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Draft Report
For Review Purposes Only

prepared for
Maricopa Association of Governments
Phoenix, Arizona

by

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RESULTS OF DRY WELL MONITORING PROJECT FOR COMMERCIAL AREA AT 28TH STREET AND INDIAN SCHOOL ROAD

INTRODUCTION

Dry wells (wells normally not deep enough to reach the water table) are widely used in the urbanized parts of the Salt River Valley for disposal of storm runoff from commercial areas. There were reportedly thousands of these wells in existence in the Phoenix urban area as of 1983. The Maricopa Association of Governments (MAG) entered into an agreement with the Arizona Department of Health Services (ADHS) in late 1983 to conduct an investigation of these dry wells. Funds to conduct this program were provided by the U.S. Environmental Protection Agency (EPA), through the Underground Injection Control (UIC) Program. The ADHS desired an evaluation of the impact of dry well disposal of storm runoff from commercial areas on groundwater quality. Information from this monitoring program could then be used as a management tool to mitigate any adverse impacts of this practice.

There were three major aspects of this investigation. A commercial area was selected where storm runoff and the underlying groundwater could be monitored. One part of the program was thus to sample and analyze storm runoff from both winter and summer precipitation. The purpose of this part was to characterize the chemical composition of the storm runoff, particularly with respect to potential groundwater pollutants. A second part of the program was to install and routinely sample water from four shallow monitor wells near the dry wells that were selected for monitoring. This

would allow the impact on groundwater at a specific site to be determined. The third part of the program was to determine the relation between depth of dry well and depth to groundwater for sites throughout the urbanized parts of the Salt River Valley. This information was essential for several reasons. First, it provides an indication of the separation between the total depth of dry wells and the water table throughout the urban area. Second, the results of monitoring at one specific location, under a specific set of circumstances, can be interpreted in light of regional conditions. That is, perspective is given as to the applicability of the results of monitoring at a specific site to a much larger area.

RELATION OF DRY WELL DEPTH TO THE WATER TABLE

Locations and Depths of Dry Wells

McGuckin Drilling, Inc. of Phoenix has installed many of the dry wells in the Phoenix urban area since 1974. Historically, one of the limiting factors in the usefulness of dry wells was that suspended and/or floating materials tended to clog the dry well. McGuckin Drilling, Inc. introduced the Max Well in 1974, to address these previous limitations. Basically this type of dry well contains a settling chamber that removes some of the suspended materials in storm runoff that would otherwise clog a dry well. In addition, an overflow pipe is attached to the settling chamber. This pipe contains a debris screen, which precludes much of the floating material in the settling chamber from clogging the

dry well. Gravel or pebbles are installed below the settling chamber, in the lower part of the dry well. Water is carried downward to this part of the well by the overflow pipe. There are several varieties of those Max Wells, depending on the location, use, and specific geologic materials present at a site.

McGuckin Drilling, Inc. cooperated in this program by making available their extensive records covering the installation of more than 2,500 dry wells in the Phoenix urban area during the past decade. These records are meticulously maintained and are of excellent quality. Maps are maintained to show the location of the dry wells. These maps are similar to City Street maps and are on a one inch equals one-half mile scale. An index is kept which shows the number of dry wells at a site, the date of installation, the name of the job or client, the location, the depth of the dry wells, and the type of dry well. In addition, drillers logs are made during drilling of each dry well, noting the types of subsurface geologic material encountered at various depths. If shallow groundwater is encountered, this is also noted on the logs.

Records were collected from McGuckin Drilling, Inc. in late Spring 1984. Locations and depths of dry wells were then plotted on U.S. Geological Survey 7.5-minute quadrangle sheets. Most of the dry wells drilled by McGuckin Drilling, Inc. in the Phoenix urban area are located in an area covered by the following quadrangle sheets: Chandler, Curry's Corner, El Mirage, Fowler, Glendale, Guadalupe, Hedgepeth Hills, Mesa, Paradise Valley, Phoenix, Sunnyslope, Tempe, and Union Hills. Records on a total of slightly more than 2,500 dry wells were found in the area covered

by these quadrangle sheets. Depths of most dry wells in the Phoenix urban area range from about 30 to 80 feet, however, some exceed 120 feet. In general, the dry well is sufficiently deep to tap from 5 to 20 feet of permeable materials, into which the storm runoff is disposed. Thus in areas where clay, caliche, or other materials of relatively low permeability are predominant at shallow depths, deeper dry wells are necessary.

Depth to Water

Information on depth to water was obtained from two primary sources. First, the Arizona Department of Water Resources (ADWR) conducted an intensive water-level measurement program in the Salt River Valley during Winter 1982-83. Most of these measurements were made during December 1982 or January 1983. Water-level measurements were available for about 300 wells within the area of interest. Second, supplemental information on shallow water levels was obtained from sources such as dry well drilling records and monitor well measurements for various parts of the Phoenix urban area. Information on depth to water at the time of drilling is available for about 80 dry wells. Only information from the past several years was used. There are shallow monitor wells at numerous landfills, some industrial waste sites, and in the Gilbert Area, as a result of the MAG 208 Program. Information on depth to water was available for about 40 monitor wells in the area of interest. Measurements for a time period as close to Winter 1982-83 as possible were used in this evaluation.

Depth to water measurements were then plotted on the same U.S.

Geological Survey 7.5-minute quadrangle sheets on which the dry wells had been plotted. Before the depth to water measurements were contoured, hydrogeologic judgment had to be used to determine the shallowest water level in specific areas. This was necessary because some of the wells for which measurements were available do not tap the shallowmost deposits. Wells tapping deeper strata in the Salt River Valley normally have lower hydraulic heads (a greater depth to water) than do wells tapping shallow strata. For purposes of this evaluation, depth to water in the shallowest saturated deposits was the primary interest. The Mesa area is an example of an area where many wells are present that do not tap the shallow materials near the water table. Records from shallow wells, including dry wells and monitor wells, are most useful in such areas.

Contours of depth to water were then drawn, with preference given to shallow measurements, as compared to deeper ones, in any specific area. A 20-foot contour interval was used for contours above a depth of 100 feet, and a 50-foot contour interval was used for depths between 100 and 250 feet. Water levels below a depth of 250 feet were not contoured as part of this study.

Figure 1 shows these water-level contours. In general they are similar to measurements for Spring 1972 by the U.S. Bureau of Reclamation (1977), but the 1982-83 depths are somewhat shallower. Depth to water in 1982-83 was less than 20 feet in an area between Indian School and Thomas Roads and 40th and 48th Streets. Depth to water was less than 50 feet in a moderately sized area west of Papago Buttes in central Phoenix. Most of this area is east of

16th Street, between Van Buren Avenue and Camelback Road. Depth to water was less than 50 feet along the Salt River, from near Tempe Buttes to the confluence with the Gila River.

In the Chandler Quadrangle, depth to water was about 140 feet beneath the west edge and increased to the east, to about 200 feet. Depth to water was between 120 to 150 feet beneath most of the Guadalupe Quadrangle, and increased toward South Mountain. There is a localized area of perched water along Williams Field Road between I-10 and Kyrene Road. In this area, depth to the top of the perched water was less than 50 feet. This area was described by Schmidt (1981) as part of the MAG 208 program. In the Mesa Quadrangle, depth to water was shallowest (about 90 feet) near the Salt River in the western part, and increased to the southwest (130 feet) and the east (greater than 250 feet).

Depth to water exceeded 250 feet beneath the north half of the Sunnyslope Quadrangle. Depth to water generally increased to the north and northwest and was usually less than 100 feet east of I-17 and south of Bethany Home Road.

In the Tempe Quadrangle, depth to water exceeded 100 feet southeast of Tempe Butte and east of the Papago Buttes and north of the Salt River. Depth to water increased to the southeast, to about 130 feet. In the Phoenix Quadrangle, depth to water exceeded 100 feet near South Mountain and in the northwest part. In the Paradise Valley Quadrangle, depth to water exceeded 250 feet except for a small area southwest of Camelback Mountain. In the Glendale Quadrangle, depth to water was about 150 feet in the southeast corner and increased to the north. Northeast of Grand Avenue,

depth to water exceeded 200 feet. In the El Mirage Quadrangle, depth to water was about 130 feet near the southeast corner and increased to the northwest. Depth to water exceeded 200 feet beneath Sun City, Lake Air Force Base, and lands to the northwest. Depth to water increased to the north in the Fowler Quadrangle, exceeding 100 feet north of McDowell Road. Depth to water was about 170 feet near the north edge of the quadrangle.

