# SAMPLING AND ANALYSIS PLAN

## Section 9.0

## Ground Water

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# 9.0 Ground Water

## 9.1 Introduction and Background

The Roca Honda permit area is located in the southeastern part of the San Juan structural basin, within the southeast part of the Ambrosia Lake uranium subdistrict, which was the site of previous uranium mining and associated mine dewatering activities from the 1960s through the 1980s. The permit area lies within the Bluewater Underground Water Basin as extended by the New Mexico State Engineer on May 14, 1976.

Large amounts of data on ground water exist for the San Juan basin because it contains deposits of recoverable uranium and valuable ground water resources. The USGS, the New Mexico Bureau of Mines and Mineral Resources, and the New Mexico State Engineer cooperated in several hydrogeologic studies of the San Juan basin which have compiled and analyzed ground water quality data, hydraulic parameter estimates, and descriptions for area aquifers (Brod and Stone 1981, Frenzel and Lyford 1982, Stone et al. 1983, Craigg et al. 1989, Dam et al. 1990, Dam 1995, and Craigg 2001). Moreover, as part of the Regional Aquifer System Analysis (RASA) program, the USGS developed a steady–state multi–aquifer ground water flow model of the San Juan basin (Kernodle 1996).

The Roca Honda mine permit area is approximately three miles northwest of the Mount Taylor uranium mine, formerly operated by Gulf Mineral Resources Company (GMRC) and others and now is owned by Rio Grande Resources Corporation (RGRC). This mine was dewatered during the 1970s and early 1980s. Ground water quality data and hydraulic parameter estimates were collected both at the Mount Taylor mine and at various mines west of the Roca Honda permit area in the Ambrosia Lake subdistrict (NMEI 1974, GMRC 1979a, and Kelley et al. 1980). The ground water quality and hydraulic characteristics of the Westwater Canyon Member of the Morrison Formation were re-evaluated more recently by HRI and the NRC during site licensing in the Crownpoint and Church Rock areas (HRI 1988 and 1991 and NRC 1997).

The earlier studies demonstrated that the strata beneath the permit area represent the same sequence of rocks found in the San Juan structural basin. Potentiometric data collected from wells in and near the permit area indicate that ground water moves continuously through the permit area in the same aquifers found to the west. The aquifers and aquitards encountered in the permit area probably have hydraulic characteristics similar to those found in the same units elsewhere in the San Juan structural basin.

In general, the hydraulically significant structural features of the southeastern San Juan basin have been previously identified, and the ground water quality and hydraulic characteristics of the aquifers in the Roca Honda permit area are expected to lie within the ranges identified in previous studies. Currently available data on water quality and hydraulic characteristic within the permit area, however, are sparse, and consequently, Roca Honda Resources has compiled the relevant published and unpublished information near the permit area. This effort included an inventory of water wells that may be present near the Roca Honda permit area. The inventory included location, completion dates, well depth, producing formation, measured water levels, and availability of chemical data for each well.

The inventory, earlier studies, and recent drilling by RHR provide a great deal of baseline information for the ground water in and adjacent to the proposed permit area. The following sections of this report present this existing data as it pertains to regional hydrogeology (Section 9.1.1), hydrology of the general permit area (Section 9.1.2), aquifer and ground water characteristics of the general permit area (Section 9.1.3), and aquitards (Section 9.1.4). The sufficiency of the existing information to characterize ground water conditions within the Roca Honda permit area is discussed in each section, and data needs are identified. The plan to fill these data needs is discussed in Section 9.3.

### 9.1.1 Regional Hydrogeology

The Roca Honda permit area is in the southeastern part of the San Juan structural basin in northwestern New Mexico (Figure 9–1). The basin is a roughly circular asymmetric structural depression at the eastern edge of the Colorado Plateau. It is bounded on the northwest by laccoliths associated with the Four Corners platform, on the north by the San Juan uplift, and on the northeast by a broad arch. The basin is bounded on the east by the structurally complex Nacimiento uplift and on the southeast by the extensively fractured Rio Grande rift, the Ignacio monocline, and the Lucero uplift. The Precambrian dome of the Zuni uplift (the southwestern limb of which is known as the Nutria monocline) and the Defiance uplift form the south-central and southwestern margins of the basin, and the northern end of the Defiance uplift forms the western margin of the basin (Craigg 2001 and Woodward 1987). These structural boundaries appear to also form hydrogeologic boundaries.

The San Juan structural basin is an artesian basin. In general, recharge enters the ground water flow systems as precipitation on permeable formations which crop out along the southern margin of the basin and on the flanks of the Zuni, Chuska, and San Mateo Mountains. Ground water then flows downgradient northwestward to discharge along the San Juan River, and northeastward and eastward to discharge to tributaries of the Rio Grande including the Rio Salado, Rio Puerco, and Rio San Jose, and to springs which discharge along faults (Stone et al. 1983). Discharge also occurs artificially from wells and mines. An undetermined amount of subsurface, inter-formational movement of water may occur. As ground water moves downgradient from the recharge area within permeable formations, it is prevented from moving vertically by overlying shale units which act as aquitards, and at the center of the basin, high artesian heads are present in most bedrock aquifers.

The San Juan structural basin contains a number of internal structural boundaries that affect the movement of ground water through aquifers. Potentiometric surface maps indicate that the pattern of ground water movement in the southeastern part of the basin is greatly influenced by the Zuni uplift, San Mateo dome, and McCartys syncline. Figure 9–1 shows the general pattern of deep ground water flow in the Jurassic and Cretaceous aquifers. Additional information on deep ground water flow is in Stone et al. (1983) and Kernodle (1996). The movement of ground water through the alluvium of stream valleys and through shallow aquifer systems in some Upper Cretaceous rocks is influenced by topography and surface water drainages, and is independent of and sometimes in a different direction than ground water movement in the deep aquifers.

According to Stone et al. (1983), the steady-state inflow/outflow rate of ground water through the basin is approximately 40 cfs for Cretaceous and Jurassic sandstone aquifers and less than half of that for Cenozoic aquifers. Kernodle (1996) simulated a total steady-state outflow from the entire 19,380-square-mile San Juan basin aquifer system of 195 cfs, all of which was

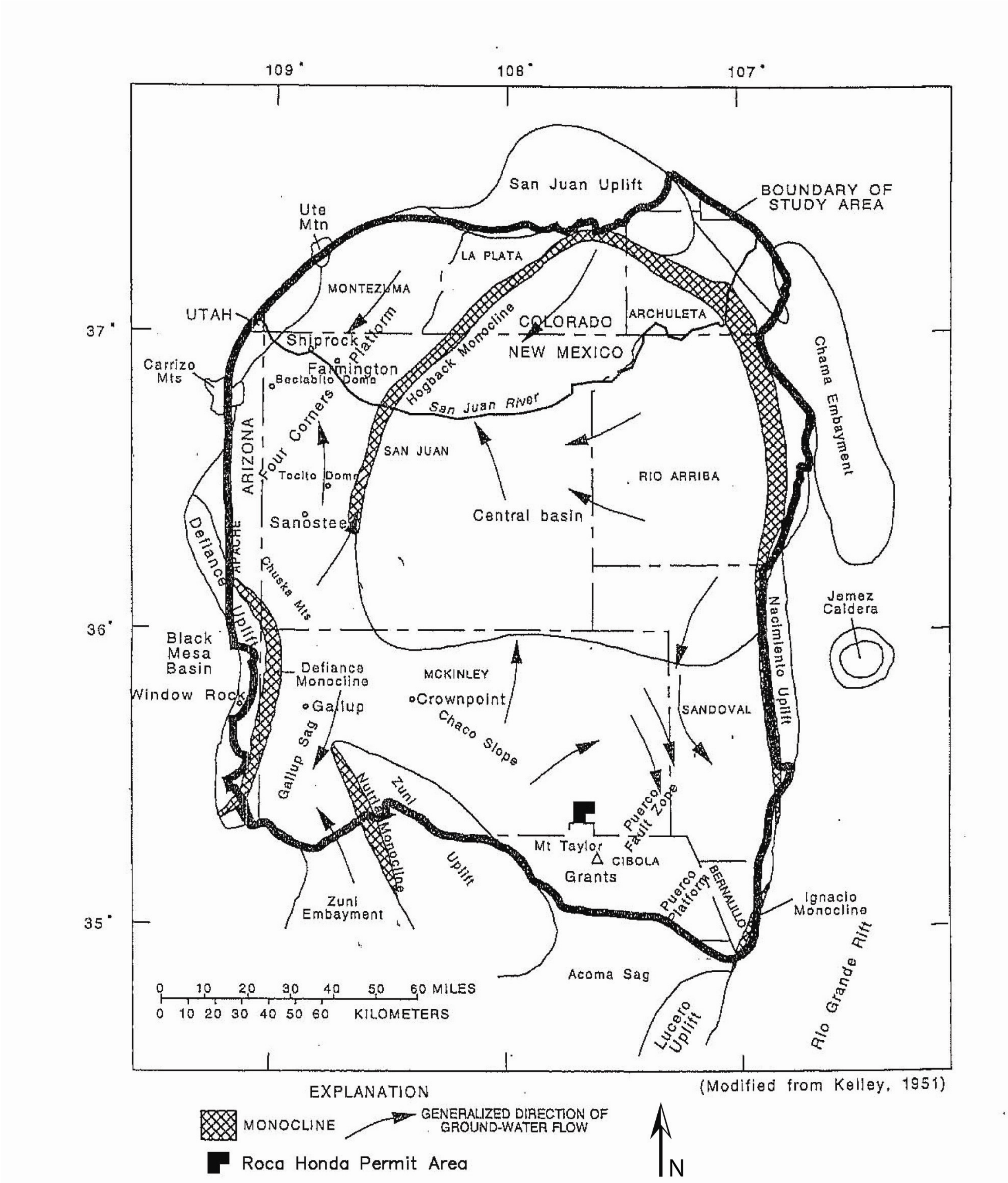


*Figure 9-1. Structural Elements of the San Juan Structural Basin and Adjacent Areas and Generalized Patterns of Ground Water Flow in Rocks of Jurassic and Cretaceous Age*

*(Modified from Dam, 1995, Figure 2)*

simulated as being discharged to the surface water system in the lower reaches of the San Juan River and Rio Puerco (Kernodle 1996). That simulation indicated 135 cfs of the recharge to the aquifers was from stream bed infiltration, 56 cfs was from direct precipitation, and 4 cfs was leakage from the Chuska Sandstone.

Aquifers within the southeastern part of the San Juan basin include, from deepest to shallowest, the Permian Glorieta Sandstone and San Andres Limestone, the Middle Jurassic Entrada Sandstone, the Upper Jurassic Westwater Canyon Member of the Morrison Formation, the Upper Cretaceous Dakota Sandstone, the Upper Cretaceous Gallup Sandstone of the Mesaverde Group, the Upper Cretaceous Crevasse Canyon Formation of the Mesaverde Group, and the Upper Cretaceous Point Lookout Sandstone and Menefee Formation of the Mesaverde Group. Within stream valleys, Quaternary alluvium can contain local aquifers. Although formations deeper than the San Andres Limestone may contain ground water, their depths generally preclude ground water exploration or development except along the margins of the basin where they are close to the surface. Whether a particular formation is used as an aquifer in an area of the basin is dependent on the depth to ground water, formation yield, and quality of ground water (NMEI 1974, Stone et al. 1983, Brod and Stone 1981, and Kernodle 1996) as well as the presence of shallower aquifers.

Thick aquitards separate the aquifers. Ground water in the Westwater Canyon Member is hydraulically isolated from ground water in underlying rocks by the Recapture Member of the Morrison Formation and, in unfaulted areas, from ground water in the overlying Dakota Sandstone by the Brushy Basin Member of the Morrison Formation. The main body of the Mancos Shale functions as an aquitard between the Dakota Sandstone and the Gallup Sandstone, and a similar aquitard, the Mulatto Tongue of the Mancos Shale, lies above the Gallup Sandstone between the Dilco Coal Member and the Dalton Sandstone Member of the Crevasse Canyon Formation. The Satan Tongue of the Mancos Shale splits the sandstones of the Point Lookout Sandstone. Shale units in the lower Menefee Formation may form hydraulic barriers between ground water in it and the Point Lookout Sandstone.

### 9.1.2 Hydrogeology of the Permit Area Locality

The term “Roca Honda/San Mateo area” is used herein to refer to an area which encompasses T13N R8W and a few additional miles to the east and west. It includes the upper and middle San Mateo Creek valley and the Roca Honda mine permit area. Ground water is present in the Roca Honda/San Mateo area within the stream bed alluvium of San Mateo Creek and in the following bedrock formations, from deepest to shallowest: the Westwater Canyon Member of the Morrison Formation, the Dakota Sandstone, the Gallup Sandstone, the Crevasse Canyon Formation, the Point Lookout Sandstone, and the Menefee Formation (Cooper and John 1968, NMEI 1974, Brod and Stone 1981, OSE 2008, GMRC 1979a, and Metric 2005a). The Dalton Sandstone of the Crevasse Canyon Formation is a minor source of water to stock wells north and east of the permit area. Ground water is probably present within deeper permeable formations (e.g., the San Andres Limestone and Entrada Sandstone), but these rocks lie at great depth in the Roca Honda permit area and are separated from mining activities in the Westwater Canyon Member by the Recapture Member of the Morrison Formation and the Wanakah Formation. Ground water within these deep formations will not be impacted by the proposed mining or dewatering and will not be discussed further.

Area geologic structure and the presence of multiple aquifers and aquitards have caused the development of complex aquifer systems in the Roca Honda/San Mateo area. From deepest to shallowest, these include: (1) a deep confined system in the Westwater Canyon Member, which may be in local hydraulic connection with ground water in the Dakota Sandstone and the lower sandstones in the Mancos Shale; (2) a confined system is probably present in the Gallup Sandstone, although sufficient wells completed in this formation in the Roca Honda/San Mateo area are not available to verify this; (3) an unconfined system in the Point Lookout Sandstone, which transforms into a confined system as ground water moves eastward downgradient; (4) an unconfined system in the Menefee Formation in hydraulic connection with San Mateo Creek; and (5) a shallow unconfined system in the alluvium of the stream bed of San Mateo Creek that is locally perched. These aquifer systems are described in more detail below.

#### *9.1.2.1 Westwater Canyon Member of the Morrison Formation*

The deepest aquifer system of interest in the Roca Honda/San Mateo area and the Roca Honda permit area is a deep confined system present within the Westwater Canyon Member of the Morrison Formation and possibly the overlying Dakota Sandstone and the sandstones in the lower part of the Mancos Shale. Faulting may have allowed local inter-aquifer connection of ground water among these formations in the faulted areas, and the rock units may function as a single aquifer system in these areas. Movement of ground water within this deep confined system is controlled largely by geologic structure. The rate of ground water movement is influenced by intergranular and fracture permeability of the rocks.

The Westwater Canyon Member is an aquifer as well as the major uranium ore horizon in the Grants district (Stone et al. 1983). It is an example of a classic artesian aquifer. Recharge occurs when surface water infiltrates the geologic strata in and around the Zuni and Defiance uplifts and moves downdip toward the deeper parts of the San Juan basin. Brod and Stone (1981) indicate that much of the ground water recharge to the deep confined system occurs in drainage-ways on the bedrock outcrops along the western basin margins, and as seepage into fractures. They note that San Mateo Creek is a source of recharge to this deep aquifer system, contributing recharge where it flows over outcrop areas. The topographically high recharge area produces high hydraulic head in the aquifers in the center of the basin where ground water is under confined pressure (NRC 1997). Dewatering of the Westwater Canyon Member for the purpose of underground mining lowered the potentiometric surface in the local area of uranium mines during the 1970s, but water levels have substantially recovered since mining ceased (see Figure 6 in Kelley et al. 1980, for a 1979 potentiometric contour map). Figures 9–2 and 9–3 show two interpretations of the potentiometric surface for the Westwater Canyon Member in the San Juan basin.

Ground water within this deep system moves through the Roca Honda permit area. RHR has completed three deep monitor wells in the Westwater Canyon Member within the Roca Honda permit area. The water level elevations measured in these wells indicates that the ground water system within that aquifer is continuous with the system in the Westwater Canyon Member in the southern San Juan basin. The projected potentiometric surface for the Westwater Canyon Member in the Roca Honda/San Mateo area as constructed from available data is shown in Figure 9–4. The potentiometric surface in the Westwater Canyon Member through the Roca Honda permit area is shown in the cross sections in Section 7.0, Geology (Figures 7–8 and 7–10).

