3.2 Water Resources and Geochemistry

3.2.1 Affected Environment

3.2.1.1 Hydrologic Setting

The Phoenix Project is located within two major hydrographic areas of Nevada, the Humboldt River basin and the Central Region (***Figure 3.2-1***). The hydrologic study area for the project encompasses approximately 470 square miles of terrain, ranging from mountains and hillslopes to alluvial fans and playas. Major drainage features within the study area are shown in greater detail in ***Figure 3.2-2***. Elevations within the hydrologic study area range from approximately 4,500 feet amsl along the Humboldt River near the town of Battle Mountain to approximately 8,550 feet amsl at North Peak. Elevations in the proposed project area range from about 4,360 feet to 6,750 feet amsl. Major surface channel networks within the hydrologic study area include a portion of the Humboldt River to the northeast, part of the Reese River drainage in the south and east, and Buffalo Valley in the west.

Mean annual precipitation within the hydrologic study area varies according to elevation, as is typical within the Basin and Range province (Maxey and Eakin 1949). Typically, the months with the greatest precipitation are March, May, and November. During the winter months, precipitation generally occurs as snow at elevations higher than 5,500 feet amsl (Baker Consultants, Inc. 1997a).

As is typical for arid areas, the actual amount of precipitation in the region varies considerably from year to year. This is exemplified in the recent wet and dry cycles that have occurred over the last 10 years in northern Nevada. As an illustration, ***Table 3.2-1*** presents precipitation data for several National Weather Service precipitation stations in the region. As can be seen from the data, precipitation amounts have been higher in more recent years (particularly 1996 and 1998) than the historical averages. In addition, rain-on-snow events caused high runoff conditions in much of Nevada in early 1997 (U.S. Geological Survey 1998). Such events have occurred at other times and locations, most notably in the project area during late March and early April of 1998 (Brown and Caldwell 1998c). Average annual snowfall near the town of Battle Mountain is 21.43 inches (Brown and Caldwell 1999a) and may be considerably higher in the project area. Monitoring records indicate that snow accumulations in the Battle Mountain area were 240 to 250 percent above normal in early 1998 (Natural Resources Conservation Service 1999). Calendar year 1998 was by far the wettest year of record (1944 to 1999) at the weather station near the town of Battle Mountain; in the first half of the year, over 13 inches of precipitation fell (Western Regional Climate Center 1999), and it is likely that additional precipitation occurred at the higher elevations of the project area. Although these station values are not necessarily representative of precipitation magnitudes in the project area, they do indicate the general precipitation trends in the region.

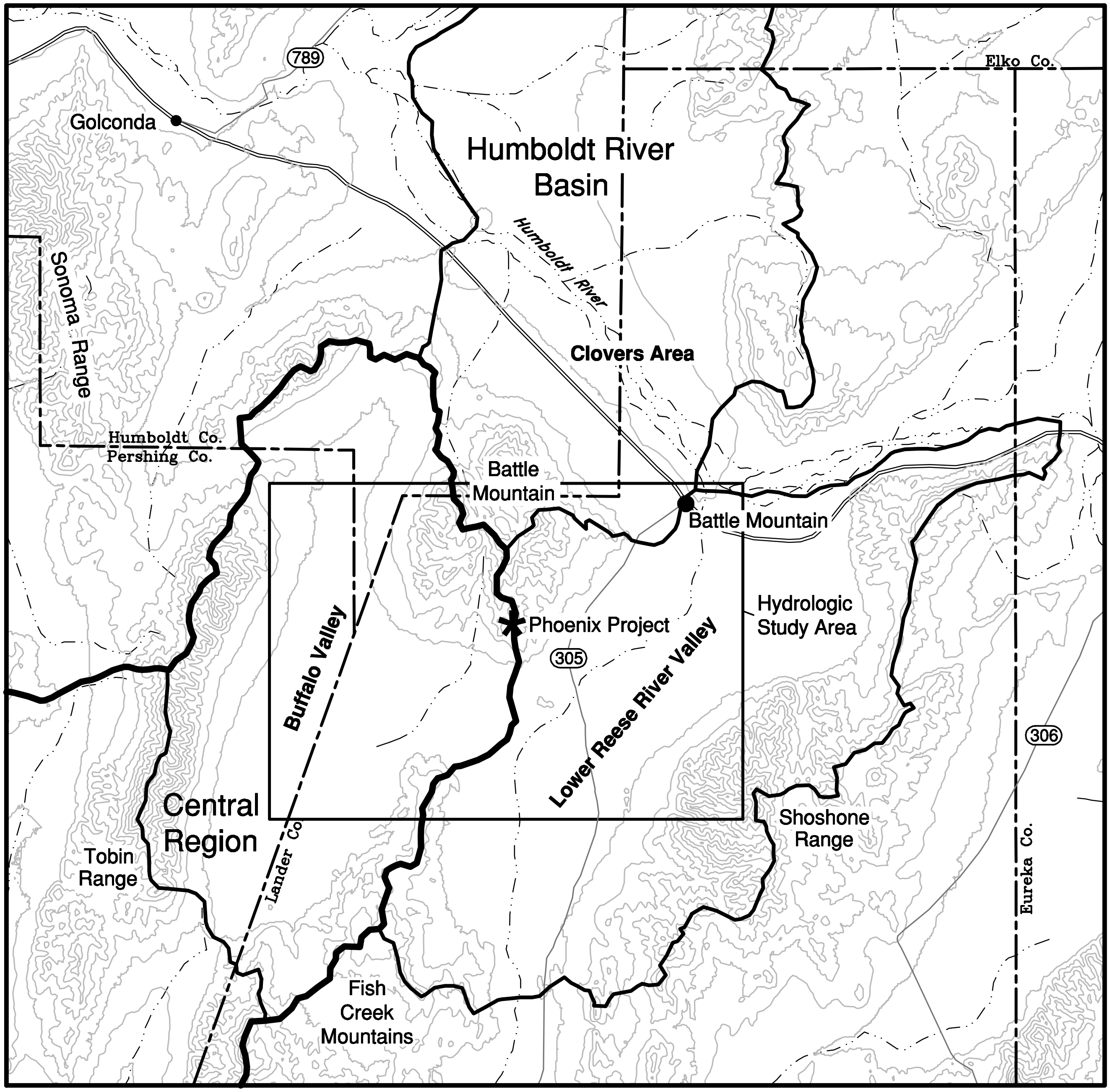
Evaporation from shallow lakes, wet soils, or other moist natural surfaces is estimated to be 42 to 44 inches per year in the Battle Mountain vicinity (National Oceanic and Atmospheric Administration 1982, Baker Consultants, Inc. 1997a, Houghton, et. al. 1975). On average, approximately 32 inches of evaporation occurs from May to October. Rates somewhat less than these may occur at higher elevations. The amount of water consumed by evapotranspiration may vary considerably from these values. Evapotranspiration is discussed later in more detail in the Aquifer Recharge and Discharge subsection.

3.2.1.2 Surface Water

<u>**Surface Water Flows**</u>

Flow measurements have been made at selected gaging locations throughout the Humboldt River basin. Historically, gaging by federal and state agencies has been concentrated on the Humboldt River itself and its major tributaries.

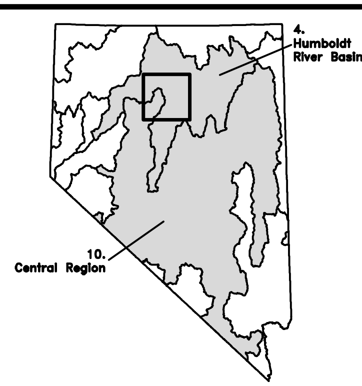
As shown in ***Figure 3.2-3***, the reach of the Humboldt River nearest the hydrologic study area lies near the existing U.S. Geological Survey gage at the town of Battle Mountain (gage number 10325000). The Battle Mountain gage has had a stage recorder in place since 1945, with non-recording measurements taken sporadically since 1896. The modern record at this location is discontinuous; there is a gap in the data between September 1981 and February 1991. Based on the recorded data, the average annual flow rate at this gage was 343 cubic feet per second, or approximately 248,500 acre-feet per year. The highest recorded annual mean was 889 cubic feet per second (644,000 acre-feet per year) in 1971.