For each dry well plotted, a determination was then made of the distance between the total drilled depth of the dry well and the water table. A tabulation was then prepared, showing depth of the dry well, depth to water, and the difference between the two for each of the 2,520 wells. The depth of dry well used in this analysis refers to the total depth drilled. The bottom of the settling chamber is normally no greater than 20 feet in depth for most dry wells. In cases where water was penetrated, native materials were normally backfilled in the hole to some depth above the water table at the time of drilling. Thus the total depth to which gravel and pebbles were added may be 20 to 30 feet less than the total dry well depth reported. In addition, storm runoff cannot pass directly from the settling chamber and into the groundwater without passing through some gravel or pebbles which are placed below the settling chamber.

Distance Between Total Depth of the Dry Well and the Water Table

Table 1 summarizes the extent of separation between the total depth of the dry well and the water table, by quadrangle. Dry wells were categorized by separation distances of less than zero

TABLE 1 - SUMMARY OF DISTANCES BETWEEN TOTAL DEPTH OF DRY WELLS AND WATER TABLE

NUMBER OF WELLS

	Depth (feet)								
Quad Sheet	<0	0-25	26-50	51-75	76-100	101-150	151-200	>200	Total
Chandler	0	2	10	7	71	12	0	0	102
Curry's Corner	0	0	0	0	0	0	3	11	14
El Mirage	0	0	0	0	0	0	6	11	17
Fowler	0	4	27	44	36	38	0	0	149
Glendale	0	0	0	0	3	61	59	83	206
Guadalupe	19	20	18	62	41	14	0	0	174
Hedgepeth Hills	0	0	0	0	0	0	0	64	64
Mesa	0	0	0	0	11	51	81	164	307
Paradise Valley	0	0	12	3	4	32	37	94	182
Phoenix	37	67	162	62	6	0	0	0	334
Sunnyslope	17	61	30	31	17	12	11	150	329
Tempe	7	125	95	65	156	32	14	55	549
Union Hills	0	0	0	0	0	4	10	83	97
Total	80	279	354	274	345	256	221	715	2,524
Percent of Total	3	11	14	11	14	10	9	28	100

Water table is generally for Winter 1982-83. Dry wells are only those in records of McGuckin Drilling, Inc. as of Spring 1984. Bottom of dry well is total depth drilled.

(total depth of dry well is below the water table), zero to 25, 26 to 50, 51 to 75, 76 to 100, 101 to 150, 151 to 200, and greater than 200 feet. A total of 80 wells, or 3 percent of the total, extended to below the estimated water level as of Winter 1982-83. Most of these wells were located in central Phoenix or near Tempe, where depth to water was less than 50 feet. The 19 dry wells in the Guadalupe Quadrangle in this category are primarily located east of I-10 and along Williams Field Road and tap perched groundwater, as opposed to the regional aquifer. The other 61 dry wells are believed to have reached water in the regional aquifer.

More than one-quarter of the dry wells tabulated in Table 1 are at least 200 feet above the water table. Many of these wells are in the Glendale, Hedgepeth Hills, Mesa, Paradise Valley, Sunnyslope, and Union Hills Quadrangles. Almost half of the dry wells (1,190) are at least 100 feet above the water table. In contrast, 279 wells, or 11 percent of the total, were within 25 feet of (and above) the water table. Most of these dry wells were in the west part of the Tempe Quadrangle, and the south parts of the Phoenix and Sunnyslope Quadrangles. Slightly more than one-quarter of the dry wells are located in areas where the underlying water level is 50 feet or less below the total depth of the dry well. It should be kept in mind when interpreting Table 1 that the effective bottom of some dry wells (depth to which gravel and pebbles were placed) does not extend to the total drilled depth of the well. This is particularly true where shallow groundwater was encountered.

SELECTION OF COMMERCIAL AREA FOR MONITORING

Several criteria were developed for selecting a commercial area to monitor storm runoff and shallow groundwater. First, a site with relatively shallow groundwater was favored, in order to simplify the groundwater monitoring effort and to minimize the cost of monitor well installation. Second, a site where dry wells had been used for as long as possible was favored. In such a situation, a more noticeable impact on groundwater could be expected to be present. Third, a site with a larger drainage area and more than one dry well was favored, in order to maximize the opportunity for observing an impact on groundwater. Lastly, and most importantly, a cooperative owner of such a commercial center had to be found. Cooperation was essential to allow access for installing, testing, and sampling the monitor wells. Access for frequent sampling of storm runoff and a secure site for installation of a recording raingage were also needed.

The extensive records of McGuckin Drilling, Inc. were reviewed with these criteria in mind. The criterion on depth to water basically limited potential sites to central Phoenix or Tempe, where depth to water was known to be less than 100 feet. Three candidate sites in northeast Phoenix and three in Tempe were selected for further consideration. Based on field observations and preliminary contacts with the owners of these commercial centers, one of these sites was selected for the monitoring. This site is located in the commercial area at the northeast corner of Indian School and 28th Street, in central Phoenix. The Alpha Beta

Corporation, owners of this shopping center, which is called Los Olivos Plaza, was extremely cooperative during this program. The shopping center is about five acres in size, and has a total of five dry wells. The westernmost two dry wells, near 28th Street, were selected for monitoring. The paved area tributary to these wells is estimated to be about two acres in size.

PRECIPITATION MEASUREMENTS

Long-term precipitation records for Phoenix are available for stations at the Sky Harbor Airport, Indian School (Central and Indian School Road), and at the downtown post office (Sellers and Hill, 1974). These records indicate that there are normally two major rainfall periods each year, which is normal for central Arizona. Winter storms, originating from advected air masses from the Pacific Ocean, are normally of lower intensity and of a longer duration. Summer storms, convective in nature and originating in the Gulf Coast, are normally of higher intensity and are shorter in duration. The highest monthly rainfall is normally during December through March and July through September. The lowest monthly rainfall is normally during May and June. Of the average annual rainfall of 7.41 inches at Indian School from 1941-70, 3.02 inches fell during the period December-March and 2.92 inches fell during the period July-September.

Rainfall is routinely measured by recording raingages at three City of Phoenix fire stations in the vicinity of the site. These include Station No. 5, near 14th Street and Thomas Road, which is

about two miles southwest of the site; Station No. 17, near 16th Street and Missouri, which is about two miles northwest of the site; and Station No. 13, which is about three miles southeast of the site. Such records were used in the second phase of the MAG 208 water quality management program, when runoff from two storm drains in Phoenix was monitored (Schmidt, 1981). These records are of good quality and generally agree well with records maintained for the station at Sky Harbor Airport. Records from these stations were obtained from the Hydraulics Section of the Engineering Department of the City of Phoenix, for the period October 1, 1983-September 30, 1984.

Because of the variability of precipitation from place to place in the valley, particularly during summer storms, it was necessary to measure precipitation at the site. A continuously recording tipping bucket raingage, manufactured by Weathertronics of Sacramento, California (Model 6015-A) was installed at the site on November 21, 1983. A location was chosen so as to provide representative measurements and also to minimize the chances for vandalism. The gage was placed on the roof of the Alpha Beta Market, which is at the northeast corner of the shopping center. No obstructions were present extending above the gage that could interfere with collection of representative measurements. The gage was equipped with a spring-wound seven-day clock. The gage was normally serviced on a weekly basis. The amount of rainfall can be determined to the nearest 0.01 inch from the recorder charts, and the time of an event can be determined to the nearest ten to fifteen minutes.

Records at the nearby three precipitation stations indicated that there had been some rainfall on November 20 and 21, 1984, just prior to installation of the gage. On the basis of these records, it is estimated that 0.18 inch of rain fell on November 20 and 0.16 inch on November 21 at the site. Records for the nearby stations indicate that no rain fell during October 25-November 19, 1983. A small amount of rain (about 0.06 inch) fell on October 24, and no rain fell during October 2-23. An estimated 0.44 inch of rain fell at the site on October 1, and this was thus the last large event prior to commencement of the monitoring program. The Winter 1983-84 rainfall period thus began on November 20, 1983.

Table 2 shows rainfall at the site for November 1983 through April 1984. There were nine measurable rainfall events during this period. Much of the winter rainfall occurred during three storms, one of which was in early December, and the other two of which were in April 1984. There was a prolonged dry period, during which no rain fell (January 5 through April 6, 1984). Thus monitoring was continued through April. The total rainfall during December 1983-April 1984 was thus about two-thirds of normal, based on long-term records at other stations.

