# Geology and hydrology of the Payson – Strawberry – Diamond Rim area, Gila and Coconino Counties, central Arizona

by

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# GEOLOGY AND HYDROGEOLOGY

## PREVIOUS INVESTIGATIONS

The study area, which Feth and Hem (1963) refer to as the Payson Basin, has been the focus of attention for both the United States Geological Survey (USGS) and the State of Arizona, Bureau of Geology and Mineral Technology. Titley (1962) describes this area to be transitional between the Basin and Range Province to the south and the Colorado Plateau to the north relative to topography, elevation, climate, and geology. The topography of the area is dominated by the scarp forms of the Diamond and Mogollon Rims. Peirce and Nations (1986) studied the Buckhead Mesa gravels at the base of the Diamond Rim fault along the classic Tonto segment with the purpose of explaining the developmental history of the Mogollon escarpment. Owen-Joyce and Bell (1983) provided an appraisal of the water resources of the upper Verde River Basin north of the Buckhead Mesa site. Except for the reconnaissance study of springs in the Gila River Basin by Feth and Hem (1963), and the hydrogeologic investigation in the Pine-Strawberry area by Hix (1977) for E&R Water Company, no detailed regional hydrogeologic investigations have been undertaken in the Payson-Pine area.

## REGIONAL GEOLOGY

Reconnaissance geologic mapping in the Payson-Pine area has been undertaken by Wilson et al. (1959), Peirce (1959), and Feth and Hem (1963). Figure 6 summarizes the geologic mapping from the Mogollon Rim to the East Verde River.

A generalized distribution of rock assemblages is as follows: Paleozoic sedimentary rocks crop out at the surface to the north and Precambrian rocks crop out in the south and west parts of the study area. These rocks are separated by the Diamond Rim fault zone located immediately north of the Buckhead Mesa site and along which considerable displacement and movement has occurred. The occurrence of this fault zone has given rise to several hypotheses on the origin of Mogollon Rim (Titley, 1962). The Buckhead Mesa site is located on the western edge of and immediately beneath the Diamond Rim Fault. The basin is structurally a graben (Titley, 1962; and Feth and Hem, 1963).

A generalized stratigraphic sequence of rocks from the oldest to the most recent deposits consists of the following: Precambrian rocks; Cambrian Tepeats Sandstone; Devonian, Mississippian, and Pennsylvanian rocks; Permian rocks; and Tertiary sediments and basalt.

The schematic cross-section along the Tonto Segment, shown in Figure 7, is taken from Peirce et al. (1979) and shows a complete geologic sequence from Buckhead Mesa to Baker Butte located near the top of the Mogollon Rim. Well logs, showing the subsurface geology in the area surrounding the Buckhead Mesa site, are displayed schematically in Figure 8. The nearest well is located about two miles west of the Buckhead Mesa site.

Except for a few shallow holes drilled by the Arizona Department of Transportation (ADOT), there are no subsurface geologic data for the Buckhead Mesa site.

The following discussion summarizes the stratigraphic sequence of rocks including the oldest Precambrian rocks and the most recent deposits.

## Precambrian Rocks

Precambrian rocks form the basement of the region over which the younger Paleozoic rocks were deposited. Granite and greenstone crop out in the south part of the study area. Rhyolite and Mazatzal Quartzite crop out in the west part of the study area south of Pine. Along the Diamond Rim Fault, the granite has been altered (chloritized) to a dark green sheared rock. The granite has been weathered to form a mixture of sand and pea-sized pebbles of feldspar and quartz. Gila County uses these rocks as construction material and is actively mining the pit immediately above the proposed landfill. These rocks are easily eroded, cover the banks, and fill the channels of many of the washes in the area (Titley, 1962).

Red Rock metarhyolite and Mazatzal Quartzite occur in the Natural Bridge area, approximately 3.0 miles west of the Buckhead Mesa site. The quartzite is a silicified sandstone of low porosity. The springs at Natural Bridge emerge just above the contact between the younger Paleozoic sandstone and the metarhyolite (Feth and Hem, 1963).

## Cambrian Tepeats Sandstone

The Tepeats Sandstone was deposited on an old erosion surface of the granite and is the oldest Paleozoic sedimentary formation in the area. This unit composed of sandstone, siltstone, and mudstone, with lenses of conglomerate, is moderately to well cemented and yields small amounts of water to wells and springs (Owen-Joyce and Bell, 1983). On fresh surfaces, it is reddish brown to buff and weathers buff to brown. This unit reaches a thickness of up to 60 feet, crops out across the top of the Diamond Rim Fault, and is displaced a considerable distance south, cropping out north and west of Payson on both sides of the East Verde River.

## Devonian, Mississippian, and Pennsylvanian Rocks

Devonian, Mississippian, and Pennsylvanian rocks have been mapped as one unit where the boundaries between the units have not been identified during the reconnaissance mapping of the area by Peirce (1959). Where the boundaries have been identified, the separate units are delineated in Figure 6.

The Upper Devonian Martin Formation is a grey, thinly-laminated sandy limestone that lies unconformably upon the

Tepeats Sandstone. A thick zone of blue-grey limestone containing large nodules and bands of chert, jasper, and agate lies above this zone. The Martin Formation reaches a maximum thickness of 500 feet and is capable of yielding water to wells up to several hundred gallons per minute in the upper Verde Basin (Owen-Joyce and Bell, 1983). Such well yields have not been found in the Payson-Pine area.