Explanation

- County Boundary
- 80 Interstate
- Road
- Drainage
- Hydrographic Region Boundary
- Hydrographic Area Boundary
- Hydrologic Study Area
- City

Source: Nevada State Engineer's Office 1992a



Index Map of Nevada showing Hydrographic Regions

N

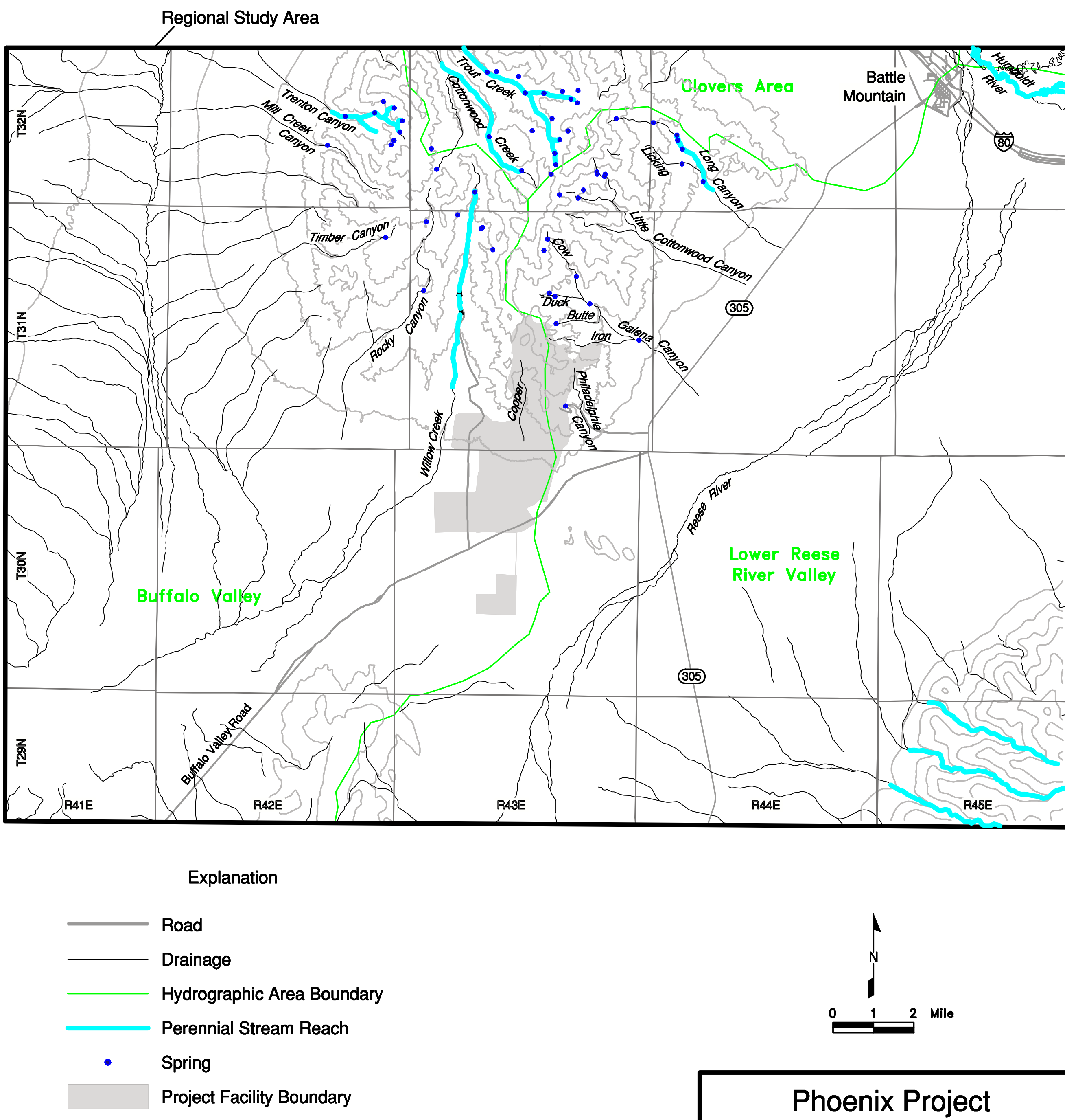
0 5 10 Miles

Contour Interval is 500 Feet

Phoenix Project

Figure 3.2-1

Regional Hydrographic Features



Source: JBR 1996d,g and Baker Consultants, Inc. 1997a, 2000a

Phoenix Project

Figure 3.2-2

Local Drainage Features

Table 3.2-1
Precipitation Amounts

Precipitation Station	Average Annual Precipitation (inches)	1995 Precip. (inches)	1996 Precip. (inches)	1997 Precip. (inches)	1998 Precip. (inches)
Battle Mountain	7.77	5.74	12.20	9.05	16.79
Golconda	7.46	9.72	10.61	6.33	10.73
Paradise Valley 1 NW	9.53	13.98	13.97	7.20	19.59
Winnemucca Municipal Airport	8.33	9.82	10.70	7.88	15.61

Source: Western Regional Climate Center 1999.

The lowest annual mean was 54.5 cubic feet per second (39,500 acre-feet per year) in 1955. The largest recorded instantaneous peak flow was 5,800 cubic feet per second on May 3, 1952, but other measurements in the region indicate that larger flows probably occurred in the early 1980s, when the Battle Mountain gage was not operating (U.S. Geological Survey 1998). During the low-flow months of September and October, gage records indicate that the flow rate in the Humboldt River often falls to zero cubic feet per second.

Beneficial uses of surface water in the Humboldt River basin include agriculture, mining, and other industrial uses and municipal and domestic uses. Agricultural activities comprise the dominant human uses of surface water in the region. Irrigation withdrawals of approximately 194,000 acre-feet/year occur above the Battle Mountain gage (Emmet et. al. 1994). Numerous legal cases and decisions are used to administer water rights in the region. The surface water resources of the Humboldt River area are over appropriated, meaning that there is more legally registered demand than supply.

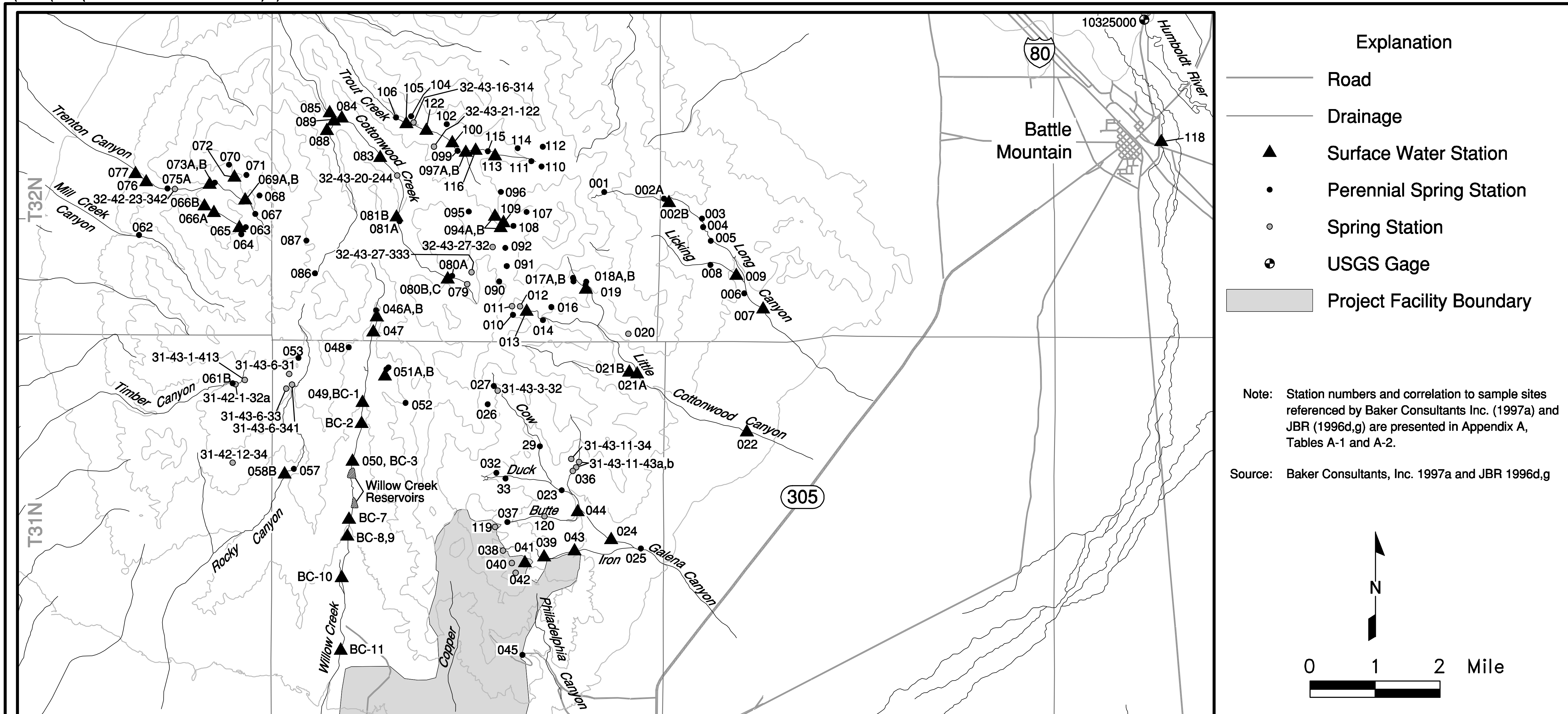
During 1995 and 1996, additional surface water baseline information was collected in the hydrologic study area by JBR and Baker Consultants, Inc. Surface water flow monitoring stations (including springs) are shown in ***Figure 3.2-3***. Flow monitoring data at these stations are presented in JBR 1996d, 1996g, and Baker Consultants Inc. 1997a. The flow characteristics of surface water features are discussed in the following paragraphs.