There was no rainfall at the site during May 1 through June 24, 1984. The Summer 1984 rainfall period began during the last week of June. Table 3 summarizes rainfall events for the site during Summer 1984. There were a total of 21 rainfall events during this period. A total of 8.97 inches of rain fell during this period, which is about three times the average value, based on long-term records from other stations. Heavier rainfall events began to

TABLE 2 - SUMMARY OF WINTER
1983-84 RAINFALL AT DRY WELL SITE

Date	Rainfall (inches)
November 20, 1983	0.18*
November 21	0.16*
November 25	0.06
December 1-2	0.64
December 4	0.12
December 25	0.11
January 5, 1984	0.25
April 6	0.50
April 28	0.45
Total Nov-April	2.47
Total Dec-April	2.07

*Value extrapolated from records at nearby stations.

TABLE 3 - SUMMARY OF SUMMER
1984 RAINFALL AT DRY WELL SITE

Date	Rainfall (inches)
June 25	0.09
June 30	0.06
July 1	0.01
July 6	0.04
July 12	0.06
July 14	0.04
July 18	0.69
July 20	0.02
July 21	1.10
July 26	0.17*
July 27	0.55*
July 28	1.00*
August 11	0.02*
August 14	0.85*
August 22	0.24
August 23	0.22
September 1	1.31
September 10	1.57
September 22	0.08*
September 25	0.35*
September 26	0.50*
Total June-September	8.97
Total July-September	8.82

*Value extrapolated from nearby stations.

wet year
nearly 1"

occur in mid-July and continued through mid-September. There were four events when more than one inch of rainfall fell. The recording raingage at the site was inoperative from July 26-August 21, and from September 11-30, 1984, due to damage that required factory repairs. Records from nearby stations were used for these periods.

SAMPLE COLLECTION, PRESERVATION, AND ANALYSES

Samples of storm runoff were collected and analyzed for major inorganic chemical constituents, trace inorganic chemical constituents, trace organic chemical constituents in the EPA Priority Pollutant list, and for selected pesticides. Samples for analysis of dissolved trace metal content were filtered through a 0.45 micron Millapore filter and then placed in acidified one pint polyethylene containers. Samples for analysis of total trace metal content were placed in one-pint polyethylene containers treated with nitric acid. Samples for analysis of most of the major inorganic chemical constituents were collected in untreated one pint polyethylene containers. Samples for nitrogen forms were placed in one pint polyethylene containers treated with sulfuric acid. Samples for total organic carbon were collected in 50 ml amber glass bottles treated with phosphoric acid. Sample containers for the inorganic chemical constituents and organic carbon were provided by BC Laboratories, Inc. of Bakersfield, California, who performed the analyses. Samples for organic carbon and nitrogen forms were kept cool after collection and during shipment.

These samples were normally sent by U.S. Postal Service express mail service (with guaranteed next day delivery). Analyses generally follow those of Standard Methods, as reported by Schmidt (1983).

Samples for analysis of volatile organic chemical constituents were collected in duplicate glass vials, with care taken that no air bubbles were present. Samples for analysis of acid and base-neutral trace organic chemical constituents were placed in duplicate amber, one-quart, glass containers. These containers were provided by California Analytical Laboratories, Inc. of Sacramento, California, who performed the analyses. These samples were kept cool after collection and during shipment. Shipment of samples was by air-freight directly to Sacramento, generally with same day delivery. EPA Method 601, GC with a Coulson detector was used for the analysis of volatile organics. EPA Methods 624 and 625, GC/MS, were used for the acid and base neutral compounds.

Samples for volatile pesticides were collected in duplicate 100 ml amber glass vials. Samples for the remaining pesticides were collected in duplicate clear, one-quart glass bottles. The containers were provided by Stoner Laboratories of Santa Clara, California, who performed the analyses. Samples were kept cool after collection and during shipment. The samples were shipped by air-freight, directly to San Jose Airport, which is located close to the laboratory. Pesticide analyses to the low levels and for the constituents analyzed during this investigation are complicated. A summary of these is provided in the appendix. The pesticides selected for analyses were generally the same as those

used in the final monitoring phase of the MAG 208 program (Schmidt, 1983). However, one pesticide commonly used in urban areas (diazinon) was added for this investigation.

RESULTS OF WINTER STORM RUNOFF SAMPLING

Measurements of rainfall and observations of runoff at the two dry wells indicated that under normal conditions, about 0.15 to 0.2 inch of rain was necessary before enough runoff occurred that it reached the dry wells. Lesser amounts of rain tended to be largely absorbed by the asphalt, and subsequently lost to evaporation. Of the nine winter rainfall events, only four resulted in runoff at the two dry wells:

Date	Rainfall (inches)
Dec. 1-2, 1983	0.64
Jan. 5, 1984	0.25
April 6	0.50
April 28	0.45

Grab samples were collected during three of these four events. It normally required from 15 minutes to one hour to fill all of the containers required. This largely depended on the amount of runoff. Samples were collected near the grates covering the dry wells, just before the runoff entered the dry well. During the winter runoff events sampled, all samples were collected at the East Dry Well. During heavy runoff periods, the East Dry Well fills and overflows to the West Dry Well. The West Dry Well thus serves as a backup for the East Dry Well. During low runoff events

(i.e. January 5), no runoff enters the West Dry Well. During one long duration runoff event (April 28), two sets of samples were collected.

Table 4 shows the results of analyses of inorganic chemical constituents in winter storm runoff. The runoff event in January is considered a low one, whereas the two in April are considered moderate, based on the amount of rainfall. Winter storm runoff was of the calcium-sodium bicarbonate type, with total dissolved solids (TDS) contents ranging from about 70 to 130 mg/l. Salinity and contents of nitrate, fluoride, and boron were all low compared to standards for drinking water and irrigation use. Total trace metal contents shown in Table 4 represent a combination of the suspended and dissolved fractions. Total iron contents ranged from about 0.5 to 1.0 mg/l, exceeding the recommended level of 0.3 mg/l for drinking water in all samples analyzed. Total manganese contents ranged from 0.08 to 0.15 mg/l, exceeding the recommended level of 0.05 mg/l for drinking water in all samples analyzed. The only other trace metal that was detected at significant levels was lead, which is commonly found in storm runoff. Total lead contents ranged from 0.06 to 0.23 mg/l, exceeding the maximum contaminant level (MCL) of 0.05 mg/l in all samples analyzed. These values agreed well with the range (0.02 to 0.24 mg/l) in storm runoff sampled at the 15th Avenue storm drain during Winter 1979-80 (Schmidt, 1984). Total organic carbon contents ranged from about 50 to 250 mg/l, and were thus far above background levels in native groundwater in the Salt River Valley (normally less than 5 mg/l).

Table 5 shows the results of analyses of dissolved trace metals

TABLE 4 - INORGANIC CHEMICAL CONSTITUENTS IN WINTER STORM RUNOFF

Constituent (mg/l)	At Entry to East Dry Well			
Calcium	15	10	11	-
Magnesium	2	1	2	-
Sodium	9	8	11	-
Potassium	2	2	2	-
Carbonate	0	0	0	-
Bicarbonate	50	35	43	-
Sulfate	13	11	11	
Chloride	10	7	8	-
Nitrate	1	<1	<1	-
Fluoride	0.4	0.2	0.3	-
Boron	-	-	0.3	-
pH	7.3	6.3	6.9	-
Electrical Conductivity (micromhos/cm @ 25°C)	161	112	150	-
Total Dissolved Solids	137	73	127	-
Iron	1.0	0.48	0.70	0.93
Manganese	0.13	0.08	0.10	0.15
Arsenic	-	-	<0.01	<0.01
Barium	-	-	<0.5	<0.5
Cadmium	<0.005	<0.005	<0.005	<0.005
Chromium	0.02	<0.01	<0.01	<0.01
Copper	0.04	0.01	-	-
Lead	0.12	0.06	0.07	0.23
Mercury	-	-	<0.0002	<0.0002
Nickel	/0.05	<0.05	-	-
Selenium	<0.005	<0.005	<0.005	<0.005
Silver	-	-	<0.01	<0.01
Organic Carbon	250	48	71	180
Ammonia-Nitrogen	-	1.4	1.8	-
Date	1/5/84	4/6/84	4/28/84 3:30 PM	4/28/84 7:30 PM

Values for trace metals and organic carbon are total (dissolved plus suspended).
Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

TABLE 5 - DISSOLVED CONSTITUENTS IN WINTER STORM RUNOFF

Constituent (mg/l)	At East Dry Well		
Iron	0.12	0.14	0.15
Manganese	0.08	0.06	0.12
Arsenic	-	-	<0.01
Barium	-	-	<0.5
Cadmium	<0.005	<0.005	<0.005
Chromium	0.02	0.01	<0.01
Lead	0.01	0.02	0.02
Mercury	-	-	<0.0002
Selenium	<0.005	<0.005	<0.005
Silver	-	-	<0.01
Copper	-	0.01	-
Nickel	-	<0.05	-
Organic Carbon	56	38	153
Date	1/5/84	4/6/84	4/28/84 7:30PM