The Lower Mississippian Redwall Limestone is exposed near the Diamond Rim Fault zone, but its lower portion was faulted below the ground surface and its upper parts removed by erosion (Titley, 1962). This unit contains thin beds of maroon shale and sandy shale overlain by maroon, grey, and grey-green mottled limestone. The Redwall reaches a maximum thickness of 75 feet in the area. Hix (1977) has mapped the Redwall in the Pine-Strawberry area, and shows the unit draped over the Mazatzal Quartzite two miles south of Pine along Highway 87. Although Owen-Joyce and Bell (1983) report the potential for high yields to wells in the upper Verde Basin, this has not been found in the Payson-Pine area. Feth and Hem (1963) note the occurrence of solution openings in exposures acting as conduits for groundwater and springs.

The Early Pennsylvanian Naco Formation rests unconformably upon the Devonian Martin Formation east of the Buckhead Mesa site. Huddle and Dobrovolny (1952) indicate that the predominantly carbonate Naco Formation grades conformably into a red-bed unit, the Lower Permian Supai Formation. Kottlowski and Havenor (1962) note that between Pine and Payson these dominantly clastic rocks rest unconformably on Mississippian Redwall limestone. The basal part is made up of reddish sandy shale and chert breccia, while the rest of the Naco is mainly red to grey limey siltstone and fine-grained sandstone with a few interbeds of grey to pink arenaceous limestone. Thicknesses of the Pennsylvanian are based upon estimates as to how much of the Supai is of Pennsylvanian age. Huddle and Dobrovolny (1952) indicate the Naco Formation is 475 feet thick in the Pine Area. Peirce (1959) shows the Naco Formation to have thinned out just east of the Buckhead Mesa site where parts of the unit have been removed by erosion and by the upward and downward movement along the Diamond Rim Fault.

## Permian Rocks

Permian Rocks consisting of the Supai Formation, the Coconino Sandstone, and Kaibab Limestone crop out in the north part of the area forming the Mogollon Rim. Peirce and Nations (1986) refer to these rocks as cliff formers. These rocks do not persist south of the Mogollon Rim near the Buckhead Mesa site and are believed to have been removed by erosion.

The Supai Formation is exposed along the base of the Mogollon Rim and rests conformably upon the Naco Formation. Huddle and Dobrovolny (1952) divided the Supai Formation into three members that grade laterally into each other.

The lower unit is 200 to 540 feet thick and contains sandstone, siltstone with some limestone, and shale. It crops out typically as a gentle slope broken by a few resistant ledges and interfingers with the underlying Naco Formation. Some of the beds are gypsiferous containing recrystallized gypsum (Kottlowski and Havenor, 1962).

The middle member of Supai is 250 to 400 feet thick containing dark reddish-brown siltstone, sandstone, and shale. This unit crops out as cliffs and steep slopes.

The upper member of the Supai Formation is up to 625 feet thick containing a sequence of very fine to coarse-grained siltstone and sandstone beds, some of which are calcareous.

The Coconino Sandstone forms a major part of the upper section of the Mogollon Rim and rests conformably upon the Supai Formation. This eolian sandstone is a massive, fine- to medium-grained, white to light brown quartz arenite and is weakly to well cemented by silica and calcite. This unit is up to 650 feet thick.

North of the Mogollon Rim, the Kaibab Limestone unconformably overlies the Coconino Sandstone. This unit, which is about 400 feet thick, is a fractured limestone or dolomite limestone and contains fissures and caverns.

Tertiary Sediments and Basalt

Tertiary sands and gravels have been mapped near Pine and Payson, and along Pine Creek and the Buckhead Mesa portions of the study area. The gravels at the Buckhead Mesa site have been the subject of considerable interest to Peirce and others in providing clues to the development of the Mogollon Rim. Peirce and Nations (1986) indicate that these gravels contain clasts of Precambrian, Paleozoic, and Cenozoic rocks and rest on an erosional surface cut down to the Naco Formation. Feth and Hem (1963) describe the gravels in the Payson Basin as buff to light rusty red, lacustrine deposits containing gypsum. They note that these and other lake-bed areas are aligned in a depressed region southwest of and parallel to the Mogollon Rim.

Peirce et al. (1979) note that the older Tertiary gravels capping the Mogollon Rim should not be equated with the Buckhead Mesa gravels. A possible Oligocene erosional event removed the entire Permian section at the Buckhead Mesa site and deposited the Buckhead Mesa gravels. Movement along

Diamond Rim Fault occurred after these gravels were deposited and prior to the deposition of the Tertiary basalt, which crops out at the ground surface of Buckhead Mesa (Peirce, 1987). Tertiary or Quarternary basalts, or both, cap the rocks above the Mogollon Rim, south along Buckhead Mesa, and along the western boundary of the study area.

## REGIONAL GROUNDWATER HYDROLOGY

Feth and Hem (1963) conducted a reconnaissance study of spring discharge in the Gila River Drainage Basin, Arizona, including a discussion of the Payson Basin. Although the discharge to wells was not emphasized, the recharge, occurrence, and discharge of groundwater in the Payson Basin was discussed. Ross (1977) produced a map showing the groundwater conditions in the lower Verde River basin including the Payson-Pine area. One spring located at the base of the Mogollon Rim in the Payson-Pine area was shown on this map. Hix (1977) conducted a hydrogeologic investigation in the Pine-Strawberry area; this included geologic mapping, a well inventory assessment, and preliminary water-level contours in two small areas.

Owen-Joyce and Bell (1983) provided an appraisal of the water resources of the upper Verde River Basin north of the study area. They produced a map showing regional water-level contours extending south to the edge of the Mogollon Rim. Groundwater was shown to move regionally from west to east towards the Verde River. In the region immediately north of the study area the water levels were bent parallel to the Mogollon Rim. Groundwater in this area was shown to move south from the Colorado Plateau into the Payson-Pine area along the southern boundary of the upper Verde River Basin.