Within the hydrologic study area, the major tributary to the Humboldt River is the Lower Reese River Valley (Hydrographic Area). Intermittent flows occur along most of the Reese River within the hydrologic study area. In general, most of the surface flow either infiltrates the regional ground water system or is consumed by evapotranspiration. Site visits indicate that reaches of the Reese River in the project vicinity often contain water in isolated pools and that sporadic changes from flowing to dry conditions occur over a matter of a few days (Baker Consultants, Inc. 1997b).

Although no regular monitoring or gaging has occurred on lower portions of the Reese River, recent visual observations indicate that the lower reaches (within 4 miles of the town of Battle Mountain) contained water in the winter of 1995 and the summer of 1996 (Baker Consultants, Inc. 1997a). Small flow rates were measured there and farther upstream in the spring of 1996 (Baker Consultants, Inc. 1997a; JBR 1996d, 1996g). In past years, flows from the Reese River have been estimated to contribute approximately 5,000 acre-feet seasonally to the Humboldt River during the spring when higher flows from snowmelt and precipitation reach the mainstream (Eakin and Lamke 1966).

In the Lower Reese River Valley Hydrographic Area, existing and proposed BMG project components are located in two watersheds: Philadelphia Canyon and Galena Canyon (***Figures 3.2-2*** and ***3.2-3***). Philadelphia Canyon, Iron Canyon, and the drainage downstream, Galena Canyon, and their tributaries are ephemeral streams.

Smaller watersheds in the northcentral section of the project hydrologic study area are located in the Clovers Hydrographic Area (***Figure 3.2-1***). The dominant drainages within this area are Cottonwood Creek and Trout Creek (***Figure 3.2-2***), which drain northward to the Humboldt River. A flow of approximately 163 gallons per minute (0.36 cubic feet per second) was measured at the most downstream monitoring



Phoenix Project

Figure 3.2-3

Flow Measurement Stations

location on Cottonwood Creek in June of 1996. The most downstream measurement along Trout Creek was approximately 506 gallons per minute (1.25 cubic feet per second) at the same time. These streams may be perennial in their upper reaches within mountainous terrain. No stream flow measurements have been taken at downstream locations closer to the Humboldt River. It is reasonable to expect that these streams become intermittent or ephemeral in their lower reaches because of seepage losses on the alluvial fan system to the north. Other than small seasonal flows from snowmelt runoff or an occasional storm, contributions to Humboldt River flows from these drainages are probably insignificant. No existing or proposed BMG project components lie within the Clovers Area.

The majority of the existing BMG operations, as well as many of the proposed project components, are located in Copper Canyon ***(Figure 3.2-2***), which lies within the Buffalo Valley Hydrographic Area (***Figure 3.2-1***). Drainages within Buffalo Valley all feed into the playa in the southern part of the valley, where any remaining water eventually infiltrates the ground water flow system or is consumed by evapotranspiration. Buffalo Valley is a closed basin, and consequently does not contribute surface flow to the Humboldt River. Additional streams within this part of the study area include Willow Creek, Rocky Canyon, Timber Canyon, Mill Canyon, and Trenton Canyon. With the exception of Willow Creek and upper Trenton Canyon, these streams are all predominantly ephemeral drainages where surface flows occur as a result of runoff from snowmelt and the occasional thunderstorm. With the exception of isolated spring-fed headwater reaches, losses from evapotranspiration and seepage into the channel bed prevent long-term surface flows along most of these stream courses.

The general locations of perennial stream reaches are shown in ***Figure 3.2-2***. The locations and extents of perennial stream reaches have been determined using the surface water data obtained in the baseline monitoring program (JBR 1996d, 1996g; Baker Consultants, Inc. 1997a), and U.S. Geological Survey topographic maps.

Since the available surface water data do not contain monthly measurements, the best estimate of baseflows from the available data are those observed in October 1995. Consequently, if water is flowing at the surface during this month, it is presumed that water would be present the entire year.

The resulting data form a reasonable characterization of typical surface water conditions in the study area. Precipitation amounts varied considerably in late 1994 and the earlier part of 1995, with individual months being substantially wetter or dryer than their averages (Western Regional Climate Center 1999). Precipitation amounts historically have varied considerably in the region, and this is true of the period when the field efforts were conducted.

Springs and seeps in the region were inventoried in the summer and fall of 1995 and monitored periodically during 1996 (JBR 1996d, 1996g; Baker Consultants, Inc. 1997a). For this evaluation, it was assumed that any spring or seep with recorded flows during the month of August, September, or October was perennial and dependent on ground water discharge. Conversely, springs that did not have reported flows during these late summer and early fall months were assumed to be ephemeral or intermittent. The locations of the perennial springs and seeps and ephemeral springs and seeps are distinguished by symbols in ***Figure 3.2-3***. The various baseline studies have used different surface water (stream, seep, or spring) monitoring stations numbers to refer to the same site. Tables presented in Appendix A (***Tables A-1 and A-2***) correlate the map reference numbers used in this document to those used in the various baseline reports.

In the Buffalo Valley Hydrographic Area, portions of two drainages were determined to be perennial: Willow Creek and Trenton Canyon (***Figure 3.2-2***). The location of inventoried springs and seeps, surface water flow monitoring stations (JBR 1996d, 1996g; Baker Consultants, Inc. 1997a), and reservoirs along Willow Creek are shown in ***Figure 3.2-3***. Two small earthen dams with reservoirs (herein referred to as the upper and lower Willow Creek reservoirs) are located along Willow Creek and provide water for water appropriation and recreation.

Stream flow in Willow Creek consists of seasonal runoff and ground water inflow in the form of perennial spring discharge adjacent to and within the stream channel. A major source of perennial flow in upper Willow Creek is ground water discharge from two perennial springs located approximately 2 miles upstream of the upper reservoir (springs 46A and 51A, ***Figure 3.2-3***). Stream flow data collected by Baker Consultants, Inc. in early June 1996 indicate that (at least during this time of year) stream flows increased (or gained) along stream reaches located both above and below the reservoirs. Below the lower reservoir, stream flow is controlled in part from reservoir release. However, stream flow data (Baker Consultants, Inc.1997a) indicate that flows generally increased (or gained) in the reach that extends approximately 2 miles below the lower reservoir. Below this point, the steam flows gradually decreased and eventually terminated in an alluvial fan along the margin of Buffalo Valley from the combined effects of evaporation and infiltration. Based on available information, it is not possible to define the downstream extent of the perennial reach of Willow Creek. (Note: based on the stream flow data and piezometer information provided by Baker Consultants, Inc. [1997a], it is assumed that portions of the stream that exhibited gains are in direct contact and interconnected with the regional ground water system. Conversely, losing stream reaches are assumed not to be interconnected with the water table or regional ground water system.)

In summary, upper reaches of Willow Creek are in contact with the ground water system. Gains in stream flow occur by net ground water inflow along the reach extending from the headwaters to a position on the local alluvial fan where it leaves the mountain front and begins to coalesce with a more extensive fan system. Downstream of this locale, Willow Creek loses flow to evaporation and channel seepage and eventually becomes an ephemeral stream. It drains to the playa in Buffalo Valley in the southwestern part of the hydrologic study area.

Perennial reaches in Trenton Canyon originate from springs located on both the north and possibly the south forks of the canyon (***Figure 3.2-2***). Although the October 1995 records indicate that much of the main channel was dry, a surface water re-emergence (i.e., surface water that seeps into the ground upstream and then re-appears) occurred in the south fork approximately 0.5 mile upstream of the confluence with the north fork. Thus, it is possible that a perennial reach occurs between this point and the confluence with the north fork. The perennial reach on the north fork extends much farther upstream to a pair of headwater springs (Stations 067 and 068) located in Sections 24 and 25, Township 32 North, Range 42 East (JBR 1996d). Flows continue downstream of the confluence to a point near Station 76, where 30 gallons per minute (0.1 cubic foot per second) were observed in October 1995.

Other drainages in the Buffalo Valley basin (Rocky Canyon, Timber Canyon, and Mill Canyon) contain potentially perennial springs, but none have a sufficient flow rate or duration to keep the downstream channels wet all year. Copper Canyon also contains an ephemeral stream.

In the Lower Reese River Valley (***Figure 3.2-1***), only one perennial stream reach was identified from the data available. The channel in Long Canyon (***Figure 3.2-2***) produced a continuous flow beginning with an alluvial re-emergence in the northeast quarter of Section 30, Township 32 North, Range 44 East (JBR 1996d). A series of springs and stream channel measurements indicate the perennial flow continues until the drainage reaches the Reese River Valley in the middle of Section 32, Township 32 North, Range 44 East (JBR 1996d). Natural perennial springs are scattered in a number of different canyons from Long Canyon south to Iron Canyon.

Other discharge measurements in the Lower Reese River Valley were taken at three spring sites, two of which appear to be springs created by mining activity. These three sites are near adits located in Duck Creek (Station 032) and Butte Canyon (Station 037), and at a headwater spring in Philadelphia Canyon (Station 045) (***Figure 3.2-3***). Given the discharge data, these springs are assumed to be perennial. A review of the wildlife and vegetation data (WESTEC 1995a, 1995b, 1995c, 1995d) indicates that no riparian habitat was observed in these three monitoring site locations. A vested water right (Appropriation Number 01725 [SEA Incorporated 1995]) is located near the spring in Duck Creek (see the Surface Water Rights section below).