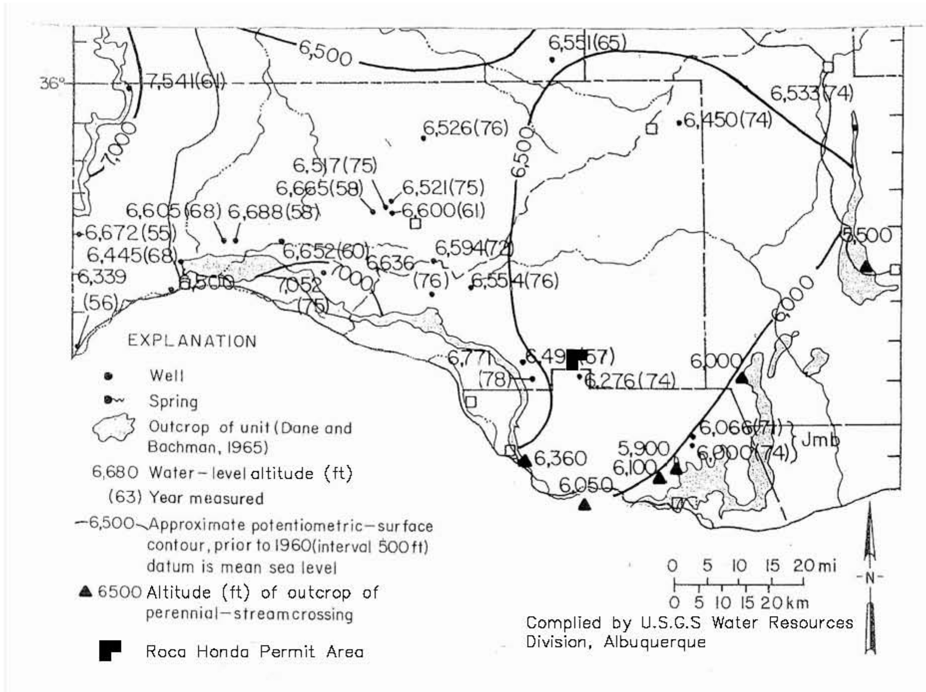


*Figure 9-2. Water-Level Elevations and Potentiometric Surface for Westwater Canyon Member in the Southern Portion of the San Juan Basin*

*(Modified from Stone et al. 1983, Figure 72)*

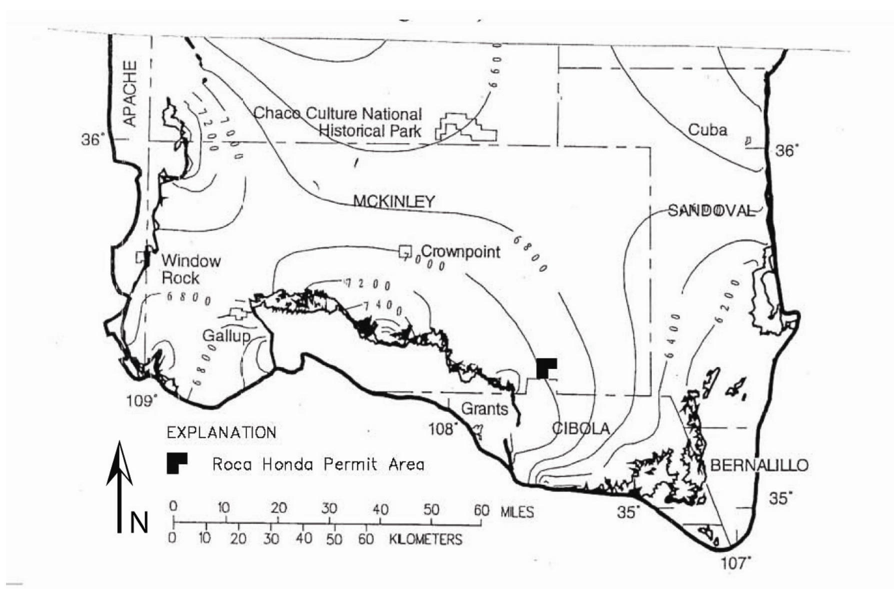


*Figure 9-3. Simulated Steady-State Head in the Westwater Canyon Member*

*(Modified from Kernodle 1996, Figure 52)*

#### 9.1.2.2 Gallup Sandstone

The Gallup Sandstone is present in the subsurface within the permit area. Ground water moves though the Gallup Sandstone in a confined system separate from the deep aquifer system, although an unknown amount of inter-formation movement of ground water may occur. Dam (1995) and Kernodle (1996) show the potentiometric surface of the Gallup Sandstone that indicates flow to the east-northeast in the Roca Honda/San Mateo area. An irrigation well recently drilled by the Lee Ranch may produce partially from the Gallup Sandstone in the Roca Honda/San Mateo area. Few water level or water quality data are available for the Gallup Sandstone in this area. Figure 9–5 shows the water level elevation, potentiometric surface, and outcrop areas for the Gallup Sandstone in the San Juan basin as interpreted by Stone et al. (1983).

#### 9.1.2.3 Point Lookout Sandstone

The Point Lookout Sandstone is present at the surface within the Roca Honda permit area (see Figure 7–3 “Geologic Map of the Roca Honda Permit Area,” in Section 7.0, Geology). It is probably not saturated in most areas, but functions as a recharge zone on the eastern side of the Fernandez monocline and an aquifer in the vicinity of the community of San Mateo.

Ground water moves eastward through sandstones of the Point Lookout Sandstone under both unconfined and confined conditions. Recharge enters the fractured sandstones along San Mateo Creek, where the stream flows over the outcrops and along the Fernandez monocline, where the formation crops out extensively (see Figure 7–3, Section 7.0, Geology). As ground water within the Point Lookout Sandstone moves eastward, it is confined by the overlying Menefee Formation. Figure 9–6 shows the water-level elevation and potentiometric surface for the Point Lookout Sandstone in the San Juan basin.

#### 9.1.2.4 Menefee Formation and Alluvium

Unconfined aquifer systems are also present in the Roca Honda/San Mateo area, both in the alluvium of San Mateo Creek stream bed and in the Menefee Formation. The Menefee Formation is present only in a small area of the Roca Honda permit area and is probably unsaturated. The alluvium of San Mateo Creek is not present in the permit area. The water tables within these aquifers conform to area topography rather than geologic structure and are therefore closely related to surface drainages (Brod and Stone 1981). Although Menefee Formation strata dip eastward into the McCartys syncline like the underlying rocks, ground water within it follows the topography and moves westward generally parallel to San Mateo Creek rather than eastward down the dip of geologic strata. Ground water in the Menefee Formation is recharged from infiltration at San Mateo Creek, from mountain front recharge along the flank of Mount Taylor, and from precipitation on outcrops. East of the community of San Mateo, ground water in the Menefee Formation appears to have a slight confined head, probably caused by mountain-front recharge and the presence of shale and silt within the formation which impede vertical movement of ground water and cause local confined and perched conditions. As ground water moves westward through the Menefee Formation, unconfined conditions prevail and the potentiometric surface merges with the unconfined surface of the stream bed alluvium. Water level elevation and the projected water table in the Menefee Formation are shown in Figure 9–4. The stream bed alluvium contains an unconfined aquifer fed by the flow of San Mateo Creek, which flows westward over the Menefee Formation, losing water to that formation (Brod and Stone 1981). In some areas on the flats west of the community of San Mateo, the stream and

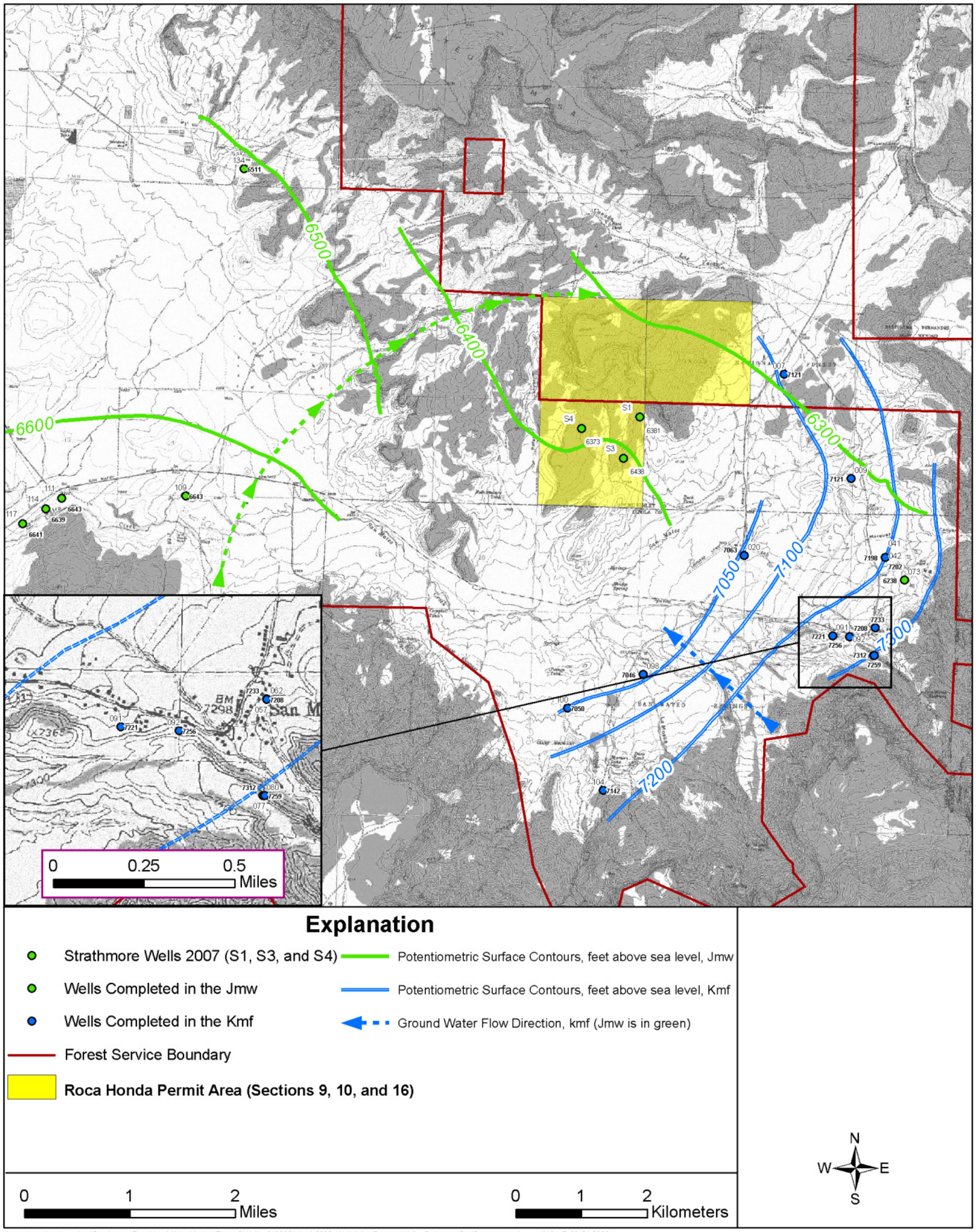


*Figure 9-4. Roca Honda/San Mateo Area Wells with Menefee Formation and Westwater Canyon Member of the Morrison Formation Potentiometric Surfaces*

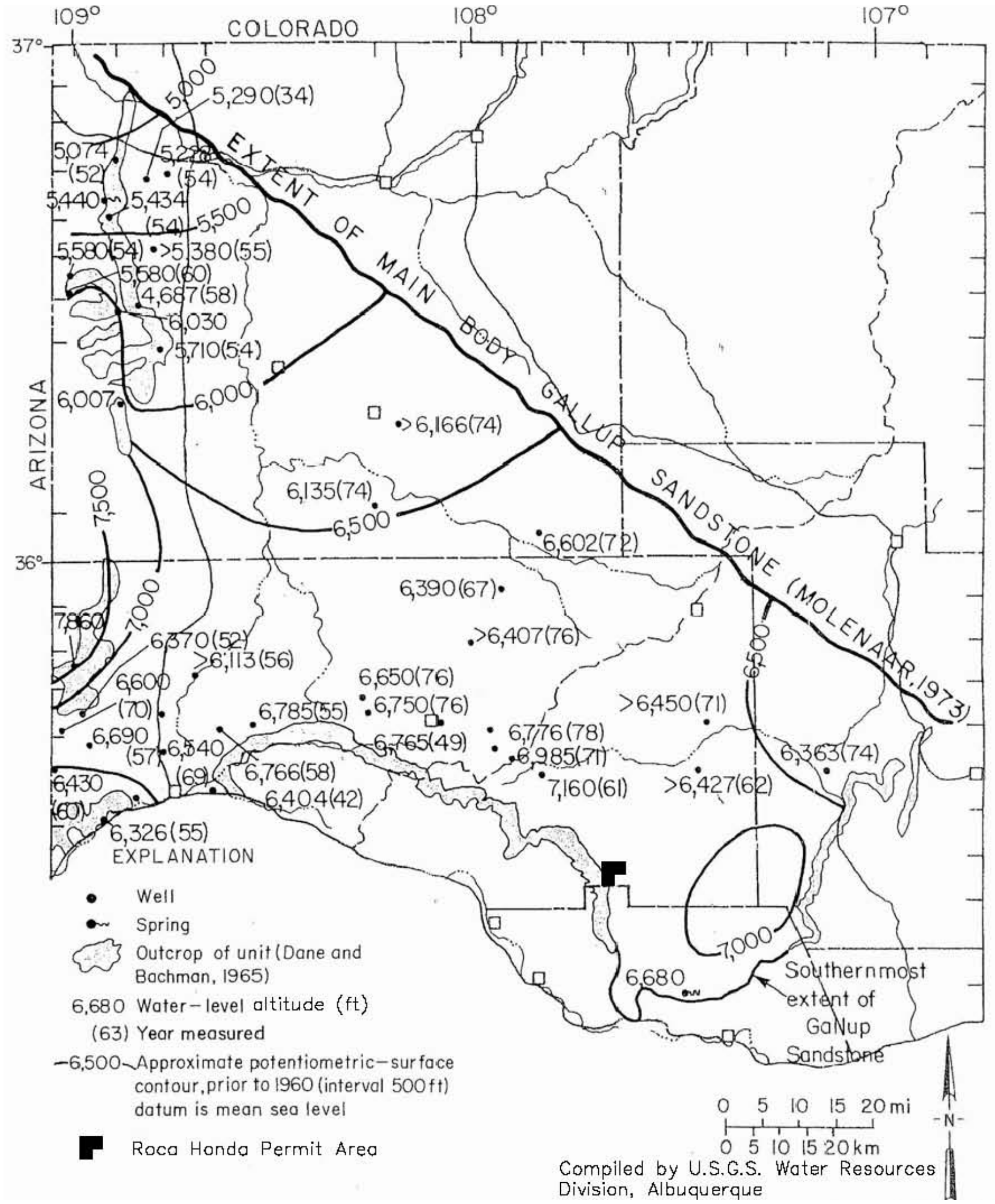


*Figure 9-5. Regional Water Level Elevations and Potentiometric Surface for Gallup Sandstone (Modified from Stone et al. 1983, Figure 59)*

unconfined aquifer may be locally perched on the Menefee Formation shales. It appears that where San Mateo Creek crosses the outcrop contact between the Menefee Formation and the more permeable fractured sandstones of the Point Lookout Sandstone a few miles west of the community of San Mateo, the stream loses flow and becomes intermittent (see Figure 8–6 in Section 8.0, "Surface Water"). The stream infiltration is probably a major source of recharge to the Point Lookout Sandstone.

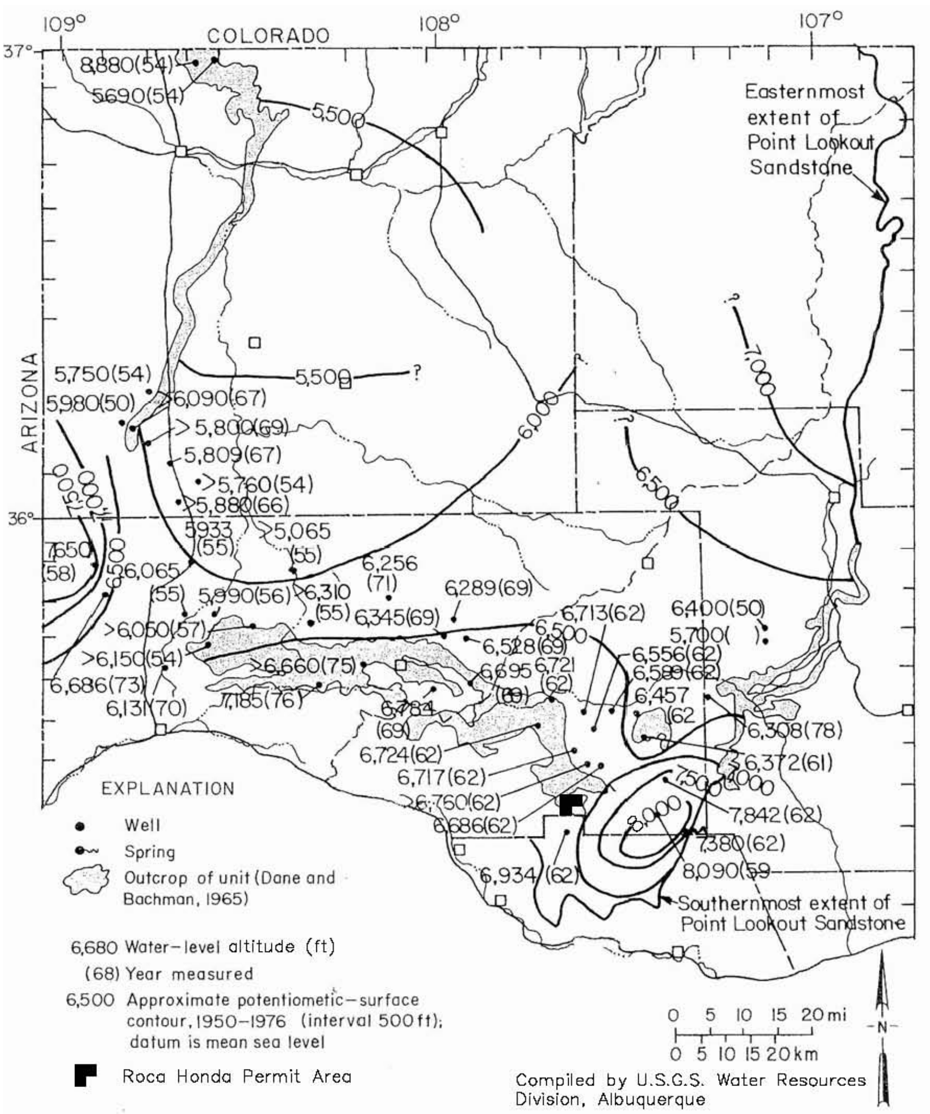


*Figure 9-6. Water Level Elevations and Potentiometric Surface for Point Lookout Sandstone (Modified from Stone et al. 1983, Figure 51)*

### 9.1.3 Aquifer Characteristics in Permit Area

Geologic formations that function as aquifers within the Roca Honda/San Mateo area are discussed below and the terminology follows that of the geology section presented earlier (Figure 7–4, Section 7.0, Geology). Descriptions of the physical nature, hydraulic characteristics, and typical ground water quality are readily available in published and unpublished reports. Reports that contain data or information specific to the Roca Honda/San Mateo area include: Cooper and John (1968), NMEI (1974), Brod and Stone (1981), GMRC (1979a), RGRC (1994), and Metric (2005a). The hydraulic parameters of all the aquifers are heterogeneous and anisotropic, meaning that they are spatially and directionally variable.

