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9 Groundwater

Groundwater is a major supply of water for domestic and agricultural use in southern New Mexico. The high evaporation rate during the long, hot summers coupled with low average annual precipitation in the area result in surface waters being an unreliable source of water on a year-round basis. The Rio Grande is the only significant surface water resource in the Copper Flat Mine Permit Area (Site). Intermittent streams that feed the Rio Grande, such as Las Animas Creek and Percha Creek in the Site area, are local sources of water for at least part of the year. The river and associated shallow alluvial deposits of its inner valley also served as the ultimate discharge zone for pre-development groundwater flow from the adjacent Greenhorn Arroyo, Las Animas Creek, and Percha Creek drainage basins (Hawley et al., 2005, Wilson et al. 1981). Additional water comes from shallow domestic and agricultural wells. This section provides a description of the regional and local groundwater along with a proposed sampling and analysis approach to characterizing baseline conditions of groundwater resources. Baseline studies have been completed in the project area since the 1960s, and relevant information and data are referenced in subsequent sub-sections throughout Section 9.

9.1 Regional Hydrogeology

The Site is located in the Lower Rio Grande Underground Water Basin (LRGB), which extends from Elephant Butte Dam to the Texas Border near El Paso and is one of New Mexico's principal agricultural regions (Figure 9-1). The LRGB was declared by the NM State Engineer on September 11, 1980. In doing so, the underground waters of the LRGB are administered by the State Engineer. In response to drought conditions in New Mexico, the Office of the State Engineer (OSE) designated the LRGB for Active Water Resource Management (AWRM) in 2004, emplacing additional restrictions on groundwater development. In addition, a water master district that encompasses Hot Springs, Las Animas Creek, and LRGB Underground Water Basins was created to assist with water administration in the region.

Groundwater in the LRGB generally flows from the highlands on either side of the basin through bedrock and valley alluvium to the center of the basin and to the Rio Grande. Figure 9-2 illustrates the conceptual model of groundwater flow at the Site. The bedrock aquifer in the Paleozoic sedimentary rocks are recharged by rainfall and snowmelt through bedrock faults and bedding planes exposed in the highlands west of the site. This water generally flows along a hydraulic gradient toward the approximate center of the Rio Grande Valley. Occasionally, this deep regional flow discharges at the ground surface as springs along faults where the Paleozoic bedrock crops out within the valley. This occurs in at several locations within the Las Animas Creek and Percha Creek drainage basins (Figure 9-3). The water table elevation near the existing pit lies at approximately 5,450 to 5,500 feet (ft) above mean sea level (amsl). Groundwater near Caballo Reservoir lies at about 4,200 ft amsl, indicating a drop of 1,300 ft over approximately 14 to 15 miles.

Valley alluvium is generally recharged by precipitation along mountain fronts where the alluvial fans are exposed and by streams that flow out of the highlands and lose water to the alluvium as they flow toward the Rio Grande. Many intermittent streams in the area are "losing streams" over at least part of their courses and provide recharge to the alluvial groundwater system. This alluvial groundwater then flows downgradient to the Rio Grande. Most areas within the LRGB that have not been significantly disturbed by human activity are in hydraulic equilibrium. That is, water coming into the system by precipitation recharge is balanced by outflow to major streams, evapotranspiration, and interbasin flow.

9.1.1 Hydrogeology of the Permit Area

Three aquifers exist in the Site area, as shown schematically on Figure 9-2. The deepest aquifer is the crystalline bedrock aquifer that receives water from the highlands to the west of Animas Peak and carries this water along bedding planes, faults, and solution cavities toward the center of the LRGB. The crystalline bedrock aquifer consists of Cretaceous andesite and monzonite breccias underlain by Paleozoic rocks in the Animas Uplift area, Tertiary volcanic rocks to the west of the pit lake in the graben associated with the Animas uplift, and Paleozoic sedimentary rocks to the east of the pit lake area in the Palomas Basin (see Section 7.0). The Santa Fe Group aquifer system, which consists of interbedded sandstones, silts, and clays, overlies the Paleozoic bedrock units to the east of the pit lake area within the Palomas Basin. This aquifer system receives water from precipitation and from the losing reaches of streams. The uppermost aquifer at the Site is the Quaternary alluvial aquifer along Las Animas and Percha Creeks (Figure 9-2). This alluvium is up to 40-ft thick in the Las Animas Creek area and carries water that is in hydraulic equilibrium with the water flowing in Las Animas Creek (BLM, 1999). The Percha Creek alluvial aquifer is less studied than the Las Animas Creek alluvial aquifer, and as a result, less historical data about its aquifer characteristics are available. The aquifers of greatest importance in terms of water supply in the area are within the Palomas Basin to the east of the pit lake and include the intermediate Santa Fe Group aquifer system and the alluvial aquifer associated with Las Animas Creek.

Figure 9-4 from the Adrian Brown Consultants (ABC) (1998b) presents a piezometric contour map showing the general configuration of groundwater level elevations at the Site as interpreted at that time. Groundwater levels near the existing pit are approximately 5,450 ft amsl, and at Caballo Reservoir, the levels are about 4,200 ft amsl. The map indicates that groundwater flow is generally to the east toward Caballo Reservoir. Hydraulic gradients are relatively large (closely spaced contours) in the western portion of the Site, reflecting lower transmissivity in the bedrock aquifer and in the western portion of the Palomas Basin in the Santa Fe Group aquifer system. The wider spacing of contours in the eastern portion of the Site suggests that transmissivity of the Santa Fe Group aquifer increases toward Caballo reservoir. The widest spacing of contours (highest transmissivity) appears to occur in the area of the groundwater production wellfield (wells PW-1, 2, 3, and 4 on Figure 9-4). This area coincides with an interpreted graben structure (see Section 7), which reflects an increased thickness of the Santa Fe Group in this area.

9.1.2 Aquifer Characteristics in the Permit Area

9.1.2.1 Crystalline Bedrock Aquifer Characteristics

Groundwater within the mining district and the area of the present open pit occurs in andesitic volcanic rocks and quartz monzonite breccia intrusive rocks (Figure 9-2). The current pit lake was reported by SRK (1997) to be at an elevation of 5,442 ft amsl, which is about 50 to 100 ft below the pre-mining ground elevation (5,500 to 5,540 ft amsl reported in the Preliminary Final Environmental Impact Statement (PFEIS) (BLM, 1999). Groundwater levels measured in the pit and tailings areas as of 1997 are shown on Figure 9-5. Newcomer et al. (1993) reported a pre-mining (1981) water level of 5,370 ft amsl in well GWQ-5, which is approximately 4,000 ft east-southeast from the pit and within the old plant site area. These authors also reported a water level of 5,360 ft amsl in the Hillscher West well (GWQ-6), which lies approximately 2,500 ft southeast from well GWQ-5. These limited groundwater elevation data suggest that the groundwater gradient in the andesitic volcanic rocks may be to the east or southeast from the current pit lake area as shown on Figure 9-5. Within 500 ft of the pit lake (see Figure 9-6, however, groundwater gradients are toward the pit lake, which may act as a local evaporative sink (BLM, 1999).

In January 2010, NMCC resurveyed the pit lake and as many of the groundwater monitoring wells established for the PFEIS as could be located. The pit lake elevation was 5,444 ft amsl in January 2010, revealing that the pit lake elevation remains below the pre-mining water level elevation of 5,500 to 5,540 ft amsl.

9.1.2.2 Santa Fe Group Aquifer System

Overview

Overlying the crystalline bedrock aquifer at the Site is the Santa Fe Group aquifer system, a system that is locally represented by two hydrostratigraphic units (HSUs): (1) the Upper Santa Fe Group hydrostratigraphic unit (USF), and (2) the Middle Santa Fe Group hydrostratigraphic unit (MSF). As defined by Hawley and Kennedy (2004), these hydrostratigraphic units are mappable bodies of basin and valley fill that are grouped according to genesis and position in both lithostratigraphic and chronostratigraphic sequences. Informally, these HSUs comprise the major basin-fill aquifer zones, and correspond roughly to the upper (Palomas) and middle (Rincon valley) lithostratigraphic subdivisions of the Santa Fe Group used in local and regional geologic mapping (Hawley and Kennedy, 2004).

The Santa Fe Group is composed chiefly of coalescing alluvial fan deposits that are discontinuous and locally heterogeneous with inter-bedded sandstones, silts, and clays of varying percentages. The Upper Santa Fe Group Palomas Formation (Lozinsky and Hawley, 1986) represents the USF at the Site. This formation grades eastward from the Animas Uplift from coarse alluvial fan material to braided-stream and deltaic sands and silts to clays near the Rio Grande. The interfingering with clays begins approximately 3 to 5 miles west of the current position of the Rio Grande and is responsible for the flowing wells common in this part of the Site (Murray, 1959; Figure 9-2). A basalt flow dated at 4.2 million years before present caps the Palomas Formation gravels near Copper Flat (Seager et al., 1984).

The Middle Santa Fe Group Rincon Valley Formation (Seager and Hawley, 1973) is exposed near Hillsboro, New Mexico, where the reddish-brown clays and clayey silts characteristic of this basal unit are interbedded with basalts dated at 28 million years before present (Seager et al., 1984). The Rincon Valley Formation represents the MSF at the Site and generally contains water, but the yield is low due to the low hydraulic conductivity of the clays. The Rincon Valley Formation lacustrine red clays underlie the Palomas Formation and thicken southward toward Hatch, New Mexico, and the Rincon Basin (Wilson et al., 1981).

Tailings Dam Vicinity

The present tailings impoundment facility overlies the old placer workings of Greyback Arroyo and Hunkidori Gulch (Figure 9-3). A study of these placer workings by Segerstrom and Antweiler (1975) showed that the placers were found in paleo-stream terrace alluvium approximately 25 to 30 ft thick that is underlain by a calcium carbonate horizon and reddish-brown clay. SRK (1995) and SHB (1980) confirmed and expanded the areal extent of this reddish-brown clay layer and determined that the top of the Palomas Formation is stratigraphically below the red clay layer. According to the studies completed by SRK and SHB, the clay layer and the 25 to 30 ft of paleo-stream terrace gravels that lie above the clay, have acted to prevent downward migration of water draining from the eastern half of the existing tailings. This clay layer has enabled a mound of water beneath the tailings impoundment to develop and was determined by SRK and SHB to extend eastward beyond the tailings dam. This mounding of water, due to drainage of the tailings, became evident in some tailings dam monitor wells completed above the clay layer. The central and western sections of the existing tailings facility appear to communicate hydrologically with the USF that lies beneath the tailings area because the clay zone thins and disappears in this area, as shown in Figure 9-7.

The thickness of the Palomas Formation increases locally over a graben structure (labeled Dutch Gulch in Figure 9-8), which is reflected in higher transmissivity and relatively low hydraulic gradients in the USF. Based on a 7-day aquifer pumping test (ABC, 1996), the transmissivity of the USF in the tailings dam area is about 187 ft^2/day. East of the tailings area (see Figure 9-8) is a 10- to 30-foot thick clayey sand and gravel layer, underlain by a 25- to 100-foot-thick clay layer, which in turn is underlain by a silty sand and gravel layer (SRK, 1995). The lower silty sand and gravel layer is considered by ABC (1996) to be the USF and, based on drilling information, has a thickness of at least 200 ft. The hydraulic gradient in this area is about 30 ft per mile.

East of the graben structure, labeled as Dutch Gulch in Figure 9-8, the Palomas Formation (labeled Tsfp) thins and is interpreted to have significantly reduced transmissivity. The hydraulic gradient in this area ranges from about 130 to 330 ft/mile. The contact between the Palomas Formation and the underlying Rincon Valley Formation clay unit (labeled Tsf in Figure 9-8) is a highly irregular depositional contact. Locally, the Palomas Formation (USF) may be unsaturated, with the water table existing in the underlying Rincon Valley Formation (MSF) (BLM, 1999).

Production Wellfield Vicinity

Farther to the east, the hydraulic gradient decreases from 330 ft/mile to about 34 ft/mile in the vicinity of the production wellfield (identified as PW wells on Figure 9-9). This suggests a progressive increase in transmissivity toward the area of the production wellfield. A graben structure below the production wellfield locally increases the thickness of the Palomas Formation to as much as 1,000 ft (Figure 9-8). The transmissivity of the USF in the production wellfield area ranges from about 2,675 to 5,750 ft^2/day (SRK, 1995). Farther to the east, towards Caballo Reservoir, sands and gravels in the Palomas Formation are interbedded with clays of the ancient Rio Grande. As a consequence, the transmissivity decreases slightly and the hydraulic gradient Increases to 45 ft/mile. In this area, the USF appears to be confined, leading to artesian flow in wells along the lower reaches of both Las Animas Creek and Percha Creek.

Although the Palomas Formation is described as “sand and gravel” (Davie and Spiegel, 1967), there exist numerous discontinuous clay layers within the sequence. This causes the bulk vertical hydraulic conductivity of the USF to be much lower than the horizontal conductivity. As a consequence, groundwater in deeper portions of the USF can be semiconfined, leading to relatively high vertical hydraulic gradients. The low vertical hydraulic conductivity has two important effects on the groundwater flow system. First, within about 4 miles of Caballo Reservoir, confinement of groundwater is sufficient to create artesian conditions in deeper portions of the USF. Wells drilled to these depths have groundwater levels aboveground surface and produce flowing wells, the locations of which are shown on Figure 9-9. Flow rates for uncapped wells range between a few gallons per minute (gpm) to as high as 40 gpm.

The second effect of low vertical conductivity is to reduce downward leakage between the Quaternary alluvial aquifer in the Las Animas Creek drainage basin and the underlying USF. At the location of monitoring wells MW-9, 10, and 11, north of the production wellfield, the groundwater level in the USF is some 58 ft lower than the water level in the overlying Quaternary alluvial aquifer (ABC, 1996). This results in a downward vertical hydraulic gradient from the Quaternary alluvial aquifer in the vicinity of Las Animas Creek drainage basin to the USF approaching 1 ft/ft. Such downward gradients are interpreted to occur along a substantial length of Las Animas Creek (ABC, 1996). In spite of these gradients, the amount of surface water loss from the Quaternary alluvial aquifer in the Las Animas Creek drainage basin is not significant; suggesting that vertical hydraulic conductivity in the USF is relatively low. Analytical calculations (ABC, 1997) suggest that if the vertical conductivity were much greater than 1 ft/year (10^{-6} cm/second), the Las Animas surface water system would lose essentially all of its water and become an intermittent stream, which clearly does not occur.