Perennial stream reaches also are found in the drainages on the west flank of the Shoshone Range in the southwest corner of the hydrologic study area. However, these streams are separated hydrologically from the project area by the Reese River itself, and so are not considered further.

Based on the available data, the hydrologic study area includes two perennial stream reaches in the Clovers Hydrographic Area (***Figure 3.2-2***). One perennial reach begins on the main channel of Trout Creek at a headwater spring (Station 091) located in the southwest quarter of Section 27, Township 32 North, Range 43 East (JBR 1996d). This perennial stream is fed by several near-channel and tributary springs and extends down to a stream flow monitoring site in the northwest quarter of Section 16, Township 32

North, Range 43 East (JBR 1996d). In addition, the East and Dewitt Mine tributaries of this canyon also contain perennial reaches beginning at Stations 108 and 110, respectively.

The other perennial stream is located in the Cottonwood ***Creek drainage***. This reach extends from a colluvial headwater spring located in the northwest quarter of the northeast quarter of Section 33, Township 32 North, Range 43 East. Surface water measurements along a main channel indicate continuous flow occurred in October 1995 down to Station 85, approximately 4 miles downstream from the headwater spring. (JBR 1996d)

Surface Water Rights

Water rights and applications for water rights were reviewed and summarized by Brown and Caldwell (1998b) and SEA Incorporated (1995). These data were collected from the Nevada Division of Water Resources records. For this inventory, all rights and applications owned by BMG were excluded. Of the 37 water rights and applications for water rights, 14 were associated with surface water sources (e.g., creeks and springs); 3 were associated specifically with springs. ***Table 3.2-2*** summarizes these surface water rights. The point of diversion locations listed for the water rights are shown in ***Figure 3.2-4***.

Watershed Characteristics

The principal drainages within the immediate project vicinity are Willow Creek, which drains into Buffalo Valley to the south, and Galena ***Canyon***, which drains into the Lower Reese River Valley to the east (see ***Figure 3.2-2***). Other drainages that flow into Buffalo Valley include Copper Canyon, Rocky Canyon, ***Timber Canyon***, Trenton Canyon, and miscellaneous canyons originating from the Battle Mountain range. Tributaries of the Lower Reese River basin include Philadelphia Canyon, Little Cottonwood Canyon, and Long Canyon. The hydrologic study area also encompasses the headwaters of Trout ***Creek*** and Cottonwood ***Creek***, both of which fall within the Wild Horse basin and drain into the Humboldt River.

The topography of these basins varies from steep mountain ridges and canyons in the Battle Mountain range to mild sloping alluvial fans and nearly level lake deposits (JBR 1997d). Soil survey information (JBR 1997d) indicates that higher elevations contain moderately deep and typically well-drained soils. The fans contain coarse and gravelly material with deep and well-drained soils. The valley floor consists of very deep soils that are poorly drained (see Section 3.3, Soils). Water losses from seepage and evapotranspiration are potentially high within the alluvial fill areas of the watershed.

The Willow Creek watershed is a long, linear basin with steep canyons in the headwaters. The basin opens up into a narrow valley and finally fans out into Buffalo Valley, where it eventually drains into a playa. The majority of the runoff occurs above the first of the two small reservoirs located in the basin (***Figure 3.2-3***). In addition, these reservoirs collect the majority of sediment originating from upstream watersheds, and consequently reduce the sediment loads below them.

The hydrologic study area includes the entire Galena Canyon watershed. This drainage has a typical dendritic pattern consisting of several large canyons, including Cow, Scott, Butte, Iron, and Galena canyons. A piedmont fan exists at the base of the Galena Canyon catchment and eventually drains into the Reese River Valley. No major reservoirs are present in this watershed to impede sediment transport.

Field observations in the basins near the project site revealed the existence of ephemeral channels or wetlands in Willow Creek, Galena Canyon (including Butte, Cow, Galena, Iron, and Scott canyons), and Philadelphia Canyon (Gibson & Skordal Wetland Consultants 1996).

These field determinations have been verified by the U.S. Army Corps of Engineers; therefore, these canyons are officially delineated as containing waters of the U.S. The stream channel in Iron Canyon is not continuous with the downstream channel system in Galena Canyon. For this reason, only the reach of Iron Canyon that contains a wetland and small associated ephemeral channel is considered a water of the U.S. This reach of Iron Canyon extends along the northern headwater tributary upstream of the section line, Sections 22 and 23, Township 31 North, Range 43 East. All of the other Galena Canyon tributaries mentioned above have surface channels that extend continuously down to the main channel in Galena Canyon. Galena Canyon itself has a discernible surface channel within the project boundary, and has been delineated as waters of the U.S. within the project area (Gibson & Skordal Wetland Consultants 1996). An earlier report (Gibson & Skordal Wetland Consultants 1993), which was later verified by the U.S. Army Corps of Engineers, indicates that no waters of the U.S. exist in Copper Canyon.

Table 3.2-2
Surface Water Rights

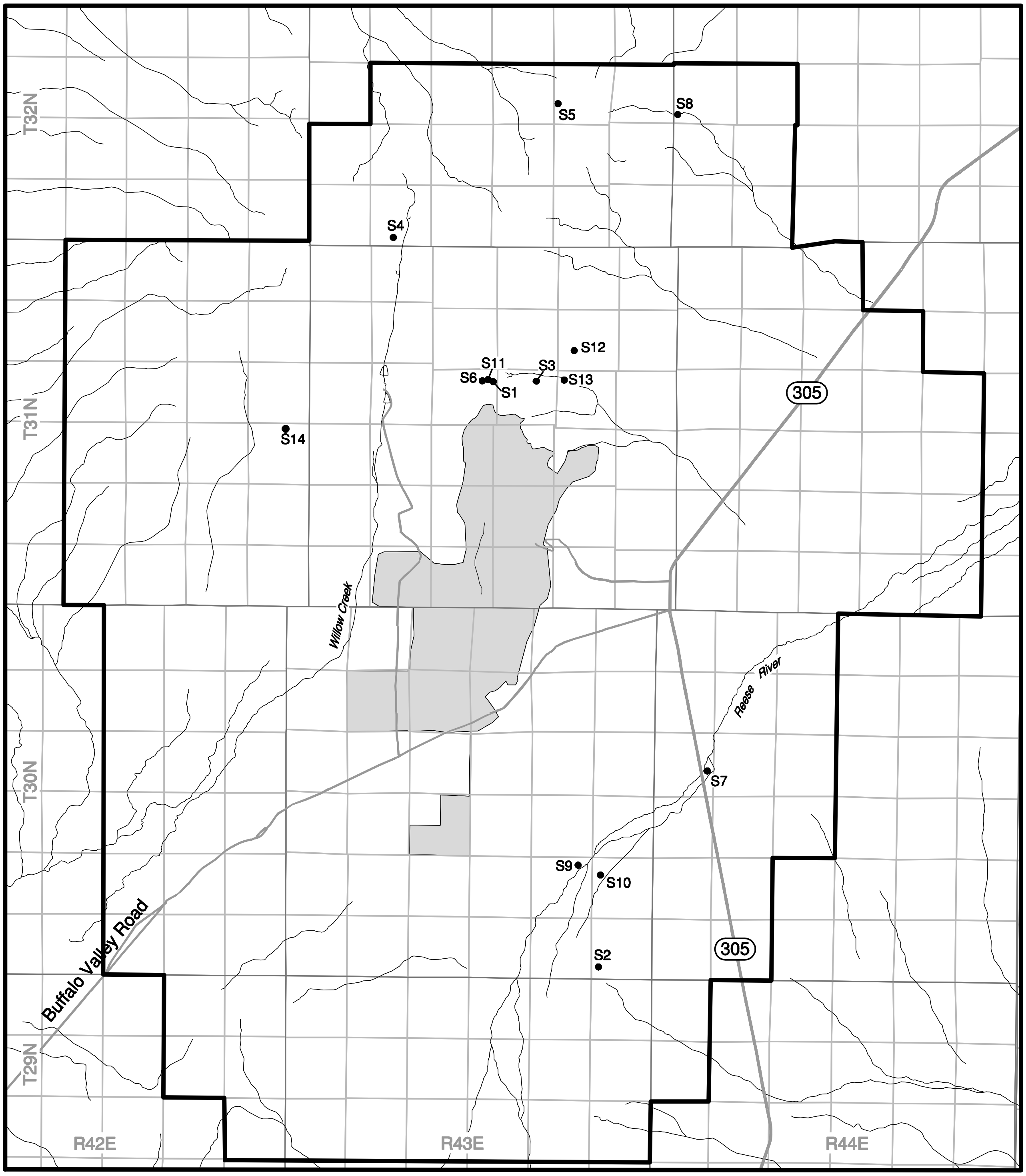
Map #[1]	Application Number	Certificate #	Status[2]	Point of Diversion					Cubic Feet/ Second	Acre-Feet	Use	Owner
S1	0723	---	VST	NE NW NE NW		16 15 15 14	31N	42E	---	---	Irrigation	Edward Labadie
S2	01563	---	VST	SW	SW	36	30N	43E	---	---	Irrigation	Daniel Filippini
S3	01725	---	VST	NW	NE	15	31N	43E	---	---	Irrigation	Minnie Hider
S4	03744	---	VST	SW NW	SW SE	27 32	30N 32N	43E 43E	---	---	Stock	Venturacci Ranch
S5	04089	---	VST	NW	SW	23	32N	43E	---	---	Stock	Venturacci Ranch
S6	04228	---	VST	NE	NE	16	31N	43E	0.015	---	Stock	Venturacci Ranch
S7	07560	---	VST	NE	SE	18	30N	44E	0.016	3.80 MGA	Stock	Julian Tomera Ranches, Inc.
S8	2865	417	CER	SW	SW	19	32N	44E	1.000		Placer mining	W.G. Lee & Paul Baugh
S9	3864	900	CER	NE	NE	26	30N	43E	1.4429	432.87	Irrigation	R.E. & W.B. Chiara
S10	6456	901	CER	SW	NW	25	30N	43E	0.2749	---	Irrigation	R.E. & W.B. Chiara
S11	22759	7592	CER	NE	NE	16	31N	43E	0.1506	35.527 MGA	Milling & domestic	Frank W. Lewis
S12	24497	7684	CER	NW	SW	11	31N	43E	0.500	20.00	Irrigation & domestic	Frank W. Lewis
S13	28960	9811	CER	NW	NW	14	31N	43E	0.478	4.52	Irrigation & domestic	S. Styles & Frank W. Lewis
S14	42650		RFP	NW	NE	24	31N	42E	0.500	3.77 MGA	Domestic & stock	Louie & Eddie Venturacci