In the Roca Honda/San Mateo area, aquifers are the Westwater Canyon Member of the Morrison Formation, Dakota Sandstone, Gallup Sandstone, Point Lookout Sandstone, Menefee Formation, and the San Mateo Creek alluvium. The Westwater Canyon Member is regionally an important aquifer in the San Juan basin, but east of the R8W line and within T13N, the Westwater Canyon Member is too deep to be targeted by local wells. The principal locally used aquifers within the

Roca Honda/San Mateo area are the Menefee Formation and the Point Lookout Sandstone. Some wells also produce from stream valley alluvium. The Dalton Sandstone Member of the Crevasse Canyon Formation is not relied on as an aquifer within the area, but supplies poor quality water to a stock well northeast of San Mateo Mesa (Brod and Stone 1981). There are no production wells from any aquifers within the Roca Honda permit area.

The available water quality analyses of ground water from the alluvium, Menefee Formation, Point Lookout Sandstone, and Westwater Canyon Member of the Morrison Formation are presented in Tables 9–1 through 9–8 located in the discussion section for each respective formation that follows. These tables generally provide information on ground water quality from the 1960s and 1970s within approximately 5 miles of the Roca Honda permit area. The precision, accuracy, and comparability of the data are commonly unclear because information is not available about well construction, sampling methods, or laboratory analytical methods. Nevertheless, the data can be considered a good general indication of background water quality. Supplemental ground water sampling and analysis is needed to characterize baseline conditions, and sampling will be implemented to obtain ground water quality data with known levels of precision, accuracy, and comparability.

Except for stream bed alluvium, the geologic units in the Roca Honda/San Mateo area crop out or are in the shallow subsurface of the three-section Roca Honda permit area (Sections 9, 10 and 16). The Menefee Formation, Point Lookout Sandstone, and Crevasse Canyon Formation are not everywhere saturated within the permit area. Figure 7–3 (Section 7.0, “Geology”) shows where these units crop out in the permit area.

Water level data collected from three monitor wells drilled by RHR into the Westwater Canyon Member in the permit area indicate that the potentiometric surface within that unit beneath the permit area is continuous with the potentiometric surface in the Westwater Canyon Member in the southeastern San Juan structural basin. It is expected that the hydraulic characteristics and ground water quality within the aquifers beneath the permit area will be within the same range as those encountered in the same geologic units in the southeastern portion of the basin, an area which includes the Ambrosia Lake and Roca Honda/San Mateo areas. Within the Roca Honda permit area, northwest-striking faults related to the San Rafael fault zone and strain features over the crest of the San Mateo dome may have increased hydraulic conductivity in that direction. Detailed information on the aquifers within the Roca Honda permit area is presented below from shallowest to deepest.

#### *9.1.3.1 Alluvium*

Quaternary alluvial material overlies bedrock throughout the San Mateo Creek valley, and although it probably accepts and transmits ground water from precipitation to underlying bedrock units, it is most likely unsaturated except near San Mateo Creek. San Mateo Creek alluvial materials consist of unconsolidated sands and silts. Well logs indicate this material is from 10 to 80 ft thick although it may be significantly thicker in some areas (OSE 2008). A few wells produce solely from the alluvium, but most also penetrate the underlying Menefee Formation.

Ground water in stream bed alluvium is under unconfined conditions, and the depth to water is typically a few tens of feet. The stream bed alluvium is recharged by San Mateo Creek, which receives flow from precipitation and runoff from Mount Taylor. The stream bed aquifer loses water to sandstone layers in the underlying Menefee Formation, but because the Menefee Formation contains a significant amount of shale and siltstone (65 percent), the unconfined aquifer may be semi-perched in some areas (GMRC 1979b). GMRC speculated that the many springs within the valley may represent local unconfined or perched ground water conditions caused by impermeable shale or siltstone units that interrupt vertical infiltration and force water horizontally to valley walls. A few miles west of the community of San Mateo, San Mateo Creek usually disappears into the alluvium and the fractured sandstones of the Point Lookout Sandstone.

Aquifer tests conducted in San Lucas Canyon as part of GMRC's pipeline and mill siting investigations indicated that the transmissivity of the stream bed alluvium was 708 to 1,450 $ft^2$/day, and hydraulic conductivity was 27 ft/day (Hydro-Search, Inc., and Jacobs Engineering Group, Inc. 1979). The stream bed alluvium of San Mateo Canyon probably exhibits similar values. It is expected that the permeabilities will be less than those of other stream bed deposits composed of sandier source materials because the stream bed alluvium within San Mateo and San Lucas Canyons was derived from bedrock formations composed largely of shale and siltstone.

Water is of the sodium-bicarbonate-sulfate type with total dissolved solids (TDS) of 500 mg/L in the upper portion of the canyon (Brod and Stone 1981). The TDS concentration is much higher, reaching as much as 14,000 mg/L, below the confluence of San Mateo Creek and Arroyo del Puerto. Tables 9–1 and 9–2 show analyses of major and minor chemical constituents, respectively, in ground water samples from a well producing from the alluvium.

#### *9.1.3.2 Menefee Formation*

The Menefee Formation has been removed by erosion and does not crop out in the Roca Honda permit area or in the western part of the San Mateo Creek valley. It is present only in the extreme eastern part of the permit area beneath colluvium in the southeast part of Section 10. The formation is preserved east of the Fernandez monocline in the McCartys syncline. The formation crops out in places in the San Mateo Creek valley around the community of San Mateo.

The Menefee Formation is the uppermost unit of the Mesaverde Group present in the Roca Honda permit area. It is composed of shales interbedded with thin to thick sandstones and minor coal seams. The fine-grained, fluvial sandstone units constitute the aquifer beds. Logs from Mount Taylor mine wells indicate that the thickness of the Menefee Formation is 767 ft in that area (RGRC 1994). Logs for domestic wells indicate that in the upper San Mateo Creek Valley, the Menefee Formation lies at the surface or under a veneer of alluvial material, and the thickness of the Menefee Formation penetrated was several hundred feet (most of the wells did not penetrate the entire thickness of Menefee Formation).

Ground water is present within the Menefee Formation under slightly confined conditions in the area of the community of San Mateo and unconfined conditions a few miles to the west. The depth to water ranges from a few feet along the western outcrop area to several hundred feet in the community of San Mateo area. As shown on Figure 9–4, the movement of ground water within the Menefee Formation is topographically controlled. Ground water in the Menefee Formation moves westward through the formation, parallel to San Mateo Creek at a gradient of 150 ft per mile. Ground water from San Mateo Creek recharges the Menefee Formation in some areas. Ground water in the Menefee Formation probably moves laterally into the Point Lookout Sandstone at the outcrop contact between the units and downward into the Point Lookout Sandstone in the subsurface.

*Table 9-1. Major Water Quality in Alluvium*

| Roca Honda/San Mateo Area Ground Water Major Constituent Quality Data for Alluvium (mg/L unless otherwise specified) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WELL LOCATION | | | | | | | | | | | | | | | | | | | | | | | |
| Well ID # | Township (N) | Range (W) | Section | 1/4 1/4 1/4 | Data Source | Sample Date | Specific conductance (µmhos) | pH (s.u.) | Temp. °C | Hardness (mg/L as $CaCO_3$) | Alkalinity (as $CaCO_3$) | Ca (dissolved) | Mg | Na (dissolved) | K (dissolved) | Bicarbonate as $HCO_3$ | Sulfate as $SO_4$ | Cl | F | Silica as $SiO_2$ | Nitrogen Nitrate as $NO_3$ | TDS |
| 131 | 14 | 8 | 25 | 212 | DE | 10/23/1979 | 1,010 | 8 | 11.9 | | | 75 | 69 | 70 | 1.7 | 454 | 202 | 18 | 0.8 | | 0.09 | 672 |

µmhos = micromhos
s.u. = standard units
**References:**
A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper and John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

*Table 9-2. Minor Water Quality in Alluvium*

| Roca Honda/San Mateo Area Ground Water Minor Constituent Quality Data for Alluvium (mg/L unless otherwise specified) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID # | Township (N) | Range (W) | Section | 1/4 1/4 1/4 | Data Source | Sample Date | Ba | B | Se | Zn | Cu | Pb | As | Cr | Co | Mn | Fe | Cd | Ni | Mo | Hg | Ag | Al | Gross Alpha (pCi/L) | Ra-226 (pCi/L) | Ra-228 (pCi/L) | U (pCi/L) |
| 131 | 14 | 8 | 25 | 212 | DE | 10/23/1979 | 0.9 | 0.15 | <0.002 | 250 | 10 | 20 | <10 | <20 | <10 | 550 | 100 | <5 | <20 | <50 | <2 | <5 | 200 | <5 | 0.06±0.03 | <1 | <0.013 |

s.u. = standard units
References:
A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper and John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
Fa Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

The Menefee Formation is a sufficiently productive aquifer for domestic and stock purposes within the upper San Mateo Creek valley, and a number of wells within the valley reportedly produce from the Menefee Formation. Production is small, probably from discrete sandstone beds, but the depth to water is relatively shallow and in this area the ground water quality is good. Brod and Stone (1981) estimated that the maximum yield of wells producing from the Menefee Formation is less than 0.05 cfs (22 gpm). They report that the water is of sodium-bicarbonate type and that the TDS concentration ranges from 179 to 1,400 mg/L with an average of 400 mg/L. Tables 9–3 and 9–4 present reported analyses of major and minor chemical constituents, respectively, in ground water samples from wells producing from the Menefee Formation.

GMRC performed aquifer tests using the pilot hole for the Mount Taylor mine shaft and, though the Menefee Formation was not tested, it was concluded that it probably had transmissivity and hydraulic conductivity values similar to the Point Lookout Sandstone which, within the San Lucas Canyon area, was determined to have a hydraulic conductivity of 3.7 ft/day (Hydro-Search, Inc. and Jacobs Engineering Group, Inc. 1979). Stone et al. (1983) noted that the transmissivity of the Menefee Formation as calculated in aquifer tests depends largely on the total thickness of the sandstone units penetrated. They reported a range of transmissivity values for the Menefee Formation from 10 to 100 $ft^2$/day.

*9.1.3.3 Point Lookout Sandstone*

The Point Lookout Sandstone underlies the Menefee Formation and is another unit of the Upper Cretaceous Mesaverde Group. The Point Lookout Sandstone is a very fine- to medium-grained sandstone with thin interbeds of dark shale in the lower part (Craigg 2001). In the Roca Honda permit area, the sandstone is dense, with low primary permeability. Logs from Mount Taylor mine wells indicate that the Point Lookout Sandstone in that area consists of two sandstone units, each 115 ft thick, separated by the Satan Tongue of the Mancos Shale (RGRC 1994). Within the middle San Mateo Valley, the Point Lookout Sandstone crops out in a northeast-striking band about 2 miles west of the community of San Mateo. This outcrop band along the Fernandez monocline passes through Sections 9 and 10 of the Roca Honda permit area. The formation dips eastward beneath the Menefee Formation.

Ground water moves eastward through sandstones of the Point Lookout Sandstone under both unconfined and confined conditions. Recharge enters the fractured sandstone along San Mateo Creek where it flows over the outcrops, along the Fernandez monocline where the formation crops out extensively, and probably from inter-formation movement of ground water from the Menefee Formation. Well and water level data indicate that as ground water within the Point Lookout Sandstone moves downdip eastward, it becomes confined. There are insufficient data to create a potentiometric surface for the Point Lookout Sandstone in the immediate vicinity of the permit area.

The Point Lookout Sandstone is an aquifer in the area of the community of San Mateo, probably because fracturing and faulting has enhanced permeability. The Point Lookout Sandstone is reported to yield up to 0.1 cfs (50 gpm) to wells, though smaller rates are more common. The quality of the ground water in the Point Lookout Sandstone is sodium bicarbonate, similar to that of the Menefee Formation, and contains from 200 to 700 mg/L TDS concentration (Brod and Stone 1981). Tables 9–5 and 9–6 present analyses of major and minor chemical constituents, respectively, in ground water samples from wells producing from the Point Lookout Sandstone. The Point Lookout Sandstone is present at the surface within the Roca Honda permit area (see

*Table 9-3. Major Water Quality in Menefee Formation Wells*

| Roca Honda/San Mateo Area Ground Water Major Constituent Quality Data For Menefee Formation (mg/L unless otherwise specified) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID # | Township (N) | Range (W) | Section | 1/4 1/4 1/4 | Data Source | Sample Date | Specific conductance (µmhos) | pH (s.u.) | Temp °C | Hardness (mg/L as $CaCO_3$) | Alkalinity (as $CaCO_3$) | Ca (dissolved) | Mg | Na (dissolved) | K (dissolved) | Bicarbonate as $HCO_3$ | Sulfate as $SO_4$ | Cl | F | Silica as $SiO_2$ | Nitrogen Nitrate as $NO_3$ | TDS |
| 4 | 13 | 8 | 1 | 23 | DE | 10/16/1979 | 1,050 | 8.3 | 14.4 | | | 30 | 10 | 200 | 3.3 | 460 | 50 | 65 | 3.8 | | 0.62 | 625 |
| | | | | | I | 3/10/1978 | 960 | | | | | 4 | 17.8 | 89 | 4.6 | 386 | 90.5 | 19 | | | 0 | 494 |
| 9 | 13 | 8 | 14 | 422 | AI | 10/11/1972 | 2,123 | 7.61 | | | | 78.6 | 36 | 350 | 4.6 | 514.9 | 430 | 18.1 | 0.5 | 11.1 | 1.45 | 1,445 |
| 8 | 13 | 8 | 14 | 422 | C | 3/10/1976 | | 8.6 | | 20 | | 5.4 | 1.6 | 370 | 1.7 | 456 | 277 | 12 | 4.5 | | | 476 |
| 10 | 13 | 8 | 17 | 223 | I | 8/23/1977 | 1,100 | | | | | 29 | 22 | 170 | 5.5 | 254 | 289 | 7.3 | | | 2.9 | 669 |
| 20 | 13 | 8 | 22 | 242 | AC | 10/18/1972 | 332 | 7.86 | | | | 6.1 | 2.1 | 60 | 1.3 | 217.2 | 8 | 4 | 0.56 | 24.8 | 0.02 | 324 |
| | | | | | C | 3/9/1976 | | 8.2 | | 20 | | 5.6 | 1.4 | 81 | 1.2 | 172 | 6.9 | <2 | 0.62 | | | 222 |
| | | | | | C | Dec-76 | | 7.8 | | 31 | | 5.5 | 1.9 | 75 | <2 | 202 | 9 | | 1.2 | | | 189 |
| | | | | | I | Aug-77 | 360 | | | | | 7 | 1.7 | 76 | 1.5 | 207 | 22 | 4.9 | | 22 | 0.8 | 240 |
| 26 | 13 | 8 | 23 | 324 | I | 2/9/1978 | 460 | | | | | 45 | 3.2 | 21 | 3.3 | 188 | | 5 | | | 0 | 172 |
| 31 | 13 | 8 | 23 | 431 | A | 10/17/1972 | 315 | 7.38 | | | | 42.3 | 6.4 | 20 | 3.4 | 197.7 | 9.5 | 8 | 0.32 | 70.8 | 0.03 | 358 |
| | | | | | C | 3/9/1976 | | 7.4 | | 113 | | 41 | 4.9 | 20 | 2.8 | 136 | 12 | 8 | 0.22 | | | 214 |
| | | | | | C | Dec-76 | | 7.2 | | 153 | | 49 | 8.1 | 25 | 3.6 | 226 | 20 | | 0.64 | | | 253 |
| | | | | | I | Feb-78 | 310 | | | | | 40 | 6.1 | 20.1 | 3.3 | 188 | | 0.14 | | | 0 | 169 |
| 42 | 13 | 8 | 24 | 141 | I | 2/21/1978 | 1,150 | | | | | 3 | 0.8 | 268 | 1.1 | 431 | 185 | 6 | | | 0 | 680 |
| 41 | 13 | 8 | 24 | 141 | C | 3/9/1976 | | 8.8 | | 11 | | 3.4 | 0.97 | 270 | 1.3 | 300 | 199 | 8 | 1.3 | | | 702 |
| | | | | | I | 3/9/1978 | 880 | | | | | 1.2 | 0.4 | 206 | 1.1 | 385 | 99 | 4 | | | 0.1 | 510 |
| 45 | 13 | 8 | 24 | 144 | C | 3/9/1976 | | 8.4 | | 16 | | 5.1 | 1.4 | 165 | 1.2 | 363 | 82 | 3 | 1.7 | | | 534 |
| | | | | | C | Dec-76 | | 8.5 | | 9 | | 2.3 | 0.61 | 220 | 0.82 | 380 | 99 | | 2.2 | | | 513 |
| 48 | 13 | 8 | 24 | 223 | AB | 9/10/1962 | 836 | 9 | 13.8 | | | 1.6 | 0 | 206 | 0.9 | 379 | 70 | 4.2 | | 12 | 0.4 | 674 |
| | | | | | A | 10/17/1972 | 800 | 8.75 | | | | 3 | 0.5 | 190 | 0.9 | 417.3 | 48.5 | 12 | 1.7 | 13 | 0.11 | 685 |
| | | | | | C | 3/9/1976 | | 8.9 | | 4 | | 1.1 | 0.17 | 205 | 0.71 | 250 | 69 | 6 | 1.7 | | | 478 |
| | | | | | C | Dec-76 | | 7.8 | | 63 | | 9.7 | 2.8 | 300 | 1.4 | 552 | 165 | | 4 | | | 731 |
| 56 | 13 | 8 | 24 | 334 | I | 2/9/1978 | 790 | | | | | 26.4 | 9.2 | 154 | 1.5 | 365 | 96 | 18 | | | 0 | 448 |
| 57 | 13 | 8 | 24 | 334A | I | 2/9/1978 | 1,000 | | | | | 74 | 25 | 131 | 1.5 | 381 | 169 | 42 | | | 13 | 647 |
| 58 | 13 | 8 | 24 | 342 | C | 3/9/1976 | | 7.9 | | 65 | | 19 | 4.4 | 165 | 1.4 | 285 | 104 | 5 | 0.73 | | | 462 |
| 58 | 13 | 8 | 24 | 342 | C | 3/10/1976 | | 7.9 | | 65 | | 18 | 4.4 | 165 | 1.4 | 267 | 104 | 10 | 0.71 | | | 978 |
| 91 | 13 | 8 | 26 | 221 | AI | 10/24/1972 | 964 | 8.25 | | | | 3.1 | 0.9 | 258 | 1.3 | 654 | 9.9 | 8 | 3 | 17.5 | 0.27 | 953 |
| 89 | 13 | 8 | 26 | 221 | I | Jul-76 | 729 | | | | | 54 | 27 | 74 | 3.1 | 375 | 71 | 10 | | | 1.4 | 460 |
| 92 | 13 | 8 | 26 | 222 | I | 2/21/1978 | 450 | | | | | 55 | 9.5 | 27 | 5.4 | 244 | 37 | 8 | | | 0.65 | 265 |
| 98 | 13 | 8 | 27 | 133 | I | 8/22/1977 | 850 | | | | | 4 | 1.4 | 205 | 2 | 502 | 1.1 | 15 | | | | 531 |
| 133 | 14 | 8 | 25 | 212 | DE | 10/13/1979 | 2,970 | 7.5 | 13.8 | | | 205 | 73 | 460 | 15 | 785 | 1,120 | 20 | 0.3 | | 0.13 | 2,299 |