Samples for trace metals were filtered through a 0.45 micron filter prior to analysis. Samples for dissolved organic carbon were filtered through a silver membrane filter prior to analysis. Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

and organic carbon in winter storm runoff. Dissolved iron contents ranged from 0.12 to 0.15 mg/l, below the drinking water limit. Thus most of the iron in the storm runoff was associated with the suspended fraction. Dissolved manganese contents ranged from 0.06 to 0.12 mg/l, exceeding the recommended level for drinking water. These results indicate that contrary to the situation for iron, most of the manganese in the storm runoff was associated with the dissolved fraction. Dissolved lead contents ranged from 0.01 to 0.02 mg/l, below the MCL. Thus most of the lead in the storm runoff was associated with the suspended fraction. This agrees with findings at the 15th Avenue Storm Drain for Winter 1979-80 monitoring. No other trace metals were found at significant levels in the winter runoff. Dissolved organic carbon contents ranged from about 40 to 150 mg/l. These values indicate that a significant part of the organic carbon in the storm runoff is in the dissolved fraction. Constituents primarily present in the suspended fraction would be expected to remain in the settling chamber of the dry wells, and to not move downward to the underlying groundwater. There appear to be no inorganic constituents in the storm runoff that could adversely impact the quality of the groundwater, except possibly manganese. The low salinity of storm runoff and low levels of most constituents likely signifies that recharge of this water would improve the inorganic chemical quality of the groundwater.

Table 6 lists pesticides that were analyzed in the runoff samples collected on April 6 and 28. Sufficient amounts of water could not be obtained during the January 5 runoff event to allow

TABLE 6 - LIST OF PESTICIDES
ANALYZED BY STONER LABORATORIES

Name	DetectionLimit (ppb)
Aldrin	0.01
BHC isomers (includes lindane)	0.01
Chlordane	0.10
DDE	0.01
DDD (TDE)	0.10
DDT	0.10
Dieldrin	0.01
Endrin	0.04
Endosulfan	0.05
Heptachlor	0.01
Heptachlor expoxide	0.01
Hexachlorobenzene	0.01
Methoxychlor	0.10
PCNB	0.01
Polychlorinted biphnyl mixtures	1.0
Toxaphene	2.0
Parathion	1.0
Diazinon	0.1
2,4-D	0.1
2,4,5-T	0.1
2,4,5-TP	0.1
EDB	0.01
DBCP	0.01
Cis-1,3-dichloropropene	0.5
Trans-1,2-dichloropropane	0.5
Aldicarb	1.0

pesticide analysis. For the sample collected on April 6, the only pesticide found was diazinon, which was analyzed at 29 ppb. Diazinon is a commonly used pesticide in residential and commercial areas, and has been found in storm runoff of other areas, such as Fresno, California (Brown and Caldwell, 1984). Diazinon was detected at 3 ppb in the sample collected on April 28. Malathion was also detected at 1 ppb, or near the detection limit. A trace of the herbicide DCPA (Dacthal) was also found in this sample. These two pesticides were detected during analyses for other pesticides listed in Table 6.

The detection limit for volatile organics (EPA Method 601) was 0.5 ppb, and none were detected in any of the samples of winter storm runoff. Detectable levels of some acid and base/neutral compounds were found in winter storm runoff. Table 7 lists the constituents detected and the levels found. Detection limits for the acid and base/neutral compounds were 10 to 20 ppb for most constituents during the initial sampling round. However, lower detection limits, normally 1 to 5 ppb, were used thereafter. The only acid compound detected was phenol, which was found during one sampling round. The base/neutrals detected can be grouped into two categories: phthalates and polynuclear aromatic hydrocarbons. Phthalates are components of plasticizers and are commonly found in some types of wastewater, such as sewage effluent. Plastic debris was commonly observed in the parking lot tributary to the dry wells and also floating on water standing in the settling chambers of the dry wells. Contents of phthalates found in winter storm runoff were well below levels considered harmful in drinking water.

TABLE 7 - CONTENTS OF TRACE ORGANIC CONSTITUENTS IN EPA PRIORITY POLLUTANT LIST

Constituent (ppb)	1/5/84	4/6/84	4/28/84
Bis (2-ethylhexyl) phthalte	24	290	25
Butyl benzyl phthalate	<10	3.0	<5
Di-n-butyl phthalate	<10	4.6	<5
Di-n-octyl phthalate	<10	5.0	<5
Benzo(a)anthracene	<10	2.2	<1
3,4-benzofluoranthene	<20	2.6	<1
Benzo(k)fluoranthene	<20	2.6	<1
Chrysene	<20	4.4	<1
Pyrene	<10	3.2	<1
Fluoranthene	<10	3.6	<1
Phenol	<10	4.0	<1

Analyses by California Analytical Laboratories, Inc. of Sacramento, California.

Asphalt is a common source of low levels of polynuclear aromatic hydrocarbons. Levels ranging from 2.2 to 4.4 ppb were found in the sample of runoff from April 6, but were below the detection limits in the other two samples. Even these low levels could be of concern for drinking water. However, most of the polynuclear aromatic hydrocarbons are not highly mobile in alluvial groundwater systems.

Overall, the results of sampling and analyses of winter storm runoff indicated that only a few constituents were possible groundwater pollutants. These included lead, iron, manganese, diazinon, and some polynuclear aromatic hydrocarbons. Of these, diazinon is probably the only real concern.

RESULTS OF SUMMER STORM RUNOFF SAMPLING

Of the twenty-one rainfall events during June 25-September 26 (Table 3), twelve were large enough to produce runoff at the two dry wells. Samples of summer runoff were much more difficult to collect than for winter runoff, because of the high intensity and short duration of the summer storms. Driving conditions during some of the storms were difficult. In addition, intense rainfall made sampling activities at the site difficult. Water samples were collected during five of the summer events. Runoff was sampled for the following events:

Date	Rainfall (inches)
July 26, 1984	0.17
August 23	0.22
September 1	1.31
September 10	1.57
September 26	0.50

The first two runoff events resulted from relatively low rainfall events, barely sufficient to produce runoff. The events on September 1 and 10 were the largest rainfall events during the entire storm runoff program. The last event for which a sample was collected was from a moderate rainfall event for summer storms that produce runoff. Thus the summer runoff events that were sampled represent a variety of conditions.

In addition to samples of storm runoff, a sample was collected of tailwater from local landscape irrigation. Some of this tailwater was observed running directly into the West Dry Well during a site visit on August 9. An estimated 50 gpm of this tailwater was observed entering the West Dry Well for a period of about five minutes, during which the bermed area west of the dry wells was being irrigated. The design of the landscaping and irrigation system apparently either does not preclude tailwater from draining to the dry well, or the system was malfunctioning. This practice has the potential to introduce pollutants from pesticides or fertilizers into the dry well.

Table 8 shows the results of analyses of inorganic chemical constituents in summer storm runoff. Storm runoff for the July and August samples was of the sodium bicarbonate-chloride type and TDS contents ranged from 100 to about 300 mg/l. These samples are representative of low runoff events, early in the summer. Storm runoff on September 1 was of the sodium bicarbonate type, with a TDS of 200 mg/l. The two samples of storm runoff collected later in September were generally of the calcium-sodium bicarbonate type,

TABLE 8 - INORGANIC CHEMICAL CONSTITUENTS IN SUMMER URBAN STORM RUNOFF

Constituent (mg/l)	At East Dry Well	At West Dry Well	At East Dry Well	At East Dry Well	At East Dry Well	At West Dry Well*
Calcium	9	4	24	14	4	47
Magnesium	2	1	7	4	<1	16
Sodium	21	3	75	40	2	81
Potassium	3	1	8	5	1	7
Carbonate	0	0	0	0	0	0
Bicarbonate	28	15	113	73	5	156
Sulfate	18	5	60	30	<5	75
Chloride	25	<2	77	28	<2	118
Nitrate	<1	1	1	<1	1	2
Fluoride	0.5	0.1	0.3	0.2	0.1	0.6
Boron	0.2	0.1	0.6	0.3	-	0.2
pH	5.9	6.8	6.4	7.0	5.8	7.0
Electrical Conductivity (micromhos/cm @ 25°C)	197	48	550	260	36	790
Total Dissolved Solids	100	27	308	200	20	467
Iron	0.17	0.41	1.0	5.2	0.42	0.07
Manganese	0.10	0.04	0.33	0.50	0.04	0.02
Arsenic	<0.01	<0.01	0.01	0.02	<0.01	<0.01
Barium	<0.5	<0.5	<0.5	<0.5	<0.5	-
Cadmium	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
Chromium	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
Lead	0.03	<0.01	0.09	0.25	0.03	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	-
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005	-
Silver	<0.01	<0.01	<0.01	<0.01	<0.01	-
Total Organic Carbon	103	11	110	130	22	-
Date	7/26/84	9/26/84	8/23/84	9/1/84	9/10/84	8/9/84

*This sample is irrigation runoff from nearby bermed area. Chemical analyses by BC Laboratories, Inc. of Bakersfield, California. Values for trace metals are total (dissolved plus suspended).

with TDS contents of 20 to about 30 mg/l. These two samples represent conditions of moderate to high runoff, and also were collected following periods of substantial storm runoff during previous weeks. Thus contents of most inorganic chemical constituents were present at much lower levels.