Sources: SEA Incorporated 1995, Brown and Caldwell 1998b.

[1]See Figure 3.2-4.

[2] Status: CER=Certificate
RFP=Ready for Action (protested)
VST=Vested Right

Note: Excludes water rights owned or controlled by BMG.



Explanation

Road

Drainage

Limits of Research

Project Facility Boundary

S9 Water Right on File at State Engineer's Office

Source: Brown and Caldwell 1998b

N

0 1 2 Mile

Note: Water rights owned or controlled by BMG are excluded.

Phoenix Project

Figure 3.2-4

Surface Water Permits on File at the State Engineer's Office

Flood Hydrology and Storm Water Management

Potential discharges to waters of the State for current operations in the Copper Canyon mining area are controlled in accordance with Nevada Water Pollution Control Permit NEV87061. In addition, current storm water management requirements and potential discharges to waters of the U.S. are addressed by ongoing compliance with the Nevada General Discharge Permit for Storm Waters Associated with Industrial Activity – Permit Number NVR300000. The General Permit requires operators of metal mining facilities to prepare a Storm Water Pollution Prevention Plan to identify potential pollution sources and the controls necessary to reduce their potential impact. The General Permit authorizes certain discharges of storm water associated with industrial activity to waters of the U.S. The Copper Canyon mining operations, and associated Best Management Practices for storm water pollution prevention, are currently managed under an existing Storm Water Pollution Prevention Plan submitted to the State in 1997 under the General Permit. Permit renewals and modifications are made periodically in accordance with the permit terms, changes in operations, or regulatory revisions.

In order to design retention ponds for current operations, runoff from storm events was modeled for four points of concentration. This modeling is presented in the Storm Water Pollution Prevention Plan and Monitoring Plan [Simon Hydro-Search 1993a]. Precipitation amounts for the 10-year, 24-hour; 25-year, 24 hour; and 100-year, 24-hour storm events at the site are 1.65 inches, 2.05 inches, and 2.6 inches, respectively. The design storm precipitation data were obtained from the National Oceanic and Atmospheric Administration's Precipitation-Frequency Maps of Nevada. The Soil Conservation Service Curve Number Method was used to compute the storm water runoff volumes. All ponds, ditches, and diversion channels are designed in accordance with state requirements to retain or withstand appropriate storm events. This includes the 100-year, 24-hour event for both process facilities and the storm water control system after operations cease and reclamation and closure are completed.

A storm water runoff event occurred in the project area in late March 1998, in the Iron Canyon vicinity in the northeastern part of the project area. Initially, approximately 18 inches of snow fell (Brown and Caldwell 1998c); subsequently, approximately 0.75-inch of warm rain fell on the snowpack within a 36-hour period on March 24, 1998. Over the next 3 weeks, the Iron Canyon area received over 2.1 inches of precipitation, which is slightly more than one-third the annual average. This unusual event generated a substantial amount of runoff through the waste rock areas in Iron Canyon. BMG immediately collected runoff samples, and analyses indicated that these samples exceeded water quality standards. Upon receiving the sampling results, BMG notified appropriate state authorities and immediately established a storm water collection, treatment, and monitoring program. Further documentation of this event is presented in reports submitted to the Nevada Division of Environmental Protection in Carson City (Brown and Caldwell 1998c).

As part of the response actions, an interim storm water collection and treatment system was designed and constructed, and its long-term design adequacy was reviewed as part of the current project planning. The new storm water system for Iron Canyon is lined and monitored (as is the system for Copper Canyon); its capacity is based on the complete capture of the abnormally high runoff observed during the entire March - August 1998 period (Brown and Caldwell 1998c).

Surface Water Quality Standards

Waters of the State of Nevada are defined in the Nevada Revised Statutes Chapter 445, Section 445.191 and include, but are not limited to 1) all streams, lakes, ponds, impounding reservoirs, marshes, water courses, waterways, wells, springs, irrigation systems, and drainage systems; and 2) all bodies of accumulations of water, surface and underground, natural or artificial.

Water quality standards for state waters have been established by the State of Nevada under Nevada Administrative Code, Chapter 445, Sections 445A.117 through 445A.128. Standards for toxic materials applicable to designated beneficial uses of surface water are described in the Nevada Administrative Code 445A.144 and summarized in ***Table 3.2-3***. Water quality criteria to protect the beneficial uses of perennial surface waters within the project area are described in Nevada Administrative Code 445A.119. For the purpose of establishing beneficial uses and appropriate water quality standards, the State of Nevada has various surface water classifications.

Table 3.2-3
Nevada Water Quality Standards

Constituent (mg/L)[1]	Ground Water: Nevada Drinking Water Standards: Primary MCL[2]	Ground Water: Nevada Drinking Water Standards: Secondary MCL	Surface Water: Municipal or Domestic Supply	Surface Water: Nevada Agriculture: Irrigation	Surface Water: Nevada Agriculture: Livestock Watering	Surface Water: Aquatic Life
Physical Properties						
Dissolved Oxygen			Aerobic		Aerobic	***5.0***
Color (color units)		15[3]	75			
TDS (@180ºC)		500[3]; 1000[4]	500[3]; 1000[4]		3000	
Turbidity (NTU)						
Inorganic Nonmetals						
Ammonia unionized (Total NH_3 as N)			0.5			
Chloride		250[3]; 400[4]	250[3]; 400[4]		1500	
Cyanide (as CN)	0.2		0.2			***0.0052[8]***
Fluoride	4.0	2.0[4]	--	1.0	2.0	
Nitrate (as N)	10		10		100	
Nitrite (as N)	1.0		1.0		10	
pH (standard units)		6.5-8.5[3]	5.0-9.0	4.5-9.0	6.5-9.0	***6.5-9.0***
Sulfate		250[3,6], 500[4]	250[3]; 500[4]			
Metals[5]/Elements						
Aluminum		0.05-0.2[6]				
Antimony	0.006		0.146			
Arsenic (total)	0.05[7]		0.05[7]	0.10	0.20	***0.18[8,9]***
Barium	2.0		2.0			
Beryllium	0.004			0.10		
Boron				0.75	5.0	
Cadmium	0.005		0.005	0.01	0.05	***0.0006[8,10]***
Chromium (total)	0.1		0.1	0.10	1.0	***0.015[8,10]***
Copper	1.3[11]	1.0[3]		0.20	0.50	***0.0065[8,10]***
Iron		0.3[3]; 0.6[4]		5.0		***1.0***
Lead	0.015[11]		0.05	5.0	0.10	***0.0004[8,10]***
Magnesium		125[3]; 150[4]				
Manganese		0.05[3]; 0.1[4]		0.2		
Mercury	0.002		0.002		0.01	***0.00012[8]***
Nickel	0.1		0.134	0.20		***0.087[8,10]***
Selenium	0.05		0.05	0.02	0.05	***0.005[8]***
Silver		0.1[6]				***0.0014[8,10]***
Thallium	0.002		0.013			
Zinc		5.0[3]		2.0	25	***0.584[8,10]***

Source: Nevada Administrative Code 445A.119, 445A.144, 445A.453, and 445A.455.
[1]Units are milligrams per liter (mg/L) unless otherwise noted.
[2]Federal primary standards of 7-1-93 are incorporated by reference in NAC 445A.453.
[3]Nevada Secondary recommended maximum contaminant levels.
[4]Nevada Secondary (enforceable) maximum contaminant levels.
[5]The standards for metals are expressed as total recoverable unless otherwise noted.
[6]Federal Secondary maximum contaminant levels.
[7]Federal Primary standard for arsenic will change to 0.01 mg/L effective February 22, 2002.
[8]96-hour average.
[9]Standard for As(III).
[10]Standard is dependent on site-specific hardness; displayed value is for a hardness of 60 mg/L as $CaCO_3$ (approximate lower limit of site values). See NAC445A.144 for equations.
[11]Value is action level for treatment technique for lead and copper.
MCL = Maximum contaminant level.
NTU = Nephelometric turbidity unit.
TDS = total dissolved solids.