### Existing Data

Published water level contours are not available for the Payson-Pine area and the direction of groundwater movement is uncertain. Owen-Joyce (1987) extended the water level contours into the Payson-Pine area, but this was limited to very few control points. The available well and spring records within an approximate 5.0 mile radius of the Buckhead Mesa site were collected from the data banks of the USGS Tucson office and the Arizona Department of Water Resources (ADWR) in Phoenix. All well locations and springs in the region surrounding the site are shown in Figure 9. There are no wells located on the site or within 0.25 miles of it. The nearest well is located in Section 9, 2.0 miles west of the site on the western edge of Buckhead Mesa. Three wells are located 3.0 miles west of the site in Pine Creek Canyon above Natural Bridge. Four wells are located between 3.0 and 4.0 miles northeast of the site in Webber Creek Canyon. Six wells and three springs are located 3.0 miles southeast of the site in Webber Creek Canyon along the East Verde River. A cluster of fifteen wells is located 3.0 miles south of the site in Sycamore Creek Canyon along the East Verde River. Approximately 70 wells are located near Payson and 97 wells are located near Pine.

The use of water in the Payson-Pine area is primarily domestic and public safety (Arizona Water Commission, 1977). About 90 percent of the drinking water supply comes from groundwater resources. There is no one main aquifer unit in this area from which the groundwater is drawn. Several rock units provide groundwater to wells.

Groundwater Levels

The depth to groundwater in wells located within the Payson-Pine area ranges from 8 to 800 feet; 150 wells have depths to water between 8 and 100 feet; 45 wells between 100 and 200 feet; and 32 wells have depths to water greater than 200 feet. Groundwater reaches the ground surface at springs, along small streams, and the East Verde River where parts of the water table are exposed.

Well A-11-9-9abb, located 2.0 miles west of the Buckhead Mesa site, first encountered water at a depth of 87 feet at the contact of the base of the Tepeats Sandstone and the Precambrian granite. The water level rose to a depth of 60 feet after the well was completed. Five wells, located 3.0 miles west of the site in Oak Spring Canyon, were drilled to depths of about 80 feet. These wells are located near the contact of the Paleozoic rocks to the east and Precambrian rocks to the west. Well A-11½-9-32dab2 is representative of this well cluster. Groundwater was encountered at a depth of 22 feet in the Redwall Limestone and the boring was terminated in the Tepeats Sandstone. The well is screened between depths of 40 and 64 feet in the Redwall and cased above and below this section. The static level in the well is 22 feet.

Well A-11-10-9bcd, located 3.25 miles east of the site, is in a cluster of five wells near the East Verde River and was drilled to a depth of 200 feet. The well is cased in the upper 20 feet, but is open in the Tepeats Sandstone and underlying Precambrian granite. The depth to water was 10 feet.

Fifteen wells are located approximately 3.0 miles southeast of the site along the East Verde River just west of Highway 87. Well A-11-10-18dad has a total depth of 235 feet, is screened between 30 and 60 feet, and is open below 77 feet. This well receives water from the Precambrian rocks and first encountered water at a depth of 18 feet during drilling. The static level in the well was 17 feet.

Approximately 70 wells are located south of the East Verde River in the study area just north of Payson. The depth to water in these wells ranges from 10 to 200 feet. Data from these wells were used to construct water table contours and to establish the direction of groundwater movement as discussed below.

Four wells were constructed in Webber Creek Canyon between two and four miles northeast of the site at the base of the Mogollon Rim. These wells provide data on the occurrence of groundwater above the Diamond Rim Fault zone. Well A-11½-10-20bdb was drilled to a total depth of 200 feet and first encountered water at a depth of 25 feet in a fractured limestone, possibly the Martin Formation. A second water-bearing zone was encountered in the Tepeats Sandstone at a depth of 100 feet. This well receives groundwater from both the Martin and the Tepeats Formations; the static level in the well is 25 feet.

Two wells located in Webber Creek Canyon near Shannon Gulch are situated immediately adjacent to an arm of the Diamond Rim Fault. Well A-11½-10-30abd was drilled to a depth of 125 feet and encountered groundwater at a depth of 30 feet in the Precambrian granite. Well A-11½-10-30aca was drilled to a depth of 405 feet and the depth to water was 300 feet. Well A-12-9-36cbb is located upstream in Webber Creek Canyon and was canvassed by the USGS. The hole was drilled to a depth of 740 feet and the static water level was 680 feet. The lower 100 feet of the boring was interpreted by Royse (1971) as Martin limestone and sandstone.

Records from 17 wells located near Bear Canyon and the East Verde River, some 7 miles northeast of the site, provide groundwater data along the eastern boundary of the study area along the Diamond Rim Fault. The depth to groundwater ranges from 10 to 60 feet. Well A-11½-10-24abb is an open hole encountering Martin limestone to 58 feet, Cambrian Tepeats Sandstone to 135 feet, and Precambrian granite to 200 feet. The depth to water was not recorded, but the well provides a relatively complete stratigraphic sequence.

Approximately 97 well records have been collected in the Strawberry-Pine area, 5.0 miles upgradient of the Buckhead Mesa site. Hix (1977) summarized the hydrogeology of the area. The depth to water in this area is variable, ranging from about 20 to 800 feet. Many of the wells that encountered caverns and fractures are dry. Well A-12-8-35daa was drilled to a depth of 850 feet and encountered the following geologic sequence: Supai to 318 feet; Redwall to 447 feet; Martin to 810 feet; and Tepeats Sandstone to 850 feet.