s.u. = standard units

**References:**

A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper and John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

*Table 9-4. Minor Water Quality in Menefee Formation Wells*

**Roca Honda/San Mateo Area Ground Water Minor Constituent Quality Data For Menefee Formation**

| Well ID # | Town-ship (N) | Range (W) | Section | 1/4 1/4 1/4 | Data Source | Sample Date | Sr | Ba | B | Li | Si | Se | Zn | Cu | Pb | Bi | As | Cr | Co | Mn | Fe | Sb | Cd | Ni | Mo | Hg | Ag | Al | V | $PO_4$ | Gross Beta | Gross Alpha | Ra-226 | Th-230 | Ra-228 | U | Sr-90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | mg/L | pCi/L | pCi/L | pCi/L | pCi/L | pCi/L | mg/L | pCi/L |
| 4 | 13 | 8 | 1 | 23 | DE | 10/16/1979 | | 0.2 | 0.3 | | | <0.002 | 300 | 60 | 20 | | 10 | <20 | <10 | 20 | <10 | | <5 | <20 | <50 | <2 | <5 | 700 | | 2.01 | | <6 | 0.13±0.03 | | <1 | <0.006 | |
| 9 | 13 | 8 | 14 | 422 | A | 10/11/1972 | 1.5 | <1 | 1.2 | 0.04 | 12 | | 30 | 3.1 | 2.6 | <0.5 | <0.5 | | <1 | 115 | 9,000 | <0.6 | 1.6 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| 8 | 13 | 8 | 14 | 422 | C | 3/10/1976 | | <0.5 | 0.73 | | | <0.005 | 20 | 30 | 40 | | <10 | <5 | | 80 | 6,900 | | 2 | | | | <2 | | | | | | | | | <0.002 | |
| 20 | 13 | 8 | 22 | 242 | AC | 10/18/1972 | <0.2 | <1 | <0.1 | 0.03 | 17 | | 60 | 5.9 | <0.25 | <0.5 | 13 | | <1 | 3 | 132 | <0.6 | 1.9 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| | | | | | C | 3/9/1976 | | <0.3 | 0.1 | | | | 30 | <5 | 10 | | <10 | 40 | | 8 | 640 | | <2 | | | | <5 | | | | | | | | | <0.002 | |
| | | | | | C | Dec-76 | | 0.5 | 0.1 | | | | 30 | <5 | <10 | | <10 | <5 | | <2 | 30 | | <2 | | | | <2 | | | | | | | | | 0.005 | |
| 26 | 13 | 8 | 23 | 431 | A | 10/17/1972 | 0.5 | <1 | <0.1 | 0.03 | 33 | | 138 | 30 | 1.4 | <0.5 | <0.5 | | <1 | 0.8 | 90 | <0.6 | 3 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| | | | | | C | 3/9/1976 | | <0.5 | <0.1 | | | <0.005 | 170 | <5 | <10 | | <1 | <5 | | <2 | 40 | | <2 | | | | <2 | | | | | | | | | <0.002 | |
| | | | | | C | Dec-76 | | <0.5 | 0.1 | | | <0.005 | 240 | 10 | 20 | | <10 | <5 | | <2 | 100 | | <2 | | | | <2 | | | | | | | | | 0.004 | |
| 41 | 13 | 8 | 24 | 141 | C | 3/9/1976 | | <0.5 | 0.31 | | | <0.005 | 220 | <5 | 10 | | <10 | <5 | | 20 | 490 | | <2 | | <10 | | <2 | | <1 | | | | | | | 0.002 | |
| 41 | 13 | 8 | 24 | 141 | C | 3/9/1976 | | <0.1 | 0.3 | | | <0.01 | 370 | <3 | <1 | | <10 | 9 | | 24 | 800 | | <1 | | 2 | | <1 | | <10 | | | | | | | 0.0053 | |
| 45 | 13 | 8 | 24 | 144 | C | 3/9/1976 | | <0.5 | 0.42 | | | <0.005 | 80 | <5 | 90 | | <190 | <5 | | 10 | 200 | | <2 | | 50 | | <2 | | <1 | | 2±9 | 2.3±2.0 | 0.1±0.2 | 0.0±0.4 | | <0.002 | |
| | | | | | C | Dec-76 | | <0.5 | 0.3 | | | <0.005 | 60 | <10 | 10 | | <10 | <5 | | 8 | 150 | | <2 | | <10 | | <2 | | <2 | | 6±10 | 0.9±1.5 | 0.0±0.2 | 0.0±0.1 | 2±3 | 0.004 | |
| 48 | 13 | 8 | 24 | 223 | AB | 9/10/1962 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | A | 10/17/1972 | <0.2 | <1 | 0.7 | 0.03 | 11 | | 30 | 7.6 | <0.25 | <0.5 | <0.5 | | <1 | 2.4 | 170 | <0.6 | 0.5 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| | | | | | C | 3/9/1976 | | <0.5 | 0.5 | | | <0.005 | 40 | <5 | <10 | | <10 | <5 | | 5 | 60 | | <2 | | | | <2 | | | | | | | | | <0.002 | |
| | | | | | C | Dec-76 | | <0.5 | 0.4 | | | <0.005 | 1,000 | 30 | 30 | | 30 | <5 | | 7 | 330 | | <2 | | | | <2 | | | | | | | | | <0.002 | |
| 62 | 13 | 8 | 24 | 334B | AB | 9/10/1962 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | C | 3/9/1976 | | <0.5 | 0.2 | | | <0.005 | 80 | <5 | 10 | | <10 | <5 | | 5 | 30 | | <2 | | | | <2 | | | | | | | | | 0.002 | |
| | | | | | C | Dec-76 | | <0.5 | 0.2 | | | <0.005 | 350 | 50 | 90 | | <10 | <5 | | <2 | 50 | | <2 | | | | <2 | | | | | | | | | 0.008 | |
| 58 | 13 | 8 | 24 | 342 | C | 3/9/1976 | | <0.5 | 0.11 | | | <0.005 | 150 | 20 | | | <10 | <5 | | 20 | 170 | | <2 | | | | <2 | | | | | | | | | <0.002 | |
| 58 | 13 | 8 | 24 | 342 | C | 3/10/1976 | | <0.5 | 0.13 | | | <0.005 | 170 | 20 | 10 | | <10 | <5 | | 30 | 270 | | <2 | | | | <2 | | | | | | | | | <0.002 | |
| 68 | 13 | 8 | 24 | 412 | C | 8/26/1976 | | 0.4 | 0.2 | | | | 4 | ? | <1 | | <10 | <1 | | 13 | 129 | | <1 | | <1 | | | | | | 0±1 | | 3.62±1.29 | | 3.7±1.8 | | 0±0.3 |
| 80 | 13 | 8 | 25 | 114 | A | 10/11/1972 | <0.2 | <1 | <0.1 | 0.03 | 16 | | 295 | 24 | 8.4 | <0.5 | <5 | | <1 | 1 | 1,550 | <0.6 | 6.4 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| 91 | 13 | 8 | 26 | 221 | AB | 9/11/1962 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | A | 10/24/1972 | <0.2 | <1 | 1.3 | 0.03 | 20 | | 740 | 120 | 2.5 | <0.5 | 26 | | <1 | 35 | 4,300 | <0.6 | 3.8 | <1 | <3 | <1 | | | | | <0.02 | | | | | | |
| 133 | 14 | 8 | 25 | 212 | DE | 10/13/1979 | | 1 | 0.85 | | | <0.002 | 620 | 20 | 30 | | <10 | <20 | <10 | 530 | 170 | | <5 | <20 | <50 | <2 | <5 | 100 | | | | <7 | 2.9±0.03 | | <1 | <0.006 | |

**References:**

A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper & John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

Figure 7–3, Section 7.0, Geology). It is probably not saturated within the permit area, but may capture recharge on the eastern side of the Fernandez monocline.

GMRC performed aquifer tests using the pilot hole for the Mount Taylor mine shaft, and found the Point Lookout Sandstone to have a transmissivity of 200 $ft^2$/day and a hydraulic conductivity of 1.5 ft/day (Brod and Stone 1981). Within the San Lucas Canyon area, the Point Lookout Sandstone was determined to have a hydraulic conductivity of 3.7 ft/day (Hydro-Search, Inc., and Jacobs Engineering Group, Inc. 1979). Stone et al. (1983) reported that a test by Dames and Moore northeast of Crownpoint gave a transmissivity of about 240 $ft^2$/day for the main body of the Point Lookout Sandstone and a transmissivity of about 70 $ft^2$/day for the Hosta Sandstone Tongue.

*9.1.3.4 Crevasse-Canyon Formation*

A unit of the Mesaverde Group, the Crevasse Canyon Formation is divided into three members, in descending order: the Gibson Coal, the Dalton Sandstone, and the Dilco Coal (Stone et al. 1983). The Dalton Sandstone Member is the most permeable unit and consists of interbedded sequences of lenticular sandstone, siltstone, shale, and claystone with carbonaceous shale and coal common in the lower and upper parts (Craigg 2001). In the area of the community of San Mateo, the Dalton Sandstone Member is generally a clean, white to buff, massive fine- to medium-grained sandstone that is as much as 70 ft thick (NMEI 1974). The unit lies approximately 500 feet below land surface in the San Mateo Creek valley, and wells in that area do not appear to produce from the Dalton Sandstone Member, probably because sufficient water is available in the shallower Menefee Formation and the Point Lookout Sandstone. The Gibson Coal and Dilco Coal Members contain more coal and shale, and are less permeable. NMEI (1974) reports that the Dilco Coal Member is about 90 ft thick and the Gibson Coal Member is about 165 ft in the area of the Mount Taylor mine.

The Dalton Sandstone is exposed in Sections 9 and 16 of the Roca Honda permit area along the Fernandez monocline, but is probably not saturated. There are insufficient data to contour the potentiometric surface in the Dalton Sandstone Member, but it is highly likely that ground water within it moves eastward where the formation is saturated.

Brod and Stone (1981) report that a stock well producing from the Dalton Sandstone Member northeast of San Mateo Mesa has sodium sulfate water with a TDS of 4,500 mg/L. Stone et al. (1983) report that in other parts of the San Juan basin, TDS concentrations in the Dalton Sandstone Member are approximately 2,000 mg/L.

Brod and Stone (1981) note that because of the lower concentration of matrix material, the sandstone units in the Dalton Sandstone Member can be expected to have a higher intergranular permeability than the Point Lookout Sandstone. Stone et al. (1983) report that the transmissivity of the Dalton Sandstone Member is probably less than 50 $ft^2$/day, and note that Dames and Moore reported a possible transmissivity range for the Dalton Sandstone Member of 10 to 30 $ft^2$/day (Stone et al. 1983). As part of its assessment of potential tailings impoundment sites, GMRC extensively evaluated the field permeability of the Dilco Coal Member in the area of La Polvadera Canyon and the area of the community of San Mateo. It was determined that the Dilco Coal Member had a weighted average permeability (hydraulic conductivity) of 4.43 ft/yr in La Polvadera Canyon and 5.3 ft/yr in the area of the community of San Mateo, with a range of 0 to 56 ft/yr. The transition zone between the Dilco Coal Member and the underlying Gallup Sandstone had a permeability range of 0 to 1,200 ft/yr (GMRC 1979a).

*Table 9-5. Major Water Quality in Point Lookout Sandstone Wells*

| Roca Honda/San Mateo Area Ground Water Major Constituent Quality Data for Point Lookout Sandstone (mg/L unless otherwise specified) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well ID #** | **Township (N)** | **Range (W)** | **Section** | **1/4 1/4 1/4** | **Data Source** | **Sample Date** | **Specific Conductance (micromhos)** | **pH (s.u.)** | **Temp. °C** | **Hardness (mg/L as $CaCO_3$)** | **Ca (dissolved)** | **Mg** | **Na (dissolved)** | **K (dissolved)** | **Bicarbonate as $HCO_3$** | **Sulfate as $SO_4$** | **Cl** | **F** | **Silica as $SiO_2$** | **Nitrogen Nitrate as $NO_3$** | **TDS** |
| 66 | 13 | 8 | 24 | 412 | C | 3/8/1976 | | 8.2 | | 24 | 6.4 | 1.8 | 78 | 1.3 | 174 | 6 | 2 | 0.63 | | | 276 |
| | | | | | C | Dec-76 | | 7.8 | | 26 | 5.5 | 2 | 75 | 1.3 | 197 | 7 | | 1.2 | | | |
| | | | | | C | Dec-76 | | 8.45 | | 64.4 | 5.11 | 1.84 | 89 | <0.1 | 176 | <1 | | 0.46 | | | |
| 78 | 13 | 8 | 25 | 114 | A | 10/11/1972 | 509 | 7.4 | | | 22.6 | 5.7 | 70.1 | 21.9 | 263.6 | 11.5 | 17 | 0.72 | 20.6 | 0.84 (total Nitrogen) | 434 |
| | | | | | C | 3/10/1976 | | 7.4 | | 149 | 44 | 10 | 44 | 2.7 | 184 | 40 | 16 | 0.4 | | | 320 |
| 90 | 13 | 8 | 26 | 221 | ABCI | 9/11/1962 | 808 | 8.1 | 13.8 | | 74 | 24 | 76 | 3 | 365 | 103 | 22 | | 14 | 14 (total Nitrogen) | 695 |
| 102 | 13 | 8 | 33 | 234 | C | 6/1/1972 | 730 | 8 | | 29 | 6.4 | 3.2 | 170 | 1.2 | 348 | 83 | 10 | | | | 490 |
| 103 | 13 | 8 | 33 | 234 | I | 8/2/1977 | 940 | | | | 2 | 0.4 | 218 | 4 | | 10 | 20 | | | 0 | 538 |
| 122 | 14 | 7 | 34 | | E | Mar-July, 1979 | | 7.1 | | 260 | 130 | 41 | 64 | 3 | | 400 | 6.7 | 0.79 | 7.3 | <0.1 (N) | 850 |
| 132 | 14 | 8 | 25 | 212 | DE | 10/18/1979 | 909 | 7.9 | 14.7 | | 75 | 27 | 109 | 3 | 419 | 156 | 10 | 0.2 | | 0.04 | 595 |

μmhos = micromhos
s.u. = standard units
**References:**
A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper and John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