Surface waters in the hydrologic study area have been designated as either Class A, B, C, or Humboldt River waters based on water quality and beneficial use. The waters in the hydrologic study area that fall into A, B, C, or Humboldt River waters classifications include 1) the Willow Creek reservoirs (class B waters), 2) the Reese River north of old U.S. Highway 50 (Class C waters), and 3) the Humboldt River upstream from the control point at the Battle Mountain gage to the control point at the Palisade gage (including all tributaries that flow into the Humboldt River at this segment).

Surface Water Quality

PTI and Exponent characterized surface water quality in the Phoenix Project study area by compiling analyses of samples collected from the major surface water features in 1995 through 1998 (PTI 1997a,***e***; Exponent 1999). For the most part, the surface water features are located in the northern half of the study area (***Figure 3.2-5***). Creeks that were sampled include Duck Creek, Willow Creek, ***and intermittent streams in*** Little Cottonwood ***Canyon***, Cow ***Canyon***, and Long ***Canyon***. Springs and seeps located in the following areas also were sampled: Scott Canyon, Galena Canyon, Iron Canyon, Butte Canyon, Philadelphia Canyon, Licking ***Creek***, Rocky Canyon, and Wildhorse Basin. In addition, samples were collected from Trenton Canyon and Trout Creek, which are located just north of the study area and have similar water quality characteristics to surface water features within the study area.

Water samples were analyzed for most of the standard water quality indicators, including pH, alkalinity, major solutes, and metals. Analytes for which water quality standards exist either for drinking water or aquatic organisms, but that were not reported by PTI (1997a,e) or Exponent (1999), include aluminum, boron, cobalt, lithium, molybdenum, tin, and dissolved oxygen.

The surface water quality data for the study area show a wide range of composition. Samples from the northern part of the study area and upgradient from current mining facilities (Little Cottonwood Creek, Duck Creek, Willow Creek, Wildhorse Basin, Rocky Canyon, Trenton Canyon, and Trout Creek) generally had near-neutral to alkaline pH values (7.0 to 8.0) and total dissolved solids concentrations below the State of Nevada secondary drinking water standard of 500 milligrams per liter (***Figure 3.2-6***).

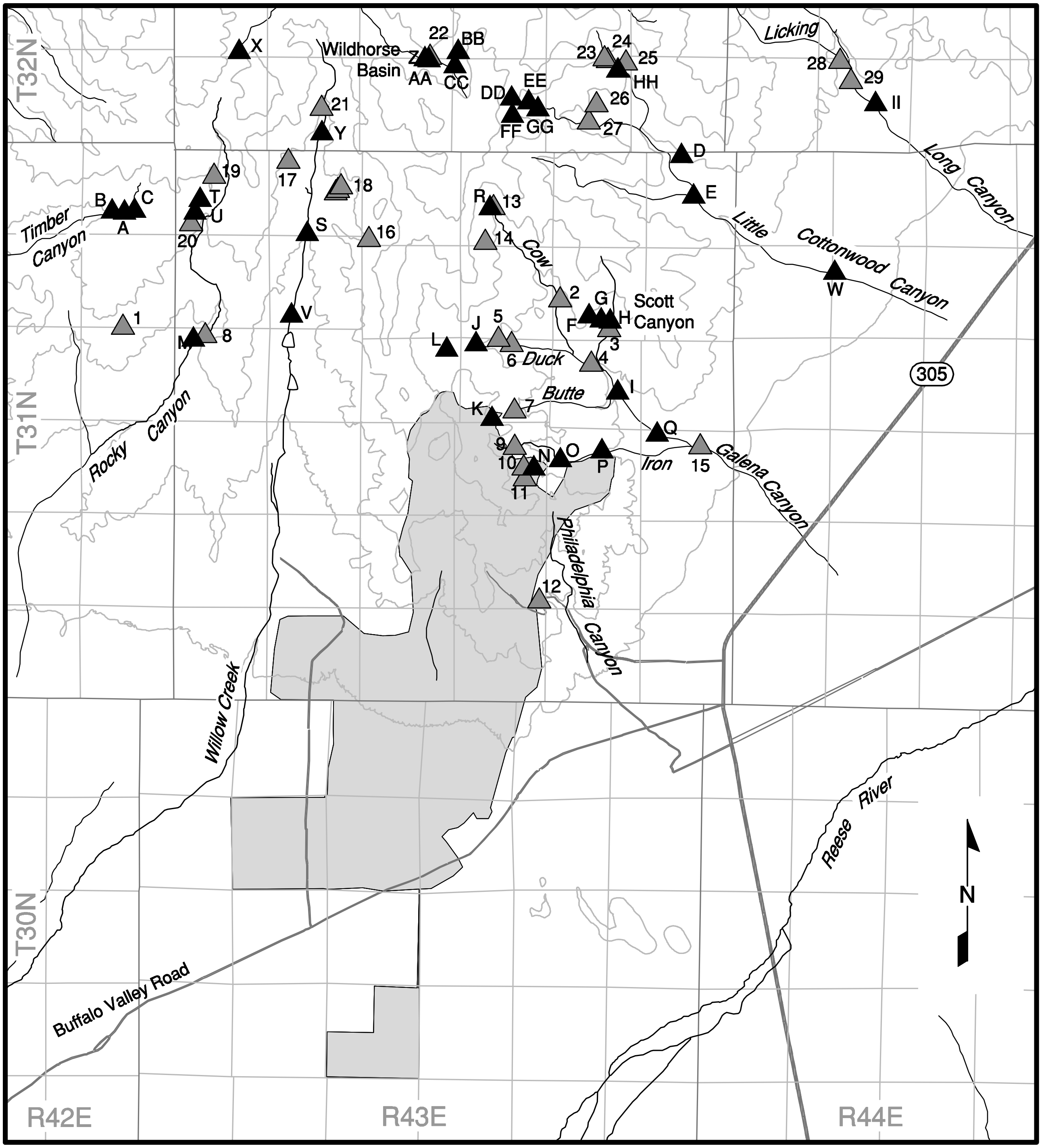
Metal concentrations in these same surface waters generally were low (***Figure 3.2-7***), although sporadic exceedences of drinking water standards for arsenic, copper, fluoride, iron, manganese, or nickel were observed in a few samples. For example, the headwater spring to Little Cottonwood ***Canyon*** had drinking water standard exceedences for arsenic, cadmium, copper, iron, manganese, and nickel. Another spring source to Little Cottonwood ***Canyon*** had exceedences for arsenic, iron, and manganese, and the lower reach had an exceedence for fluoride in one sample from the summer of 1996. In Duck Creek, exceedences were reported for arsenic, cadmium, manganese, and iron. Willow Creek had one exceedence for manganese in one sample from the summer of 1996. No exceedences were reported for samples from Wildhorse Basin, and one sample from Rocky Canyon had an arsenic concentration that equaled the drinking water standard of 0.05 milligram per liter.

Surface waters from Cow Canyon, Galena Canyon, Philadelphia Canyon, and Scott Canyon have compositions that are between the near-neutral solutions of the northern creeks and the more acidic surface waters, such as the waters from Iron and Butte canyons, that are immediately adjacent to historic mining areas. Surface water samples from these locations have weakly acidic to neutral pH values, generally between 6.0 and 7.0. Some of these surface waters also had slightly elevated total dissolved solids concentrations (***Figure 3.2-6***) primarily because of increased sulfate.

Exceedences for various solutes for these surface waters occurred but were sporadic; for the most part, metal concentrations were low (***Figure 3.2-7***). Cow Canyon had exceedences for mercury, manganese, and total dissolved solids. For Galena Canyon samples, exceedences occurred for arsenic, iron, sulfate, and total dissolved solids.

For Scott Canyon, exceedences occurred for sulfate and total dissolved solids. For Philadelphia Canyon, exceedences occurred for arsenic, beryllium, manganese, and sulfate.