The hydraulic connection between the USF and the alluvial aquifer of the Rio Grande has not been evaluated, but groundwater gradients at the Site strongly suggest that water flows from the Palomas Formation to the floodplain alluvium of the Rio Grande.

An aquifer pumping test conducted at the locations of monitor wells MW-9, 10, and 11 suggests that the vertical conductivity of the USF is low in this area (ABC, 1997). Pumping of the wells screened in the USF at this location did not affect a well screened in the Quaternary alluvial aquifer in the Las Animas Creek drainage basin, even though the well screened in the USF had 22 ft of drawdown. Also, monitoring of water levels along Las Animas Creek by Alta (Goff, 1998) for wells screened in both aquifers showed that fluctuations in water levels observed in shallow wells (those screened in the Quaternary alluvial aquifer) are not mirrored in the deeper wells (wells screened in the USF). These data are presented in Table A2-10 of the PFEIS (BLM, 1999).

9.1.2.3 Quaternary Alluvial Aquifer

The uppermost aquifer at the Site is the Quaternary alluvial aquifer, which is composed of channel and floodplain gravels, sands, and silts. Locally, these units are generally 30 to 50 ft thick near the mouths of Las Animas and Percha Creeks (Davie and Spiegel, 1967). Cores from monitoring wells drilled along Las Animas Creek indicate that upper alluvial gravels extend from the surface to a depth of approximately 20 to 60 ft depending on the location along the creek (BLM, 1999). There are fewer data available for the thickness of these deposits in and along Percha Creek.

The Las Animas alluvial aquifer consists of local alluvial deposits adjacent to and underlying Las Animas Creek. Groundwater in this narrow, sinuous aquifer is in direct hydraulic communication with Las Animas Creek surface water. Surface water in the creek and groundwater in the aquifer form a single surface-to-groundwater flow system. Surface water flow from one location to the next may be related, in part, to the proportion of total system flow being carried by the aquifer at each location. Along its course, the Las Animas alluvial aquifer receives recharge by rainfall infiltration. Discharge from the aquifer occurs through evaporation and evapotranspiration from riparian vegetation and existing well pumping. Between the Saladone well and an area of the Lower Animas Artesian well (Figure 9-8), the aquifer loses water to the underlying Palomas Basin alluvial aquifer by slow downward seepage. The total flow rate for surface flow plus flow in the alluvium of the creek drops from around 1,800 to 1,900 gpm to around 1,100 gpm, a loss of 800 gpm over the 8-mile stretch of creek bed. The loss is consistent with slow downward seepage of water at a rate of around 1 foot/year (ABC, 1997). This is the approximate saturated hydraulic conductivity of clay. In the area of the Lower Animas Artesian (Figure 9-9) the Las Animas surface/groundwater system may receive recharge from the USF. At Caballo Reservoir, all water in the Las Animas surface/groundwater system discharges to the reservoir. The nature of artesian conditions in the Percha Creek drainage basin have not been studied in as much detail, and therefore less historical data are available.

Upstream of the artesian wells, Las Animas Creek, the alluvial aquifer can be “perched” above the water table in the Santa Fe Group aquifer system by 20 to 60 ft of unsaturated to partially saturated alluvial sediments (SRK, 1995; ABC, 1997). The alluvial aquifer along Las Animas Creek in the lower reaches loses water to the Santa Fe Group aquifer system by slow downward seepage. The upper reach of Las Animas Creek near the Saladone Well (Figure 9-9) also may be perched above the intermediate aquifer (Minton, 1961).

9.1.3 Existing Baseline Groundwater Information

A wealth of groundwater data are available for the Site because the mine was active in the past and was characterized by previous operators that either mined the Site or worked on permit applications to mine the Site. These historical data will be used in conjunction with the baseline groundwater quality data that will be collected under the procedures set forth in this SAP to provide as thorough an understanding as possible of groundwater quality conditions prior to the re-initiation of mining at Copper Flat. Key resources that contain data to be used for the baseline groundwater analysis include: Groundwater monitoring well exceedences provided by SRK (2010); the PFEIS (BLM, 1999); the Hydrologic Assessment, Copper Flat Project Sierra County, New Mexico (Newcomer et. al, 1993); and The Natural Defenses of Copper Flat, Sierra County, New Mexico (Raugust, 2003). A brief summary of the data available in these key reports follows.

The PFEIS (BLM, 1999) provides a summary of groundwater quality data. Summary tables for key wells and key constituents are provided in Table 9-2. The wells identified in this study are illustrated in Figure 9-9. The PFEIS (BLM, 1999) concluded that groundwater quality at the Site was good and generally useable for domestic and agricultural purposes. This document also concluded that past mining in the Hillsboro District, the Copper Flat Mine tailings facility drainage, and the presence of an oxidized sulfide-bearing ore body have impacted groundwater within and immediately adjacent to the area of past mining, resulting in elevated total dissolved solids (TDS) and sulfate that exceed New Mexico Water Quality Control Commission (WQCC) Standards. These impacts were found to be localized within the immediate vicinity of the mine features or associated with wells completed in the ore body.

Newcomer et al. (1993) determined that the quality of groundwater at the Site has changed little since the early 1980s and probably since the 1800s. The authors found that there have been some increases in TDS and sulfate in some wells along Grayback Arroyo below the mine site and down-gradient of the tailings dam, associated with mining and milling activities in the 1980s. Newcomer et al. (1993) determined that the only constituents exceeding the WQCC Standards were barium from a spring sample, and, cadmium and fluoride from a pit lake water sample.

Raugust (2003) compiled historical groundwater data and summarized groundwater quality conditions and, based on his data compilation and analysis, concluded:

- Groundwater pH measurements both up and downgradient of the pit lake range from 7 to 8.2.
- TDS and sulfate values are less than WQCC standards in the wells evaluated for this analysis; however, samples downgradient of the mine have increased gradually over time and are approaching the standards for TDS.
- Historical sampling of well GWQ-5, located east and downgradient of the pit lake, indicates that water quality in the vicinity of the pit lake may have been affected naturally by the presence of the ore body prior to mining in 1982.
- The groundwater upgradient of the mine pit lake is high quality with relatively high proportions of chloride and sulfate. Groundwater downgradient of the pit lake shows relatively higher proportions of bicarbonate and calcium and relatively lower proportions of sulfates.
- Pre-Quintana mining (June 15, 1981) groundwater data collected from wells downgradient of the pit lake show similar anions and cation distributions to post-Quintana mining activities (1996 and 1998). This indicates that groundwater quality downgradient of the ore body reflects the natural weathering of the Copper Flat porphyry system.

9.1.4 NMED Stage 1 Abatement Plan Requirements

On August 20, 2008, the NMED sent a letter to the site owner at that time requiring a Stage 1 Abatement Plan (20.6.2.4101 NMAC). The purpose of the Stage 1 Abatement Plan is to provide the data necessary to select and design an effective abatement alternative. The requirements for the Stage 1 Abatement Plan are described in 20.6.2.4106 NMAC. The abatement plan proposal must include an investigation to define the extent and magnitude of any existing groundwater and surface water contamination and to characterize the hydrogeology of the site. These requirements are similar to the EMNRD requirements for completing a Baseline Characterization Report, and these efforts will be conducted in parallel; therefore, the surface water and groundwater requirements of this SAP are relevant to both characterization efforts.

NMCC's meetings with the NMED concerning the abatement requirements have revealed the following key concerns on the part of the NMED:

- Groundwater impacts from the existing unlined tailings impoundment have been documented, but have not been fully characterized.
- Samples of pit lake water quality reveal exceedances of WQCC standards, and NMED is concerned about migration of this water away from the pit, causing additional groundwater impacts as well as ongoing contact with wildlife.
- Acid leaching could be occurring due to ongoing ore exposure.

9.1.5 Statistical Analysis of Existing Baseline Data

As discussed in this section, enormous amounts of surface water and groundwater data exist for this Site. These existing baseline data are essential to completing a comprehensive Baseline Characterization Report. As discussed in the EMNRD Mining and Minerals Division (MMD) draft, Guidance Document for Part 6 New Mining Operations Permitting under the New Mexico Mining Act (MMD Guidance Document), "If historic data and information are used as part of the baseline data, the SAP will include supporting material to justify the use of this historic data." As discussed in the previous subsection, baseline data collection has been initiated at the Site. The following sections describe how these data will be collected to maintain compliance with the referenced MMD Guidance. To justify the incorporation of the existing baseline data, statistical analysis will be used to determine if the current baseline data are significantly different from existing baseline data. This subsection describes a proposed approach that may be utilized to answer this question.

To statistically evaluate and compare new and existing baseline data, an Access database will be utilized to incorporate data from the sources listed above, as well as from other key sources that are identified during the baseline characterization program. Standardized queries will be used to easily select common location and parameter combinations.

The database will include the following data-entry features:

- A data qualifier to be applied at the time of data entry. This qualifier will be based primarily on the existence of supporting documentation and the indication that the data have been previously validated.
- Fields for entry of chemical parameters and other significant data, including:
  - Well identification (ID)
  - Parameter
  - Result
  - Units
  - Detection limit
  - Method
  - Non-detect qualifier used
  - Date of collection or analysis
  - Laboratory performing analysis
  - Analytical laboratory data qualifier

- Descriptive summary statistics for the compiled existing baseline dataset and a dataset based on data collected from the current baseline monitoring well network, including:
  - Chemical name
  - Number of detections
  - Number of samples
  - Arithmetic mean
  - Geometric mean (the backtransformed mean of the logtransformed data)
  - Standard deviation
  - Arithmetic mean plus two standard deviations
  - 95-percent upper confidence limit on the arithmetic mean (likely upper value of the arithmetic mean)
  - Minimum reported concentration
  - Maximum reported concentration

Descriptive summary statistics will be calculated separately for each historical data set identified and then a historical data set will be developed to represent existing baseline data. These data will be compared to summary descriptive statistics developed for the current baseline monitoring well network. If possible, the historical data set will be classified into pre-mining, mining, and post-mining periods and summary descriptive statistics will be developed for each classification.

Summary descriptive statistics will be developed for any populations identified by the methods described above. Each historical population identified will be separately compared to current baseline data and an interpretive evaluation of the historical and current datasets will be completed.

9.2 Sampling Objectives

The objectives of the baseline groundwater characterization program are as follows:

- Obtain necessary data to evaluate quantity and quality of all aquifers at the Site that could be impacted by mining activities.
- Address data gaps identified during evaluation of the DEIS (BLM, 1996).
- Meet the requirements set forth in the regulations in NMAC Title 19, Chapter 10, Part 6.
- Meet the guidelines set forth in MMD's draft Guidance Document for Part 6 New Mining Operations Permitting under the New Mexico Mining Act.

See Table 9-1 for the activities proposed to meet these objectives.

9.3 Sampling Frequency

The MMD Guidance Document requires a minimum of two sampling events over the required 12-month period for baseline groundwater quality sampling. Quarterly groundwater quality sampling will be necessary to address NMED's Stage 1 Abatement and Discharge Plan requirements; therefore, the baseline groundwater quality sampling will be performed for a minimum of four quarters. Additionally, water levels will be obtained on a quarterly basis to evaluate baseline seasonal fluctuations. Table 9-2 provides the current list of groundwater monitoring wells and the sampling frequency for water quality and water level measurements. The locations for these proposed wells are shown in Figure 9-10. NMCC proposes a phased approach to water quality sampling, where water quality samples will be collected initially from the wells identified in Table 9-2 for water quality sampling, then reduced to a subset of ten wells based on the analytical results and consultation with the MMD.

9.4 List of Data to Be Collected

The two categories of data to be collected for baseline groundwater characterization are groundwater quality and aquifer parameters. Further discussion of these datasets is included in the following subsections.

9.4.1 Groundwater Quality Parameters

The MMD Guidance lists specific groundwater quality parameters that are recommended to comply with the baseline characterization requirements. Table 9-3 shows the list of parameters to be analyzed for and the associated analysis methods and laboratory detection limits.

9.4.2 Aquifer Parameters

Water level measurements will be taken from all wells in the monitoring well network on a quarterly basis during the baseline characterization phase to evaluate the pre-mining potentiometric surface (i.e., steady-state condition). This potentiometric surface will form the basis for future modeling required to evaluate potential impacts from mine dewatering and production well pumping. Based on comments made during Alta Gold's permit application phase, the need to install additional monitoring wells for water level measurement, particularly outside the permit area, will be evaluated (DBS&A, 1998).

In addition to water level monitoring, groundwater modeling requires hydraulic parameter data, specifically, hydraulic conductivity, transmissivity, and storativity for the key aquifers. Several pumping tests have been performed in the tailings dam, production well, and the Las Animas Creek areas to evaluate the aquifer characteristics (Greene and Halpenny, 1976; Atkins, 1992; ABC, 1996b; and ABC, 1998). The details and analytical results of these tests are summarized by SRK (1995) and in Table 9-4. The existing data and recommendations will be evaluated during the baseline characterization phase, and a determination will be made as to the adequacy of the existing data to support the hydrologic impact analysis. If necessary, additional aquifer tests may be completed.

9.5 Methods of Collection

As discussed in the previous sections, three major categories of data will be collected for the baseline groundwater characterization:

1. Well information (water levels and total depth)
2. Groundwater quality samples for general chemistry and metals
3. Aquifer parameters (hydraulic conductivity, transmissivity and storativity)

The following sections provide general Standard Operating Procedures (SOPs) for water level and total depth measurements, groundwater sampling, and aquifer testing. Procedures will be modified as necessary to conform to site-specific requirements. Additionally, if new wells are added to the monitoring well network, they will be constructed in compliance with the NMED Monitor Well Construction Guidelines.

9.5.1 Water Level and Total Depth Measurements SOP

This SOP is concerned with the measurement of water levels in monitoring wells and the total depth of wells. Step-by-step procedures are outlined in the following sections.