## Springs

Approximately 25 springs located within the area surrounding the Buckhead Mesa site are shown in Figure 9. Many of these springs are described in Feth and Hem (1963) and Arizona Water Commission (1977). Most of the springs in the area emerge at the contact of two geologic units and are termed non-artesian. The springs at Natural Bridge emerge near the contact of Cambrian Tepeats Sandstone and the Precambrian rhyolite. Feth and Hem (1963) suggest that a small graben controls the occurrence of these springs. Cold springs on Ellison Creek emerge along the Diamond Rim Fault contact with the Cambrian Tepeats. Feth and Hem (1963) suggest the fault acts as a barrier to the movement of groundwater near the water table, causing the emergence of the spring. Feth and Hem (1963) note that the wide fluctuation in discharge of this spring, 830 to 4,200 gallons per minute (gpm), indicates relatively small groundwater storage and a nearby recharge area. A similar fault occurrence causes several springs to emerge in Webber Canyon near the East Verde River in a small graben. Big Spring and Grotto Spring, located in this graben, discharge groundwater at rates from 10 to 350 gpm and 100 to 175 gpm, respectively.

Several springs north and west of the Buckhead Mesa site emerge at the contact of the Diamond Rim Fault and the Paleozoic sedimentary rocks. Pine Spring, Red Rock Spring, and Dripping Springs discharge groundwater along the base of the Mogollon Rim through the Supai Formation.

Clover Spring located west of Natural Bridge is the only spring in the area that emerges in a basalt aquifer. It is possible that groundwater in the Basalt is part of a perched water table system.

The relationship of groundwater discharge in small canyons within the Payson Basin has been discussed by Feth and Hem (1963). Flow in Webber Canyon, Bray Creek, Chase Creek, and the East Verde River decreases to zero along a line parallel to and about 3 miles south of the Mogollon Rim. They believed this line coincided with a fault zone bringing the Redwall limestone to or near the surface. The solution openings and cavernous nature of the Redwall may be acting as a sink for the flow in the canyons, but the fault zone noted by Feth and Hem (1963) has not been mapped by Peirce (1959). Flow in the East Verde River becomes perennial at Ellison Creek, decreases to zero at an undetermined point, and becomes perennial again above Webber Creek. Feth and Hem (1963) related the occurrence of perennial flow in the East Verde River to outcrops of Redwall limestone repeated by faulting.

## Water-Level Contours and the Direction of Groundwater Flow

Water-level elevations above mean sea level in wells were estimated using ground surface elevations from the USGS topographic base maps and the location given by each well record. The depth to water used in the estimate was the first occurrence of water encountered during drilling. This was interpreted as the water table. In cases where the static level in the well was higher than the first occurrence of water, the water-table measurement was the value selected. The depth to water was subtracted from the ground surface elevation producing the water table elevation. The estimated water table elevations in wells, elevations of the East Verde River, and spring elevations were contoured and used conjunctively with the regional geology map to produce the water table contours shown in Figure 9. The resulting map was discussed with and compared to the earlier map by Owen-Joyce (1987).

The water table contours are parallel to the Mogollon Rim, which acts as a seepage face along which numerous springs emerge. The Mogollon Rim acts as a discharge-recharge boundary between two basins. Groundwater moves through the Colorado Plateau and into the Payson-Pine area, passing beneath or through the Mogollon Rim.

The shape of water table contours is greatly influenced by topographic relief, geology, and structural controls. Three major surface drainage courses, the East Verde River, Pine Creek, and Webber Creek, have cut deep canyons to or near the water table. Pine Creek flows in a deep canyon cut parallel to the Precambrian/Paleozoic contact west of the Buckhead Mesa site. The headwaters of Pine Creek are located just west of Milk Ranch Point in a canyon deeply cut into the Mogollon Rim. Steep water table contours west of Pine Creek wrap around the Precambrian Mazatzal Quartzite indicating a nearly north-south groundwater flow direction towards Pine Creek and the East Verde River.

The shape of the water table contours west of the Buckhead Mesa site between Webber Creek Canyon and the East Verde River is dominated by the occurrence of the Diamond Rim Fault zone and its related arms. Feth and Hem (1963) indicated that the fault zone may be acting as a barrier to groundwater movement. The water table contours are practically parallel to the Diamond Rim Fault, spreading out beneath the mesas and tapering into the surface drainage courses. Segments of Cedar Mesa Canyon and Sycamore Creek, east and southeast of Buckhead Mesa, pass directly over a north-south arm of the Diamond Rim Fault. The water table contours are perpendicular to this arm of the Diamond Rim Fault, indicating that this fault is not acting as a barrier to groundwater movement. Instead, groundwater beneath the Buckhead Mesa site is believed to move south and southeast towards the East Verde River.

## Water Quality and Geochemistry

Geochemistry data from wells and springs in the Payson-Pine area have been collected from the USGS and ADWR and have been used to describe the ambient water quality conditions surrounding the Buckhead Mesa site. These data are summarized in Table 3.

Complete sets of water quality data including major ions and heavy metals (boron, iron, and manganese) are available for four wells in the area. Three of these wells are located near Payson and the fourth is located in Bear Canyon near the East Verde River. Water quality data from wells are available for the Pine area but these sets are incomplete in regard to major ions and heavy metals. Water quality data are available for three springs: one spring near Pine and two springs along the base of the Mogollon Rim near the East Verde River.

Data from monitoring locations were converted to equivalents-per-million and expressed as percentages. This allowed the graphic representation of each sampling point on the trilinear or Piper diagram as shown in Figure 10. The location of each well or spring is referred to in Figure 10 by a sampling point.

