alluvium is thinly deposited or is absent in areas underlain by the bedrock highlands and pediment (see Map GI-2-A, Geology). The material becomes finer with increasing distance from the highlands. The alluvium is less than 200 feet (64.6 m) thick at the western edge of the quadrangle. Some of the alluvium may contain gypsum, or other soluble minerals at depths of about 1000 feet (300 m), which reduce the quality of water obtained from those deposits. However, degradation of quality does not always increase with depth, because along Scottsdale Road, north of the river, the quality of water below about 500 feet (150 m) is generally better than that above (Kister, 1974). Robertson and others (1985) have shown areas cultivated for many years contain groundwater having concentrations of nitrate, hardness and total dissolved solids that decrease with depth, which infers influence from irrigation recharge.

The upper alluvium unit ranges from 50 to 200 feet (15 to 60 m) thick, and wells drilled into this unit have generally yielded from 75 gallons per minute (gpm) to 2000 gpm (4.7 liters per second (lps) to 126 lps). One well south of Tempe yielded more than 4000 gpm (252 lps), but the date of that test was not indicated. The upper alluvium is composed of silt, sand, gravel, and boulders. It generally thickens toward the nearby sub-basin centers, northeast and southeast. The upper unit is unconsolidated, except where calichified near the surface (see Map GI-2-G, Caliche) and is structurally undeformed and flat-lying. It is considered Quarternary in age, probably less than 2 million years old (Laney, 1986).

The middle alluvium is from 100 to 600 feet (30 to 180 m) thick, and increases to its greatest thickness in the northeast part of the quadrangle. It approaches 200 feet (60 m) thick in the western part of the quadrangle and is from 300 to 350 feet (90 to 105 m) thick in the southeastern part (Laney, 1986). The middle unit of the alluvium also consists of silt, sand, gravel, and boulders, but it may be slightly more consolidated than the upper alluvium. The individual grains are packed more closely together in the middle unit, and a cubic foot of middle alluvium could store less water than cubic foot of saturated upper alluvium. However, because the middle unit is generally thicker than the upper one, a greater volume of water may be available from the middle alluvium. The middle unit is flay-lying and has undergone little if any deformation structurally. It is considered early Quaternary or later Tertiary in age (Laney, 1986).

The lower alluvium unit is several hundred feet thick, being thicker toward the northeast and southeast. The lower unit consists chiefly of weakly to moderately cemented sand and gravel with beds of clay and silt, and may have been slightly deformed during faulting and tilting of this area during Tertiary time, probably late Miocene (see Map GI-2-A, Geology). The lower unit yields considerable water to wells penetrating it (Laney, 1986).

The bedrock highlands are crystalline rocks which have a general granitic composition and contain little water. Small quantities of a generally poor quality water may be obtained from localized, highly fractured zones (Laney et al, 1978). The Camel's Head Formation, also known as the red unit (Arteaga, 1968), underlies the alluvium in the northern part of the Quadrangle (see Map GI-2-H, Depth to River Gravel). The red unit is known to yield water to wells penetrating it.

DISTRIBUTION

The 1980 water table beneath the Tempe Quadrangle formed a ridge below the Salt River. The depth to the water table increases north or south away from the river channel. The 1980 difference in elevation between the top of the water ridge and the lowest portion of the water table, occurring in the north central part of the quadrangle, was about 350 feet (105 m). Because ground water will slowly move from its higher toward its lower surfaces, regardless of the overlying topography, the ground water of the ridge below the Salt River moves either north or south into the adjacent water table lows. Figures 1 through 7 on the reverse side are contour maps of the water table, and show the flow directions of the ground water for the years indicated.

North of the Salt River, the steadily increasing drawdown of the water table has produced a large irregular depression in the water table, or a large, complex cone of dewatered material which is 2 to 3 miles (3.2 to 4.8 km) in diameter, centered north of the quadrangle. The water table is more than 400 feet (120 m) deep at the center of that depression. South of the river, a minor depression has developed, with the water table in its center being about 200 feet (60 m) below the surface.

There are two types of water table in this area: regional and perched. The regional water table occurs at the level below which all material is saturated. It is a continuous body of water within the voids of the alluvium. The perched water table is an isolated, smaller body of water which is retained, or perched at some distance above the regional water table. The perched table is caused by a less permeable lens of material that slows the downward percolation of water in its descent toward the regional water table. The damming or slowing of the water's descent results in a mound of water being temporarily retained in or above the less permeable sediments. A well drilled to penetrate only the perched water table will generally yield considerably lower quantities of water than if drilled into the regional table below, because there is less saturated thickness of material associated with the perched water table. Also, such a well will probably be a less dependable source of water during dry years. Wells into which water cascades from some area above their water level have penetrated a perched water table.