9.5.1.1 Groundwater Level Measurement

If necessary, a plastic sheet can be placed around the well, creating a clean surface onto which the measurement and sampling equipment can be positioned. Do not place meters, tools, equipment, etc., on the sheet unless they have been cleaned first. After unlocking and/or opening a monitoring well, water level measurements will be made using an electric water level meter.

Equipment

- Socket wrenches and/or open-end wrenches
- Screw driver
- Key or combination for monitoring well lock
- Electric water level meter
- Decontamination equipment (buckets, brushes, Alconox™, distilled or deionized water, brushes, and paper towels)
- Safety equipment (sample gloves and other Personal Protective Equipment [PPE] as required for the job)
- Air monitoring equipment as required

Groundwater Level Measurement Procedures

- Unlock and/or open the monitoring well.
- Check for the measuring point at the top of the well. The measuring-point location should be clearly marked on the innermost casing or identified in previous sample-collection records. If no measuring point can be determined, a measuring point should be established. Typically, the top (i.e., the highest point or the north-facing point) of the innermost well casing will be used as the measuring point. The measuring-point location should be described on the monitoring-well gauging data form and should be the same point used for all subsequent sampling efforts.
- Obtain a water level measurement by lowering the probe of the electric water level meter into the monitoring well. Take care that the probe and electric line hang freely in the monitoring well and do not adhere to the wall of the well casing. Lower the probe into the well until the sound and light (if present) on the meter are activated. At this time, the precise measurement should be determined (to a hundredth of a foot) by repeatedly raising and lowering the tape to converge on the exact measurement. The water level measurement should be entered on an appropriate field form (i.e., monitoring-well gauging data form).
- Verify that the water level measurement is indicative of a static water level. The initial water level measurement may not be indicative of static conditions if groundwater pumping recently occured in this vicinity or if the well is screened in a confined aquifer and the well casing does not have a vent hole permitting equilibrium with the atmosphere. A second water level measurement a few minutes after the initial measurement can be used to verify static water level conditions.
- Decontaminate the electric water level meter after use. Generally only the probe and the portion of the tape that enters the well will be cleaned. Ensure that the measuring tape is not placed directly on the ground surface.

9.5.1.2 Total Depth Measurement

If necessary, a plastic sheet can be placed around the well, creating a clean surface on which the measurement equipment can be positioned. Do not place tools, equipment, etc., on the sheet unless they have been cleaned first. Total-depth measurements will be made using a stainless-steel weighted tape.

Equipment

- Socket wrenches and/or open-end wrenches
- Screw driver
- Key or combination for monitoring well lock
- Stainless steel weighted tape
- Decontamination equipment (buckets, brushes, Alconox™, distilled or deionized water, brushes, and paper towels)
- Safety equipment (sample gloves and other PPE as required for job)
- Air monitoring equipments as required

Total Depth Measurement Procedures

- Unlock and/or open the monitoring well.
- Monitor the atmosphere at the wellhead.
- Check for the measuring point of the well. The measuring-point location should be clearly marked on the innermost casing or identified in previous sample-collection records. If no measuring point can be determined, a measuring point should be established. Typically, the top (i.e., the highest point or the north-facing point) of the innermost well casing will be used as the measuring point. The measuring-point location should be described on the water level data form and should be the same point used for all subsequent sampling efforts.
- Obtain a total-depth measurement by lowering a weighted calibrated tape into the monitoring well. Take care that the weighted tape hangs freely in the monitoring well and does not adhere to the wall of the well casing. Lower the weighted tape into the well until the bottom of the well is reached. This can be determined when the weight can no longer be felt and there is slack in the tape. A precise measurement of the total depth of the well should be determined (to a hundredth of a foot) by repeatedly raising and lowering the tape to determine the exact measurement and then adding the probe tip length (e.g., 0.10 ft) that extends below the 0.00-foot mark on the tape/probe. The total-depth measurement and condition of the well bottom (i.e., hard, soft) should be entered on an appropriate field form or field logbook (i.e., water level data form).
- Decontaminate the measurement device after each use. Generally only the portion of the tape that enters the well will be cleaned. Ensure that the measuring tape is not placed directly on the ground surface.

9.5.2 Monitoring Well Sampling for Groundwater SOP

This SOP is concerned with the collection of valid and representative samples from groundwater monitoring wells. Groundwater samples are collected and analyzed to determine the presence, absence, or quantity of various contaminants as part of site characterization, remediation, and/or monitoring activities.

9.5.2.1 Equipment

The following list identifies the types of equipment that may be used for a range of groundwater sampling applications. A project-specific equipment list will be selected from this list based on project objectives and well conditions.

- Bailer with rope or string
- Pump with tubing and power source
- pH meter

- Specific conductance meter
- Temperature meter
- Dissolved oxygen meter
- eH (ORP) meter
- Turbidity meter
- Flow-through cell
- Water level measurement equipment
- Water sampling data form
- Filtration apparatus (project-dependent)
- Personal protective equipment
- Decontamination equipment
- Permanent pens
- Field logbook
- Sample coolers
- Sample containers and laboratory-supplied preservatives (if any)
- Sample labels
- Custody seals (if required by Sampling & Analysis Plan/Work Plan)
- Chain-of-custody forms
- Sample control logs

9.5.2.2 Well Purging

Prior to sample collection, purging must be performed for all groundwater monitoring wells to remove stagnant water from within the well casing and/or to ensure that a representative sample is obtained.

Standard Well Purging. Monitoring wells will be purged of at least three well casing volumes (moderate- to high-yield formations) or at least one well casing volume for low-yield formations unless micropurge methodology is followed (method described below). To determine the volume of water to be removed, the first step is to measure the depth to water (DTW) and the total depth (TD) of the well casing using the procedures described as outlined in Section 9.5.1. DTW measurements should be made within 48-hours of purging and sampling wells. Once these measurements have been obtained, the well casing volume is determined using the following equation:

$$V_{WC} = \frac{\pi D^2 h}{4}$$

where: V_{WC} (ft^3) = well casing volume

D (ft) = internal diameter of the well casing

h (ft) = length of the water column in the well casing (TD-DTW)

As a conservative measure or because of project-specific requirements, total well volumes may be required for purging rather than well casing volumes. Total well volume differs from well casing volume in that it includes the volume of water in the filter pack. Total well volume is calculated using the equation:

$$\text{Total Well Volume} = V_{FP} + V_{WC}$$

where: V_{FP} = volume of water in the filter pack

The volume of water in the filter pack is determined by calculating the volume of the water in the borehole less the well casing volume. Compensation for the porosity of the filter pack is included in the equation, and this relationship is expressed as follows:

$$V_{FP} = \left[\frac{\pi D^2 h}{4} - V_{WC} \right] (n)$$

where:	V_{FP} (ft^3)	=	filter pack volume
	D (ft)	=	diameter of the borehole
	h (ft)	=	lesser of (a) length of filter pack, or (b) length of water column in the casing
	n	=	filter pack porosity (assume 30 percent)
	V_{WC} (ft^3)	=	well casing volume

Useful conversions: 1 ft^3 = 7.48 gal

1 gal = 0.134 ft^3

Indicator parameters (pH, temperature, and conductivity) will be monitored and recorded during purging. Generally, well purging will continue until the pH is within 0.2 standard units, temperature is within 1° C, and electrolytic conductivity is within 10 percent in three consecutive measurements.

Low-yield wells are considered purged after a minimum of one well volume is removed. If possible, low-yield wells should be purged at a rate slow enough so as not to purge the well dry. If a well is purged dry, the well should be sampled as soon as it has recovered enough to have sufficient water volume for the sample. The time between purging and sampling should not exceed 24 hours.

For medium or high-yield wells, samples should be collected within two hours of purging if possible. Under no circumstances should there be more than 24 hours between purging and sampling.

Please note that purging and sampling of a well can be done within 12 hours of well installation (i.e., just after well development), if necessary. However, the greater the time lapse between well installation and well sampling, the more representative the sample will be of formation water. It is recommended that, when project schedules and budget allow, wells should be allowed to stand for 24 hours or greater prior to purging and sampling.

Micropurging. Micropurging is an alternate method for purging wells that is distinctly different from the above-mentioned purging methodology. With micropurging, also referred to as low-flow purging, water is withdrawn directly from the screened interval at low enough pumping rates to ensure that the water sampled is formation water just recently entering the screen. As with traditional sampling, the groundwater is not sampled until the water-quality parameters (pH, temperature, and conductivity) have stabilized. Micropurging does not require a certain volume of water to be evacuated from the well. The intake point of the pump or tubing should to be close to the middle of the screen, so the monitoring-well construction details must be known. Micropurging criteria include the following:

- The intake point of the pump or tubing is in the center of the screen.
- Return water is clear and free of debris and has evacuated all major air bubbles in the tubing and flow-through cell.
- The pumping rate does not exceed 1 liter per minute (L/min) (0.1 to 0.5 L/min is usually optimum).
- Drawdown in the well is minimized and does not exceed 10 percent of the screen length.

- Three consecutive measurements of pH, temperature, conductivity, redox potential, and dissolved oxygen have been taken and show changes in value no more than 0.1 for pH, 1°C for temperature, 3 percent for conductivity, 10 millivolts for redox potential, and 10 percent for dissolved oxygen.

9.5.2.3 Well-Purging Methods

Monitoring wells may be developed using either bailers or pumps. It is not recommended that bailers be used for purging, although in many cases bailing may be the most practical method.

Four general types of equipment are used for well purging:

1. Grab samplers (including bailers, Kemmerer samplers, and syringe samplers)
2. Suction-lift pumps (including peristaltic pumps, surface centrifugal pumps, and vacuum pumps)
3. Electric submersible pumps (including centrifugal submersible pumps, helical rotor pumps, and gear pumps)
4. Positive displacement pumps (including gas–drive pumps, piston pumps, inertial lift pumps, and bladder pumps)

Once the type of pump or bailer is selected, the purge rate should be set low enough to avoid turbulent flow that causes entrainment of fines in the sand pack (over development of the well) and potentially causes stripping of volatile organic compounds. As a rule of thumb, the purge rate should not exceed the pumping rate or bailing rate used for well development. In addition, the purge rate should not exceed the recovery rate for the well. Typically, purging rates should not exceed 0.2 to 0.3 L/min.

Bailing. In many cases, bailing is the most convenient method for well purging and sampling. Bailers are constructed using a variety of materials such as PVC, stainless steel, polyethylene, and Teflon®. Care must be taken to select a specific type of bailer that suits a study's particular needs. Teflon® bailers are generally the most "inert," while PVC bailers are less expensive and sufficiently resistant to small-term exposure to most common contaminants. Bailers that are not chemically inert and easily decontaminated should not be used to purge and/or sample more than one well. Typically, a bailer can be dedicated to one well and can be hung in the well for subsequent purging and sampling events Disposable bailers, usually made of polyethylene, are sometimes more practical to use when decontamination time, expense, and the number of sampling events are considered.

Bailing presents three potential problems with well purging and sampling. First, increased suspended solids may be present in samples as a result of the turbulence caused by raising and lowering the bailer through the water column. High solids concentrations may require that total suspended solids (TSS) and the chemical character of the solids be evaluated during sample analyses. In addition, rapid bailing could cause the stripping of volatile organic compounds from the groundwater as a result of bailer agitation and/or groundwater cascading down the sides of the well screen.

Second, bailing may not be practical for wells that require that more than 20 gallons be removed during purging or for wells that are deeper than 50 ft below ground surface. Such bailing conditions mandate that long periods be spent during purging and sample collection, or that centrifugal pumps be used.

Third, bailing typically withdraws water from the top of the water column in the well and this water has already been exposed to the atmosphere. Exposure to the atmosphere can cause volatilization and reactions with carbon dioxide which cause subsequent lowering of the water's pH.

Suction-Lift Pumps. Suction-lift pumps are used to purge and sample groundwater from less than 30 ft below ground surface. Suction–lift pumps include peristaltic pumps, surface centrifugal pumps, and vacuum pumps. Vacuum pumps and surface centrifugal pumps (to a lesser extent) are not as appropriate as peristaltic pumps when collecting volatile-sensitive water samples.

Electric Submersible Pumps. Electric submersible pumps are commonly used to purge and sample groundwater from a variety of depths. Electric submersible pumps include centrifugal submersible pumps, helical rotor pumps, and gear pumps. The centrifugal submersible pumps are most commonly used, yet cause considerable water agitation due to the movement of the impeller(s). The gear pumps are the best-suited electric submersible pumps for groundwater purging and sampling and one of the best overall pumps for minimizing volatilization of groundwater samples.

Positive Displacement Pumps. Positive displacement pumps are widely available pumps often useful for groundwater purging and sampling. Positive displacement pumps include gas-drive pumps, piston pumps, inertial-lift pumps, and bladder pumps. The bladder pump is generally considered the best overall type of pump to collect groundwater samples for inorganic and/or organic analyses. Inertial lift pumps are ideal for well development, but should not be used to collect volatile-sensitive groundwater samples.

9.5.2.4 Purging and Sample-Collection Procedures — Method Specific

Once purging is complete, samples can be collected with either bailers or pumps. In many cases, a well may be purged using a pump and sampled using a bailer. This section discusses specific procedures for collecting samples using bailers and pumps.

Bailer Sampling. Obtain a decontaminated or new bailer and rope or cord made out of nylon, polypropylene, or other equivalent material. Tie a bowline knot or equivalent through the bailer loop. Test the knot for security and the bailer itself to ensure that all parts are intact before inserting the bailer into the well. Remove the protective wrapping from the bailer. Lower the bailer to the bottom of the monitoring well and cut the cord at a proper length. Bailer rope should never touch the ground surface at any time during purging and sampling.

Raise the bailer by grasping a section of cord using each hand alternately in a “windmill” action. This method requires the sampler’s hands to be kept approximately 2 to 3 ft apart and the bailer rope to be alternately looped onto or off each hand as the bailer is raised and lowered. Alternate methods may be used to raise the bailer including use of a reel or a plastic-lined bucket into which the rope is manually fed. Bailed groundwater is poured from the bailer into a graduated container to measure the purged water volume.