Contents of nitrate, fluoride, and boron were low in all samples of summer storm runoff. Total iron contents ranged from 0.17 to 5.2 mg/l, and exceeded the recommended drinking water limit of 0.3 mg/l in four of the five samples. Total manganese contents ranged from 0.04 to 0.50 mg/l, and exceeded the recommended drinking water limit of 0.05 mg/l in three of the five samples. Total lead contents ranged from less than 0.01 to 0.25 mg/l, and exceeded the MCL of 0.05 mg/l in two of the five samples. Contents of other trace metals that were analyzed were generally below the detection limits. Total organic carbon content ranged from about 100 to 130 mg/l in runoff from the first three events sampled, and ranged from about 10 to 20 mg/l for the last two events sampled. Tailwater from nearby landscape irrigation was similar in composition to City of Phoenix water, which is the source of water used for irrigation. This tailwater was of the sodium bicarbonate-chloride type, with a TDS content of about 470 mg/l. Contents of nitrate, fluoride, boron, and the trace metals that were analyzed were low.

Table 9 shows contents of dissolved trace metals in summer storm runoff. Dissolved iron contents ranged from 0.04 to 0.70 mg/l, and exceeded the recommended level of 0.3 mg/l in two of the five samples. Most of the iron in the storm runoff was thus in the

TABLE 9 - DISSOLVED TRACE METALS IN SUMMER STORM RUNOFF

Constituent (mg/l)	At East Dry Well	At East Dry Well	At East Dry Well	At East Dry Well	At West Dry Well
Iron	0.10	0.42	0.70	0.04	0.05
Manganese	0.10	0.25	0.21	0.02	0.01
Arsenic	<0.10	<0.01	<0.01	-	<0.01
Barium	<0.5	<0.5	<0.5	-	<0.5
Cadmium	<0.005	<0.005	<0.005	0.011	<0.005
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	<0.01	0.04	0.03	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	-	<0.0002
Selenium	<0.005	<0.005	<0.005	-	<0.005
Silver	<0.01	<0.01	<0.01	-	<0.01
Date	7/26/84	8/23/84	9/1/84	9/10/84	9/26/84

These samples were filtered through a 0.45 micron filter prior to chemical analyses.
Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

suspended fraction. Dissolved manganese contents ranged from 0.01 to 0.25 mg/l, and exceeded the recommended level 0.05 mg/l in three of the five samples. These results indicate that a significant part of the manganese was in the dissolved fraction. Dissolved lead contents ranged from less than 0.01 mg/l to 0.04 mg/l, below the MCL of 0.05 mg/l. Dissolved lead contents were below detection limits in three of the five samples. Thus much of the lead in the storm runoff was present in the suspended fraction. Contents of the other trace metals that were analyzed were generally below detection limits.

The inorganic chemical composition of summer storm runoff was thus similar to that previously discussed for winter runoff. However, the higher precipitation, particularly in the late summer, resulted in a more dilute runoff compared to in the winter.

The same group of pesticides were analyzed as shown in Table 6. No pesticides were detected in storm runoff for the July 26 or August 23, 1984 events, or for the August 9, 1984 sampling of irrigation tailwater. However diazinon was detected in all of samples of storm runoff from the last three events:

Date	Diazinon Content (ppb)
9/1/84	1.0
9/10/84	2.0
9/26/84	0.7

Dacthal was detected at 0.02 ppb in the sample collected on September 26, 1984. These findings are thus comparable to those for winter storm runoff that were described previously.

Three volatile organic chemical constituents were detected in

the sample of irrigation tailwater:

Constituent	Content (ppb)
Chloroform	18
Bromodichloromethane	6.2
Dibromochloromethane	1.7

These constituents were likely present in the water used to irrigate the landscaping, because this water source is chlorinated.

No volatile organic or acid compounds were detected in any of the five samples of summer storm runoff. The only base-neutral compound detected was bis (2-ethyl hexyl) phthalate. This constituent was detected at a level of 18 ppb in the sample collected on September 10, 1984. Thus no polynuclear hydrocarbons were detected during the summer sampling of storm runoff. The lower levels of trace organic constituents in summer runoff, compared to those for winter runoff, are likely due to the much higher rainfall and runoff that occurred during the summer, and the resulting flushing and dilution effects.

The only chemical constituents in summer urban storm that could potentially adversely impact groundwater are iron, manganese, lead, diazinon, and bis (2-ethyl) phthalate. Of these, only manganese and diazinon appear to be a concern. This is because contents of iron and lead are mostly in the suspended fraction, which is largely retained in the dry wells. The level found for bis (2-ethyl hexyl) phthalate is far below the level of concern for drinking water.

MONITOR WELL DRILLING AND TESTING

Drillers logs provided by McGuckin Drilling, Inc. for the East and West Dry Wells indicate that clay was the predominant material encountered above a depth of 77 feet. Deposits from land surface to 29 feet in depth were primarily clay. Intermixed cobbles and clay were present from 29 to 32 feet in depth. Clay was also predominant from 32 to 44 feet in depth. Cobbles intermixed with clay and sand were present from 44 to about 49 feet in depth. Clay was predominant from 49 to 63 feet, and cobbles intermixed with clay from 63 to 77 feet in depth. The major permeable strata penetrated by the dry wells were between 77 and 83 feet in depth. Groundwater was reported at a depth of 63 feet in May 1979, thus the dry wells were drilled to a depth below the water table. However, the holes were reportedly backfilled with native materials to a depth of 50 feet, prior to completion of the dry wells.

Depth to water measurements were collected for nearby wells in order to determine water level depth and the direction of groundwater flow in the regional aquifer in recent years.

Depth to water measurements were obtained from the Groundwater Planning Division of the Salt River Project (SRP) for eight relatively shallow wells, within two miles of the site. Depths of these wells ranged from about 230 to 400 feet, and most were perforated up to at least 50 feet in depth. These wells thus tap the Upper Alluvial Unit of the U.S. Bureau of Reclamation (1977). Depth to water in these wells ranged from 26 to 80 feet in January 1983. Water-level elevations for January 1983 were contoured, and

indicated that the direction of groundwater flow was to the southwest beneath the site. This agrees with the direction of flow determined from most previous water-level maps for the area, including those by the U.S. Bureau of Reclamation (1977) and Smith, et al. (1982). Depth to water in SRP well 16E-8N, which is located one-half mile west of the site, was 63 feet in January 1983. Depth to water in SRP well 17E-8N, which is one-half mile east of the site, was 45 feet in January 1983. These measurements indicated that depth to water in the regional aquifer beneath the site could be expected to be between 50 and 60 feet. In addition, the shallow groundwater tapped by the dry wells at the site was part of the regional aquifer, as opposed to perched groundwater. Lastly, the southwest direction of flow was used to determine locations of upgradient and downgradient monitor wells near the dry wells.

The locations of four monitor wells to be installed were selected. Three were located in close proximity to the two dry wells. Because the regional direction of groundwater flow is to the southwest, one well was sited about 20 feet southwest of the West Dry Well, in a position to be downgradient of both dry wells. Another was sited about 20 feet south of the East Dry Well. A third was sited about 20 feet northwest of the West Dry Well. These three wells were sited as close to the dry wells as was feasibly possible. With this configuration, even if the local direction of groundwater flow was to the northwest, west, south, or southeast, at least one monitor well would be downgradient of at least one dry well. The fourth monitor well was placed about 200 feet north of the dry wells, to serve as an upgradient monitor

well.

Specifications were then prepared for the four monitor wells. Because of the possible presence of boulders or cobbles beneath the site and the shallow depth, the cable-tool method was selected. Because the shallowest significant water-producing strata were apparently about 80 feet deep, a well depth of 100 to 120 feet was selected. Bert Perry Drilling of Mesa was the successful low bidder and was awarded the drilling contract. The wells were completed during December 1983 and January 1984. All wells were equipped with a 20-foot, 10-inch diameter conductor casing, which was cemented on the outside to form the surface seal. A hole was drilled to a depth of 110 feet at each site. Eight-inch diameter, unperforated steel casing was driven to a depth of 100 feet in each well. After drilling was completed, the wells were developed by bailing. Drill cuttings were logged by a geologist, and subsurface geologic materials were similar to those reported by McGuckin Drilling, Inc for the dry wells. However, most of the larger-sized material was observed to be gravel and pebbles, as opposed to cobbles. During drilling, care was taken to keep drill cuttings and water from entering the dry wells.