1980 GROUNDWATER MANAGEMENT ACT

Recognition of the severity of the groundwater overdraft and related problems (primarily land subsidence and earth fissures) and their potentially severe financial consequences prompted the Arizona legislature to pass the 1980 Groundwater Management Act. This legislation established four "Active Management Areas" (AMA's) or zones where groundwater overdraft has already reached a critical state. The Tempe Quadrangle lies entirely within the Phoenix AMA, an area of more than 5500 square mi (14,250 square km) encompassing the greater metropolitan Phoenix area. Under the 1980 Act, the amount of water which can be withdrawn is restricted, and the development of new wells for anything but domestic use (wells having a discharge of less than 35 gpm) is stricly regulated. For example, land within an AMA cannot be tilled commercially if it was not cultivated between 1975 to 1980. During the projected lifespan of the Act (45 years), all groundwater withdrawn from all but domestic wells will be subject to a pump tax, with the revenue used to purchase and permanently retire from cultivation lands currently being irrigated. Other measures to be instituted include lining of irrigation canals with concrete, laser leveling of irrigated farm lands, installation of sprinkler irrigation, conversion to crops requiring less water, and recycling of sewage effluent.

QUALITY

Records of groundwater quality in the Salt River Valley have been kept since the 1920's. These records indicate a decrease in water quality accompanied the water table decline of the past several decades. Groundwater quality is affected primarily by the subsurface geology, by the quality of the waters recharged, and by pumping. Any one, or a combination of these parameters may be responsible for "non-point" sources of pollution. Poor water quality resulting from contaminated recharge may be due to landfill leachate, drywells into which contaminants have been disposed, chemical spills, agricultural activities such as irrigation and application of pesticides and fertilizer. Pumpage may lead to poorer quality water because it may alter the flow directions of groundwater, allowing poorer quality water to invade parts of the aquifer which formerly yielded higher quality water.

The quality of the ground water in the Tempe Quadrangle is good (Kister, 1974, and Osterkamp, 1974). Certain areas in the north central and southeast have concentrations of nitrate in the ground water which exceed the U.S. Environmental Protection Agency standards for drinking water of 10 mg/1 as nitrogen (Corps of Engineers and others, 1979). However, dilution of the high nitrate waters with better quality water from other sources has been found to reduce the nitrate concentration to an acceptable level for drinking. The high nitrate waters are acceptable for irrigation without further treatment or dilution (U.S. EPA, 1977). Chloride concentrations usually exceed limits proposed in a U.S. EPA secondary drinking water regulation, but the only reported detrimental effect of chloride at the levels found in the Tempe Quadrangle applies to certain crops irrigated with that water. Chromium, fluoride, and arsenic are constituents found to be health hazards in adjacent Salt River Valley areas, but in the Tempe Quadrangle there is no evidence ground water contains concentrations of these elements which approach hazardous levels. Hardness and salinity are two constituents in ground water of the Tempe Quadrangle which are relatively high for most wells listed in Table 1, below. However, there are no recommended U.S. EPA standards for those two constituents. The hardness is indicated as calcium carbonate ($CaCO_3$) in milligrams per liter of water, but represents the content of both calcium and magnesium. The salinity is shown in milligrams of total dissolved solids per liter of water.

RECHARGE

The idea of replacing water underground is not a new one; people have been doing it successfully for hundreds of years, and for a variety of reasons. In 1955, more than 2000 acre feet per day (245 hectare meters per day) were being recharged in the United States, with California storing more than half (MacKichan, 1957). By the late 1950's, Phoenix had numerous recharge wells operating for temperature exchange.

Because the water table has been lowered more than 350 feet (105 m) in areas of concentrated groundwater pumping, recharge might be utilized in the Tempe Quadrangle for filling the partially depleted aquifer. Many aquifers in the southwest, elsewhere in the United States, and worldwide, are routinely being recharged, but there are numerous problems which must be carefully monitored to ensure a successful long-time recharge operation.

Some constraints that must be considered for recharge include air binding of the aquifer, unfavorable ionic reactions between the recharged water and the sediments and groundwater where recharge will occur, the quality of the recharge water, and some major legal problems unique to Arizona.

Air binding of recharged water is the blocking of pore spaces and capillary passages through which recharge water passes into the aquifer, and may occur under several different conditions. Air bubbles can be created by recharge water free-falling inside the well casing to the water level. Recharge water should be piped to below the well water level, then released. If the recharge water is colder than the temperature of the ambient groundwater, combining the two may cause air in solution, if any, to be released as bubbles. Recharging into aquifer zones which have been dewatered for a sufficiently long period to have become completely dried may induce air binding. The uneven filling of underground pore spaces from the advancing water front may entrap air which may disperse and bind the aquifer. The complete drying of material in an aquifer entails the removal of the thin film of water which normally clings to the surface of individual grains, such as sand after the material has been drained by gravity. Complete drying of dewatered aquifer material may also occur if several unsealed wells have casings perforated at the levels of the dewatered material.

Unfavorable ionic reactions may cause deflocculation of clays, separating them into extremely small particles which may clog the recharge passages. Ionic reactions may also cause certain minerals to dissolve, which can lead to the precipitation of some ions contained in dissolved minerals, blocking the recharge passages.

The quality of the recharge water must be such that the existing quality of groundwater will not be degraded. The Arizona Department of Health Services and the Water Quality Control Council both have influence over water quality decisions.