For slowly recharging wells, the bailer is generally lowered to the bottom of the monitoring well and withdrawn slowly through the entire water column. If possible, the water should be bailed at a rate slow enough so that it does not cascade down the sides of the well screen, which causes stripping of volatile organic compounds. Groundwater should be allowed to recover to 70 percent or greater of its static volume before a sample is collected.

Typically, water samples should be collected at or near the midpoint of the well screen. To collect a groundwater sample using a bailer, slowly lower the bailer into the water column, allowing the bailer to fill slowly from the bottom. Once the bailer has been lowered to approximately the mid-point of the screen, slowly raise the bailer to minimize creating turbulence in the well and minimize drawing fine-grained sediment into the well. Gently empty water directly from the full bailer into sample containers, taking care not to allow contact between the bailer and the sample container.

Pump Sampling. When selecting the appropriate pump to use for purging and sampling a well, there are two criteria that must be considered. First, the construction material of the pump and tubing should not contain materials that interact with the constituents of interest and/or contain constituents that may cause the sample to have a false positive analysis. Second, if the sample is to be analyzed for volatile organic compounds, a pump that minimizes sample agitation and subsequent volatilization should be used. As noted previously, the most appropriate pumps under these conditions are the gear pump or the bladder pump.

Prior to inserting a pump into a monitoring well, it should be thoroughly decontaminated by pumping an Alconox™ or equivalent potable water mixture through the pump followed by pumping potable water, followed by a distilled or deionized water rinse. Tubing should be dedicated to a single well and should not be re-used.

During the collection of samples, the pumping rate should be approximately 0.1 L/min. If a greater pumping rate is used for purging, the pumping rate should be reduced during sampling. Groundwater should be pumped directly into the sample containers.

9.5.2.5 Sample Collection Procedures — Method Independent

The following are method-independent sample collection procedures:

- Collect samples intended for volatile organic analysis (VOA) first.
- Fill sample containers quickly and smoothly to avoid agitation, aeration, and loss of volatile components.
- To further avoid loss of volatile components, completely fill samples so that no headspace is present and cap securely with a Teflon®-lined lid.
- Collect samples for semivolatile, metal, or other analyses in the proper sample containers.
- Collect duplicate samples when QA/QC samples are needed for VOA. VOA samples typically consist of two sample vials, referred to as the sample set. Alternating between the primary sample set and the replicate sample set, completely fill each vial and cap immediately in the order shown below:
    - Fill vial #1 - primary sample set
    - Fill vial #1 - replicate sample set
    - Fill vial #2 - primary sample set
    - Fill vial #2 - replicate sample set
- Collect duplicate samples when QA/QC samples are required for sample analyses other than VOA by alternately filling the sample containers as in the VOA procedure, but fill containers incrementally instead of completely, continuing the filling procedure until the sample containers are full.
- Label all sample containers with the following information:
    - Project name and/or number
    - Field sample number
    - Depth interval (if applicable)
    - Initials of collector
    - Date and time of collection
    - Sample type and preservative (if any)

  Replicate and duplicate sample labels require only project name and/or number, field sample number, and sample type and preservative (if any).
- Place samples in coolers as soon as possible and, if required, store and transport them at <4°C (39°F), using frozen ice packs or double-bagged ice.
- Use protective packaging as dictated by the mode of transport.

- Record sample information in the field logbook and on the sample control log as soon as possible after sample collection, in accordance with the procedures set forth in the Quality Assurance Project Plan.
- Complete chain-of-custody forms and placed them in the cooler for shipment to the laboratory.
- If required by the SAP, place custody seals across cooler lids so that coolers cannot be opened without breaking the custody seal. Include the following information on the custody seals:
  - Collector's signature or initials
  - Date of sampling
- Ship samples to the laboratory for analysis, carefully observing all minimum holding-time requirements for degradable constituents.
- Set up a decontamination station near the sampling location to decontaminate equipment that will be reused at the next sampling location.

9.5.3 Aquifer Testing and Analysis SOP

All monitoring wells added to the monitoring well network will be installed and completed in accordance with the NMED Monitor Well Construction Guideline.

9.5.3.1 General

An aquifer test or "pumping test" is used to determine the hydraulic properties of an aquifer by pumping one well for a specified length of time while collecting periodic water level measurements. Aquifer properties that can potentially be estimated using a pumping test include transmissivity (i.e., hydraulic conductivity multiplied by aquifer thickness), horizontal or vertical hydraulic conductivity, coefficient of storage, specific yield, and confining layer leakage. The two types of pumping tests most useful in determine aquifer hydraulic properties are the constant rate pumping test and the step-drawdown pumping test. The latter is best suited to determining the well's reduction in specific capacity (i.e., specific yield per unit of drawdown) with increasing yields, while the former is the most widely used pumping test in determining the transmissivity and storage values for an aquifer.

A pumping test can be performed using only the pumping well; however, specific information such as aquifer storage will not be obtainable. The use of observation wells in obtaining additional drawdown and/or recovery data over time is recommended whenever possible, especially when information on aquifer storage, anisotropy, vertical leakage, or the distance to a recharge or no-flow (i.e., barrier) boundary is needed.

In comparison to a slug test, a pumping test is representative of a much larger area and is therefore a better estimation of the hydraulic parameters of an aquifer. Conversely, a pumping test requires a greater commitment of resources (time, money, and equipment) and produces large volumes of water that usually need to be containerized during the test.

Several analytical solution methods are available. Two of the most widely used are the Theis (1935) equation and the Cooper and Jacob (1946) equation (often referred to as the Jacob straight-line method). A multitude of pumping test analysis software is available, though users are cautioned to be sure to understand all model or spreadsheet inputs as well as the assumptions of the governing equations. Far more extensive information on the design and analysis of pumping tests is covered in texts including, to name a few, Driscoll (1986), Kruseman and de Ridder (1991), Dawson and Istok (1991), Osborne (1993), and Fetter (1988).

Analyses of pumping tests require the following assumptions:

- The water-bearing formation is homogeneous, isotropic, uniform in thickness, and infinite in areal extent.
- The formation receives no recharge from any source.
- The pumping well (i.e., the screened section) is fully penetrating the entire thickness of the water-bearing formation.
- The water removed from storage is discharged instantaneously when the head is lowered.
- The pumping well is 100 percent efficient.
- All water removed from the well comes from aquifer storage.
- Laminar flow exists throughout the well and aquifer.
- The water table or potentiometric surface has no slope.

In reality, most pumping tests violate many of the above-mentioned assumptions to some degree or another. However, it is important to take all feasible measures to limit the extent of these violations whenever possible, and discussing these assumptions and any possible violations to them is important to any pumping test report.

Design Considerations. Prior to performing an aquifer pumping test, all available site and regional hydrogeologic information should be assembled and evaluated. If retrievable, such data should include groundwater flow direction(s), hydraulic gradients, other geohydraulic properties, site stratigraphy, well construction details, regional water level trends, and the performance of other pumping wells in the vicinity of the test area. This information is used to select test duration, proposed pumping rates, and pumping well and equipment dimensions.

The precise location of an aquifer test is chosen to be representative of the area under study. In addition, the location is selected on the basis of numerous other criteria, including:

- The size of the investigation area.
- Uniformity and homogeneity of the aquifer.
- Distribution of contaminant sources and dissolved contaminant plumes.
- The location of known or suspected recharge or barrier boundary conditions.
- The availability of pumping and/or observation wells of appropriate dimension and screened at the desired depth.
- Requirements for handling discharge.

The dimensions and screened interval of the pumping well must be appropriate for the tested aquifer. For example, the diameter of the well must be sufficient to accommodate pumping equipment capable of sustaining the desired flow rate at the given water depth. In addition, if testing a confined aquifer that is relatively thin, the pumping well should be screened for the entire thickness of the aquifer. For an unconfined aquifer, the wells should be screened at least in the bottom one- to two-thirds of the saturated zone and they may be screened throughout the entire thickness of the saturated zone.

Any number of observation wells may be used. The number chosen is contingent upon both cost and the need to obtain the maximum amount of accurate and reliable data. If at least three observation wells are to be installed and there is a known boundary condition, the wells should be configured such that water levels can be monitored both perpendicular and parallel to the boundary, with the pumping well at the intersection of the two well lines. If two observation wells are to be installed, they should be placed in a triangular pattern, non–equidistant from the pumping well. If observation wells are placed at 90° angles from the pumping well, radial anisotropy can be easily calculated. When observation wells are installed for aquifer testing purposes, they should be located at distances and depths appropriate for the planned method for analysis of the aquifer test data. Observation well spacing should be determined based upon expected drawdown conditions that are the result of the studies of geohydraulic properties, proposed pumping test duration, and proposed pumping rate.

Equipment. The equipment necessary to conduct a pumping test includes:

- A pump (suited for site conditions and requirements of the test)
- Water level measuring devices (pressure transducers and/or electronic water level indicators) accurate to at least 0.01 ft
- A flow meter with totalizer (something as simple as a graduated bucket can also suffice, especially as backup)
- A digital watch with stopwatch function (used to keep time and to help determine discharge rate when using graduated containers)
- An electrical source (generator or electrical receptacle on site)
- An electronic data recorder programmed to suitable data collection intervals)
- A barometer
- Water quality meter(s) for noting changes as a function of capture zone
- Hose or pipe to route pumped water away from the test area
- A gate valve
- An adequately sized tank/container for storing water
- A portable computer for preliminary analysis of data (optional)
- Field forms and logbook
- Pen and paper
- Backup equipment if feasible

Pumping equipment should conform to the size of the well and be capable of delivering the estimated range of pumping rates. The selection of flow meter, gate valve, and water transfer lines should be based on anticipated rates of water discharge. Both the discharge rate and test duration should be considered when selecting a tank for storing discharge water if the water cannot be released directly to the ground, sanitary sewer, storm sewer, or nearby water treatment facility.

Pumping-Test Preperations. If feasible for the site, slug tests or preliminary pumping tests (constant-rate or step drawdown) should be performed on the pumping well prior to the actual test. The preliminary pumping should determine the maximum drawdown in the well, and the proper pumping rate should be determined by step drawdown testing. If the discharge rate varied by less than 5 percent (i.e., a constant-rate-pumping test), the time versus drawdown data from the pumping well can be used to estimate aquifer transmissivity. The preliminary pumping will also provide redevelopment of the pumping well by removing fines from the adjacent formation and from the filter pack. Redevelopment of the pumping well will improve well efficiency during the pumping test and thus will allow for a better estimation of the aquifer's hydraulic properties. The aquifer should then be given time to recover before the actual pumping test begins (as a rule–of–thumb, one day). A record should be maintained in the field logbook to track when pumping and discharge of other wells in the area occurs and whether the wells' radii of influence intersect the cone of depression of the test well.

Barometric changes may affect water levels in wells, particularly in semiconfined and confined aquifers. Therefore, it is advisable to monitor (perhaps hourly) the barometric pressure and water levels in key wells at least 24 hours (if possible) prior to performing a pumping test. If a groundwater fluctuation trend is apparent, the barometric pressure should be used to develop curves depicting the change in water level versus time. These curves should be used to correct the water levels observed during the pumping test. Groundwater levels and barometric pressures in the background should continue to be recorded throughout the duration of the test. If dataloggers with transducers are used, backup field measurements should be collected in case of datalogger malfunction. All measurements and observations should be recorded in a field logbook or on appropriate field forms.

All equipment should receive calibration, function checks, and fresh or charged batteries if needed.

Conducting the Pumping Test. Prior to the start of the pumping test, the following checks should be made:

- Ensure all piping, valves, and flow meters are properly installed.
- Ensure that all containers are in place to capture all pumped water.
- Ensure that the energy needs (batteries, electricity, or gas) for all equipment are provided, including backup energy sources for key equipment.
- Verify all equipment is present and place it at locations where it will be most needed.
- Verify the pump intake is located at the proper interval in the pumping well.
- Verify all transducers are placed at the proper depth and are properly secured so they will not move or be susceptible to contact from site personnel.
- Verify the datalogger is properly programmed to record (typically logarithmically).
- Lower electronic water level tapes to just above the water levels inside each well.
- Warm up all equipment (such as a generator) that perform better after initial operations.
- Ensure all personnel and field forms are in their start-of-test locations.

Immediately prior to starting the pump, the water levels should be measured and recorded for all wells to determine the static-water levels upon which all drawdowns will be based. Dataloggers should be reset for each well to a starting water level of 0.00 foot. At this time, a pumping test is initiated by starting the datalogger and then starting the pump. The datalogger needs to be started at least a split second before the pumping begins. Immediately afterwards, the time that pumping started needs to be recorded along with water level readings, especially at or near the pumping well. A suggested schedule for recording water level measurements made by hand is as follows:

- 0 to 10 minutes – 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, and 10 minutes (It is important in the early part of the test to record with maximum accuracy the time at which readings are taken.)
- 10 to 100 minutes – 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, and 100 minutes
- 120 minutes to end of test – every 1 hour (60 minutes)

At least 10 measurements of drawdown for each log cycle of time should be made both in the test well and the observation wells. Dataloggers can be set to record in log time, which is very useful for data analysis. When logging data by hand, there should initially be sufficient field personnel to station one person at each well used in the pumping test. After the first two hours of pumping, two people are usually sufficient to complete most simplistic tests. It is advisable for at least one field member to have experience in the performance of pumping tests, and for all field personnel to have a basic familiarity with conducting the test and gathering data.

The discharge rate should be measured frequently throughout the test with a flow meter equipped with a totalizer and controlled to maintain a constant pump. This can be achieved, in part, by using a control valve. If used properly, the flow control valve can be pre-set for the test and will not have to be adjusted during pumping. When the pumping is complete, the total gallons pumped are divided by the time of pumping to obtain the average discharge rate for the test.

For a confined aquifer, if possible, the water level in the pumping well should not be allowed to fall below the bottom of the upper confining stratum during a pumping test. The pitch or rhythm of the pump or generator provides a check on performance. If there is a sudden change in pitch, the discharge should be checked immediately and proper adjustments to the control valve or the generator engine speed should be made, if necessary. Do not allow the pump to break suction during the test. If the pump stops working during the test, make necessary adjustments and restart the test after the well has stabilized.