*Table 9-6. Minor Water Quality in Point Lookout Sandstone Wells*

| Roca Honda/San Mateo Ground Water Minor Constituent Quality Data for Point Lookout Sandstone | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well ID #** | **Town-ship (N)** | **Range (W)** | **Section** | **1/4 1/4 1/4** | **Data Source** | **Sample Date** | **Ba** | **B** | **Si** | **Se** | **Zn** | **Cu** | **Pb** | **As** | **Cr** | **Co** | **Mn** | **Fe** | **Cd** | **Ni** | **Mo** | **Hg** | **Ag** | **Al** | **V** | **Phenols** | **Gross Beta** | **Gross Alpha** | **Ra-226** | **Th-230** | **Ra-228** | **U** |
| | | | | | | | mg/L | mg/L | mg/L | mg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | mg/L | pCi/L | pCi/L | pCi/L | pCi/L | pCi/L | mg/L |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 66 | 13 | 8 | 24 | 412 | C | 3/8/1976 | <0.5 | 0.11 | | <0.005 | 20 | 80 | 20 | <10 | <5 | | 10 | 1,200 | <2 | | | | <2 | | | | 2±6 | 1.1±1.0 | 0.4±0.3 | 0.0±0.4 | | <0.002 |
| | | | | | C | Dec-76 | 0.5 | 0.1 | | <0.005 | 6 | <5 | 10 | <10 | <5 | | 6 | 110 | <2 | | | | <2 | | | | 0±6 | 2.3±1.3 | 0.0±0.3 | 0.0±0.2 | 0±3 | 0.004 |
| 102 | 13 | 8 | 33 | 234 | C | 6/1/1972 | <0.1 | | 13.3 | | | | | | | | <50 | <100 | | | <20 | | | | | | | | | | | |
| 122 | | 14 | 7 | 34 | E | Mar–Jul 1979 | 0.06 | <0.2 | 7.3 | <0.01 | 1100 | <10 | <50 | <10 | <10 | <20 | <10 | 2,400 | | <10 | <50 | <1 | <20 | <100 | <10 | 0.08 | 10±2 | <3 | 0.06±0.02 | | 2±1 | |
| 123 | 14 | 7 | 19 | 221 | C | 3/9/1976 | <0.5 | 0.13 | | | 5 | <5 | | <10 | <5 | | 6 | 180 | <2 | | | | | | | | 1±6 | 0.3±0.6 | 0.3±0.7 | 0.0±0.4 | | <0.002 |
| 132 | 14 | 8 | 25 | 212 | DE | 10/18/1979 | 0.45 | 0.25 | | <0.002 | 260 | 5 | 10 | <10 | <20 | <10 | 20 | <10 | <5 | <20 | <50 | <2 | <5 | <100 | | | | <7 | 0.41±0.03 | | 2±1 | <0.006 |

**Note:** There were no results for Sr, Sb, Li, Bi, $PO^4$, cyanide, Pb-210 (by analysis of Po-210), or Sr-90.

**References:**

A NMEI 1974 (see particularly Table 7.5, Table 7.7)
B Cooper & John 1968 (see particularly Table 1)
C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)
D GMRC 1979c (App. D to source E below) (see particularly Table 4)
E GMRC 1979d (see particularly Table II-4, Table III-1)
F Metric Corp. 2005b
F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)
G RGRC 1994
H NMED DP-61 file
I Brod and Stone 1981
O OSE 2008

*9.1.3.5 Gallup Sandstone*

The Gallup Sandstone is predominantly a fine-to medium-grained arkosic sandstone with some conglomerate, shale, and coal (Stone et al, 1983 and Dam 1995). It lies conformably on the main body of the Mancos Shale. The thickness of the Gallup Sandstone ranges from approximately 600 ft in the outcrop area along the southern margin of the San Juan basin to 0 ft along a northwest-trending pre-Niobrara erosion limit in the center of the basin (Stone et al. 1983 and Dam 1995). In the Roca Honda permit area, the Gallup Sandstone is composed of two sandstone units totaling approximately 85 ft thick, split by approximately 20-ft of the Pescado Tongue of the Mancos Shale. The Pescado Tongue of the Mancos Shale probably causes a hydraulic separation between the two sandstone units. The Gallup Sandstone is 265 ft thick in the area of the Mount Taylor mine (RGRC 1994). The top of the Gallup is at an elevation of about 6,700 to6,900 ft in Section 16 of the permit area, which is about 450 ft below land surface, according to RHR's geophysical logs for holes S-2, S-3, and S-4. Ground water is present in the Gallup Sandstone under unconfined conditions along the southern margin of the San Juan basin and under confined conditions farther into the basin. Although the aquifer is relied on in some areas, providing the municipal supply of the towns of Gallup and Crownpoint to the northwest and the community of Marquez to the east, in general the depth and poor quality of the ground water make it an undesirable drilling target. Discharge from 49 water wells completed in the Gallup Sandstone ranged from 0.002 to 1.4 cfs (1 to 645 gpm), with a median production rate of 0.09 cfs (42 gpm). Reported specific capacity ranged from 0.12 to 2.10 gpm/ft (Kernodle 1996).

Two unused wells in the San Mateo/Roca Honda area that may penetrate the upper Gallup Sandstone are in Section 17, T13N R8W and in Section 36, T14N R9W. The water levels in these wells are 100 to 200 ft below land surface at elevations of 7,092 and 7,132 ft, respectively. The Lee Ranch has recently drilled an irrigation well in Section 23 of T13N R8W that may produce partially from the Gallup Sandstone. It is expected that ground water will be present in the Gallup Sandstone aquifer under confined conditions in the Roca Honda permit area. Insufficient data are available to contour the potentiometric surface of the Gallup Sandstone aquifer in the Roca Honda permit area. Because ground water in the formation is deep and of poor quality, Brod and Stone (1981) do not consider the Gallup Sandstone an aquifer in the Ambrosia Lake/San Mateo area.

Ground water in the Gallup Sandstone in the southeastern part of the San Juan basin is calcium-bicarbonate in the recharge area and sodium-sulfate deeper in the basin, with a TDS of 1,100 to 2,190 mg/L (Dam 1995).

Aquifer tests performed at 17 wells in the San Juan basin indicated that the transmissivity of the Gallup Sandstone ranged from 15 to 390 $ft^2$/day, with a median value of 123 $ft^2$/day. Values of storage coefficient ranged from $2\times10^{-6}$ to $3.3\times10^{-5}$ (Kernodle 1996). As part of its assessment of potential tailings impoundment sites, GMRC extensively evaluated the field permeability of the Gallup Sandstone in the area of La Polvadera Canyon and the San Mateo area. It was determined that the Gallup Sandstone had a weighted average permeability (hydraulic conductivity) of 8.8 ft/yr in La Polvadera Canyon and 31 ft/yr in the San Mateo area, with a range of 0 to 70 ft/yr.

### *9.1.3.6 Dakota Sandstone*

In the San Juan basin, the Dakota Sandstone is a sequence of sandstone, mudstone, and coal. The generally fine- to medium-grained arkosic sandstones contain limited amounts of ground water except where secondary permeability has been created by faults or where the sandstone layers are thinly bedded rather than massive (Brod and Stone 1981). GMRC described the Dakota Sandstone in the area of the Mount Taylor mine as "yellow-gray, massive, well-cemented quartz sandstone, locally interbedded with carbonaceous shales and conglomerates." It was noted that the Dakota Sandstone is locally hydraulically connected to the underlying Westwater Canyon Member of the Morrison Formation (GMRC 1979a). Core logs indicate that in the permit area, the Dakota Sandstone has an average thickness of about 50 ft. In the area of the Mount Taylor mine, a thickness of 58 ft was reported (RGRC 1994). The top of the Dakota Sandstone is at an elevation of about 5,600 to 5,400 ft in the permit area. In the "Geologic Map of the San Mateo Quadrangle," Santos (1966) contours the base of the Dakota Sandstone.

Along the southern margin of the San Juan basin, ground water is present in the Dakota Sandstone under unconfined conditions; farther into the basin, ground water in the Dakota Sandstone is confined. Some investigators note that under pre-development conditions the hydraulic head of ground water in the Dakota Sandstone was 200 ft higher than that in the Morrison Formation aquifer. Historic underground mine workings, drill holes, and air shafts may have hydraulically connected the two aquifers in some areas, and dewatering of the Morrison Formation may have allowed ground water within the Dakota Sandstone to move into the Morrison Formation in areas of the mines. Such changes in hydraulic head appear to be localized (Stone et al. 1983, Kelley et al. 1980, Cooper and John 1968, and Dam 1995). Stone et al. (1983) speculate that because the recharge areas for the Dakota Sandstone and the Morrison Formation are at similar elevations, the original head difference probably reflected more lateral flow in the Morrison Formation because of higher transmissivities or more continuity of the sandstones. They suggest that the persistence of the hydraulic head differences in other parts of the San Juan basin indicate that the vertical permeability of the confining layer between the two units is low (Stone et al. 1983).

A few wells may produce from the Dakota Sandstone for stock purposes north of the Roca Honda permit area. A few wells penetrate the Dakota Sandstone in the south-central part of the San Juan basin, but most wells do not produce solely from the Dakota Sandstone because water of superior quality is available within a short drilling distance in the underlying Westwater Canyon Member of the Morrison Formation. Wells producing from the Dakota Sandstone yield from 0.002 to 0.17 cfs (1 to 75 gpm), with a median value of 0.3 cfs (12 gpm) (Kernodle 1996). GMRC (1979a) noted that its depressurization wells for the Mount Taylor mine had produced water at a rate of more than 0.22 cfs (100 gpm) from the Dakota Sandstone, and RHR encountered significant quantities of ground water in the Dakota Sandstone during drilling of deep monitor wells on the south side of Jesus Mesa.

Water in the Dakota Sandstone is typically sodium-sulfate, with a TDS in the range of 600 to 1,400 mg/L (Brod and Stone 1981, Kelley et al. 1980). Transmissivity values of 44 to 85 $ft^2$/day and hydraulic conductivities of 0.7 to 1.5 ft/day have been reported for the Dakota Sandstone from aquifer tests northeast of Crownpoint, though transmissivities for this formation are generally less than 50 $ft^2$/day (Stone et al. 1983). Kernodle (1996) reports that a transmissivity of 2,000 $ft^2$/day was measured in a test east of Grants. GMRC determined a transmissivity of 134 $ft^2$/day and a hydraulic conductivity of 1.6 ft/day for the Dakota Sandstone (Brod and

Stone 1981). Specific capacities in 13 wells completed in the Dakota Sandstone ranged from 0.03 to 3.67 gpm/ft (Kernodle 1996).

*9.1.3.7 Morrison Formation*

The Morrison Formation consists of fine- to coarse-grained, locally conglomeratic sandstone, sandy siltstone, shale, and claystone that contains thin beds of limestone. In the San Juan basin, the Morrison Formation consists of five members, in ascending order: the Salt Wash, Recapture, Westwater Canyon, Brushy Basin, and Jackpile Sandstone (Craigg 2001). Although coarser-grained units within each of the members function as aquifers, the numerous shaley and clayey zones within the members act as aquitards. The Westwater Canyon Member is a sequence of non-marine sandstone, conglomeratic sandstone, and mudstone deposited by a braided stream complex. The sandstones are mainly a yellow-gray to pale-red, fine- to medium-grained, poorly sorted to unsorted, arkose to lithic arkose (NMEI 1974). Geophysical logs indicate that the thickness of the Westwater Canyon Member in the vicinity of the Roca Honda permit area ranges from 100 to 250 ft.

Recent drilling in the Roca Honda permit area has determined that the Westwater Canyon Member contains large quantities of ground water under confined conditions. Ground water in the member rose to an elevation of 6,370 ft, within 850 to 900 ft of land surface, although the top of the Westwater Canyon Member is between 1,700 and 1,850 ft below land surface on the south side of Jesus Mesa, or 5,400 to 5,700 ft in elevation. This aquifer is referred to as the “deep confined aquifer” in Section 9.1.2, “Hydrogeology of General Permit Area Locality.” Ground water movement in this aquifer is eastward with a gradient of about 50 ft per mile. Figure 9–4 shows the potentiometric surface for the deep confined aquifer in the Roca Honda/San Mateo area.

Brod and Stone (1981) report that the highest measured permeability for the Westwater Canyon Member in the San Juan basin was near the community of San Mateo near the San Rafael fault zone along the Fernandez monocline. In that area, GMRC calculated hydraulic conductivity as 3.2 ft/day and transmissivity as 494 $ft^2$/day. They note that this value is 100 times the value determined in laboratory tests, undoubtedly because of the effect of fracturing. Hydraulic conductivity ranges from about 0.5 to 1.5 ft/day, though a few much higher and lower values have been reported. Kernodle (1996) reports that transmissivity, storage coefficient, and hydraulic conductivity values are available for the Morrison Formation from 31 aquifer tests. Transmissivity ranged from 2 to 480 $ft^2$/day with a median value of 115 $ft^2$/day, hydraulic conductivity for three of these wells ranged from 0.035 to 0.39 ft/day, and storage coefficient values calculated for nine wells ranged from $2\times10^{-4}$ to $2\times10^{-5}$ (Kernodle 1996).

Wells completed in the Westwater Canyon Member have been pumped at rates between 0.02 and 1.25 cfs (10 and 560 gpm), with typical values of around 0.22 cfs (100 gpm). GMRC reported that its Mount Taylor dewatering wells pumped several hundred gpm from the Westwater Canyon Member and that a well at the mine was pumped at a rate of 0.89 cfs (400 gpm) for industrial use. Specific capacity is only moderate, and pumping at high rates will cause large drawdowns.

Ground water in the Westwater Canyon Member is a sodium-bicarbonate-sulfate water with a TDS concentration ranging from 360 to 2,200 mg/L (Brod and Stone 1981). Near the confluence of San Mateo Creek and Arroyo del Puerto, several miles southwest of the Roca Honda permit area, the TDS in the Westwater Canyon Member is high (2,000 mg/L), probably because of downward movement into the aquifer of poor quality ground water from the alluvium. Table 9-7 presents analysis of major chemical constituents in Westwater Canyon Member wells, and Table 9-8 presents analysis of major and minor chemical constituents in Westwater Canyon Member wells used by GMRC for depressurization.

*Table 9-7. Major Water Quality in Westwater Canyon Member Wells*

| Roca Honda/San Mateo Area Ground Water Major Constituent Quality Data For Westwater Canyon Member (mg/L unless otherwise specified) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WELL LOCATION | | | | | Source Data | Sample Date | Specific conductance (µmhos) | pH (s.u.) | Temp °C | Hardness (mg/L as $CaCO_3$) | Alkalinity (as $CaCO_3$) | Calcium (dissolved) | Mg | Sodium (dissolved) | Potassium (dissolved) | Bicarbonate as $HCO_3$ | Sulfate as $SO_4$ | Cl | F | Silica as $SiO_2$ | Nitrogen Nitrate as $NO_3$ | TDS |
| Well ID # | Township (N) | Range (W) | Section | 1/4 1/4 ¼ | | | | | | | | | | | | | | | | | | |
| 73 | 13 | 8 | 24 | 234 | I | 1974 | 900 | | | | | 4 | 0.5 | 240 | 2 | 280 | 265 | 10 | | | 0.8 | 650 |
| 112 | 13 | 9 | 22 | 111 | I | 8/24/1977 | 2,720 | | | | | 285 | 91 | 230 | 9.2 | 192 | 1,188 | 54 | | | 47 | 2,255 |
| 113 | 13 | 9 | 22 | 121 | I | 2/26/1975 | 2,150 | | | | | | | | | | | 36 | | | 18 | 2,200 |
| 114 | 13 | 9 | 22 | 121 | I | 2/26/1975 | 3,100 | | | | | | | | | | | 40 | | | 4.7 | 2,000 |
| 119 | 13 | 9 | 23 | 212 | I | Mar-75 | 1,300 | | | | | | | | | | | 4.8 | | | 0.06 | 720 |

**Note:** Minor constituent data are not available for these Westwater Canyon Member wells. See Table 9–8.

µmhos = micromhos

s.u. = standard units

**References:**

A NMEI 1974 (see particularly Table 7.5, Table 7.7)

B Cooper and John 1968 (see particularly Table 1)

C GMRC 1979a (see particularly Pt. 1: Table 2.6-2, Table 2.6-4, Table 2.2-19; also Pt. 1 Appendix B, Table B-1, Table B-3, Table B-4, Table B-6, Table B-7, Table B-9, Table B-10)

D GMRC 1979c (App. D to source E below) (see particularly Table 4)

E GMRC 1979d (see particularly Table II-4, Table III-1)

F Metric Corp. 2005b

F[a] Metric Corp. 2005a (see particularly Figure 7, Table 1)

G RGRC 1994

H NMED DP-61 file

I Brod and Stone 1981

O OSE 2008

*Table 9-8. Average Major and Minor Element Water Quality for Westwater Canyon Member Wells*

| Constituent | mg/L | Constituent | mg/L |
|---|---|---|---|
| Al | <0.1 | Mo | <0.05 |
| Sb | <0.01 | Ni | <0.05 |
| As | 0.01 | N (nitrate) | <0.2 |
| Ba | <0.5 | P (ortho-phosphate) | nil |
| Bi | <0.01 | Phenols | 0.003 |
| B | 0.3 | K | 8 |
| Cd | <0.005 | Ra-226+228 | <7 pCi/L |
| Ca | 5 | Se | <0.01 |
| Cl | 18 | Si | 50 |
| Cr | <0.01 | Ag | <0.02 |
| Co | <0.03 | Na | 230 |
| Cyanide | <0.01 | $SO_4$ | 280 |
| F | <0.1 | TDS | 630 |
| Fe | 0.7 | U | <0.005 |
| Pb | <0.05 | V | <0.005 |
| Mg | <0.01 | Zn | <0.01 |
| Mn | 0.4 | Chemical oxygen demand | nil |
| Hg | <0.001 | pH (s.u.) | 7.6 |

From Table B-10, Appendix B of Environmental Report (GMRC 1979)
s.u. = standard units

Where the Westwater Canyon Member and the Dakota Sandstone are hydraulically separated, ground water quality in the Dakota Sandstone is generally significantly poorer than ground water quality in the Westwater Canyon Member at the same location. In the Roca Honda permit area where that faulting has facilitated inter-formational movement of ground water, it is expected that the water quality in the two formations will be similar (Brod and Stone 1981). Table 9–9 presents water quality analyses for mine dewatering water pumped from three mines near the permit area. The quality of ground water pumped from the permit area will be similar.