Arizona's unique water laws probably have the most profound influence on the attempt to recharge groundwater. The legal questions which must be answered are complicated and involve exceptionally fine points of law. Farris (1985) gave insight into the implications and importance of these legal matters. The questions included: 1) where can the recharge water be obtained; 2) who may attempt recharge; 3) where may recharge be attempted; 4) is there legal storage space for recharged water; 5) may the person(s) recharging water withdraw that recharged water; and 6) how may the recharged water be protected from being withdrawn by others?

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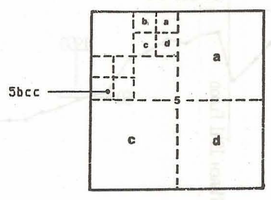
Well Numbering Data

A-1-4/5bcc

The upper case letter indicates the quadrant of the State, with "A" being the northeast quadrant and "D" being the southeast quadrant. The next two numbers indicate the township and range of that quadrant, and the number following the slash mark indicates the section within the township. The last three lower case letters specify the area of the well location, see illustration below. (Two adjacent wells are differentiated by adding a number subscript at the end, i.e. $5bcc_2$.)



BASE MAP FROM U.S. GEOLOGICAL SURVEY
TOPOGRAPHIC MAP, 1:24,000 SERIES
TEMPE QUADRANGLE (1952, PHOTOREVISED 1967)
Additional revisions compiled by the Geological Survey from aerial photographs taken 1978 and other sources. This information not field checked.
Map edited 1982.

UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

Sources:
Salt River Project well records & water level records
U.S.G.S. water level records
Arizona State Land Department well & water level data

Table 1. Chemical analyses of water from selected wells in the Tempe Quadrangle

	Well Number	Date of analysis	Temp. °C	pH units	Hardness, in Ca & Mg, mg/1	Total Dissolved solids, sum of constnts	Sulfate, disivd SO_4 mg/1	Nitrate, as NO_3 mg/1	Flouride mg/1	Chloride mg/1	Depth to bottom of interval smpld.
A	A-1-3/1ddd	4-67	22.7/54	7.7	123	1330	262/45	17	NT	340/45	155'
B	A-1-4/1aba$_2$	4-71	—	8.1/60	273	675	101	9	NT	278	493
C	A-1-4/2dbb$_2$	7-65	—	8.4	272	651	66	5	NT	255	610
D	A-1-4/11acd	11-78	29.4	7.9	320	832	60	13.2	0.5	301	545
E	A-1-4/11cda	2-61	—	7.4	488	1230	147	NT	NT	418	581
F	A-1-4/20ddd	10-56	—	7.6	373	1270	119/46	16	NT	432/46	131
G	A-1-4/24bbb$_2$	6-69	22	7.7	451	1110	58	31	NT	397	525
H	A-1-4/25ddd$_2$	11-78	25.6	7.6	382	957	58	18	0.2	348	520
I	A-1-5/18ddd$_2$	3-71	—	8.3/59	256	714	58	11	NT	255	704
J	A-2-4/19ddc	12-54	22.2	7.6	NT	1130	278/45	31	NT	224/45	145
K	A-2-4/22dcc	2-71	30/66	8.1/66	830	1380	462	93	NT	309	630
L	A-2-4/23ddd$_2$	1-66	30	8.1	170	435*	32	12	0.3	170	1200
M	D-1-4/3bbb$_2$	7-69	—	8.1/65	451	1130	111	11	NT	479	285
U.S. EPA Criteria, 1976 (1978)				5 - 9	Consumer preference		250	45[A]	1.4[B]	250	N/A

If component analyzed at different time, date is given after value obtained

Notes:
A - Also may be expressed at Nitrate-nitrogen (N), having a limit of 10 mg/1.
B - For areas having annual average max. daily temperature between 80 to 91°F (26.7 to 32.8°C; Tempe Quadrangle)
NT - Water not tested for this component.
* - Residue at 180°C.

Sources: Chemical analysis data from U.S.G.S., City of Phoenix, and City of Tempe

EXPLANATION

17 ● Well location and number

H ▲ Location and letter for well with chemical analysis of water included in Table 1

—100— Contour showing the approximate depth to water in feet below the land surface, 1979-1980 (based on water levels from 60 wells or more).

Bedrock containing little or no water. Possibly small amounts of water in highly fractured zones

Well Data

55/7-79
19/3-66
78/7-65
285/57
785/4-78

Top line: The latest water level in feet that has been recorded for this well (55), followed by the month and year that measurement was made (7-79)

2nd line: The shallowest water level recorded (19), and the date for that measurement (3-66)

3rd line: The deepest water level recorded (78), and the date of that measurement (7-65)

4th line: The depth in feet the well was drilled (285), and the year it was drilled (57)

Bottom line: Well yield in gallons per minute (785) during a pump test made on this well on the indicated month and year (4-78)

W-79 indicates the date of measurement was made during the winter of 1978-79
Dashes indicate data not available (- - -)
Queried if value of data was contradicted, latest data listed 57 (?)