Water pumped from an aquifer during a pumping test should be disposed of in such a manner as to not allow the aquifer to recharge during the test. This means that the water must be piped away from the well and associated observation wells. Also, if contaminated water is pumped during the test, the water must be stored and treated or disposed of according to project specifications. The discharge water may be temporarily stored in drums; a lined, bermed area; or tanks. If necessary, it should be transported and staged in a designated secure area.

Field personnel should be aware that electronic equipment sometimes fails in the field. It is a good idea to record key data in the field logbook or on field forms as the data are produced. That way, the data are not lost should the equipment fail.

The total pumping time for a test depends on the type of aquifer and degree of accuracy desired. Economizing on the duration of pumping may yield less reliable results. It is always recommended to pump long enough to ensure the cone of depression achieves a stabilized condition. The cone of depression will continue to expand at an ever-decreasing rate until recharge of the aquifer equals the pumping rate, and a steady-state condition is established. The time required for steady-state flow to occur varies considerably from site to site. If steady-state conditions cannot be achieved in a reasonable time frame for the project, consider a test duration of at least 24 hours. A longer duration of pumping may reveal the presence of boundary conditions or delayed yield.

Use of portable computers allows time/drawdown plots to be made in the field. If dataloggers are used to monitor water levels, the electronic data can be reviewed by scrolling with the datalogger screen or via a portable computer. It is advisable to download the water level data before transporting the datalogger from the site.

9.5.4 Monitoring Well Installation

If additional monitoring wells are required, SOPs for Monitoring-Well Installation and Hollow-Stem Auger Drilling will be followed. These SOPs will be submitted to the MMD prior to installation of additional wells and will meet state requirements for well installation.

9.6 Parameters to be Analyzed

See Table 9-3 for analytical parameters and analysis methods.

9.7 Maps Showing Proposed Sampling Locations

Figure 9-10 illustrates the current groundwater monitoring network for the baseline characterization study. This network has grown from the initial sampling program conducted in January 2010 (Figure 9-11). The wells have been categorized according to the aquifer being monitored (i.e., Quaternary alluvial aquifer, Santa Fe Group aquifer, or Bedrock aquifer) if known.

9.8 Laboratory and Field Quality Assurance Plans

The groundwater sample and data collection will be conducted in accordance with the Quality Assurance Project Plan (QAPP) (see Attachment 1) and the procedures for sampling and recording observations in a logbook. The samples will be properly preserved and sent to an accredited analytical laboratory. Water samples will be collected from Site 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 logbook.

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 logbook. Groundwater 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 groundwater 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 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 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 logbook 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 Discussion in Support of Proposal

The main objective of the proposed groundwater data collection program is to obtain the data necessary to determine potential impacts of mining activities, including mine dewatering, on local and regional groundwater systems. As this Site has been mined before and has been through several permitting cycles, historical data will play an important role in the evaluation of potential impacts caused by new mining. Therefore, all impact analysis performed using data collected in accordance with this SAP will be supported by concurrent evaluation utilizing historical data where available.

The water quality sampling program will provide current water quality data for a monitoring well network that includes wells with a history of sampling. Current and historical data will be statistically evaluated to determine a range of baseline groundwater quality values for key constituents.

The water level measurement program will provide recent baseline data on local water levels. Existing aquifer pumping test data will be used to obtain hydraulic information and additional tests will be performed as necessary.

The potential impacts of groundwater withdrawals from the Bedrock and Santa Fe Group aquifer system on groundwater levels will be determined using a three-dimensional groundwater flow model. The groundwater flow model will incorporate historical data as well as data collected under this SAP. Defensible, site-specific conceptual and numerical flow models are critical to NMCC for securing the necessary permits and stakeholder acceptance for assessment of potential impacts from dewatering, pit lake evolution, and leaching from waste rock facilities and the tailings impoundment. The potential impacts on water supply wells will be evaluated with this model as well as the potential impacts of the discharge of dewatering water on the alluvial aquifers in Las Animas and Percha Creeks. The groundwater model will be calibrated under pre-development and transient conditions and will represent the most reasonable tool available for estimating impacts of dewatering and appropriation of groundwater on both a local and regional scale.

Given that the existing groundwater flow model developed for Alta Gold (ABC, 1996; ABC, 1997; ABC, 1998b) received significant criticism, NMCC will develop a revised conceptual model for groundwater flow that will be used to construct a MODFLOW numerical model which will in turn be used to assess impacts from mine operations. The revised conceptual model will be primarily based on data collected as part of this baseline characterization work, including historical data that are statistically valid.

A new numerical flow model will be constructed, calibrated, and applied to assess potential impacts from mine dewatering and from post-mining groundwater rebound. This model, which we expect will be a sub-regional scale model, will focus on an area sufficiently large enough to defensibly determine water level and flux changes on identified resources. NMCC proposes to use either MODFLOW or MODFLOW–SURFACT as the flow model code because they have been accepted by both state and federal agencies for mining impact assessments, among other uses. The geologic model from the previous flow model will serve as the foundation for a revised geologic model to be developed by NMCC in close collaboration with MMD staff. Estimates of recharge, evapotranspiration, and other boundary conditions from the previous model will also serve as a starting point for the new numerical flow model.

To assess potential impacts, NMCC will develop and calibrate numerical flow models for the sub-regional scale that represent different periods of mine activity. First, NMCC will construct and calibrate a steady state flow model that represents pre-mining conditions. A transient model that represents mining activities to the present day will be constructed from the steady state model and calibrated to available head and flux data. Potential impacts will be determined from the final transient model that simulates mine activities such as pit deepening and dewatering as well as the post-mining period's groundwater rebound. Changes in fluxes to surface water bodies and water levels will be used as the performance metrics for the impact assessment.

NMCC efforts for the groundwater impact assessment will include:

- Develop a conceptual model for groundwater flow through the site and its vicinity, including groundwater and surface interactions, and construct a water balance for the site vicinity.
- Present the conceptual model and preliminary numerical model domain to relevant agencies.
- Construct and calibrate a steady state flow model to represent pre-mining conditions.
- Construct and calibrate a transient flow model that simulates historical mine development to the present day.

- Construct and calibrate a transient flow model that estimates drawdown from proposed mine dewatering and groundwater rebound following mine reclamation as well as any potential impacts to groundwater and surface water resources.
- Present the preliminary numerical model results to the relevant agencies.

9.10 References

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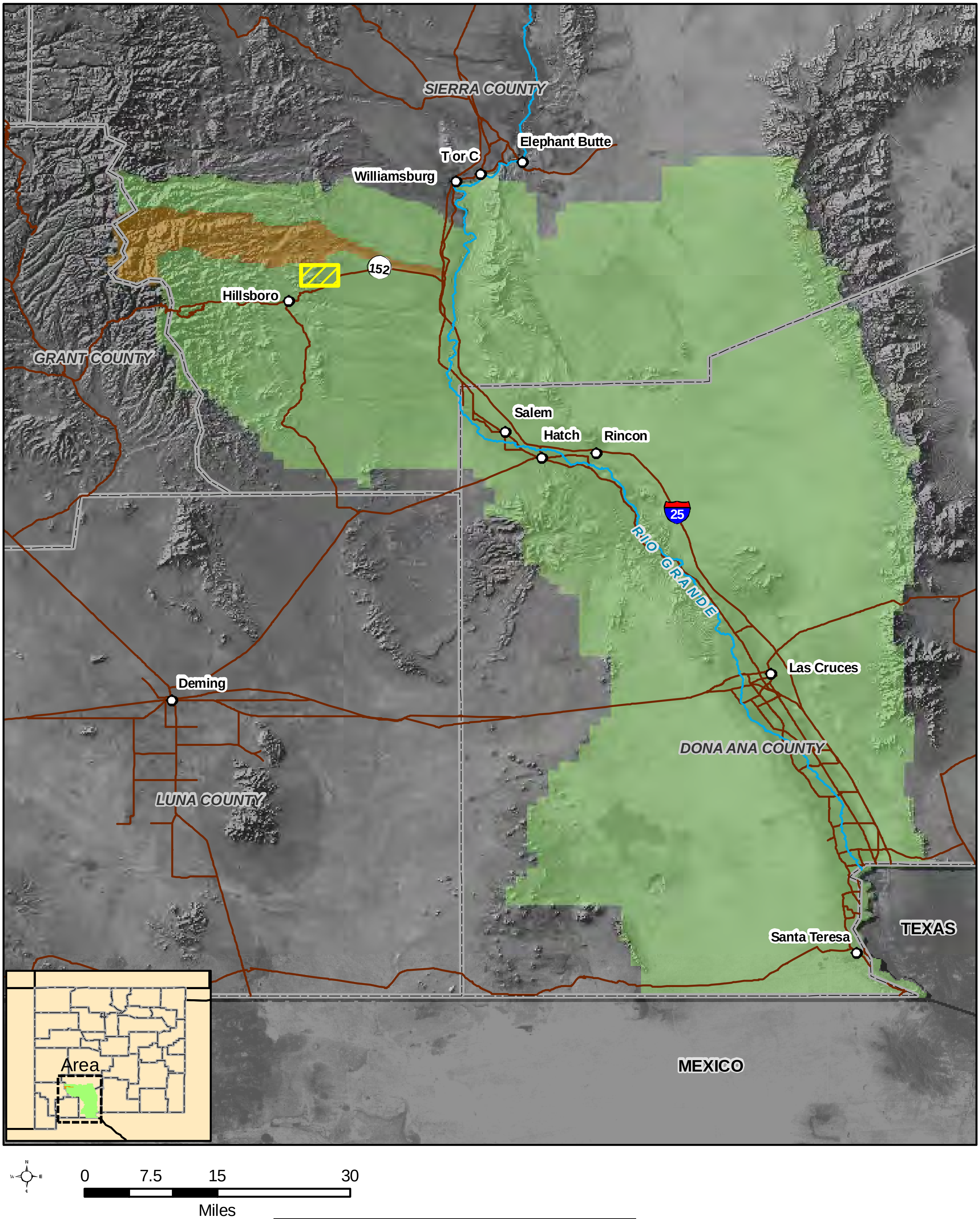
Figures



Basin Boundaries:
RGIS website/NMOSE
Imagery Information:
Landsat imagery from
University of Maryland NLCD

INTERA

Legend

City/Town
Site Location
Road
OSE Declared Basin
Lower Rio Grande
Las Animas

Figure 9-1
Lower Rio Grande Basin
New Mexico Copper Corporation

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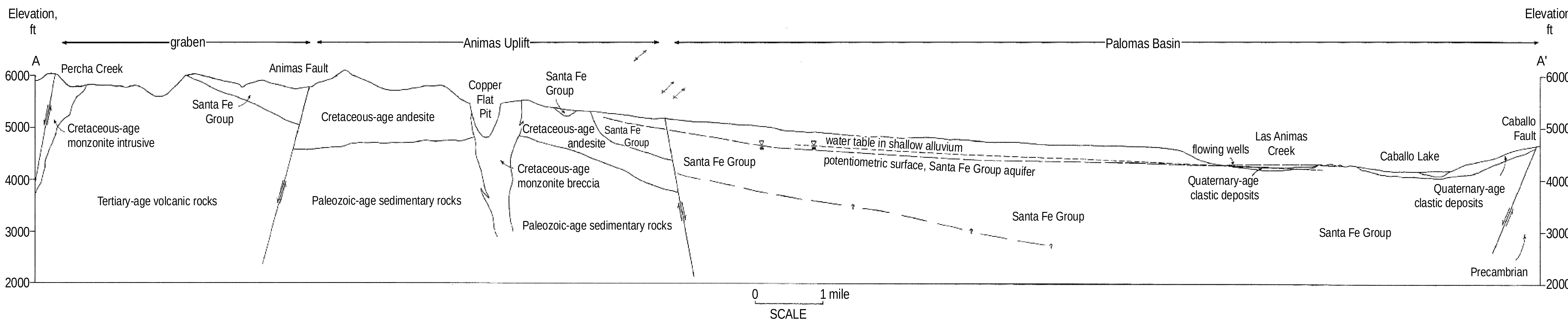
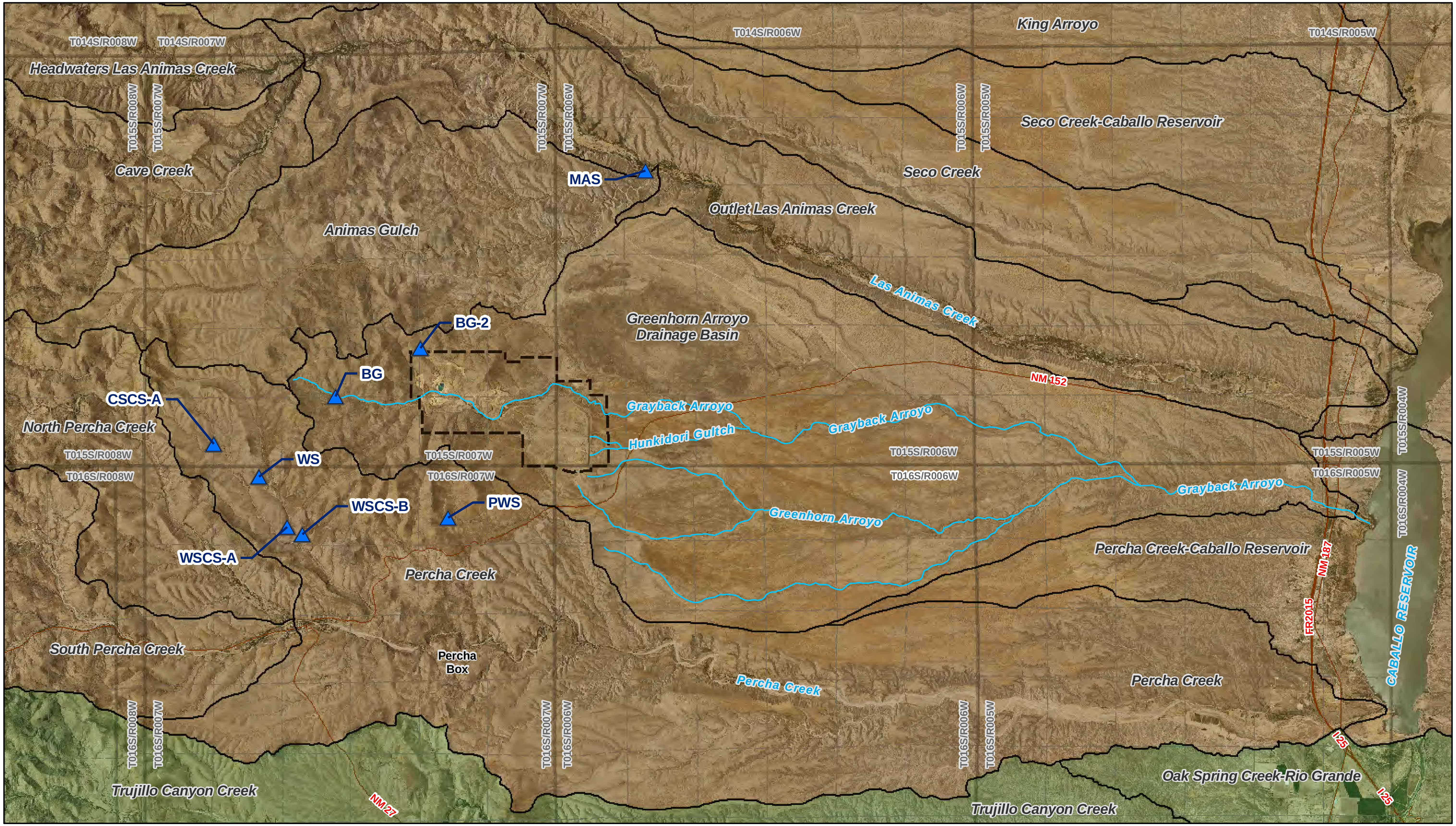


from John W. Shomaker, Inc., 1993

Figure 9-2
Conceptual Model of Groundwater Flow System
New Mexico Copper Corporation