*Table 9-9. Mine Dewatering Water Quality*

| **Mine Dewatering Water Quality<br>Primarily Westwater Canyon Member, with Some Mixing with Dakota Sandstone**<br>(except conductivity and pH, values are dissolved and in mg/L; radium and gross alpha in pCi/L) | | | |
|---|---|---|---|
| | 11/05/1979 | 11/09/1979 | 11/07/1979 |
| Constituent | Mount Taylor | Bokum Marquez | Johnny M |
| TDS | 696 | 1190 | 753 |
| Conductivity (μmhos) | 1061 | 1760 | 756 |
| pH (s.u.) | 9.02 | 8.43 | 7.85 |
| As | 0.007 | <0.005 | 0.044 |
| Ba | 0.149 | <0.001 | 0.212 |
| Se | 0.018 | 0.005 | 0.128 |
| Mo | 0.13 | <0.01 | 0.612 |
| $NH_3$ | 0.08 | 0.4 | 0.36 |
| Na | 225.4 | 361.1 | 101.2 |
| Cl | 11.9 | 38.7 | 8.53 |
| $SO_4$ | 251.9 | 574.6 | 188.5 |
| Ca | 3.2 | 25.8 | 51.6 |
| K | 1.56 | 3.9 | 3.9 |
| Bicarbonate | 246 | 277.8 | 256 |
| Cd | <0.001 | <0.001 | <0.001 |
| Nitrate/Nitrite | 0.25 | 0.18 | 0.36 |
| Mg | 0 | 0.6 | 15.6 |
| V | <0.01 | <0.01 | 1.408 |
| Zn | <0.25 | <0.25 | <0.25 |
| Al | 1.12 | 0.53 | 17.8 |
| Pb | <0.005 | <0.005 | 0.008 |
| Gross alpha | 990±50 | 450±40 | 1,700±100 |
| Ra-226 | 17±5 | 0.21± 0.06 | Not analyzed |
| U | 0.45 | <0.005 | 5.09 |

μmhos = micromhos
NMEID 1980

### *9.1.3.8 Summary of Aquifer Characteristics*

Table 9-10 summarizes the physical and hydraulic characteristics of the aquifers in the San Mateo Creek area, Roca Honda permit area, and the San Juan basin. The probable thicknesses in the Roca Honda permit area were determined from drilling conducted by RHR and previous exploration companies within the area.

*Table 9-10. Summary of Aquifer Characteristics in the Vicinity of the Roca Honda Permit Area*

| Aquifer | Thickness Range in the San Juan Basin (ft) | Probable Thickness at the Roca Honda Permit Area (ft) | Transmissivity Range (median) ($ft^2$/day) | Hydraulic Conductivity (horizontal) (ft/day) | Hydraulic Conductivity (vertical) (ft/day) | Yield Range (gpm) (median) | TDS (mg/L) |
|---|---|---|---|---|---|---|---|
| Alluvium | 10–80 | 0 | 700—1,450[h] | 27[h] | | <20[a] | 590–14,000[a] |
| Menefee Formation | 400–1,000[b] | <100[g] | 10–100[b] | 0.05–0.01[b] | 0.00001[f] | <20[a] | 200–1,400[a] |
| Point Lookout Sandstone | 40–415[b] | <120[g] | <1—240[b] | 0.002–0.02[cb] | 0.01–0.002[c]<br>0.0002–0.0001[f] | To >50[a] | 200–700[a] |
| Dalton Sandstone Member of the Crevasse Canyon Formation | 80–180[bdg] | >100[g] | 10–<50 | | 0.0001[f] | | 4,500[a] |
| Gallup Sandstone | 90–700[b] | 85[g] | 15–390 (123)[bhf] | 0.1—1.0[h] | 0.002[f] | 1–645(30)[ef] | 1,200—2,200[h] |
| Lower Mancos Shale Sandstones | 125[g] | 125[g] | 134[a] | | 0.002[f] | 0–2,000[ag] | 2,500–9,000[a] |
| Dakota Sandstone | 50–350[b] | 50–60[g] | 44–134[abf] | 0.25–1.5[b] | 0.002[f] | 1–200 (13)[e] | 600–1,400[a] |
| Westwater Canyon Member of the Morrison Formation | 100–250[bg] | 100–250[g] | 50–500[ab] | 0.1 | 0.001[f] | 1–401 (32)[e] | 360–2,200[a] |

[a]Brod and Stone 1981
[b]Stone et al., 1983
[c]Craigg et al. 1989
[d]RGRC 1994
[e]Dam 1995
[f]Kernodle 1996 (note hydraulic conductivity [vertical] values are model-simulated)
[g]Roca Honda Resources drilling
[h]GMRC 1979a
[i]Pike 1947

### 9.1.4 Aquitards

Aquitards are geologic strata which, because of low permeability, cannot transmit sufficient quantities of water to function as aquifers. An aquitard will retard or prevent ground water movement from or into overlying or underlying aquifers. In the San Juan basin, most aquifers are separated by aquitards consisting of shale. Aquitards in the Roca Honda/San Mateo area are, from deepest to shallowest, the Recapture Member of the Morrison Formation, the Brushy Basin Member of the Morrison Formation, and the Mancos Shale. The shale layers within the Menefeee Formation and the Crevasse Canyon Formation also function as aquitards. The principal water-bearing units and aquitards in the Roca Honda permit area are shown in Figure 7–4 of Section 7.0, Geology.

*9.1.4.1 Mancos Shale*

The Mancos Shale is a thick, dark gray, calcareous marine shale that represents the transgression of the Western Interior Seaway (NMEI 1974). The Mancos Shale conformably overlies the Dakota Sandstone and intertongues with the upper sandstones of the Dakota Sandstone. It is thickest in the northeastern part of the San Juan basin and consists of a main body and two tongues through most of the area. The main body of the Mancos Shale forms an aquitard above the Dakota Sandstone aquifer. The Mulatto Tongue of the Mancos Shale is an aquitard between the Dilco Coal Member and Dalton Sandstone Member of the Crevasse Canyon Formation.

The Satan Tongue of the Mancos Shale divides the Point Lookout Sandstone into upper and lower sandstones. Recent drilling in the Roca Honda permit area in Section 16 found 702 to 720 ft of Mancos Shale, the top of which was about 700 ft below land surface at an elevation of 6,500–6,700 ft (RHR geophysical logs for holes S-2, S-3, and S-4). In the San Mateo Creek valley to the southwest of the permit area, the Mancos Shale crops out about 4 miles west of the community of San Mateo. In the area of the community of San Mateo, the Mancos Shale is at a depth of more than 1,500 ft.

Shales have low primary permeability and restrict movement of ground water. The main body of Mancos Shale acts as a barrier to movement of water into or out of the Dakota Sandstone from or into overlying formations. The Nuclear Regulatory Commission (NRC) staff agreed with the determination by Hydro Resources, Inc. (HRI) that it was unnecessary to monitor rocks of the Mesaverde Group in the area of HRI’s proposed in-situ uranium recovery operation from the Westwater Canyon Member of the Morrison Formation because of the “hydrologic separation” between the aquifers and the “thick, laterally extensive Mancos Shale separating the two systems” (NRC 1997, EIS Docket 40-8968). The Mancos Shale is represented in the USGS model of the San Juan basin as a confining unit (Kernodle 1996).

In the Roca Honda permit area, the lower and middle Mancos Shale contain sandstone beds totaling about 125 ft in thickness. In the upper part of the Mancos Shale, a discontinuous, 45 ft thick sandstone unit in the Mulatto Tongue of the Mancos Shale crops out in the western half of Section 16. This sandstone may be the Borrego Pass Lentil of the Crevasse Canyon Formation, previously referred to as the Stray sandstone of local usage (Santos 1966) and is expected to be hydrologically similar to other Cretaceous sandstone aquifers in the area (Brod and Stone 1981).

Brod and Stone (1981) indicate that sandstones in the lower part of the Mancos Shale may transmit large quantities of water. Cooper and John (1968) report that two mines in the San Mateo area dewatered the middle Mancos Shale sandstones at rates of 2.0 and 4.5 cfs (900 and 2,000 gpm). Brod and Stone (1981) report that the hydrologist for GMRC indicated that the “Tres Hermanos unit” (a sandstone in the lower Mancos Shale) yielded large quantities of water at the Mount Taylor mine. RGRC reports that the Mount Taylor mine found 118 ft of sandstone in the Mancos Shale. RHR , however, recently drilled three monitor/test wells south of Jesus Mesa that penetrated the Mancos Shale and down into the Westwater Canyon Member without finding producible quantities of ground water in the Mancos Shale.

As part of its assessment of potential tailings impoundment sites, GMRC extensively evaluated the field permeability of the Mancos Shale in the area of La Polvadera Canyon and the San Mateo area. It was determined that the upper part of the main body of the Mancos Shale had a weighted average permeability (hydraulic conductivity) of 0.05 ft/yr in La Polvadera Canyon.

*9.1.4.2 Other Aquitards*

The Recapture Member of the Morrison Formation is below the Westwater Canyon Member aquifer and above the Bluff Sandstone. The Recapture Member consists of interbedded red shale and white sandstone. It is present throughout the San Juan basin, although it is thickest in the south and southeast part of the basin, where it ranges from 125 to 300 ft thick. NRC (1997) reported that the Recapture Member at HRI’s Church Rock facility is about 180 ft thick. RHR drilled 100 ft into the Recapture Member without fully penetrating the unit, although RGRC reported a total thickness of 78 ft of the Recapture Member was penetrated by the Mount Taylor mine (RGRC 1994). Geophysical logs run in RHR’s monitor well holes indicate that the top 50 ft of the Recapture Member in the Roca Honda permit area was siltstone or mudstone (hole S-4).

The Brushy Basin Member of the Morrison Formation is present between the Dakota Sandstone and the Westwater Canyon Member over most of the San Juan basin. The Brushy Basin Member consists primarily of variegated calcareous and bentonitic claystone and mudstone of lacustrine origin, with some fluvial sandstone and conglomeratic sandstone, and freshwater limestone (NMEI 1974). In some areas of the San Juan basin, the Brushy Basin Member is as much as 200 ft thick. Borehole geophysical data collected in the permit area indicate that the Brushy Basin Member is as much as 269 ft thick (Table 7–1, Section 7.0, Geology). Where the Brushy Basin Member is thickest, there is a sandstone stringer (~5 to 10 ft thick) in the upper part that may be water bearing; this thin sandstone is referred to as the Brushy Basin Member B sandstone aquifer.

There is evidence that there might be a direct fault connection between the Westwater Canyon Member and Dakota Sandstone beneath Jesus Mesa in the Roca Honda permit area Sections 9 and 10. An aquifer test conducted by HRI in September and October of 1988 to determine the degree of interconnectedness between the Westwater Canyon Member aquifer, the Dakota Sandstone aquifer, and the Brushy Basin Member B sandstone aquifer found no aquifer interconnection in the area of HRI’s proposed Church Rock In-situ Recovery facilities (HRI 1988, NRC 1997). The NRC reports that aquifer tests performed by HRI at its proposed Crownpoint mine site found no aquifer interconnection between the Westwater Canyon Member and the Dakota Sandstone (NRC 1997). However, the intensity of faulting in the Roca Honda permit area and the limited thickness of the Brushy Basin Member shales in the permit area make it possible that the formation does not form an impermeable hydrogeologic barrier to movement of ground water between the Westwater Canyon Member and the Dakota Sandstone.

## 9.2 Sampling Objectives

While there exists significant hydrogeologic data in the region it will still be necessary to determine lithology, thickness, and aquifer characteristics of near-surface geologic units and interconnectivity with deeper aquifers to determine ground water systems that could be affected by site operations. It will also be necessary to, create cross sections and potentiometric maps and determine the direction of ground water flow in the vicinity of the permit area, define the aquifer characteristics and water quality in the permit area, and obtain the data necessary to determine potential impacts of mining activities, including mine dewatering, on the ground water system. The potential impacts will be determined using a ground water model. The ground water model will incorporate published data as well as data collected under this SAP.

The proposed sampling and data analysis will be ongoing and will be implemented at the appropriate times as the proposed Roca Honda project is advanced. Table 9–11 outlines the data gathering activities that will be performed.

*Table 9-11. Ground Water Sampling and Data Analysis Plan*

| Proposed Activity | Purpose of Activity |
|---|---|
| Perform a field verification survey of wells identified by previous investigators as possibly existing within 5 miles of the Roca Honda permit area, and measure depths to water where sufficient control is available on well depth and aquifer penetrated. | Determine status and locations of local wells; measure depth to water in those wells in order to refine the water surface maps. |
| Ground water samples may be collected in some of the wells identified above if wells are topographically lower and down the hydraulic gradient from the proposed mine. | Establish baseline water quality |
| Perform aquifer tests using wells drilled in the Westwater Canyon Member within Section 16, T13N R8W in 2007. | Ascertain hydraulic parameters of Westwater Canyon Member in the permit area for use in calculation of impacts of mine dewatering and to estimate rates of ground water inflow to the mine. |
| Collect samples of ground water produced during the aquifer test performed and analyze. | Develop initial design parameters for water treatment. |
| Commence water level measurement and sampling of ground water at the Section 16 wells. | Establish baseline water levels and water quality for the confined aquifer within the Westwater Canyon Member in the permit area. |
| Install a group of monitor wells in multiple aquifers including Westwater Canyon Member, the Gallup Sandstone, the Point Lookout Sandstone, the sandstones of the Menefee Formation (if present), and the alluvium. | Obtain baseline water levels in different aquifers at same location and establish ground water monitoring; obtain baseline aquifer water quality. |

## 9.3 List of Data to be Collected

Table 9-12 summarizes the identified ground water data needs.

*Table 9-12. Data Needs Identified for Ground Water*

| Data Need | Plan to Address Data Need |
|---|---|
| Permit area specific hydraulic parameters for deep aquifer system. | Aquifer tests will be performed using wells drilled in the Westwater Canyon Member of the Morrison Formation in Section 16, T13N, R8W in 2007, or data from relevant wells . |
| Baseline ground water quality of Westwater Canyon Member at permit area. | Ground water samples will be collected from the three wells installed in 2007 in the Roca Honda permit area Section16. |
| Usability of existing San Mateo area wells for water quality and potentiometric surface data. | An inventory has been made of all wells previously identified within 5 miles of the Roca Honda permit area, including Roca Honda Resources wells. Fieldwork will be conducted to confirm the existence of these wells and to sample and measure water in the wells if owner approval can be obtained. |
| Baseline ground water quality of area aquifers. | An inventory has been made of historical ground water quality data. Once useable existing wells have been determined, water quality parameters will be measured for selected wells on a seasonal basis. |
| Recent potentiometric surface. | Once usable existing wells have been determined, the depth to water will be measured in selected local wells and Roca Honda Resources wells on a seasonal basis. |
| Quality of ground water in San Mateo Creek drainage bed alluvium. | Ground water samples will be collected, to the extent possible, from shallow auger holes or well points in the drainage bed alluvium at several locations. |
| Thickness and permeability of San Mateo Creek drainage bed alluvium. | Three boreholes will be drilled in a line perpendicular to San Mateo Creek just downstream of where the arroyo carrying treated Roca Honda mine discharge joins with San Mateo Creek. These boreholes will be completed as wells screened in the alluvium. Slug or falling head tests will be performed using these wells. |
| Estimate of potential impacts of mine dewatering. | Construct 3-D ground water model of southeast portion of San Juan basin using MODFLOW as the simulator, and data from on site and surrounding wells. |

## 9.4 Method of Collection

The existing and proposed baseline sampling and measurement locations in the Roca Honda permit area are shown on Figure 9–7. Table 9–13 summarizes the proposed aquifer testing and hydraulic data collection. Table 9–14 lists the wells to be monitored and the frequency with which water levels and water quality data will be collected. This SAP will be modified as necessary after the specific mine locations are identified to include additional long-term ground water quality and ground water level monitoring in shallow aquifers.

## 9.5 Parameters to be Analyzed

RHR will address the need for additional hydraulic parameter data for the Westwater Canyon Member specific to the Roca Honda permit area by performing aquifer tests using the wells drilled in 2007 for that purpose (Figure 9–4). Transmissivity, hydraulic conductivity, specific capacity, and storage coefficient values will be obtained from the testing (Tables 9–13 and 9-14). These data will be used to develop an understanding of the site-specific hydrology of the formation and estimate the pumping rate required to dewater the mine. The hydraulic parameter values will also be used in the ground water flow model RHR will develop for the purpose of estimating the potential impacts of mine dewatering on area water levels and surface flow.