The most acidic surface waters occurred adjacent to historic mining facilities and mineralized areas (e.g., Iron Canyon and Butte Canyon). The total dissolved solids concentrations in samples from these surface waters often exceeded the drinking water standard of 500 milligrams per liter and had pH values less than the drinking water standard of



Explanation

Drainage

Road

C Surface Water Quality Sampling Location

12 Surface Water Flow Measurement Location

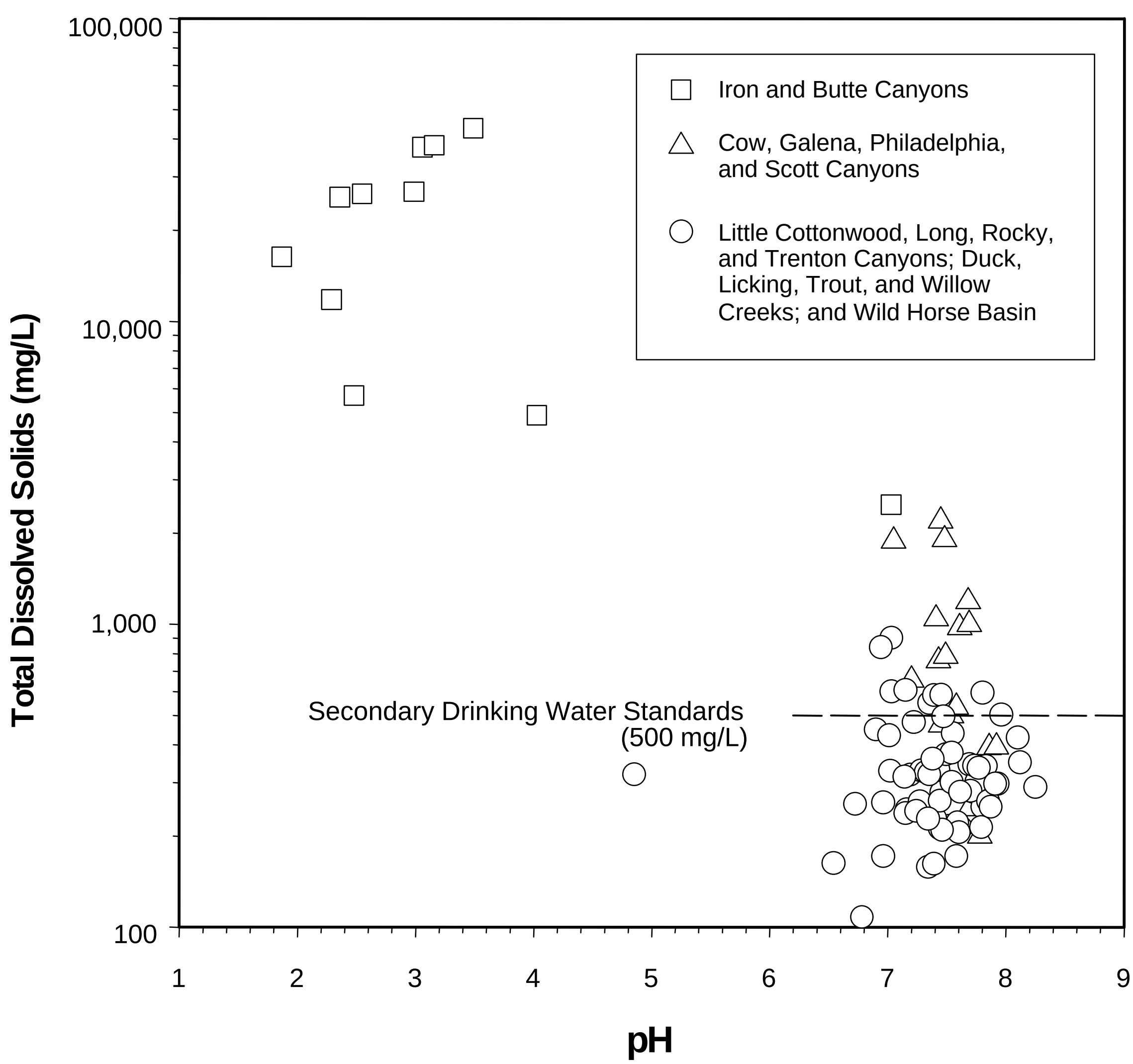
Project Facility Boundary

Source: PTI 1997a

Phoenix Project

Figure 3.2-5

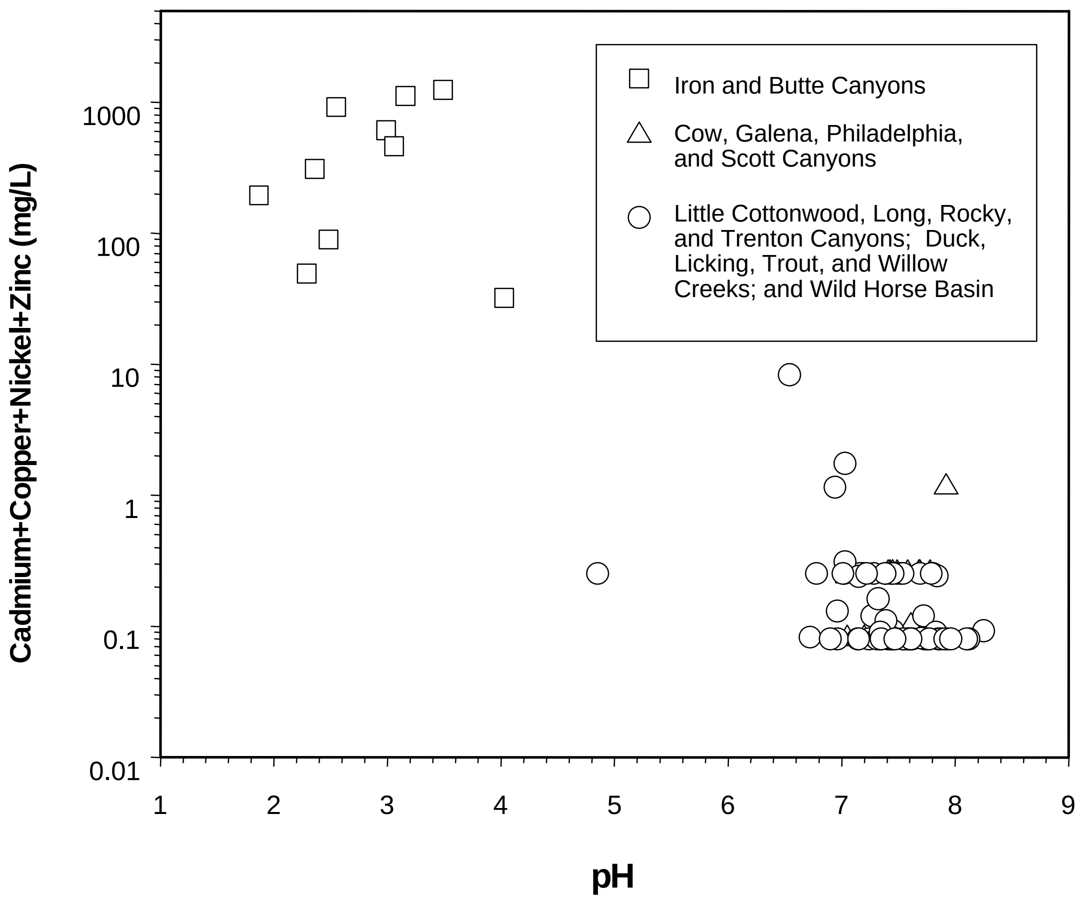
Surface Water Quality Sampling and Measurement Locations



Phoenix Project

Figure 3.2-6

Total Dissolved Solids Concentrations with pH for Surface Water



Phoenix Project

Figure 3.2-7

Sum of Cadmium, Copper, Nickel, and Zinc Concentrations with pH for Surface Water

6.5 (***Figure 3.2-6***). These surface waters also had the highest metal concentrations. In general, the metal concentrations in these springs and seeps exceed drinking water standards for antimony, arsenic, beryllium, cadmium, copper, chromium, fluoride, iron, magnesium, manganese, mercury, nickel, nitrate, pH, sulfate, total dissolved solids, and zinc. After evaluation of the 1997 monitoring data, and in response to unusually high stream flow rates in March 1998, BMG began collecting and treating acidic surface water from Iron Canyon and Butte Canyon in April 1998 (Brown and Caldwell 1998c). This collection and treatment will continue until final closure and mitigation measures have been implemented for waste rock facilities in these drainages.

Surface water quality data also have been collected for lakes that formed in the Fortitude Pit and in areas P-1 and P-2 of the Bonanza Pit. The water in the Fortitude Pit remains at approximately neutral pH due to the presence of a limestone outcrop in the pit bottom. The water meets all Nevada primary drinking water standards but exceeds secondary standards for iron, aluminum, manganese and sulfate. The water in the shallow ponds in P-1 and P-2, which have drained since their sampling, was below the Nevada criterion for pH and exceeded primary standards for several metals. Additional information on pit lake water quality is presented in Section 3.2.2.1.

An overall assessment of the surface water samples indicates that the proportion of solutes comprising total dissolved solids shifts as the total dissolved solids increase. In the lowest total dissolved solids samples typical of the northern streams, bicarbonate alkalinity is the major component of total dissolved solids. However, as total dissolved solids concentrations increase, as with surface water from Iron and Butte canyons, the percentage of total dissolved solids present as sulfate is greatly increased at the expense of bicarbonate alkalinity. Additionally, the percentage of total dissolved solids as dissolved metals is elevated in samples with total dissolved solids greater than approximately 2,000 milligrams per liter; these samples also have the lowest or most acidic pH values.