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Watersheds:
USGS Hydrologic Unit Map
Mine Boundary:
Tom Van Bebber
Imagery Information:
-USGS 7.5-Minutes County DOQQ mosaic
Sierra County, 2009
Projection Information:
-New Mexico State Plane West, NAD 1927

INTERA

0 3,500 7,000 14,000 21,000
Feet

Legend

Identified Spring
Proposed Mine Permit Boundary
Watersheds
Caballo
El Paso-Las Cruces
Sub-Watershed

Figure 9-3
Spring and Stream Locations
New Mexico Copper Corporation

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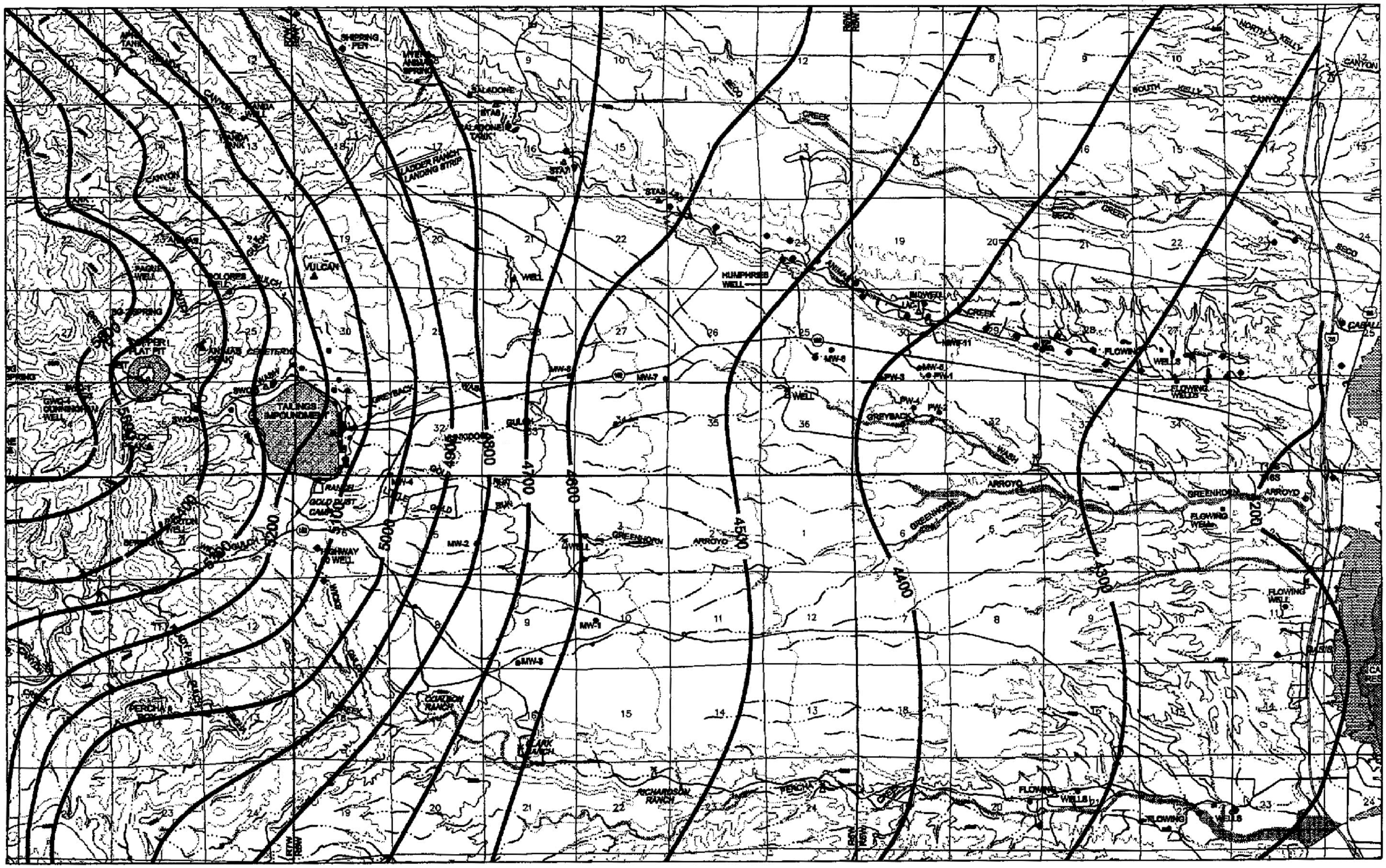