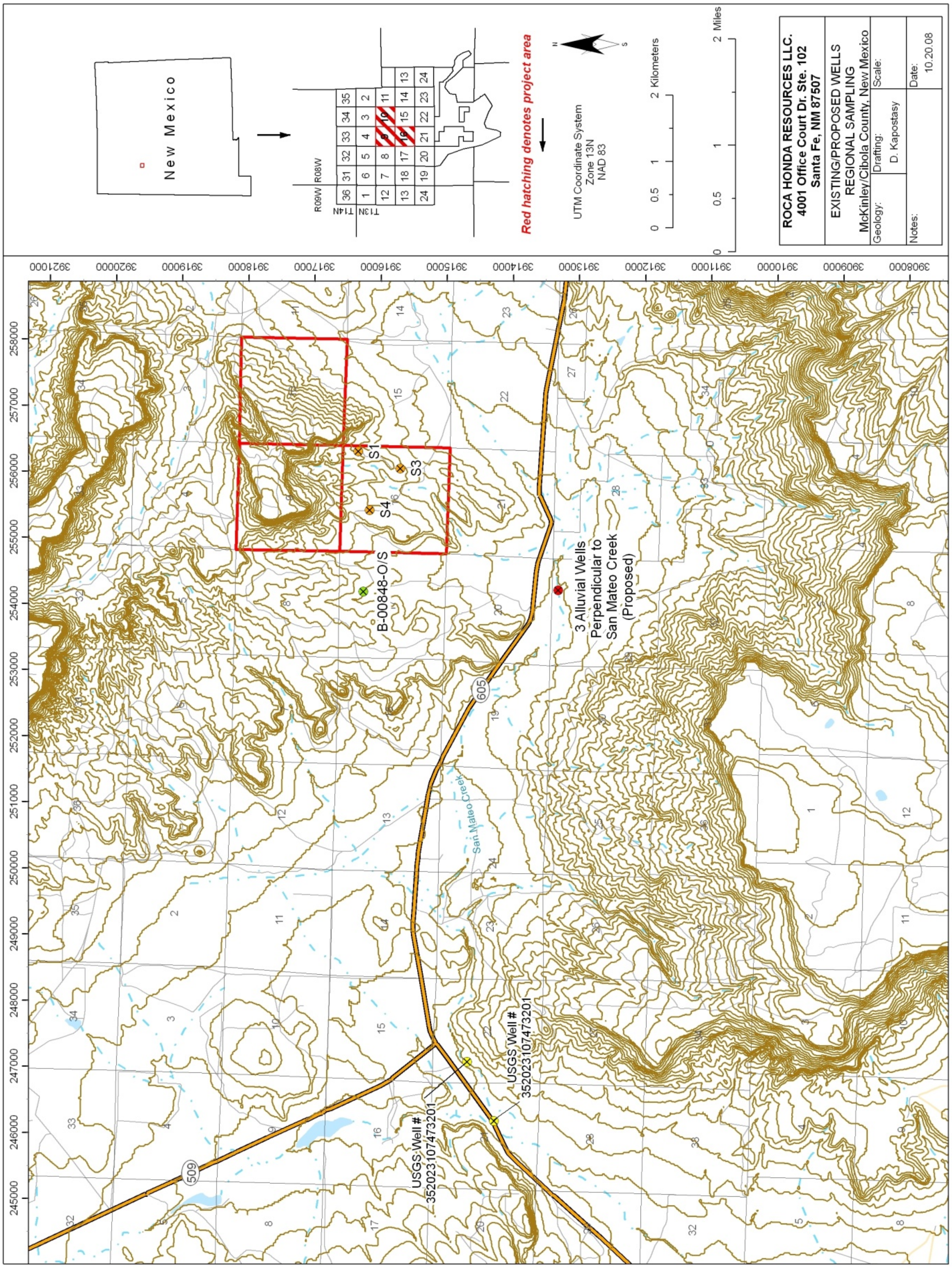


*Figure 9-7. Existing and Proposed Wells to be Used for Monitoring and Aquifer Testing*

*Table 9-13. Hydraulic/Aquifer Data Locations*

| Aquifer Pump Test | | | |
|---|---|---|---|
| **Pumping Well** | **Monitor Well(s)** | **Length of Test** | **Geologic Formation Characterization of Bedrock** |
| S1, S3 and/or S4 | S1, S3 and/or S4 | Undetermined at present | Westwater Canyon Member |
| **Ground Water Elevation Data** | | | |
| **Well Number** | **Location** | **Frequency of Monitoring** | **Geologic Formation** |
| S1 | Section16, T13N, R8W | Quarterly | Westwater Canyon Member |
| S3 | Section16, T13N, R8W | Quarterly | Westwater Canyon Member |
| S4 | Section16, T13N, R8W | Quarterly | Westwater Canyon Member |
| Undetermined at present. | Well locations for San Mateo area water level monitoring program will be added after the existing useable wells are determined. | Quarterly | Point Lookout Sandstone, Menefee Formation, alluvium |
| **Characterization of Alluvial Aquifer** | | | |
| **Well Number** | **Location** | **Frequency** | **Geologic Formation** |
| Undetermined at present. | Three boreholes in a line perpendicular to San Mateo Creek just downstream of the discharge. | Quarterly | Alluvium |

Aquifer test data will be collected with transducers and verified with electronic water level measurement tapes. Methodology for performance of an aquifer test is described in Appendix A.

Potential interconnection between ground water in the Westwater Canyon Member and ground water in overlying aquifers in the area of the proposed mine will be assessed with the installation of wells at a location yet to be determined in the vicinity of the permit area. Wells will be completed in the Westwater Canyon Member, the Gallup Sandstone, the Point Lookout Sandstone, the Menefee Formation (if present), and the alluvium (if water bearing). The Westwater Canyon Member well will be pumped while water levels in the overlying formations are monitored. It is anticipated that after completion of the aquifer test, these wells will be incorporated into the quarterly water level and water quality monitoring program. Wells will be installed and developed in accordance with standard operating procedures.

An inventory has been made of all wells previously identified within 5 miles of the Roca Honda permit area. Published hydrogeologic reports which tabulated wells in the area, and unpublished material generated during the permitting and monitoring of the Rio Grande Resources, Inc. Mount Taylor mine, were relied on to identify potentially existing wells and construct the map identified in the back of this SAP as Plate 1, and to create an initial water surface elevation map. Fieldwork is ongoing to determine which of these wells exist and can be sampled and measured, subject to owner approval. Some of the wells listed in the state WATERS database have been field checked and do not exist, as noted on Plate 1. The water surface elevation maps will be updated once new depth-to-water measurements are obtained. Water levels will be monitored in a subset of wells, of which selection criteria for inclusion in the monitoring program are being developed.

*Table 9-14. Summary of Well Locations, Baseline Water Quality Data Locatons, and Ground Water Monitoring Schedule*

| Description | Location | Geologic Unit | Aquifer | Water Level Measuring Frequency | Sampling Frequency | |
|---|---|---|---|---|---|---|
| | | | | | Complete Suite | Complete Suite Except No VOCs[a] |
| **Characterization of Bedrock** | | | | | | |
| S1 | Section 16, T13N, R8W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| S3 | Section 16, T13N, R8W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| S4 | Section 16, T13N, R8W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| B-0848-O[b] | Section 17, T13N, R8W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| USGS monitor well number 352037107465701[b] | Section 22, T13N, R9W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| USGS monitor well number 352023107473201[b] | Section 21, T13N, R9W | Westwater Canyon Member | Confined | Quarterly | Quarterly [c] | Quarterly |
| Undetermined at present. | Well locations for San Mateo area bedrock ground water quality monitoring program will be added after the existing, useable wells are determined. | Point Lookout Sandstone, Menefee Formation, alluvium | | Quarterly | | |
| **Characterization of Alluvial Aquifer** | | | | | | |
| Undetermined at present. | Locations of ground water sampling locations in drainages will be determined after location of well points has been determined. | Streambed alluvium | | Quarterly | | |

[a]VOC = volatile organic compound
[b] If accessible
[c] Unless no VOCs or SVOCs after 1 sampling event

The ability of the San Mateo Creek drainage to absorb and transmit discharged mine water will be estimated through development of cross sections and estimates of the arroyos permeability as described in the Surface Water SAP. Monitor wells will be installed to determine the thickness and extent of the alluvium at the Roca Honda permit area at a location below the proposed point of Roca Honda mine discharge. The permeability of the alluvium will be assessed by performing slug tests or falling head tests.

The data collected will allow calculated estimates to be made of the amount of ground water that will be discharged from the mine during mine dewatering activities. It will also facilitate calculation of the impact of dewatering activities on area water levels.

### 9.5.1 Ground Water Quality Data

Baseline ground water quality within the Westwater Canyon Member on the Roca Honda permit area will be obtained from the wells installed by RHR on Section 16 in 2007. RHR has constructed a data base of historical water level and quality data collected from historically existing area wells, and located those wells on Plate 1. RHR will conduct field investigations to determine the current status of each well, and then identify a set of wells from which water levels and water quality data will be collected on a quarterly basis. Selection criteria for inclusion in the monitoring program are being developed.

RHR will determine baseline ground water quality and ground water levels for water within the alluvium of San Mateo Creek below the proposed discharge point for the dewatering water. Wells will be installed in the alluvium, and water quality and water levels will be monitored quarterly.

Quarterly ground water levels will be measured and ground water samples will be collected using standard techniques. The parameters of pH, temperature, and specific conductivity will be measured in the field at the time of collection for each well. Ground water sample collection and handling will be conducted in accordance with standard procedures. Ground water quality control samples will include collection of duplicate samples. Water quality data will include the analyses shown in Table 9–15. Analytes include ground water protection standards from NMAC 20.6.2 as well as other selected constituents. The sample volumes, containers, preservation requirements, and holding times for the ground water samples are summarized in Table 9–16.

*Table 9-15. Water Quality Analytes*

| Parameter | Method[a] |
|---|---|
| **Water Quality** | |
| Alkalinity (analysis includes total alkalinity as $CaCO_3$, bicarbonate as $HCO_3$, carbonate as $CO_3$, and hydroxide as OH) | E310.1/A 2320 B |
| Calcium (Hardness as $CaCO_3$) | A 2340B |
| Carbon | |
| Chloride | E 300.0/A 4500CL B |
| Color | |
| Conductance, Specific at 25˚C | E120/A 2510 B |
| Corrosivity | |
| Cyanide, Total | Kelada mod |
| Fluoride | A 4500 F-C / Technicon 370-7WE |
| Nitrate, total (persulfate includes total Kjeldahl nitrogen, $NO_3$ and $NO_2$) | A 4500 N org. D / E 353.2 |
| Odor | |
| Organic carbon | |
| pH | E150.1/A 4500 H B |
| Phenols | E420.1 |
| Semivolatile organics | EPA Method 625 |
| Silica | E200.7 |
| Sulfate | E 300.0 |
| TDS | E160/A 2540 C |
| Volatile organics | EPA Method 624 |
| **Metals (dissolved)** | |
| Aluminum | E200.7 |
| Antimony | E200.8/E200.9 |

*Table 9-15. Water Quality Analytes (Continued)*

| Parameter | Method[a] |
|---|---|
| **Water Quality** | |
| Alkalinity (analysis includes total alkalinity as $CaCO_3$, bicarbonate as $HCO_3$, carbonate as $CO_3$, and hydroxide as OH) | E310.1/A 2320 B |
| Calcium (Hardness as $CaCO_3$) | A 2340B |
| Carbon | |
| Chloride | E 300.0/A 4500CL B |
| Color | |
| Conductance, Specific at 25˚C | E120/A 2510 B |
| Corrosivity | |
| Cyanide, Total | Kelada mod |
| Fluoride | A 4500 F-C / Technicon 370-7WE |
| Nitrate, total (persulfate includes total Kjeldahl nitrogen, $NO_3$ and $NO_2$) | A 4500 N org. D / E 353.2 |
| Odor | |
| Organic carbon | |
| pH | E150.1/A 4500 H B |
| Phenols | E420.1 |
| Semivolatile organics | EPA Method 625 |
| Silica | E200.7 |
| Sulfate | E 300.0 |
| TDS | E160/A 2540 C |
| Volatile organics | EPA Method 624 |
| **Metals (dissolved)** | |
| Aluminum | E200.7 |
| Antimony | E200.8/E200.9 |

Note: For dissolved metals, sample is filtered through a 0.45 µm membrane filter before preservation.
[a]Source: Energy Laboratories, Inc.
pCi/L = picocuries per liter
SMEWW = Standard Methods for the Examination of Water and Wastewater

*Table 9-16. Sample Volumes, Containers, and Preservation Requirements for Ground Water Samples*

| Parameter | Volume Required (mL) | Container P = Plastic G = Glass | Preservative | Holding Time |
|---|---|---|---|---|
| **Metals** | | | | |
| Dissolved metals (field-filtered samples) | 250 | P | Filter 0.45 µm, $HNO_3$ to pH<2 | 6 months |
| Total metals | 250 | P | $HNO_3$ to pH<2 | 6 months |
| **Water Quality** | | | | |
| **Major Minerals** | | | | |
| Bicarbonate | 500 | P or G | Cool, 4 °C | 28 days |
| Calcium | 500 | P or G | Cool, 4 °C | 6 months |
| Carbonate | 500 | P or G | Cool, 4 °C | 6 months |
| Chloride | 500 | P or G | Cool, 4 °C | 28 days |
| Cyanide, Total | 500 | P | NaOH | 14 days |
| Magnesium | 500 | P or G | Cool, 4 °C | 6 months |
| Potassium | 500 | P or G | Cool, 4 °C | 6 months |
| Sodium | 500 | P or G | Cool, 4 °C | 6 months |
| Sulfate | 500 | P or G | Cool, 4 °C | 28 days |
| pH | 500 | P or G | Cool, 4 °C | Analyze in field |
| Phenols | 250 | G | $H_2SO_4$ | 14 day |
| Specific conductance | 500 | P or G | Cool, 4 °C | 28 days |

*Table 9-16. Sample Volumes, Containers, and Preservation Requirements for Ground Water Samples (Continued)*

| Parameter | Volume Required (mL) | Container P = Plastic G = Glass | Preservative | Holding Time |
|---|---|---|---|---|
| TDS | 500 | P or G | Cool, 4 °C | 7 days |
| Fluoride | 500 | P or G | Cool, 4 °C | 28 days |
| Nitrate | 500 | P | $H_2SO_4$ | 48 hours |
| Nitrite | 500 | P | Cool, 4 °C | 48 hours |
| Semivolatile organics | 2,000 | G | Cool, 4 °C | 7 days |
| Silica | 500 | P or G | Cool, 4 °C | 28 days |
| Volatile organics | 3 VOA vials with zero head space | VOA vials | HCL<2 | 14 days |
| **Radiochemistry** | | | | |
| Gross Alpha (pCi/L) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |
| Gross Beta (pCi/L) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |
| Radium-226 (pCi/L) (alpha-emitting isotopes) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |
| Radium-228 (pCi/L) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |
| Radon (pCi/L) | 2 VOA vials with zero headspace | G | Cool, 4 °C | 4 days |
| Isotopic Thorium-228/230/232 (pCi/L) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |
| Uranium (µg/L) | 1,000 | P or G | $HNO_3$ to pH<2 | 6 months |

°C = degrees Celsius
$HNO_3$ = nitric acid
$H_2SO_4$ = sulfuric acid
mL= milliliter
pCi/L = picocuries per liter
µm = micromhos

## 9.6 Maps Providing Sampling Locations

See Figure 9-7 for sampling locations. Additionally, private wells will be selected from those in the San Mateo Creek drainage area based on existing data to cover different aquifers and locations. The final selection will be based on owner permission.

## 9.7 Sampling Frequency

See Tables 9-13 and 9-14 for groundwater monitoring and sampling frequency.

## 9.8 Laboratory and Field Quality Assurance Plan

The ground water sample and data collection will be conducted in accordance with the field quality plan and the procedures for sampling and recording observations in a log book. The samples will be properly preserved and sent to an EPA certified analytical laboratory. Water samples will be collected from RHR wells and private wells. Fieldwork to determine which of these wells exist and can be sampled and measured is subject to owner approval. Comments made by the well users visited will be recorded in the log book.

The parameters of pH, temperature, dissolved oxygen, turbidity, and specific conductivity will be measured in the field at the time of collection for each well. The field instruments will be calibrated by the manufacturer with calibration checks conducted by the user. The calibration certificates will be filed and the field checks will be recorded in the log book. Ground water quality control samples will include random duplicate samples.

The Field Leader for the aquifer pump test will be experienced and the field members will be trained to the procedures. The procedures to be used have been developed by professionals in ground water hydrology. The instruments used for pump tests will be calibrated by the manufacturer. A calibration certificate will be retained as a record. The main instruments used for the pump test are the pressure transducers, E-tape, vented cable, and a barometric pressure gage. A preliminary step drawdown test a few days prior to the pump test will afford the field hydrologists a chance to verify that the meter, discharge system, transducers, and generator are working properly.

Water level measurements will be monitored manually with an E-tape as a check on transducer measurements, and to ensure that a back-up set of data are available in case of transducer failure. The E-tape and transducers will be compared several times before the pump test to determine the difference in readings. This difference will be recorded. During the pump test and after the pump test several more checks will be made to compare the reading differences. The differences are typically minimal (inches) but will be used as an adjustment for the data interpretation. A similar comparison will be noted for the vented cable and the barometric pressure gage readings. Prior to installation, the transducer probe and cable will be inspected for damage, un-kinked, and cleaned.

The transducer data will be downloaded to a laptop computer on a regular basis. E-tape comparison readings will be taken often during the initial pumping and again during the initial recovery period and numerous times during the days of pumping. For safety reasons, at least two people will be on site during the entire pumping portion of the test.

Personnel will maintain a field log in which are recorded weather, field conditions, nearby pumping wells, and any circumstances which influence test results or would be useful to know during interpretation of test results.

## 9.9 Brief Discussion Supporting Proposal

The objectives of the proposed data collection are to obtain the data necessary to determine potential impacts of mining activities, including mine dewatering, on the ground water system. Aquifer pump tests will be used to obtain hydraulic information. The potential impacts will be determined using a ground water model. The ground water model will incorporate published data as well as data collected under this SAP. Additional background water quality data will be obtained by sampling several private water wells and the Strathmore wells with the permit area.

