HYDROLOGY AND WATER RESOURCES IN ARIZONA AND THE SOUTHWEST, VOLUME 7, p. 175-181.

Proceedings of the 1977 meetings of the Arizona Section of the American Water Resources Association and the Hydrology Section of the Arizona Academy of Science, held in Las Vegas, Nevada, April 15-16.

BAROMETRIC RESPONSE OF WATER LEVELS IN FLAGSTAFF MUNICIPAL WELLS

by

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Flagstaff municipal water wells at the Woody Mountain Well Field and the Lake Mary Well Field yield water from the Coconino Sandstone, which is the principal aquifer for the Flagstaff area. Locations of these well fields are shown on Figure 1. Analysis of water level data from observation wells during aquifer performance tests indicates that the Coconino is a nonartesian aquifer; however, the water levels in the municipal wells rise at times of low barometric pressure and decline at times of high barometric pressure. Jacob (1940) indicates that this kind of barometric response is interpreted to show artesian conditions, and may be used to compute the coefficient of storage of the artesian aquifer.

HYDROGEOLOGIC CONDITIONS

The sequence of rock units, from the surface, in the Lake Mary and Woody Mountain areas is as follows: alluvial and colluvial deposits, volcanic rocks, Moenkopi Formation, Kaibab Limestone, Coconino Sandstone, Supai Formation, Redwall Limestone, Martin Limestone, and Precambrian metamorphic rocks. Alluvial and colluvial deposits comprise a mixture which ranges in size from silt to boulders, lie above the water table, are permeable, and enhance rapid infiltration of surface water. Volcanic rocks include ash, cinders, bombs, and lava-flow rocks. The maximum thickness of lava-flow rocks penetrated by a Lake Mary well is 121 feet and by a Woody Mountain well is 611 feet. Pyroclastic volcanic materials provide an excellent medium for water infiltration. Intense fracturing in some lava-flow rocks may provide recharge conduits to the aquifer system. The Moenkopi Formation occurs as erosional remnants overlain by volcanics. It consists of sandstone and mudstone, lies above the water table, and where unfractured, acts as a barrier to water percollation. The Kaibab Limestone lies above the water table and ranges in thickness from 202 feet in Lake Mary well LM-4 to 428 feet in Woody Mountain well WM-3. The Kaibab contains numerous joints, fractures, and faults, which have been enlarged by solution activity, and is an excellent recharge medium.

The Coconino Sandstone is the principal aquifer at the Lake Mary and Woody Mountain well fields. The thickness of the Coconino ranges from 740 feet in Lake Mary well LM-4 to 905 feet in Woody Mountain well WM-1. The water table occurs at depths below the top of the Coconino ranging from four feet at Woody Mountain well WM-5 to 572 feet at Woody Mountain well WM-1. Water moves slowly through unfractured Coconino and wells in such strata have specific capacities of less than one gallon per minute per foot of drawdown (gpm/ft). Fracturing enhances yields from the Coconino. Wells drilled into highly fractured portions have specific capacities that exceed 4 gpm/ft.

More complete descriptions of the hydrogeological and geophysical conditions at the Woody Mountain Well Field area are given by Harshbarger and Carollo (1973), Scott and Montgomery (1974), Montgomery and DeWitt (1975) and Scott (1974), and at the Lake Mary Well Field by Koval (1976) and by Harshbarger and Associates (1976 and 1977).

AQUIFER PERFORMANCE TESTS

Aquifer performance tests have been made at individual wells in the Woody Mountain and Lake Mary well fields from 1956. Long-term aquifer performance tests using six wells at Woody Mountain and four wells at Lake Mary were made in 1972 and 1975 respectively.