—4300— WATER TABLE ELEVATION

NORTH

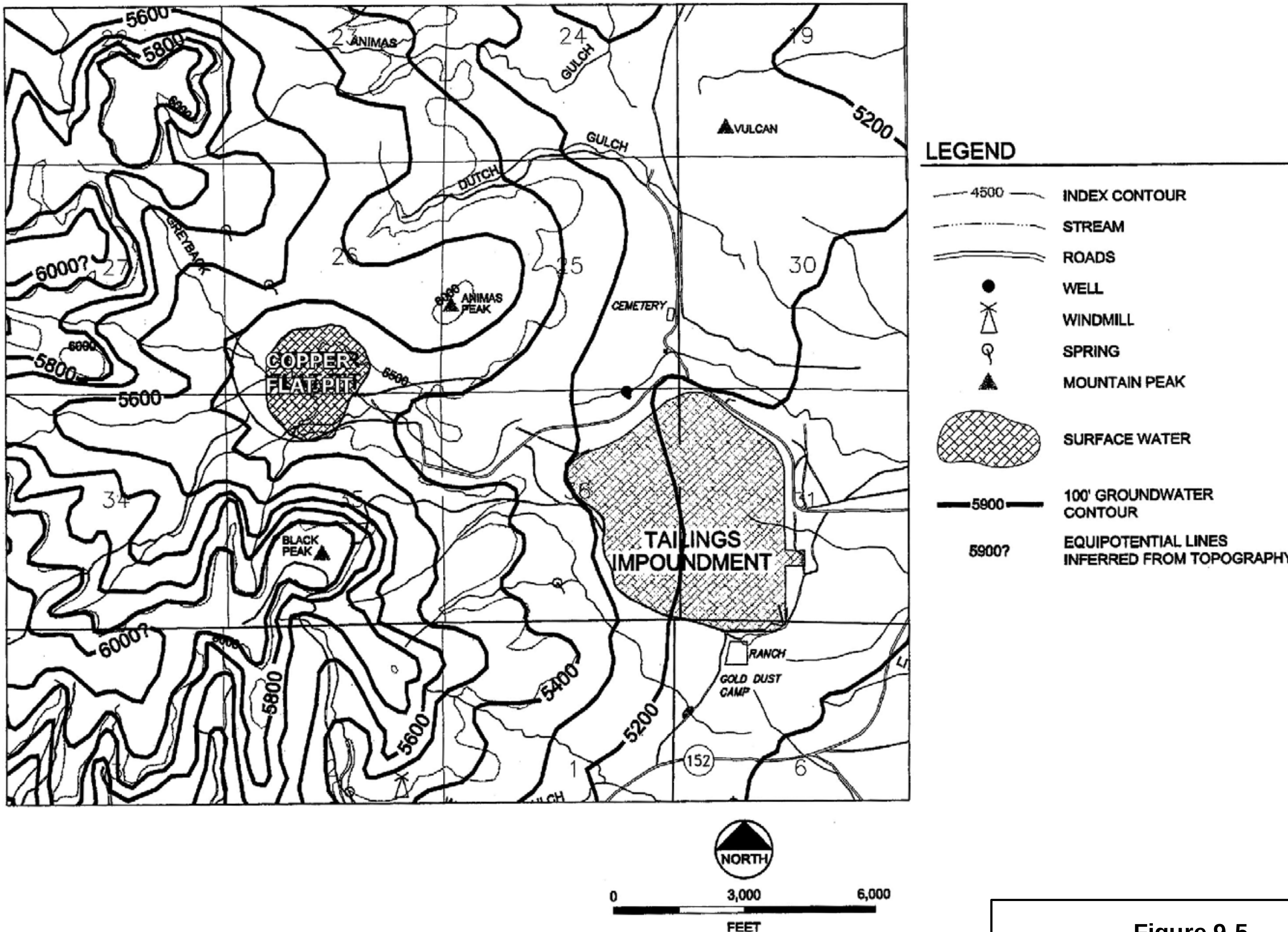
0 8,000 16,000

FEET

from ABC, 1998B

Figure 9-4
Water Level Contours

New Mexico Copper Corporation

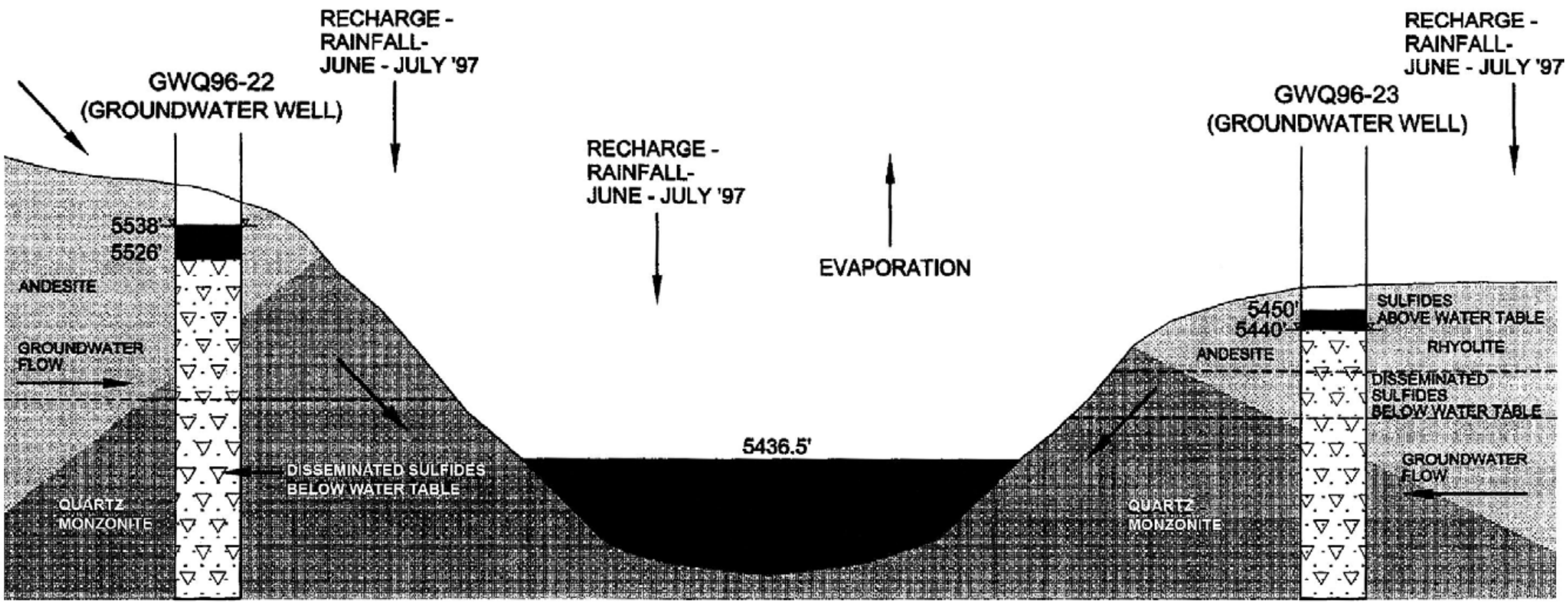


INTERA

from ABC, 1997

Figure 9-5
Water Level Map of Copper Flat Pit Area

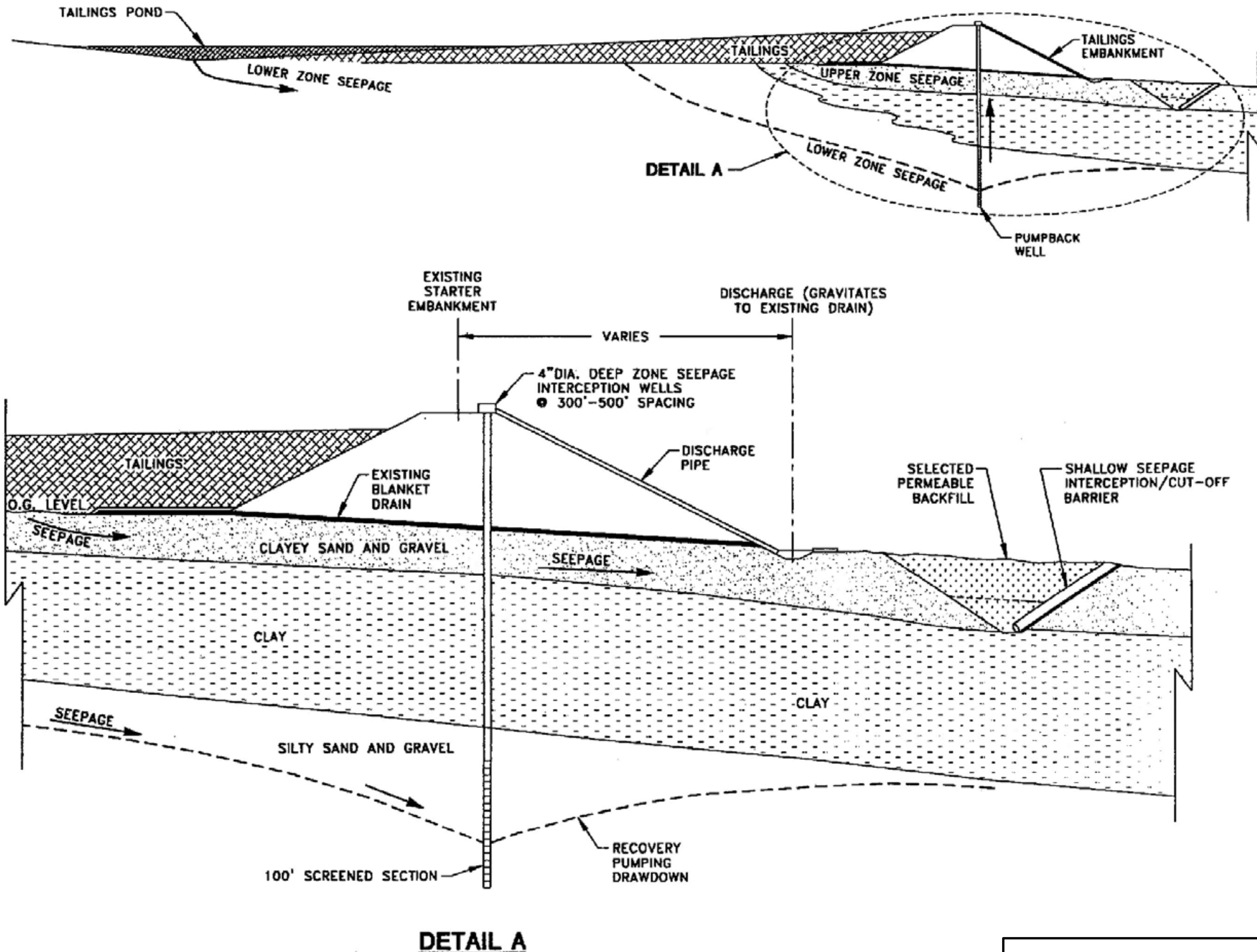
New Mexico Copper Corporation



	GWQ96-22			PIT LAKE			GWQ96-23	
	JULY '96	AUG '97		AUG '95	AUG '97		APR '97	AUG '97
pH	7.5	7.65	pH	8.31	8.16	pH	7.89	7.68
TDS	700	700	TDS	4707	5021	TDS	770	920
SO_4	250	230	SO_4	3170	3100	SO_4	150	410
Cu	<0.025	<0.025	Cu	<0.025	0.050	Cu	<0.025	<0.025
Fe	<0.05	<0.05	Fe	<0.025	<0.05	Fe	6.5	0.82

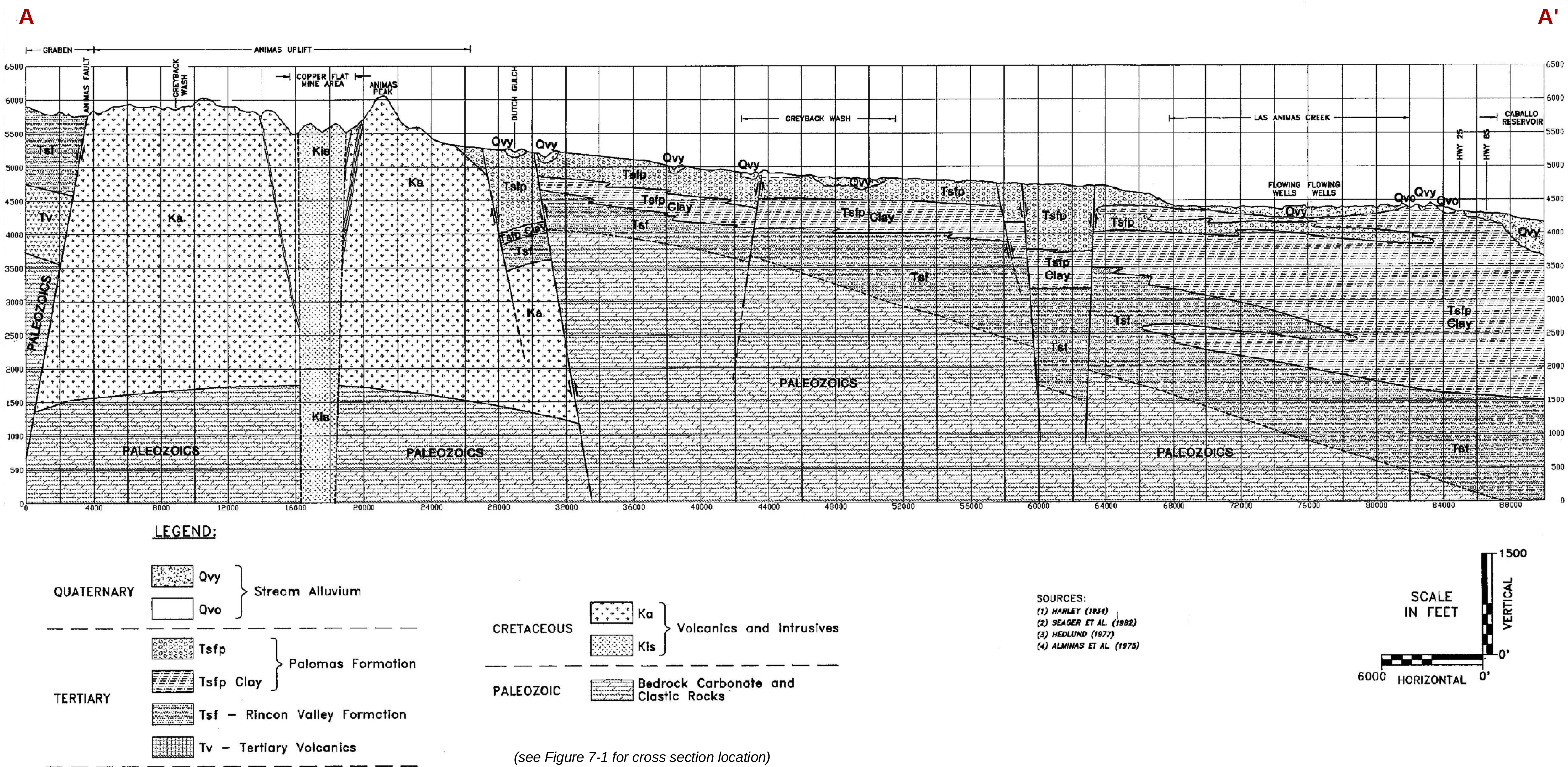
from SRK, 1998

Figure 9-6
Conceptual Model of Pit Lake Monitoring Well Relationship with Water Quality Reports
New Mexico Copper Corporation



from SRK, 1995

Figure 9-7
Conceptual Design,
Tailings Seepage Control
New Mexico Copper Corporation



(see Figure 7-1 for cross section location)

from BLM, 1999

Figure 9-8
Schematic Geologic Cross Section (A-A')

New Mexico Copper Corporation

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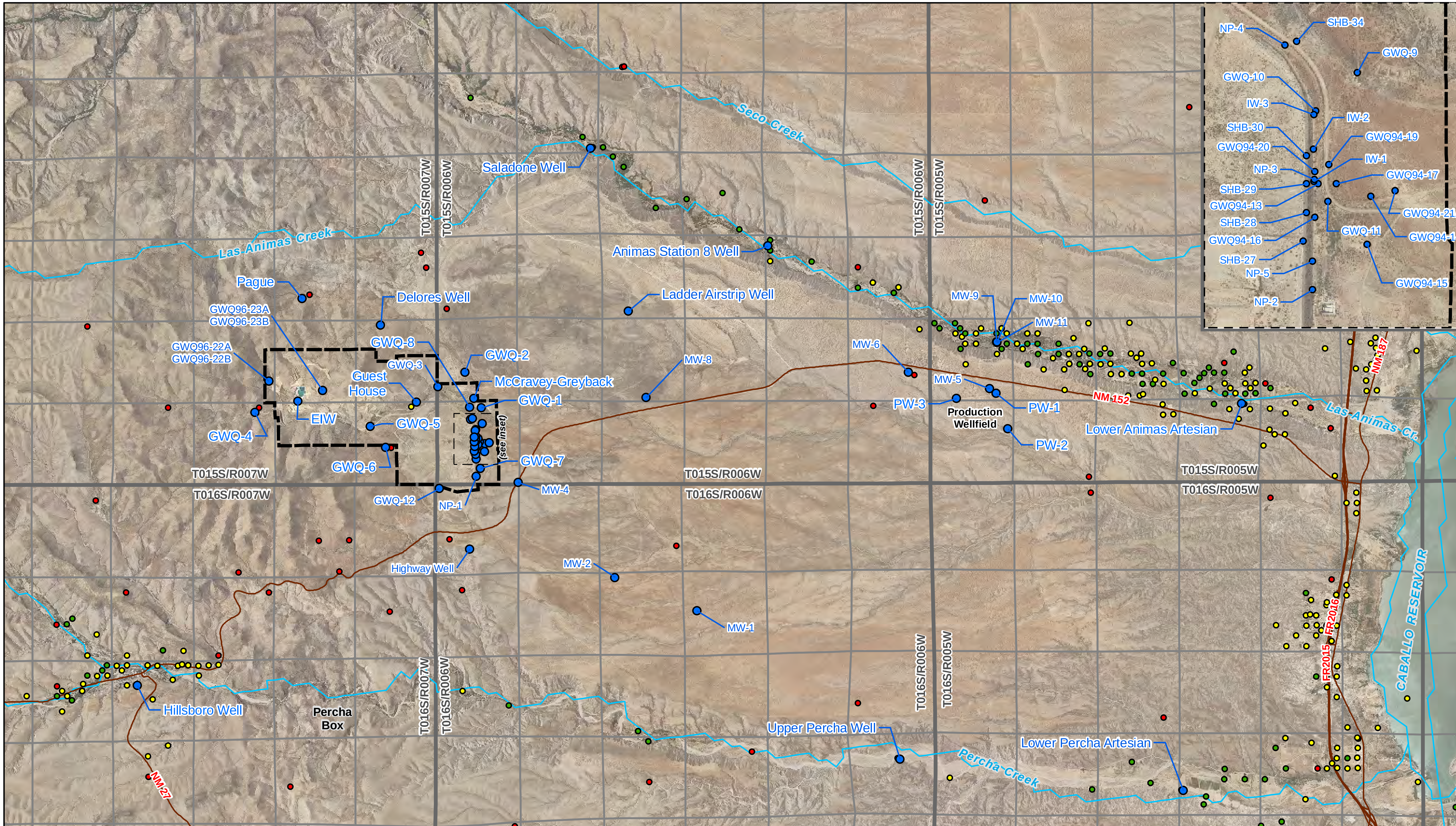

N
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Well Locations:
SRK or OSE
Mine Boundary:
Tom Van Bebber
Imagery Information:
-USGS 7.5-Minutes County DOQQ mosaic
Sierra County, 2009
Projection Information:
-New Mexico State Plane West, NAD 1927

INTERA

0 3,000 6,000 12,000 18,000
Feet

Legend

Road
Project Well
Proposed Mine Permit Boundary

NM OSE Wells (Use)
Domestic
Irrigation
Stock

Figure 9-9
Regional Groundwater Well Locations
New Mexico Copper Corporation

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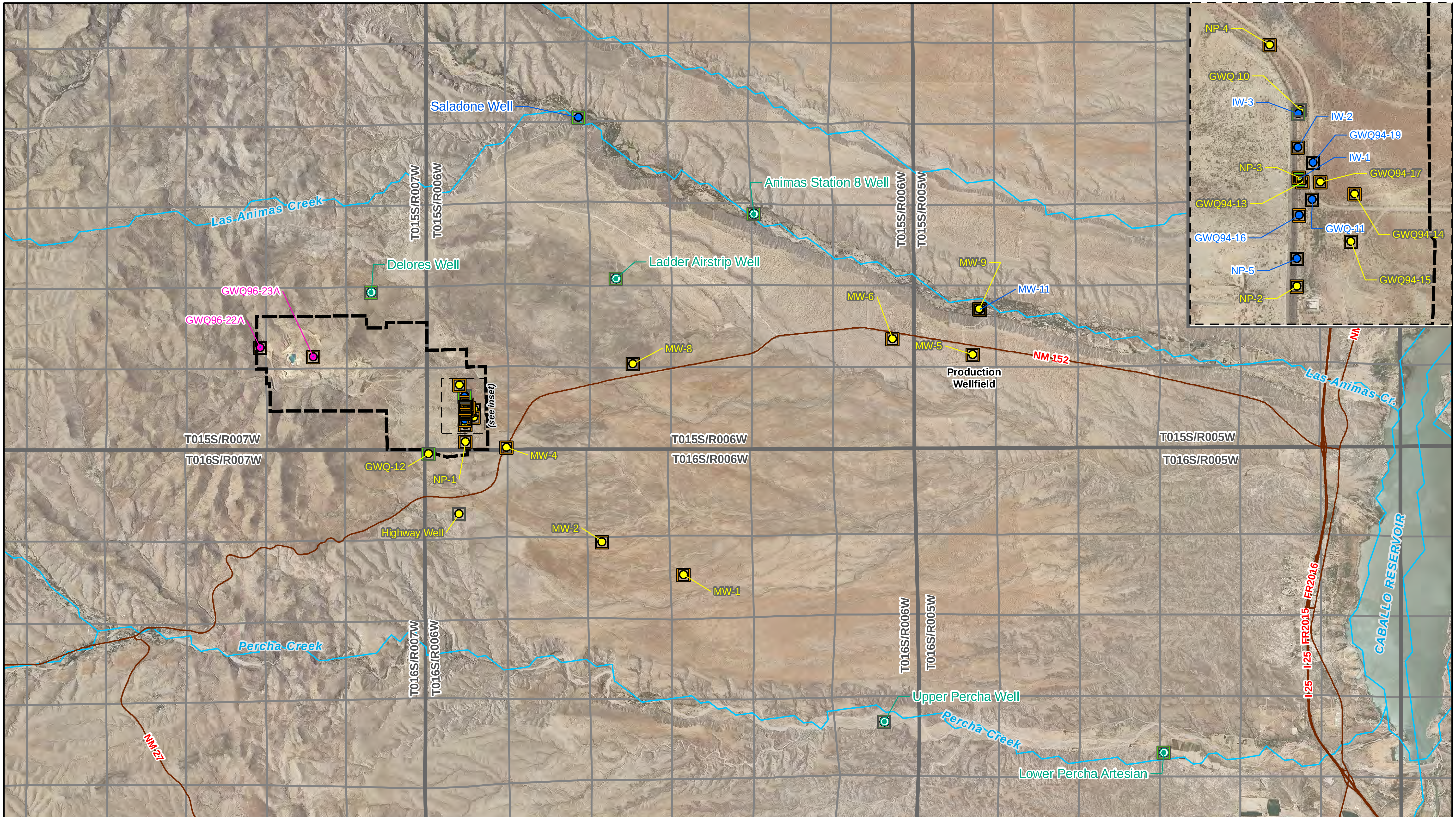