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# Appendix A

# Aquifer Test Design
# Procedure and Protocol

## Introduction

An aquifer pump test is performed by pumping a well at a constant or step-increased rate while water levels are monitored in the pumping well and in other wells (observation wells) at specified time intervals. A test performed using only the pumping well as an observation point will allow a determination of transmissivity and, if aquifer thickness is known, horizontal hydraulic conductivity. Depending on how the observation wells are completed, a multiple well test using a pumping well and observation wells can permit determination of transmissivity, horizontal and vertical hydraulic conductivity, storage coefficient, and if observation wells are completed in overlying formations, allow an assessment of inter-aquifer connectedness. Boundary conditions may be identified during single well or multiple well tests. Done properly, aquifer pump tests are the best method for obtaining hydraulic information about aquifers.

The three main data sets recorded during an aquifer test are: 1) time, 2) water levels at those times, and 3) pumping rates and cumulative volumes of water pumped. Water levels are measured and recorded at specified time intervals. Pumping rates and the volume of water pumped are recorded for the pumping well. Because the mathematical relationships depend on the quantitative way water levels respond to pumping over time as known hydraulic stress; e.g., removal of ground water from or injection of water into the aquifer, it is essential that accurate measurements of all three components be taken and that water level readings and pumping rates are taken at appropriate time intervals. The goal of the testing is to derive knowledge about the physical characteristics of a subsurface geologic formation. Therefore, it is important that the measured water levels be unaffected by external phenomena such as the discharged water and that unavoidable outside influences such as barometric pressure and other pumping in the area be quantified and accounted for.

Explanations of aquifer pump test theory and analysis are available in numerous publications. *Groundwater and Wells*, edited by F.G. Driscoll and published by Johnson Filtration Systems (1986), and *Ground-Water Hydraulics* by S.W. Lohman, published as USGS Professional Paper 708 (1979) are recommended. *Manual of Applied Field Hydrology*, by Weight and Sonderegger (2001) provides practical guidance about the proper performance of an aquifer pump test. Electronic programs that facilitate solution of the pertinent equations are readily available from the USGS, or as commercial programs such as AQTESOLV.

## Purpose of Roca Honda Resources Aquifer Pump Tests

The purpose of the RHR aquifer pump tests is to quantify the hydraulic properties of the Westwater Canyon Member of the Morrison Formation. Additional pump tests may be performed in the future for the purpose of assessing inter-aquifer connections. It is also expected that the tests will provide insight into the location and nature of sub-surface boundaries such as faults; i.e. where they are and whether they function as barriers to ground water movement or as sources of water.

# General Aquifer Pump Test Guidelines

The following general aquifer pump test guidelines will be followed:

1. The well(s) will be pumped at appropriate pumping rates so as to stress the aquifer and allow observable water level declines, but not to induce such severe water level declines so as to cause the well to pump dry.

   The optimal pumping rate for the constant discharge test will be determined by running a step drawdown test a few days prior to commencement of the constant discharge test. A step drawdown test is a single well test which involves pumping the well at several different pumping rates for ½ to 1 hour at each level, while monitoring water levels in the pumping well. Such testing will also afford hydrologists a chance to verify that the meter, discharge system, transducers, and generator are working properly prior to commencement of the constant discharge test.

2. The discharge system has been designed so that a constant discharge rate can be maintained during constant discharge tests.

   The discharge rate of a well will be monitored and adjustments made to maintain the same discharge rate during a constant rate test. A valve will be installed in the discharge pipe before the totalizing meter to allow discharge to be adjusted. Driscoll (1986, p.536) recommends that the discharge pipe and valve be sized so that the valve is one-half to three-quarters open when the well is being pumped at the desired rate. It should be noted that the discharge rate per pump rotations per minute may change as barometric pressure changes at night or during a storm.

3. A totalizing meter which reads cumulative and instantaneous pumping volumes will be correctly installed on the discharge pipe. Another method of measuring discharge, such as an orifice meter and manometer will also be installed.

   Totalizing meters typically are accurate to about 5 to 10 percent. They can be damaged by the sand being pumped through them, and should be continually checked against the other meters. The orifice meter and manometer will be used to verify that the totalizing meter is reading properly and as a backup in case the meter fails.

4. Water will be discharged at a sufficient distance from the wells to prevent discharged water from re-entering the wells or the aquifer near the wells and compromising water level measurements.

   Polyvinyl chloride pipe or other impermeable material of sufficient size will be used to transport the water away from the wells into a natural arroyo or, if necessary, into a portable treatment facility.

5. A dependable, appropriately-sized power supply (generator) for the pump will be utilized, and sufficient fuel for the test will be available.

   Generators are commonly used for aquifer pump tests located in isolated areas. A generator of sufficient size for the pump will be used. The pump and generator system will be set up by the driller or an electrician familiar with the voltage and horsepower requirements of the pump. The technical personnel who will be supervising the test will be familiar with the starting, re-fueling, and shutting down of the generator.

6. Transducers which are compatible with the water depths and expected ranges of water level declines will be installed in the pumping well and observation wells.

Transducers and a data logger will either be rented from a reputable company or purchased. Prior to installation, the transducer probe and cable will be inspected for damage, un-kinked, and cleaned. Vented transducers will be used if possible. Transducers will be properly installed in the pumping well and observation wells and connected to a data logger which will collect the data. Manufacturers' recommended procedures will be followed for installation and testing of the equipment. Transducers and data loggers will be tested several days prior to commencement of the test. The data logger will be set to record data during three log cycles of time and then switch to linear scale.

7. Water level measurements will be monitored manually as a check on transducer measurements, and to ensure that a back-up set of data are available in case of transducer failure.

   Even though the wells will be equipped with transducers and a data logger, water levels will be monitored manually with an e-tape or electronic water level measurement device. Accurate measurements of time and water level declines are important. Clocks and watches will be synchronized before the test begins. Prior to commencement of the testing, technicians will verify that the probe and line can move easily in the well casing and are giving readings consistent with those read by the transducers.

8. Personnel will maintain a field log in which are recorded weather, field conditions, nearby pumping wells, and any circumstances which influence test results and would therefore be useful to know during interpretation of test results.

   Water levels in wells may be affected by changes in weather, which bring with them changes in barometric pressure, precipitation, nearby pumping wells, heavy traffic, and changes in pumping rate. Such events will be recorded so that they can be accounted for during the interpretation phase of the test.

9. Barometric pressure readings will be collected on site during the test and for a week before and after the test. Barometric pressure data will be obtained from the nearest weather station for the period of the test and a week before and after the test. Barometric pressure will be monitored during the test.

10. One technical person will always be on site during the pumping portion of the test and during initial recovery.

    A minimum of two technical people will be necessary during the beginning few hours of the test to perform manual water level measurements and monitor the pumping rate. A technical person will be on site during the entire pumping portion of the pump test to manually measure water levels, monitor pumping rate and to troubleshoot if something goes wrong. For safety reasons, two people will be on site during the entire pumping portion of the test.

## Pre-Test Activities

Technicians will be prepared and familiar with aquifer pump test procedures. The physical site of the test will be prepared to facilitate testing activities and avoid accidents. Equipment will be collected, installed and tested several days prior to commencement of the test. Specific tasks which will be performed prior to the test include:

1. Technicians will set up a logbook in which will be recorded pertinent information concerning the well, the measuring points, initial water levels, the weather, personnel, equipment, etc.

2. A submersible pump has been installed in the Roca Honda pumping well. Electric cables have been taped to the riser at intervals and a 1-inch plastic polyvinyl chloride (PVC) tube has been attached to the riser pipe so as to provide an access tube for the e-tape.

3. Water level measurements will be recorded for all wells to be used in the tests for a week before the commencement of the test.

4. Barometric pressure will be recorded at an on-site weather station at hourly intervals for a week prior to commencement of the test. In addition, the location of the nearest weather station where barometric pressure is recorded will be identified and arrangements made to obtain those data.

5. The pumping well and observation wells be equipped with transducers and a data logger. Transducers with the appropriate range and sensitivity will be selected. The equipment will be properly installed in the wells several days prior to the test to allow the cables to stretch and straighten. Prior to installation, the transducer probe and cable will be inspected for damage, un-kinked, and cleaned. Vented transducers will be used if possible. Transducer cables will be wrapped around and taped to the well casing. The transducers will be connected to the data logger and each transducer registered, enabled and the top of casing set as the reference level. The data logger will be set to record data during three log cycles of time and then switch to linear scale. E-tape readings will be taken in the well(s) to verify that the data logger is receiving and recording data, and the transducers are correctly reading the water level. Manufacturers' recommended procedures will be followed for installation and testing of the equipment. The equipment will be tested several days in advance of the aquifer pump test.

6. Piping will be installed to transport the discharged water away from the well a sufficient distance to prevent it from flowing back down the well bore or into the aquifer near the well.

7. A totalizing meter will be installed at the proper location on the discharge pipe, and another method of measuring discharge installed. The number of gallons already registered on the totalizing meter will be recorded.

8. A ball valve or preferably a gate valve will be installed in the pipe to allow discharge to be controlled and to maintain a constant pumping rate.

9. A generator will be connected by the driller or an electrician familiar with the voltage and horsepower requirements of the pump. Technical personnel who will be

supervising the test will review the starting, re-fueling, and shutting down of the generator. Sufficient fuel will be obtained and stored in a safe place.

10. Technicians will familiarize themselves with e-tapes for taking water level measurements manually. Typical manual water level measurement devices are graduated cables or tapes with electronic probes at the end. These probes send a visual and auditory signal when water is encountered and the electronic circuit is completed. The technician reads the depth to water from the tape, as measured to a constant point, such as the top of the casing. The height of the measurement point above land surface should be recorded.

11. The work site will be set up and log books, aquifer pump test data recording schedules, pens, etc. prepared.

12. All safety issues will be reviewed. Any safety issues will be resolved prior to start-up. These include protecting cables from traffic and ensuring that the cables are not hazards to workers, ensuring that gasoline is stored in a safe place, protecting the generator and data logger from weather, and ensuring that exhausts are equipped with spark inhibitors and the area is clear of flammable material. Two people with vehicles will be on site at all times during the pumping portion of the test. A first aid kit will be on site.

## Step Drawdown Test

A few days before the constant rate test is scheduled to begin, the static water level in the well(s) will be measured, and then a step drawdown test will be run. The pumping well will be pumped for a few hours to determine: 1) the drawdown expected at various discharge rates, 2) the maximum anticipated drawdown, 3) the best method to measure discharge, 4) whether the methods of measuring discharge are giving comparable results, 5) the effectiveness of the planned method of disposing of the water, and 6) whether the observation wells are properly located. Typically, the well will be pumped at three or four increasing constant rates for approximately ½ to 2 hours at each rate (e.g., 50 gpm, 75 gpm, 150 gpm). Collecting data during this test will allow personnel to familiarize themselves with the equipment and methodology prior to the commencement of the constant rate test. After the step test, it will be verified that the transducers are at appropriate levels in the wells (i.e., the expected water levels will not drop below their levels during the constant rate test, and the elevation of the water over the top of the transducer probe does not exceed the tolerance for the instrument).

The general procedures for running the step drawdown test are the same as those detailed below for the constant rate test.

# Constant Rate Test Procedures

The constant rate test should not be started until the static water level recovers to the level it was before the step test began. Typically, 24 to 72 hours must pass for total water level recovery depending on the length of time of the initial test.

1. Personnel will survey the well site and verify that there are no remaining safety issues.

2. Personnel will review their check list of equipment and materials and verify that they have everything necessary, and they know how to use the equipment.

3. All personnel involved in the aquifer pump test will synchronize their watches.

4. The transducers/data loggers should be recording. E-tape measurements will be taken in the wells to verify that transducer measurements are accurate.

5. If a generator is being used, it will be warmed up without starting the pump for 5 to 10 minutes.

6. Pertinent information such as water level measurements, weather, totalizing meter reading, etc. will be recorded in the log book.

7. The person who will be taking measurements with the e-tape will position him/herself at the well and lower the e-tape probe to just above the water level. The recorder will check his/her watch, signal the driller to turn on the pump, and record the clock time when the pump starts. This is time zero. Time will be measured in minutes from this point.

8. Once the pump is turned on, the recorder tells the measurer when to take each water level measurement, and then records the measurements reported by the measurer. The following schedule (Table A–1) should be used for manual pumping well measurements, if possible.

*Table A–1. Water Level Measurement Intervals for Pumping Wells*

| Time since pumping began or ceased (minutes) | Measurement interval (minutes) |
|---|---|
| 0 to 10 | 0.5 |
| 10 to 20 | 1 |
| 20 to 60 | 5 |
| 60 to 90 | 10 |
| 90 to 120 | 15 |
| 120 to 300 | 20 |
| 300 to 1,440 | 30 to 60 |
| 1,440 to end | 120 to 240 |

RHR has prepared an aquifer pump test data sheet on which the data will be recorded (Attachment 1).

If it is possible to take measurements at the pumping well more frequently than at 30-second intervals during the first few minutes of the test, this should be done, particularly if a transducer is not being used. During late test times, if the technician is on site, it is always preferable that measurements be taken in the pumping well and the meter checked every 30 minutes even though this frequency of measurements is not mathematically necessary for analysis of the data. The transducer in the pumping well will be programmed to read logarithmically for the first three log cycles of time (100 minutes) and then at 15- to 30-minute intervals thereafter, if possible.

Unless the observation wells are located very near the pumping well, it is unlikely that water levels in them will respond immediately. Driscoll (1986, p. 553) recommends that water levels in observation wells be measured at the following intervals (Table A–2):

*Table A–2. Water Level Measurement Intervals for Observation Wells*

| Time since pumping began or ceased (minutes) | Measurement interval (minutes) |
|---|---|
| 0 to 60 | 2 |
| 60 to120 | 5 |
| 120 to 240 | 10 |
| 240 to 360 | 30 |
| 360 to 1,440 | 60 |
| 1,440 to end | 480 |

If observation well(s) are located more than 150 feet away from the pumping well, this schedule will be excessively frequent and will be modified. Personnel must be available and stationed at the observation wells, or the well must be equipped with transducers.

9. Pumping rates will be monitored and recorded hourly after the first hour of pumping and more frequently during the first hour. The totalizing meter will be read at regular intervals, and an instantaneous reading will be made using a stopwatch and the totalizing meter dial. Discharges measured at the back-up meter will be recorded at the same time. Direct measurement of discharge using a 55-gallon drum and a stopwatch, or an orifice meter and manometer will be used. During a constant-rate test, it is important that the pumping rate remains constant, and adjustments may be necessary as time goes on. If adjustments are not possible, it is even more important to record the changes in pumping rate.

   Drawdowns will follow a logarithmic function. There will be large drawdowns at the beginning of the test (i.e., the first 10 minutes to approximately one hour). Drawdowns will gradually decline and may be very small after 12 hours. They may not totally stabilize. If drawdowns prove so high that the well is in danger of drying up, it may be necessary to lower the pumping rate. If drawdowns stabilize too soon and the aquifer is insufficiently stressed to allow calculation of hydraulic parameters, it may be necessary to increase the pumping rate. However, changing the pumping rate in the middle of the test is undesirable unless absolutely necessary.

10. Periodically during the test, the technician will download a portion of the data from the data logger and store it in another location.

11. Initial analysis of the data will be performed while the test is in process, so as to identify anomalies that might have a man-made cause, such as infiltration of discharge water back into the aquifer.

Ideally, the aquifer test will continue until water levels in the pumping well have stopped dropping and the cone of depression has stabilized. Pumping a well for 72 hours is usually considered sufficient time for aquifer tests on unconfined aquifers although delayed yield effects may make a longer test desirable, and 24 hours is a sufficient time for confined aquifer tests. If time and funding are available, longer tests are always preferable.

12. Water samples will be collected at the beginning of the test and then at 12-hour intervals until the test is over at hour 72. Electrical conductivity, temperature, and pH readings will be taken occasionally through the test.

13. When the pumping portion of the test is complete, the pump will be turned off and the recovery portion of the test will commence. This portion of the test is as important as the pumping portion and may yield more accurate data for the pumping well because turbulence caused by the pump is eliminated. The recovery section of the test is performed using the same methodology as the pumping portion of the test. The time at which the pump is turned off is recorded, and water level recovery measurements are taken at the same time intervals as the water level drawdown measurements (see tables above), with zero time being the time when the pump was turned off. Total time and time since the pump was turned off are recorded. Full recovery often takes longer than the length of the pumping test. It may be necessary to measure water levels at intervals for several weeks before full recovery occurs.

Even with the best planning, errors and mishaps occur. The effects of most errors (e.g., erroneous readings, missing readings, or fluctuations in pumping rates) can be accounted for during the analysis if the technician keeps adequate and accurate notes. RHR personnel will maintain a field log book in which all pertinent information, such as weather, temperatures, barometric pressure, changes in pumping rates, pump shutdowns, etc. will be logged.

# Attachment 1

# Groundwater Aquifer Testing Field Data Sheet

Strathmore Minerals Corp.

# Groundwater Aquifer Testing Field Data Sheet

Strathmore Project ______________________ Date: __________

Well ID: ______________________ Temp. ________ F° C°

Field Personnel ______________________ Weather: __________

Test Started: Date__________ Time__________

Pre-Test Static Water Level: __________ FT

Test Finished: Date__________ Time__________

Post-Test Static Water Level: __________ FT

Initial Flow Meter Reading (gal): __________ Final Flow Meter Reading (gal): __________

Pump/Capacity (type/hp): ______________________

Range of Pumping Rates ______________ Average Pumping Rate __________

Test conducted by: ______________________ Date: __________

**Observations**

| Date/Time | Time | Elapsed Time | Depth to Water | Total Water Flow (gal) | Notes |
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