Groundwater upgradient of the Buckhead Mesa site, as determined by using the water level contours in Figure 9, is characterized by the well in Bear Canyon (sample point D, 7.0 miles northeast of the site). Using the classification of Back (1961), Figure 10 shows that these ambient groundwaters are a calcium-bicarbonate type with a high percentage of magnesium. The total dissolved solids (TDS) ranges between 115 and 280 milligrams per liter (mg/l); dissolved silica is comparatively low (11 mg/l). Trace metals were only determined on the well groundwater: boron 0.02 mg/l, iron 0.01 mg/l, and no manganese.

Two wells near Payson, sample points B and C, 6.0 and 9.0 miles southeast of the Buckhead Mesa site, and one well on Houston Mesa, sample point A, 6.5 miles southeast of the site, provide data on downgradient ambient groundwater quality. Figure 10 shows these bicarbonate groundwaters have increased percentages of chloride, sodium, and potassium with significant calcium and magnesium percentages. TDS ranges between 180 and 260 mg/l, boron has decreased to 0.01 mg/l, iron not detectable to 0.1 mg/l, and manganese 0.01 to 0.02 mg/l. Dissolved silica has increased significantly to values as high as 29 mg/l.

Recharge to the groundwater in the Payson-Pine area occurs along the base of the Mogollon Rim. These waters are typical of water from limestone or dolomite with calcium, magnesium, and bicarbonate making up nearly all the dissolved matter. Increases in sodium, potassium, chloride, and silica in the downgradient groundwater are attributed to dissolution of mineral matter from the underlying Precambrian granite. Feth and Hem (1963) note that some of the spring waters appear to be supersaturated with carbon dioxide. This would shift the carbonate equilibrium towards greater production of bicarbonate and carbonic acid allowing for the dissolution of mineral matter in the evolutionary downgradient groundwater.

## Buckhead Mesa ~~Conceptual~~ Site Hydrogeology

Figure 7 is a schematic illustration of a geologic cross-section including Buckhead Mesa. Rock units range from (oldest to youngest): granites and meta volcanics, Tepeats Sandstone, Martin Formation, Redwall Limestone, Naco Formation, and unnamed basalts. Basalt caps the mesa and crops out extensively along the margins. Drilling data from soil borings at the landfill site indicate the basalt is underlain by red shales, siltstones, and limestones. This lithology is characteristic of both the Redwall Limestone and Martin Formation in the vicinity.

Beds appears to dip 5° to 10° to the north. The major structural feature of the site is the Diamond Rim Fault. This fault is nearly vertical. Total displacement across this structure is not known but it appears to be hundreds, perhaps over 1,000, feet. Peirce (1987) has dated movement along the fault as late as Oligocence (approximately 40 million years ago). The Buckhead Mesa ~~landfill~~ site appears to be on the down thrown block of this structure.

The regional groundwater contours shown in Figure 9 indicate the depth to groundwater varies between approximately 150 and 250 feet beneath land surface at the site. Local groundwater flow appears to be to the south-southeast. The regional hydraulic gradient in the vicinity is approximately $10^{-2}$ to $10^{-3}$ ft/ft.

The geologic unit comprising the uppermost aquifer is not known. However, it is anticipated that the top of the saturated zone will occur in the Martin Formation. Hydrologic parameters of shales, silts, and limestones in the Martin will vary greatly; therefore, accurate estimates of hydraulic conductivity and storage coefficient cannot be made.

Site geologic features that may influence the local groundwater flow system include:

- Diamond Rim Fault. This zone may act as a groundwater sink, barrier, or may have very little impact.
- Local drainage features (Cedar Mesa Canyon and Sycamore Creek). These may be a source of local recharge. The occurrence of a spring one mile north of the site in Sycamore Canyon is evidence of shallow groundwater in the area. Phreatophytes growing in these drainages indicate a shallow possibly perched water table probably localized in the canyons.
- The sedimentary layering or bedding may inhibit direct downward infiltration of precipitation and may cause the formation of perched aquifer zones.
- The northerly dip of bedding could have an influence on the rate and direction of flow.

## REFERENCES

Arizona Water Commission, 1977. Basic Data for Selected Wells and Springs in the Pine-Payson-Kohl's Ranch Area, Gila County, Arizona. Arizona Water Commission Report No. 9, August, 1977.

Back, W., 1961. Techniques for Mapping of Hydrochemical Facies. U.S. Geol. Surv. Prof. Paper 424-D.

Feth, J. H., and Hem, J. D., 1963. Reconnaissance of Headwater Springs in the Gila River Drainage Basin, Arizona. U.S. Geol. Surv. Water-Supply Paper 1619-H.

Hix, G. L., 1977. A Hydrogeologic Investigation of the Pine-Strawberry Area, Arizona. Prepared for E&R Water Company, Mesa, Arizona.

Huddle, J. W., and Dobrovolny, E., 1952. Devonian and Mississippian Rocks of Central Arizona. U.S. Geol. Surv. Prof. Paper 233D.

Kottlowski, F. E., and Havenor, K. C., 1962. Pennsylvanian Rocks of the Mogollon Rim Area, Arizona. In Weber, R. H., and Peirce, H. W. (eds), Mogollon Rim Region, New Mexico Geological Society, 13th Field Conference Guidebook.

Owen-Joyce, S. J., and Bell, C. K., 1983. Appraisal of Water Resources in the Upper Verde River Area, Yavapai and Coconino Counties, Arizona. Prepared by the U.S. Geol. Survey for the Arizona Department of Water Resources Bull. No. 2, March 1983.

Owen-Joyce, S. J., 1987. Personal Communication.

Peirce, H. W., 1959. In Wilson, W. D., Moore, R. T., and Peirce, H. W., Geologic Map of Gila County, Arizona, Arizona Bureau of Mines, 1:375,000.