Figure 2 shows the locations of the four monitor wells. Depth to water was about 50 feet in each well after the completion of development. After the wells were completed, a two-horsepower submersible pump, capable of producing 30 gpm, was installed in each well. A 3/4-inch PVC access tube was also installed in each well to allow water-level measurements by electric sounder. A concrete pump base was poured and a locking metal cover installed

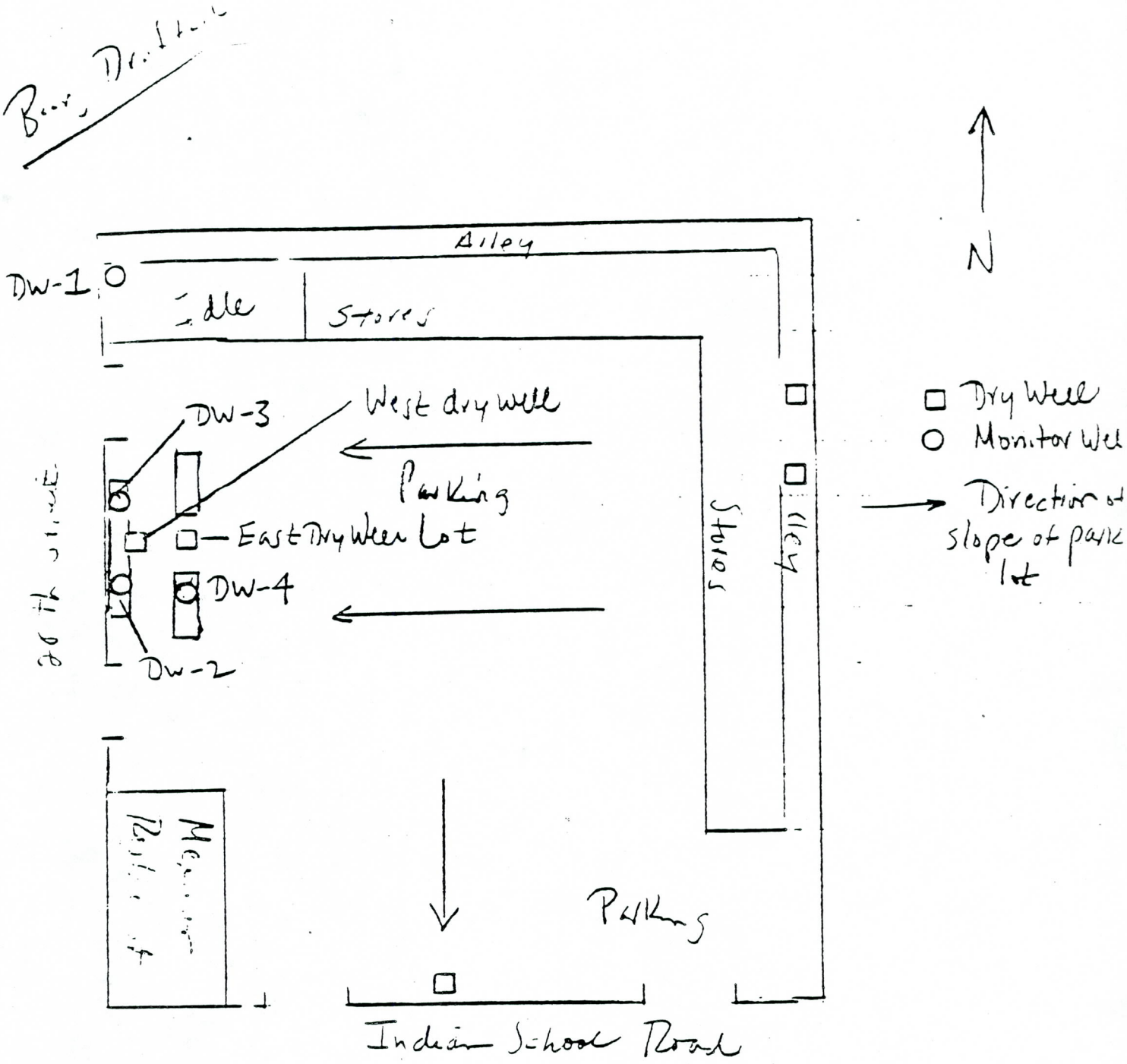

FIGURE 2 - LOCATION OF DRY WELLS AND MONITOR WELLS

to control access to the well and prevent vandalism. Electrical connections were provided to allow running the pumps with a portable generator.

During February 2-6, 1984, each monitor well was pumped continuously for a period of four hours. Table 10 shows static levels, pumping levels, drawdown, and specific capacities for the monitor wells. Specific capacities ranged from 2.4 to 3.3 gpm per foot. Based on these values aquifer transmissivity is estimated to be about 5,000 gpd per foot. The electrical conductivity, water temperature, and pH of the discharged water were measured frequently during the pumping period, and water samples were collected for laboratory analyses at the end of the pumping period. Measurements of pumping level and water temperature, pH, and electrical conductivity indicated that a two-hour pumping period would suffice for future sampling rounds. Pumped water was conveyed to the street gutter to precluded this water from running into the dry wells.

RESULTS OF MONITOR WELL SAMPLING

Water samples from the monitor wells were generally collected, preserved, shipped, and analyzed following similar procedures to those previously described for the storm runoff. However, because only water free of suspended material was collected from the monitor wells, no filtering was performed prior to analyses for trace metals or organic carbon. Values for these constituents should thus be considered as total (suspended plus dissolved).

TABLE 10 - SUMMARY OF PUMP TESTS FOR MONITOR WELLS

Well	Date	Discharge (gpm)	Static Level (feet)	Pumping Level (feet)	Drawdown (feet)	Specific Capacity (gpm/ft)
DW-1	2/6/84	30	50.6	62.4	11.8	2.5
DW-2	2/2/84	30	50.9	63.4	12.5	2.4
DW-3	2/2/84	30	50.4	60.5	10.1	3.0
DW-4	2/6/84	30	48.7	57.9	9.2	3.3

Pumping was continuous for four hours in each case.

Water samples were collected from the monitor wells during five sampling rounds.

Depth to water declined from an average of about 50.2 feet in early February to 54.9 feet in late July 1984. This was primarily due to pumping of nearby SRP wells. Pumping of these wells stopped in late August, and by mid September, water levels had already risen about 0.6 feet from the late July measurements. Thus the main control on depth to water in the vicinity is the pumping of large capacity SRP wells.

Tables 11, 12, 13, and 14 show the results of analysis of inorganic chemical constituents in water from the four monitor wells. DW-1 is the upgradient monitor well. Water from DW-1 was of uniform inorganic chemical composition throughout the period February-September 1984. The water was of the sodium bicarbonate-chloride type, with TDS content ranging from about 1,350 to 1,390 mg/l. Chloride contents ranged from about 320 to 390 mg/l and nitrate contents ranged from 20 to 22 mg/l. These chloride contents exceeded the recommended level for drinking water of 250 mg/l. Boron contents were high, ranging from 2.4 to 2.8 mg/l, and exceeded levels established for irrigation of most crops. Fluoride contents were very high, ranging from 6.1 to 8.6 mg/l, greatly exceeding the MCL of 1.4 mg/l. Iron contents ranged from 0.20 to 0.53 mg/l, and appeared to increase during the monitoring program. Iron contents exceeded the recommended level of 0.3 mg/l for drinking water in samples collected after March 1984. Arsenic contents ranged from 0.08 to 0.10 mg/l, exceeding the MCL of 0.05