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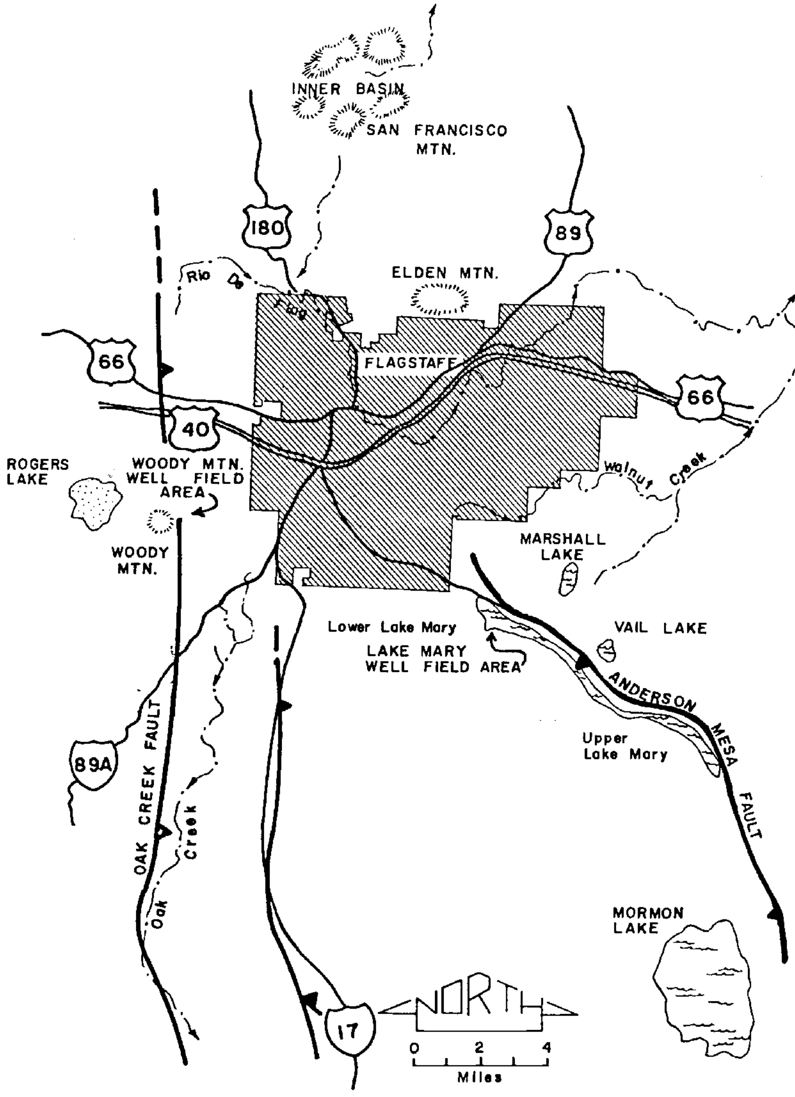

Figure 1

LOCATION MAP

WOODY MOUNTAIN AQUIFER TEST

Beginning on April 10, 1972, Woody Mountain wells WM-2, WM-3, WM-4, and WM-6 were individually turned-on at eight to seventeen day intervals. By May 20, 1972, all four wells were operating at a continous composite rate of 1,702 gpm. WM-1 and WM-5 were not pumped and served as observation wells. The pumping phase was completed on November 4, 1972 after 202 continuous days of pumpage. The recovery phase extended into 1973. Transmissibility at individual wells ranged from 7,400 to 31,300 gallons per day per foot (gpd/ft). Coefficient of storage computed using water level data from both observation wells was 0.08 (Harshbarger and Carollo, 1973). These coefficients are interpreted to indicate nonartesian conditions in the Coconino aquifer at Woody Mountain.

LAKE MARY AQUIFER TEST

The Lake Mary aquifer test began by pumping LM-2 on March 7, 1975. Pumping was initiated at LM-4 on April 3, 1975. Wells LM-1 and LM-3 were not pumped and served as observation wells. The pumping phase was completed on October 18, 1975 after 225 days of discharge at a continuous composite rate of 1,301 gpm. The transmissibility at individual wells ranged from 4,000 to 15,000 gpd/ft. Coefficients of storage computed from observation well water level data ranged from 0.05 to 0.10. These coefficients are interpreted to indicate nonartesian conditions in the Coconino aquifer at the Lake Mary well field.