Peirce, H.W., Shafiqullah, M., and Damon, P. E., 1979. An Oligocene (?) Colorado Plateau Edge in Arizona. Tectonophysics, V. 61, p. 1-24.

Peirce, H. W., and Nations, J. D., 1986. Tectonic and Paleogeographic Significance of Tertiary Rocks of the Southern Colorado Plateau and Transition Zone, in Geology of Central and Northern Arizona, Field Trip Guidebook, Geol. Soc. of America, Nations, J. D., Conway, C. M., and Swann, G. A. (eds).

Peirce, H. W., 1987, Personal Communication.

Ross, P. P., 1977. Map Showing Ground-Water Conditions in the Lower Verde River Area, Maricopa, Yavapai, and Gila Counties, Arizona - 1976. U.S. Geol. Surv. Water-Resources Investigation 77-113 Open-File Report, October, 1977.

Royse, C. F., 1971, Letter to Swister describing Geology of Boring A-12-9-36cbb, Arizona State University, Dept. of Geology.

Titley, S. R., 1962. Geology Along the Diamond Rim and Adjoining Areas, Gila and Navajo Counties, Arizona, in Weber, R. H. and Peirce, H. W. (eds), Mogollon Rim Region, New Mexico Geological Society, 13th Field Conference Guidebook.

Wilson, W. D., Moore, R. T., and Peirce, H. W., 1959. Geologic Map of Gila County, Arizona, Arizona Bureau of Mines, 1:375,000.

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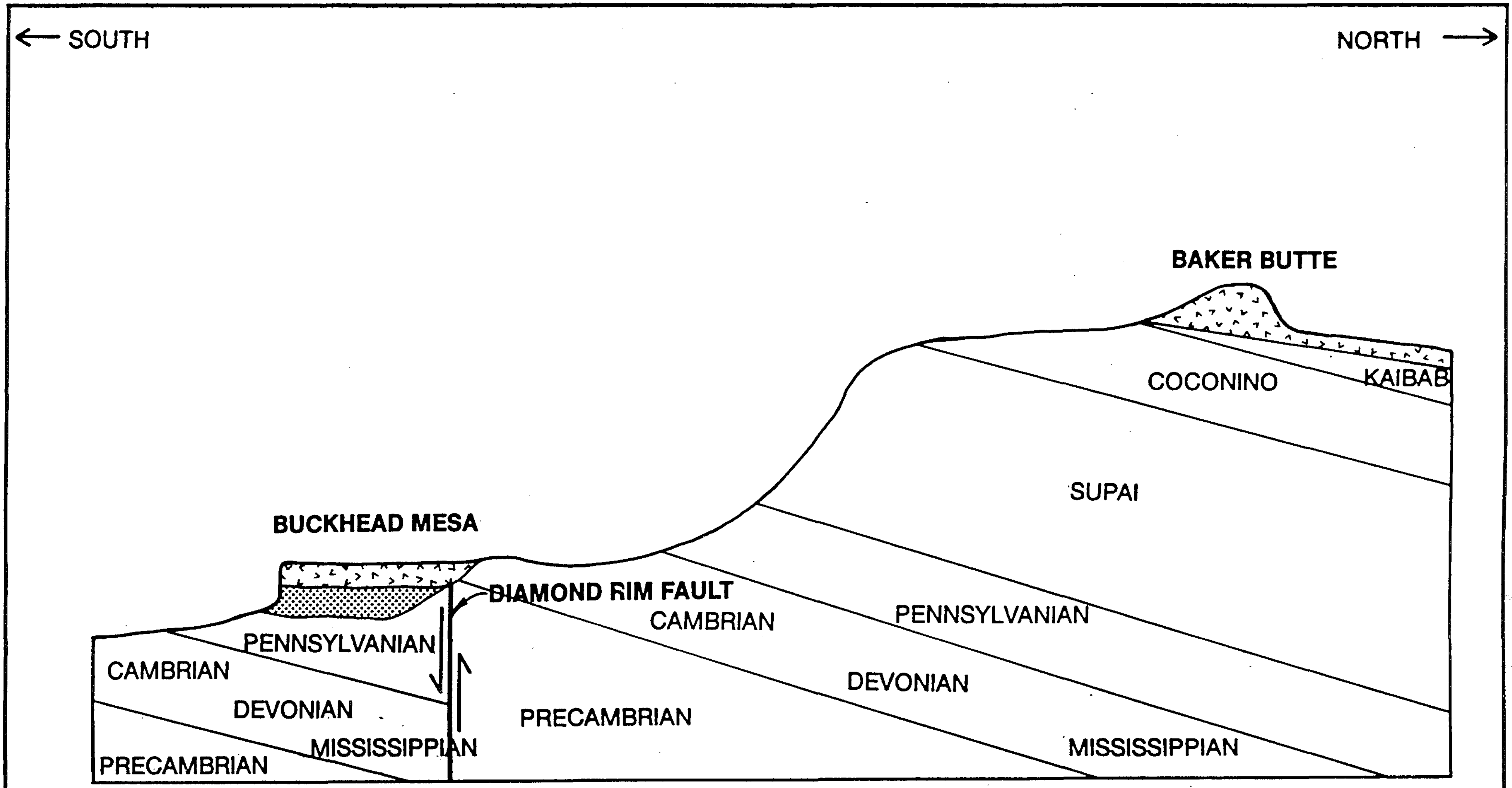



NOTE: COMPOSITE SCHEMATIC OF THE TONTO SEGMENT LOOKING WESTERLY, TAKEN FROM PIERCE ET.AL. (1979).