TABLE 11 - INORGANIC CHEMICAL CONSTITUENTS IN WATER FROM DW-1

Constituent (mg/l)	2/6/84	3/13/84	6/6/84	7/26/84	9/11/84
Calcium	6	7	6	6	5
Magnesium	8	9	10	8	7
Sodium	500	480	500	505	480
Potassium	2	2	1	2	1
Carbonate	0	0	0	0	0
Bicarbonate	608	605	575	617	580
Sulfate	115	125	115	120	115
Chloride	337	336	389	333	321
Nitrate	22	21	20	21	22
Boron	2.8	2.5	2.6	2.4	-
Fluoride	7.6	8.6	7.6	6.1	8.4
pH	8.1	8.1	8.0	6.0	8.1
Electrical Conductivity (micromhos/cm @ 25°C)	2,500	2,400	2,500	2,300	2,400
Total Dissolved Solids	1,350	1,363	1,390	1,367	1,347
Iron	0.20	0.23	0.42	0.53	0.47
Manganese	0.01	0.01	0.01	0.02	<0.01
Arsenic	0.08	0.08	0.09	0.10	0.08
Barium	<0.5	<0.5	-	<0.5	<0.5
Cadmium	<0.005	0.01	-	<0.005	<0.005
Chromium	0.01	<0.01	-	<0.01	<0.01
Lead	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	<0.0002	0.0003	<0.0002	<0.0002	<0.0002
Selenium	<0.005	<0.005	-	<0.005	<0.005
Silver	<0.01	<0.01	-	<0.01	<0.01
Total Organic Carbon	8.0	2.2	9.1	1.3	10.6
Ammonia Nitrogen	0.2	0.2	-	-	-
Static Level (feet)	50.6	51.6	54.5	55.8	55.5

Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

TABLE 12 - INORGANIC CHEMICAL CONSTITUENTS IN WATER FROM DW-2

Constituent (mg/l)	2/2/84	3/13/84	6/6/84	7/26/84	9/11/84
Calcium	6	8	8	8	8
Magnesium	9	10	13	12	14
Sodium	365	340	330	345	300
Potassium	2	1	1	2	1
Carbonate	0	0	0	0	0
Bicarbonate	497	483	420	480	473
Sulfate	102	95	100	95	80
Chloride	206	207	223	219	159
Nitrate	13	15	14	12	9
Boron	2.2	2.0	1.9	1.9	-
Fluoride	7.4	7.6	7.2	5.6	6.8
pH	8.1	8.1	8.1	6.0	8.1
Electrical Conductivity (micromhos/cm @ 25°C)	1,630	1,690	1,700	1,680	1,450
Total Dissolved Solids	1,066	1,063	973	1,103	953
Iron	0.34	0.25	0.32	0.51	0.11
Manganese	<0.01	0.01	<0.01	0.02	<0.01
Arsenic	0.07	0.05	0.07	0.06	0.05
Barium	<0.5	<0.5	-	<0.5	-
Cadmium	<0.005	0.008	-	<0.005	<0.005
Chromium	0.01	<0.01	-	<0.01	0.01
Lead	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	-
Selenium	<0.005	<0.005	-	<0.005	<0.005
Silver	<0.01	<0.01	-	<0.01	<0.01
Total Organic Carbon	9.3	2.2	2.5	7.1	40.0
Ammonia Nitrogen	0.4	<0.2	-	-	-
Static Level (feet)	50.9	50.4	53.7	55.4	54.4

Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

TABLE 13 - INORGANIC CHEMICAL CONSTITUENTS IN WATER FROM DW-3

Constituent (mg/l)	2/2/84	3/13/84	6/6/84	7/26/84	9/11/84
Calcium	7	7	6	7	6
Magnesium	8	8	8	9	10
Sodium	445	415	400	428	405
Potassium	2	13	1	2	1
Carbonate	0	0	0	0	0
Bicarbonate	553	553	463	546	528
Sulfate	130	115	115	112	104
Chloride	264	255	280	272	253
Nitrate	20	20	19	19	18
Boron	2.4	2.5	2.4	2.2	-
Fluoride	12.5	12.0	11.0	9.0	10.0
pH	8.1	8.0	8.0	8.0	8.1
Electrical Conductivity (micromhos/cm @ 25°C)	2,000	2,100	2,100	2,000	1,970
Total Dissolved Solids	1,243	1,210	1,180	1,227	1,290
Iron	0.09	0.14	0.15	0.19	0.14
Manganese	<0.01	0.01	<0.01	<0.01	<0.01
Arsenic	0.06	0.05	0.05	0.05	0.05
Barium	<0.5	<0.5	-	<0.5	<0.5
Cadmium	<0.005	0.010	-	<0.005	<0.005
Chromium	0.02	<0.01	-	<0.01	0.01
Lead	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Selenium	<0.005	<0.005	-	<0.005	<0.005
Silver	<0.01	0.01	-	<0.01	<0.01
Total Organic Carbon	7.7	2.5	0.5	6.9	7.0
Ammonia Nitrogen	0.5	<0.2	-	-	-
Static Level (feet)	50.4	50.3	53.6	55.2	54.4

Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

TABLE 14 - INORGANIC CHEMICAL CONSTITUENTS IN WATER FROM DW-4

Constituent (mg/l)	2/6/84	3/13/84	6/6/84	7/26/84	9/11/84
Calcium	8	8	8	8	7
Magnesium	9	8	9	9	9
Sodium	460	440	470	480	450
Potassium	2	1	1	2	1
Carbonate	0	0	0	0	0
Bicarbonate	565	561	580	592	577
Sulfate	135	130	130	140	122
Chloride	285	277	302	298	265
Nitrate	20	20	21	20	19
Boron	2.5	2.8	2.6	2.8	-
Fluoride	11.5	11.0	11.0	7.0	10.0
pH	8.0	8.0	8.0	7.9	8.0
Electrical Conductivity (micromhos/cm @ 25°C)	2,100	2,200	2,200	2,200	2,100
Total Dissolved Solids	1,250	1,383	1,277	1,317	1,303
Iron	0.27	0.13	0.10	0.14	<0.05
Manganese	<0.01	<0.01	<0.01	0.01	<0.01
Arsenic	0.05	0.06	0.05	0.04	0.04
Barium	<0.5	<0.5	-	<0.5	-
Cadmium	<0.005	0.010	-	<0.005	0.008
Chromium	0.01	<0.01	-	<0.01	0.02
Lead	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	-
Selenium	<0.005	<0.005	-	<0.005	<0.005
Silver	<0.01	<0.01	-	<0.01	<0.01
Total Organic Carbon	9.3	2.5	<0.5	1.1	18.0
Ammonia Nitrogen	0.3	<0.2	-	-	-
Static Level (feet)	48.7	48.7	52.0	53.5	52.7

Chemical analyses by BC Laboratories, Inc. of Bakersfield, California.

mg/l. Contents of other trace metals analyzed were not significant. Total organic carbon contents ranged from 1.3 to 10.6 mg/l, and there was substantial variation in contents between sampling rounds.

The sources of most recharge in the Salt River Valley are canal seepage or deep percolation of irrigation return flow. The Los Olivos Park, comprising about 15 to 20 acres of land, is immediately upgradient of the site and is irrigated with Salt River Project water. In addition, as of the 1950's, the lands presently comprising the shopping center were citrus orchards, which had been irrigated for many decades. The chemical composition of the shallow groundwater at DW-1 indicates that it was derived primarily from deep percolation of irrigation return flow. The TDS content of the groundwater (1,350 to 1,390 mg/l), compared to that for average canal water in the area (TDS of about 400 mg/l), indicates a concentration of about 3.3 times due to evapotranspiration losses. An irrigation efficiency of about 70 percent, common in the Salt River Valley, could explain this concentration. This phenomenon is similar to that observed in the Gilbert area during the MAG 208 program monitoring project (Schmidt, 1983).

Water from DW-3 and DW-4 was generally of a similar inorganic chemical composition to that of water from DW-1, although salinity, sodium, chloride, iron, and arsenic contents were slightly lower, and fluoride contents slightly greater, in water from DW-3 and DW-4. TDS in water from DW-3 ranged from 1,180 to 1,290 mg/l and from DW-4 ranged from about 1,250 to 1,380 mg/l. Total organic carbon contents in water from DW-3 and DW-4 also showed substantial

variation between sampling rounds.

Water from DW-2 had distinctly lower contents of many inorganic chemicals constituents compared to water from the other three monitor wells. The water was also of the sodium bicarbonate-chloride type, and TDS content ranged from about 950 to 1,100 mg/l. Chloride contents ranged from about 160 to 220 mg/l, and fluoride contents ranged from 5.6 to 7.6 mg/l, exceeding the MCL of 1.4 mg/l. Iron contents ranged from 0.11 to 0.51 mg/l, and exceeded the recommended level of 0.3 mg/l in three of the five samples. The main difference in inorganic chemical composition of water from DW-2 compared to that from other monitor wells is that water from DW-2 is more dilute than the other waters.

There are two possible sources of water that could cause this dilution. The first is tailwater from landscape irrigation, which was observed entering the West Dry Well on one occasion. A trilinear diagram was prepared to compare chemical types of water for storm runoff, shallow groundwater, and irrigation tailwater. This diagram indicated that water from DW-2, particularly near the end of the summer rainfall season, was a mixture of native groundwater (sampled at DW-1) and storm runoff, particularly from the summer events. Water from DW-2 was more different in chemical composition compared to irrigation tailwater, than was water from the other monitor wells.