Well Locations:
SRK or OSE
Mine Boundary:
Tom Van Bebber
Imagery Information:
-USGS 7.5-Minutes County DOQQ mosaic
Sierra County, 2009
Projection Information:
-New Mexico State Plane West, NAD 1927

0 3,000 6,000 12,000 18,000
Feet

Legend

Proposed Monitoring Well
Aquifer
- Crystalline Bedrock
- Qauternary Alluvium
- Santa Fe Group
- Unknown

- Water Level Only
- Water Level & Water Quality
- Proposed Mine Permit Boundary
- Road

Figure 9-10
Proposed Monitoring Well Program
New Mexico Copper Corporation

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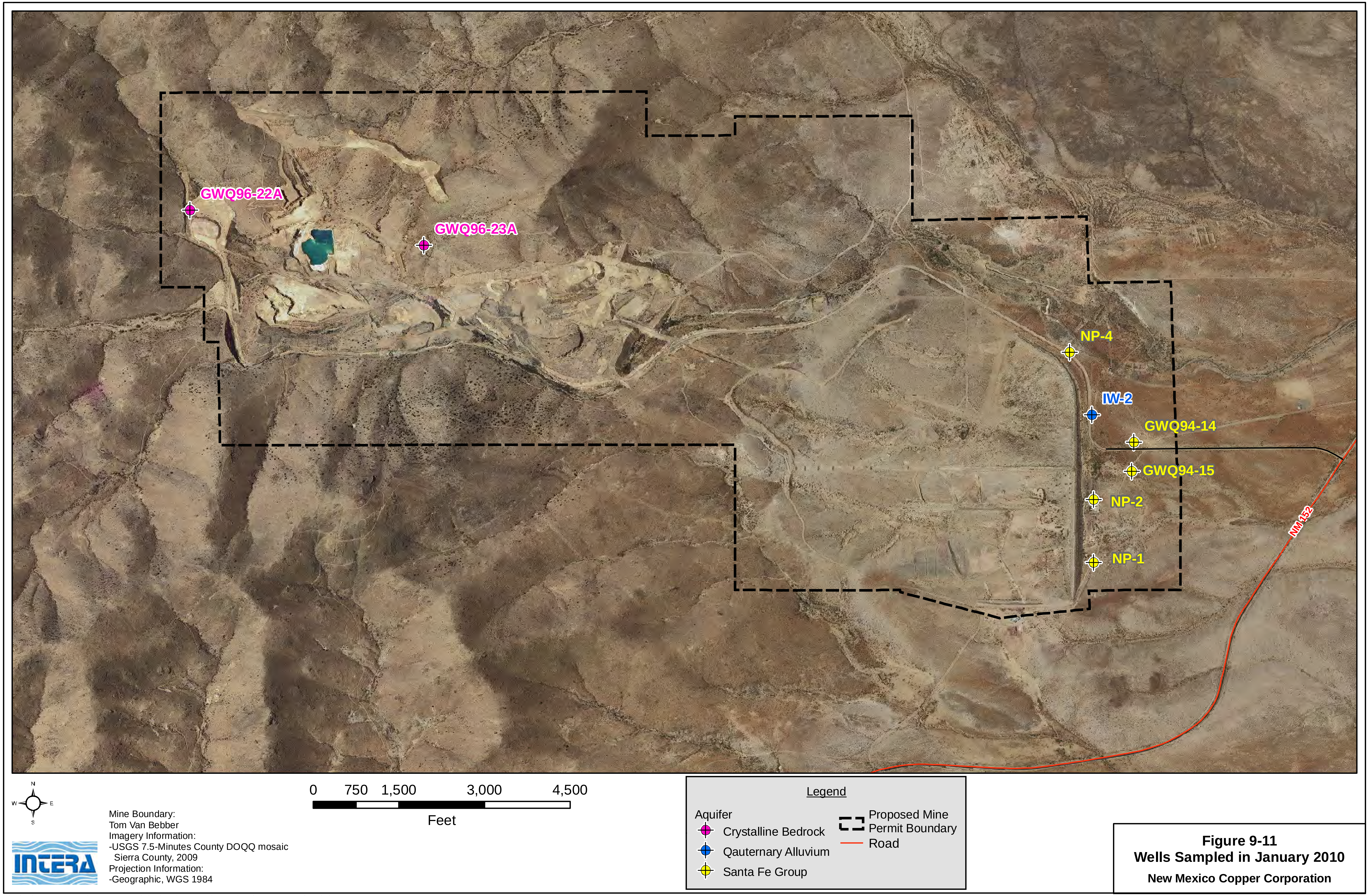

Mine Boundary:
Tom Van Bebber
Imagery Information:
-USGS 7.5-Minutes County DOQQ mosaic
Sierra County, 2009
Projection Information:
-Geographic, WGS 1984

Figure 9-11
Wells Sampled in January 2010
New Mexico Copper Corporation

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Tables

Table 9-1

Groundwater Sampling and Data Analysis Plan

Proposed Activity	Purpose of Activity
Perform a field verification survey of monitoring wells identified by previous investigators, measure depths to water and total depths of wells.	Confirm existing monitor well network in order to evaluate need for additional wells in key aquifers and finalize baseline monitoring well network
Install background monitoring wells in Santa Fe and alluvial aquifers.	Establish background water quality for Santa Fe Group and alluvial aquifers
Continue water level measurement and sampling of groundwater monitoring network.	Establish baseline (pre-mining) water quality and water levels for the Bedrock, Santa Fe Group, and Alluvial Aquifers
Install additional monitor wells as necessary to meet to address data gaps	Further define potential impacts from earlier mining activities and obtain additional pre-mining water levels
Determine hydraulic parameters for Bedrock, Santa Fe Group, and Alluvial aquifers	Obtain necessary input for groundwater model to evaluate drawdown from mine dewatering and production well activities

Table 9-2

Proposed Monitoring Wells for Water Quality Sampling and Water Level Measurements

Well Name	Total Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Year Drilled	Diameter (inches)	Inferred Aquifer	Water Quality Sample	Water Level Measurement
Animas Station 8 Well	NA	NA	NA	NA	NA	ND		X
Delores Well	NA	NA	NA	1932	NA	ND		X
GWQ-10	121.0	NA	NA	1981	3	Santa Fe Group		X
GWQ-11	84.5	NA	NA	1981	3	Quaternary Alluvium		X
GWQ-12	130.0	NA	NA	1981	3	Santa Fe Group		X
GWQ94-13	112.0	74.0	104.5	1994	5	Santa Fe Group	X	X
GWQ94-14	158.0	127.5	157.5	1994	5	Santa Fe Group	X	X
GWQ94-15	148.0	112.0	142.0	1994	5	Santa Fe Group	X	X
GWQ94-16	45.0	25.0	45.0	1994	5	Quaternary Alluvium	X	X
GWQ94-17	158.0	120.0	150.0	1994	5	Santa Fe Group	X	X
GWQ94-18	60.0	10.0	50.0	1994	4	Quaternary Alluvium	X	X
GWQ94-19	54.0	10.0	50.0	1994	4	Quaternary Alluvium	X	X
GWQ96-22A	240.0	170.0	240.0	1996	2	Bedrock	X	X
GWQ96-23A	100.0	50.0	100.0	1996	2	Bedrock	X	X
Highway Well	NA	NA	NA	1934	NA	Santa Fe Group		X
IW-1	49.0	NA	49.0	1982	4	Quaternary Alluvium		X
IW-2	45.0	NA	45.0	1982	4	Quaternary Alluvium	X	X
IW-3	45.0	NA	45.0	1982	4	Quaternary Alluvium		X
Ladder Airstrip Well	NA	NA	NA	NA	NA	ND		X
Lower Percha Artesian	NA	NA	NA	NA	NA	ND		X
MW-1	1000.0	350.0	1000.0	1975	8	Santa Fe Group	X	X
MW-11	65.0	12.0	32.0	1994	8	Quaternary Alluvium	X	X

Well Name	Total Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Year Drilled	Diameter (inches)	Inferred Aquifer	Water Quality Sample	Water Level Measurement
MW-2	1500.0	133.0	1500.0	1975	8	Santa Fe Group	X	X
MW-4	2000.0	123.0	1500.0	1975	8	Santa Fe Group	X	X
MW-5	1380.0	306.0	1000.0	1975	8	Santa Fe Group	X	X
MW-6	1112.0	310.0	1000.0	1975	8	Santa Fe Group	X	X
MW-8	1004.0	366.0	1000.0	1975	8	Santa Fe Group	X	X
MW-9	250.0	200.0	250.0	1994	8	Santa Fe Group	X	X
NP-1	115.0	NA	106.0	1981	4	Santa Fe Group	X	X
NP-2	115.0	NA	110.0	1981	4	Santa Fe Group	X	X
NP-3	109.5	NA	100.0	1981	4	Santa Fe Group	X	X
NP-4	117.0	NA	117.0	1981	4	Santa Fe Group	X	X
NP-5	44.0	24.0	39.0	1981	4	Quaternary Basalt	X	X
Saladone Well	NA	NA	NA	NA	NA	Quaternary Alluvium		X
Upper Percha Well	NA	NA	NA	NA	NA	ND		X

Notes:

NA = not available

ND = not determined

Table 9-3

Analytical Parameters and Analysis Methods for Groundwater Samples

Analytical Parameter	Analysis Method	Lab Detection Limit (mg/L unless noted)
Anions		
Fluoride	EPA Method 300.0	0.1
Chloride	EPA Method 300.0	0.1
Nitrogen, Nitrite (as N)	EPA Method 300.0	0.1
Nitrogen, Nitrate (as N)	EPA Method 300.0	0.1
Sulfate	EPA Method 300.0	0.5
Dissolved Metals		
Aluminum	EPA Method 200.7	0.02
Antimony	EPA Method 200.8	0.005
Arsenic	EPA Method 200.8	0.02
Barium	EPA Method 200.7	0.002
Beryllium	EPA Method 200.7	0.002
Boron	EPA Method 200.7	0.04
Cadmium	EPA Method 200.7	0.002
Calcium	EPA Method 200.7	0.50
Chromium	EPA Method 200.7	0.006
Cobalt	EPA Method 200.7	0.006
Copper	EPA Method 200.7	0.0003
Iron	EPA Method 200.7	0.02
Lead	EPA Method 200.7	0.005
Magnesium	EPA Method 200.7	0.50
Manganese	EPA Method 200.7	0.002
Mercury	EPA Method 7470 CVAA	0.0002
Molybdenum	EPA Method 200.7	0.008
Nickel	EPA Method 200.7	0.01
Potassium	EPA Method 200.7	1.0
Selenium	EPA Method 200.8	0.02
Silicon	EPA Method 200.7	0.08
Silver	EPA Method 200.7	0.005
Sodium	EPA Method 200.7	0.5

Analytical Parameter	Analysis Method	Lab Detection Limit (mg/L unless noted)
Thallium	EPA Method 200.7	0.01
Titanium	EPA Method 200.7	0.005
Uranium	EPA Method 200.8	0.01
Vanadium	EPA Method 200.7	0.005
Zinc	EPA Method 200.7	0.005
Solids		
Total Suspended Solids (TSS)	SM 2540D	1.0 µg/L
Total Dissolved Solids (TDS)	SM 2540C	10
Alkalinity		
Alkalinity, total (as $CaCO_3$)	SM 2320B	20
Carbonate	SM 2320B	20
Bicarbonate	SM 2320B	20
Other		
pH	150.1	12.45
Specific Conductance	120.1	0.01 µS/cm
Cyanide	Kelada-01	0.005

Note: NA = not applicable as sample will not be analyzed for a given parameter.

Table 9-4
Groundwater System Characteristics (from SRK, 1995)

Unit	Crystalline Bedrock	Santa Fe Group System	Quaternary Alluvium
Material	Rock	Alluvium	Alluvium
K_h (ft/yr)	10	1,000 – 4,000	~78,000
K_v (ft/yr)	10	1-40	~7
Porosity	2%	25%	25%
Storage Coefficient	1%	0.1 – 0.001%	0.1%
Depth of Unit	>2,000’	0 – 2,000’+	~30’
Depth to Water	0’-50’	50’-300’	~5’
Notes	Variable, fractured	Higher K to east; heterogeneous	Perched, low communication