**FIGURE 7**
**SCHEMATIC GEOLOGIC CROSS-SECTION**
**BUCKHEAD MESA**

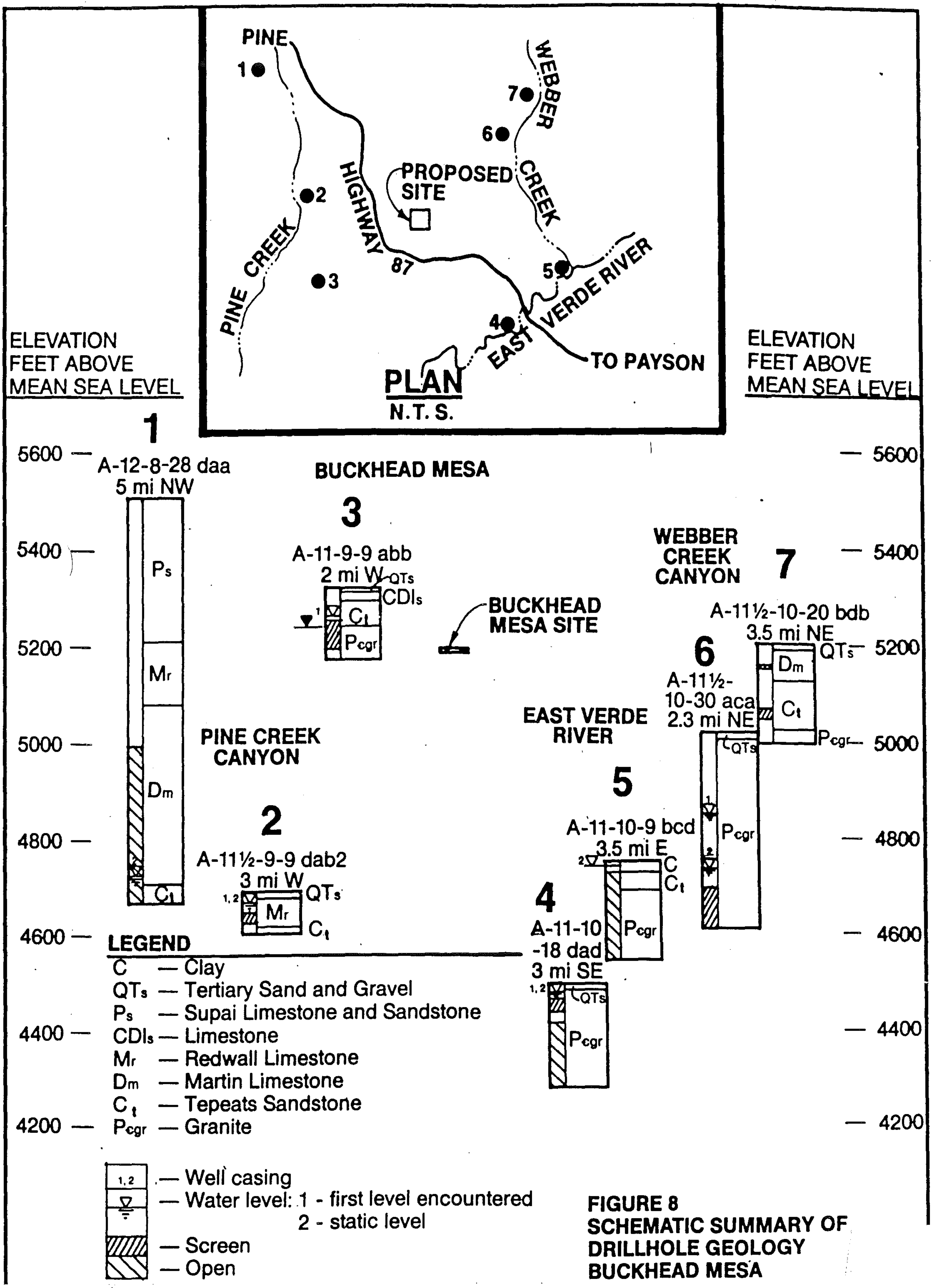
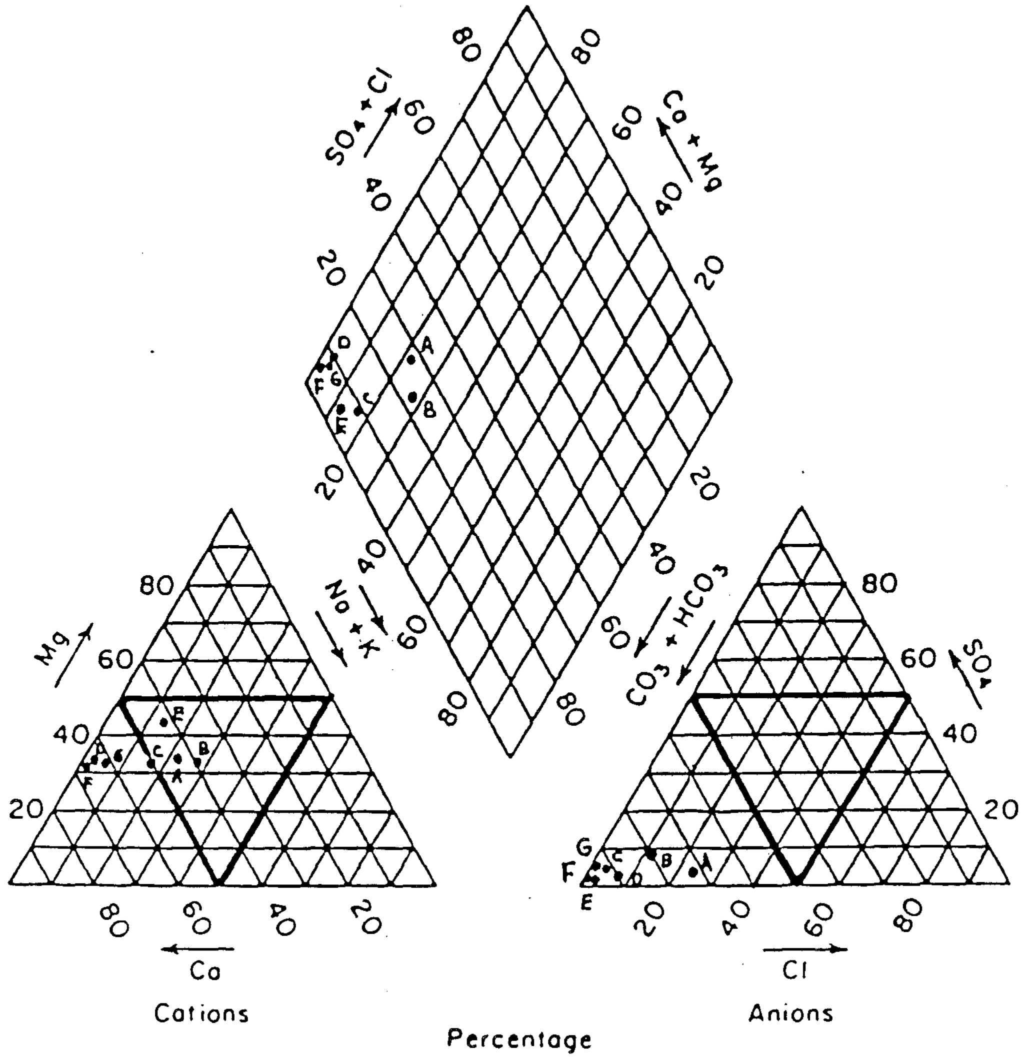