TDS, chloride, sulfate, sodium, fluoride, boron, and nitrate contents in what is considered average runoff were compared to contents in water from DW-1 and DW-2. Next it was assumed that water from DW-2 is a mixture of background groundwater (as sampled

from DW-1) and storm runoff. Mixing volume calculations utilizing this assumption indicated that approximately 30 percent of the water from DW-2 was from urban storm runoff. Comparing average storm runoff and water from DW-1 and DW-3, it appears that water from DW-3 was about 10 percent storm runoff and 90 percent native groundwater. Water from DW-4 appears to be almost entirely native groundwater, and no influence of storm runoff is apparent. The reason that DW-2 showed the most effect, compared to DW-3 and DW-4, was that DW-2 was directly downgradient of the two dry wells.

The only pesticide detected in water from any of the monitor wells was 2,4-D, which was found at trace levels in water from DW-2 during the September 11, 1984 sampling. The detection limit for 2,4-D was 1.0 ppb. This value appears to be atypical, based on the results from other sampling rounds. Since this constituent was not found in the storm runoff, it may have originated from other sources. Tetrachloroethylene (PCE) was found in water from DW-1 (the upgradient monitor well) at levels ranging from 0.6 to 0.7 ppb on June 6, July 26, and September 11, 1984. PCE was also detected in water from DW-4 on July 26, 1984, at a level of 0.6 ppb. These levels are only slightly above the detection limit of 0.05 ppb. Since no PCE was detected in the storm runoff, the source may be elsewhere. Significant contents of PCE (exceeding 50 ppb) have been found in water from two SRP wells in the vicinity, one of which is 17E-18N, which is located only one-half mile east of the site. The source of the PCE is presently unknown. A diethyl phthalate content of 60 ppb was found in water from DW-4 for the March 13, 1984 sampling, but this value also appears to be

atypical, based on sampling during the other rounds.

Overall, there is no indication that storm runoff has degraded groundwater quality at the site. High contents of fluoride, boron, and arsenic in the shallow groundwater are due to other factors. Storm runoff has improved the quality of local groundwater because of dilution. Although lead, manganese, the pesticide diazinon, and some polynuclear aromatic hydrocarbons were found at significant levels in some samples of storm runoff, there has been no adverse impact on groundwater. This is probably because most of these constituents are not mobile in the vadose zone or aquifer. In addition, the relatively small amount of recharge originating from urban storm runoff is substantially diluted by recharge from other sources.

CONCLUSIONS

Storm runoff entering dry wells and shallow groundwater were monitored at a commercial area in central Phoenix. Storm runoff was sampled during three storms in Winter 1983-84 and during five storms in Summer 1984. Four monitor wells were installed near two dry wells in order to monitor shallow groundwater during February-September 1984.

The amount of precipitation during Winter 1983-84 was only about two-thirds of the long-term normal for the winter. However, the amount of precipitation during Summer 1984 was about three times the long-term normal for the summer. Results of monitoring both winter and summer storm runoff indicated that only a few

chemical constituents were potential groundwater pollutants. Significant contents of lead, iron, and manganese were present in the storm runoff. However, lead and iron contents were primarily associated with the suspended fraction, and would be expected to largely be retained in the settling chambers of the dry wells. In addition, lead is not normally highly mobile in alluvial aquifers, particularly where significant contents of bicarbonate and sulfate are present. Manganese in the runoff could be oxidized and removed from solution above or near the water table. Potential pollutants reaching the groundwater would likely be highly diluted by other water, because the amount of storm runoff disposed to dry wells is small compared to other sources of recharge.

Trace organic chemical constituents in the runoff that were found included two pesticides, diazinon and Dacthal. Diazinon was frequently detected in the storm runoff, although contents were normally less than 3 ppb. Diazinon is a commonly used pesticide in residential and commercial areas, and has been detected in urban storm runoff in other areas. The mobility of this pesticide in alluvial aquifers is not well known. Contents of Dacthal were near the detection limit in two of the storm runoff events that were sampled, and this pesticide was not found in samples collected during other events.

Two types of base-neutral compounds in the EPA priority pollutant list were found in some samples of storm runoff. These included four forms of phthalates, which are common components of plasticizers. Phthalates are common constituents of wastewaters, such as sewage effluent. The levels found in storm runoff during

the program (normally less than 25 ppb) are well below levels considered harmful in drinking water. Low contents (less than 5 ppb) of six polynuclear hydrocarbons were found in runoff from one storm in the winter. These constituents likely originated from asphalt in the parking lot tributary to the dry wells. Sampling during other runoff events indicated that these results were unusual, as polynuclear aromatic hydrocarbons were not detected.

The water level in the regional aquifer beneath the site was only about 50 to 55 feet deep during this program. The base of the two dry wells (depth to which gravel or pebbles were placed) is 50 feet in depth. Thus there is a minimal vertical separation between where some of the storm runoff can be injected and the water table. High contents of fluoride, boron, arsenic, chloride, and some other constituents are present in shallow groundwater in the vicinity. Irrigation practices and natural factors appear to be the major influence on the chemical quality of shallow groundwater upgradient of the dry wells. Shallow groundwater in a monitor well downgradient of the dry wells was noticeably affected by storm runoff. However, the major influence was not adverse, as levels of many inorganic chemical constituents in the groundwater were reduced due to recharge of urban storm runoff. None of the potential pollutants in storm runoff were found in shallow groundwater near the dry wells. Chemical precipitation, oxidation, adsorption, biodegradation, and dilution are probably the main factors in mitigating any potential adverse impacts of storm runoff disposal at the site.

Total depths of more than 2,500 dry wells in the Phoenix urban

area were compared to depth to water measurements for shallow wells. Depth to water measurements for Winter 1982-83 are believed to represent relatively shallow conditions, based on long-term records. Of these dry wells, only three percent were located in areas with as small a vertical separation between the bottom of the dry well and the water table as was present at the monitored site. The total drilled depths of almost one-half of the dry wells in the Phoenix urban area for which records were readily available were more than 100 feet above the water table. The drilled depths of more that 85 percent of these wells were more than 25 feet above the water table. Results of this monitoring program thus indicate that overall, the use of dry wells for disposal of storm runoff from commercial areas does not pose a substantial threat to the quality of groundwater in the Phoenix urban area.

RECOMMENDATIONS

There are several areas where improvements could be made in dry well construction, operation, and maintenance and in shopping center design and operation. These primarily involve record keeping for dry well construction, techniques used when groundwater is encountered, removal of accumulated solids in the dry wells, and design of systems for landscape irrigation.

In terms of record keeping, all firms involved in dry well drilling in the Phoenix urban area apparently do not maintain the type of records needed, such as good maps, drillers logs for the

geologic materials encountered, notes on where water was encountered, and details of the dry well construction. A program should be established by some agency to establish standardized forms and reporting requirements, similar in some respects to those used for water wells.

Dry well drillers and engineers involved with development of commercial areas have sometimes been unaware of the depth to water in the regional aquifer at specific sites, and the location of areas underlain by perched groundwater. Thus dry wells have been drilled into the regional aquifer and through perched zones, in some cases. Information on depth to water in the valley, such as that shown in Figure 1, should be made available to both dry well drillers and engineers involved in development of commercial areas. When water is encountered in a dry well, the Arizona Department of Water Resources (DWR) should be notified and provisions made so that the portion of the hole below the water table can be properly abandoned. The present procedures are not adequate in this regard. In addition, because of bacteriologic concerns, it is advisable to have at least 10 feet of separation between the bottom of a completed dry well and the water table. The primary location where there appears to be inadequate separation at present appears to be in central Phoenix and near Tempe, where water within 50 feet of the land surface is present in the regional aquifer. When perched water is encountered, provisions should be made so that water cannot drain down the well to lower levels.

Presently, solid materials accumulating in the settling chambers of dry wells are normally removed periodically. This

material is treated as if it were normal soil. Studies in other areas, such as Fresno, California (Brown and Caldwell, 1984), indicate that substantial levels of trace metals and other chemical constituents accumulate with the suspended material from the storm runoff. Some of this material may be classified as a hazardous waste, depending on constituent levels. Thus solid material should be analyzed prior to disposal, and then disposed in an appropriate manner. Analyses for trace metals and selected pesticides is advisable.

Lastly, care should be taken in the design and operation of landscape irrigation systems. Runoff from irrigation of high berms above dry wells should be precluded from directly entering dry wells. In large part, runoff from these areas could be controlled by installation of more efficient irrigation systems and by limiting the use of steep berms that slope toward nearby dry wells.

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