BAROMETRIC PRESSURE

Barometric pressure was measured at Pulliam Airport. The airport is located approximately four miles east of the Woody Mountain well field and approximately five miles northwest of the Lake Mary well field. Barometric pressure in inches of mercury was converted to barometric pressure in feet of water for use in determining barometric response and barometric efficiency of water wells.

BAROMETRIC RESPONSE

Barometric response in the observation wells at Woody Mountain and at Lake Mary were apparent during both the pumping and recovery phases of the 1972 and the 1975 aquifer tests. The relationship of barometric pressure and hydrographs for water levels in the Woody Mountain wells is shown on Figure 2 and in the Lake Mary wells on Figure 3. Both Figures indicate a close inverse relationship between changes of barometric pressure and changes in water levels. The least squares line of best-fit was calculated for each hydrograph and a line parallel to the best-fit line was constructed to establish a datum for measuring water level change.

BAROMETRIC EFFICIENCY

The barometric efficiency of the Woody Mountain and Lake Mary wells treated on Figure 2 and 3 was determined by plotting the water level changes as ordinates and the corresponding changes in atmospheric pressure as abscissas on rectangular coordinate graph paper (Ferris and others, 1935). The slope of the line of least squares best-fit drawn through the plotted points is the barometric efficiency. The plot used to determine barometric efficiency for well LM-3 is shown on Figure 4. The barometric efficiency computed for selected Flagstaff wells, together with the correlation coefficient (r^2) which measures the degree of dependency of water level on atmospheric pressure, are tabulated below:

WELL	BAROMETRIC EFFICIENCY	(r^2)
LM-1	100%	0.93
LM-3	96%	0.96
LM-4	100%	0.84
WM-5	112%	0.84

COEFFICIENT OF STORAGE

Jacob (1940) has shown that barometric efficiency can be used to calculate the coefficient of storage of an artesian aquifer. The relationship is as follows:

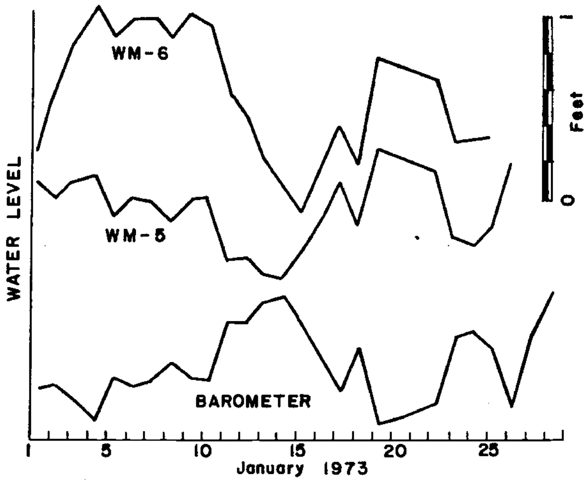

Figure 2

WOODY MOUNTAIN WELLS
RELATIONSHIP OF BAROMETRIC PRESSURE
AND HYDROGRAPHS FOR WATER LEVELS

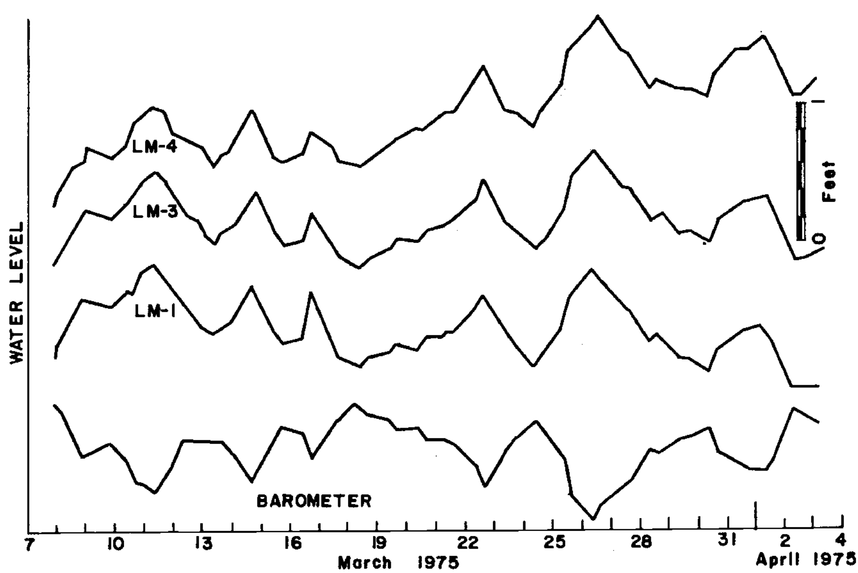

Figure 3

LAKE MARY WELLS
RELATIONSHIP OF BAROMETRIC PRESSURE
AND HYDROGRAPHS FOR WATER LEVELS

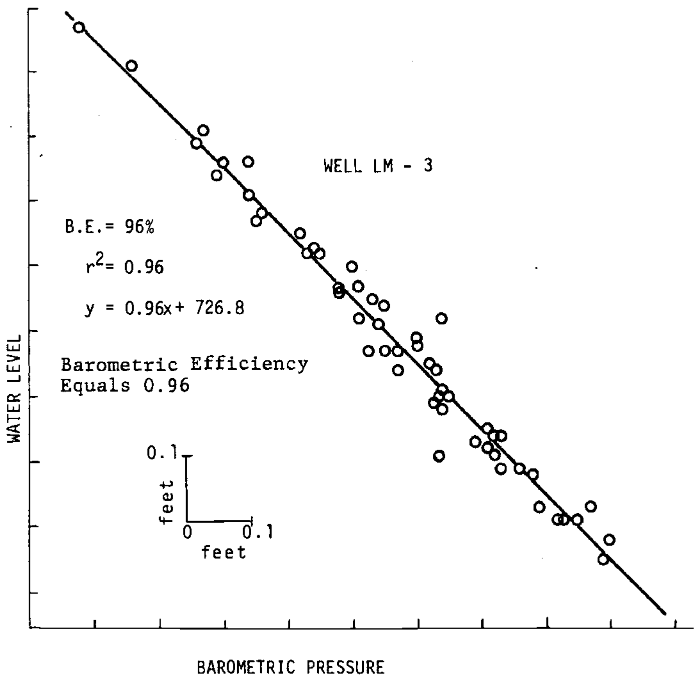

Figure 4

BAROMETRIC EFFICIENCY OF
LAKE MARY WELL LM-3

$$S = (G\ P\ m\ B)\frac{1}{B.E.}$$

Where S = coefficient of storage

G = unit weight of water

P = porosity

m = saturated thickness

B = bulk modulus of compression of water

$B.E.$ = barometric efficiency

The coefficient of storage calculated for the Coconino aquifer using this relationship and the saturated thickness for the Woody Mountain and Lake Mary wells are tabulated below:

WELL	SATURATED THICKNESS IN FEET	CALCULATED COEFFICIENT OF STORAGE
LM-1	899	$2.5x10^{-4}$
LM-3	395	$1.2x10^{-4}$
LM-4	882	$2.5x10^{-4}$
WM-5	1100	$2.8x10^{-4}$

CONCLUSIONS

The barometric efficiencies and the coefficients of storage calculated from the barometric response of water levels in the Woody Mountain and the Lake Mary wells are within the range which indicates artesian conditions, although it is known that the Coconino aquifer is non-artesian. The reason for the strong barometric response is not known but may be due to the thick and fine-grained character of the rocks which lie between the land surface and the water table. Barometric changes are transmitted slowly through this rock sequence, which allows the water levels in the wells to respond to short-term changes in barometric pressure as if the aquifer were artesian. The relations given in this paper, indicate that coefficients of storage computed from barometric efficiency in aquifers which are overlain by thick and fine-grained sedimentary strata may be incorrect and should be viewed with caution until confirmed with other analysis.

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