**FIGURE 8**
**SCHEMATIC SUMMARY OF DRILLHOLE GEOLOGY BUCKHEAD MESA**

## Water Quality in the Payson — Pine Area




### Description of Geochemical Sample Points

| Sample Point | Well Location | Miles[1] | Area |
|---|---|---|---|
| A | A-11-10-23 aca | 6.5 d | Horton Mesa |
| B | A-11-10-27 ccb | 6 d | Payson |
| C | A-11-11-31 ada1 | 9 d | Payson |
| D | A-11½-10-24 bdb | 7 u,ne | Bear Canyon |
| | **Spring Location** | | |
| E | A-12-8-35 cad | 5.3 u | Pine |
| F | A-12-10-11 cc | 10.5 u,ne | East Verde River |
| G | A-12-10-14 a | 10.5 u,ne | East Verde River |

[1] — distance from Buckhead Mesa Site:
d - downgradient
u - upgradient
ne - northeast

**FIGURE 10**
**WATER QUALITY**
**BUCKHEAD MESA**

# Table 3
## WATER QUALITY DATA FOR WELLS AND SPRINGS NEAR THE BUCKHEAD MESA SITE
## BUCKHEAD MESA SANITARY LANDFILL

| Well | Well Location | Miles From Site[a] | Date | Temp. °C | pH | SC[b] | TDS | Hardness | Ca | Mg | Na | K | $HCO_3$ | $SO_4$ | Cl | F | $SiO_2$ | $NO_2+NO_3$ | B | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (all concentrations are mg/l) | | | | | | | | | | | | | | |
| A | A-11-10-23aca | 6.5d | 75 | NM | 7.6 | 700 | 257 | 180 | 40 | 19 | 20 | 1.5 | 188 | 5.5 | 35 | 0.2 | 27 | 3.7 | ND | NM | NM |
| B | A-11-10-27ccb | 6 d | 75 | NM | 7.9 | 290 | 180 | 110 | 24 | 12 | 18 | 0.4 | 140 | 12 | 6.8 | 0.6 | 29 | 1.8 | ND | ND | 0.010 |
| C | A-11-11-31adal | 9 d | 75 | NM | 7.7 | 330 | 193 | 140 | 34 | 13 | 14 | 0.5 | 194 | 5.4 | 5.0 | 0.7 | 23 | 0.4 | ND | 0.010 | 0.020 |
| D | A-11½-10-24bdb | 7 ne | 75 | NM | 7.8 | 340 | 175 | 180 | 48 | 15 | 2.1 | 0.6 | 182 | 6.7 | 5.9 | 0.1 | 6.3 | 0.12 | 0.020 | 0.010 | ND |
| | **Spring Location** | | | | | | | | | | | | | | | | | | | | |
| E | A-12-8-35cad | 5.3u | 46 | NM | NM | 557 | 280 | 280 | 56 | 34 | 18[c] | NM | 370 | 2.9 | 8 | 0.4 | NM | 0.5[d] | NM | NM | NM |
| F | A-12-10-11cc | 10.5ne | 52 | NM | NM | 383 | 214 | 214 | 58 | 17 | 0.5[c] | NM | 250 | 6.6 | 2 | 0.1 | 11 | 0.2[d] | NM | NM | NM |
| G | A-12-10-14a | 10.5ne | 52 | NM | NM | 207 | 116 | 116 | 30 | 10 | 1.6[c] | NM | 136 | 5.8 | 1 | 0.2 | 11 | 0.1[d] | NM | NM | NM |

[a] Distance from Buckhead Mesa Sanitary Landfill site: d = downgradient; u = upgradient; ne = northeast.

[b] Specific conductance (μmhos/cm at 25°C).

[c] Na+K.

[d] $NO_3$.

Note: Well letters A through G correspond to sample points in Figure 10.
NM = not measured.
ND = not detected.