In addition, dissolved metal concentrations show a strong dependence on pH, with the highest values occurring in the lowest pH surface waters sampled near historic mining facilities or mineralized zones. This pH dependence is illustrated by the plot of the sum of cadmium, copper, nickel, and zinc versus pH shown in ***Figure 3.2-7***. A plot of arsenic compared to pH would show a similar relationship, with the highest concentrations reported for the surface water from Iron and Butte canyons.

The combination of low pH and high dissolved metal and sulfate concentrations reported for surface waters, found near historic mining facilities and mineralized areas, indicates that acid rock drainage exists. Acid rock drainage is caused by water and air interacting with sulfide minerals commonly present in ore deposits. Acid rock drainage can degrade water quality by releasing acid and metals into the water. This result has been observed in surface water from Iron and Butte canyons.

3.2.1.3 Ground Water

A series of hydrogeologic investigations have been performed to provide information on the existing ground water conditions at the project area:

- Hydrogeologic investigations to support ground water flow modeling to simulate pit dewatering and construction of a proposed drainage conduit for underground workings (Baker Consultants, Inc. 1997a; Hydro-Search, Inc. 1991)

- Quarterly ground water elevation measurements to obtain baseline data (Baker Consultants, Inc. 1997a)

- Drilling and monitoring well installation reports (Water Quality Consultants, Inc. 1995a, Baker Consultants, Inc. 1997a)

- Water rights research (Brown and Caldwell 1998b, SEA Incorporated 1995)

- Water quality investigation (PTI 1997a,e; Exponent 1999) and geochemical characterization to predict pit lake water quality (Exponent 2000a)

These investigations provide the baseline information for describing the hydrogeologic conditions in the hydrologic study area and beneath the project site.

<u>Hydrogeologic Setting</u>

Recharge, storage, and movement of ground water is dependent in part on the geologic conditions and the topography of a site. The general stratigraphic and structural framework throughout the hydrologic study area and the project site is described in Section 3.1, Geology and Minerals. The geologic formations and lithologic units can be grouped into 11 hydrostratigraphic units in the regional study area (Baker Consultants, Inc. 1997a). The correlation between the geologic formations and the hydrostratigraphic units is provided in ***Table 3.2-4***. These 11 hydrostratigraphic units can be grouped into 2 principal categories: 1) a regional bedrock assemblage composed of Paleozoic bedrock and Tertiary Intrusives, and 2) valley fill deposits composed of Tertiary volcanic rock, volcaniclastic valley fill, and alluvial basin fill.

The general distribution of these units is presented in ***Figure 3.1-3***. In the bedrock assemblage, recharge, storage, flow, and discharge of ground water are generally controlled by porosity, permeability, and structure (i. e., fault and fracture zones) of the geologic material. In the valley fill sediment, the ground water is stored and transmitted through interconnected pores within the consolidated to unconsolidated sediments.

Bedrock Assemblage

The bedrock assemblage consists of a structurally complex assemblage of Paleozoic-age sedimentary, metasedimentary, and metavolcanic and Tertiary intrusive rocks. These rocks are exposed in the Battle Mountain range and underlie the basin fill sediments in the valleys. Aquifer test data (Baker Consultants, Inc. 1997a) from bedrock wells show hydraulic conductivity values (the capacity of a porous medium to transmit water) ranging from 0.0013 to 88 feet per day. The widest ranges of hydraulic conductivity values are associated with the Antler Peak and Battle Unit (***Table 3.2-5***). The higher hydraulic conductivity values are derived from packer tests conducted in the heavily mineralized and fractured area of the units and probably are representative of aquifer properties near the pits (Baker Consultants, Inc. 1997a). This heavily fractured area has produced a localized high permeability zone that provides for an increase in ground water movement, resulting in higher hydraulic conductivity.

In addition to aquifer test data collected in the field, the intrinsic permeability of unfractured bedrock from each bedrock hydrostratigraphic unit was measured in the laboratory. ***Table A-3*** in Appendix A summarizes the results of the laboratory tests. Total porosity of the major bedrock units is low; only the Harmony Formation siltstone sample (Ch4), the upper Battle Formation meta-conglomerate sample (Pbu1), and the Granodiorite samples (Tgd1 and 2) have porosities above 4 percent. Hydraulic conductivities generally are low.

The rock core hydraulic conductivity values generally are an order of magnitude lower than hydraulic conductivities derived from pumping tests. This difference in hydraulic conductivities between the test types is probably caused by the small sample size of the cores, which may miss a fault or fracture. These faults or fractures in the bedrock help localize the increase in ground water movement, resulting in higher hydraulic conductivity.

Tertiary Volcanics and Sediments

The Tertiary deposits can be separated into three principal hydrostratigraphic units, including 1) local basalt flows (TB), 2) Tertiary Tuffaceous material deposited as valley fill (TT), and 3) Tertiary alluvium (TA, which is combined with the Quaternary Alluvium). Tertiary basalt flow forms a ridge along the eastern boundary of the tailings disposal area (***Figure 3.1-4***). This feature extends to the west and south dipping under the tailings area and Quaternary/Tertiary alluvium. The basalt acts as an aquitard, locally restricting water movement between the overlying alluvium and underlying Tertiary alluvium and tuffaceous sediments (Baker Consultants, Inc. 1997a). Falling head test data were used in this analysis (Baker 1997a).

The Tertiary Tuffaceous material consists of an assemblage of various interbedded tuffaceous strata that have been encountered in deep boreholes recently drilled in the Buffalo and Reese river valleys south and east of the tailings disposal area. The tuff is often interfingered with gravel and other Tertiary alluvial deposits. Aquifer tests within this unit indicate an average hydraulic conductivity of 1.5 feet per day (Baker Consultants, Inc. 1997a).

Quaternary/Tertiary Alluvium

In the hydrologic study area, the alluvium is derived from the adjacent Battle Mountain range, Tobin Range, Fish Creek Mountains, and Shoshone Range. The alluvium consists of coarse-grained sands and gravel with silts and clay deposited by alluvial fans, intermittent streams and associated floods, wind, and lakes

Table 3.2-4
Correlation of Hydrostratigraphic Units with Geologic Formations and Units

Hydrostratigraphic Unit		Geologic Formation or Unit	
Symbol	**Name**	**Symbol**	**Name**
Valley Fill Deposits			
QA	Quaternary Alluvium	Qa	Quaternary Alluvium
TB	Basalt	Tb	Tertiary Basalt Flows
TA	Tertiary Alluvium	Ta	Tertiary Valley Fill - Alluvium Unit
TT	Tuffaceous Material	Ta Tc	Tertiary Valley Fill - Tuff and Pyroclastic Unit Caetano Tuff
Regional Bedrock Assemblage			
TI	Igneous/Intrusives	Kgd Tgd	Cretaceous Granodiorite Tertiary Granodiorite
PP	Pumpernickel Group	PMh PPp	Havallah Formation Pumpernickel Formation
PEM	Edna Mountain Unit	Pem	Edna Mountain Formation
PAP	Antler Peak Unit	PPap	Antler Peak Formation
PB	Battle Mountain Unit	Pb	Battle Formation
CH	Harmony Unit	Ch	Harmony Formation
DSC	Scott Canyon Unit	Ov Dsc	Valmy Formation Scott Canyon Formation

Source: Baker Consultants, Inc. 1997a.

Table 3.2-5
Summary of In Situ Aquifer Test Results

Hydrostratigraphic Unit	Hydraulic Conductivity (feet/day)				Specific Storage (feet^{-1})			
	Number of Measure-ments	Range (min)	Range (max)	Geo-metric Mean	Number of Measure-ments	Range (min)	Range (max)	Arith-metic Mean
Quaternary Alluvium	6	78	210	130	5	$5.0x10^{-5}$	$3.8x10^{-5}$	$1.2x10^{-5}$
Tuffaceous Material	5	0.67	22	1.5	----	----	----	----
Pumpernickel Group	8	0.017	0.83	0.12	6	$2.4x10^{-6}$	$9.8x10^{-5}$	$4.7x10^{-5}$
Edna Mountain Unit	4	0.11	0.83	0.40	----	----	----	----
Antler Peak Unit	11	0.0013	88	5.7	----	----	----	----
Battle Unit	28	0.037	20	0.17	17	$3.3x10^{-5}$	$7.7x10^{-4}$	$2.3x10^{-4}$
Harmony Unit	12	0.013	1.07	0.13	8	$1.7x10^{-6}$	$7.1x10^{-4}$	$3.6x10^{-4}$
Scott Canyon Unit	2	0.012	0.022	0.017	1	$1.5 x10^{-5}$	$1.5x10^{-5}$	----
Granodiorite	2	0.0022	0.033	0.0086	2	$2.2x10^{-4}$	$1.5x10^{-5}$	$2.6x10^{-4}$

Source: Baker Consultants, Inc. 1997a.

(Buffalo Playa). These deposits gradually thicken from a thin veneer at the margin of the valley to several thousand feet in the valley's center. As shown in ***Figure 3.1-1***, these sediments cover extensive areas in the Buffalo and Reese river valleys. In the vicinity of the tailings facility, Simon Hydro-Search (1993b) reported at least 400 feet of alluvium.

Saturated alluvial sediments, which partially fill structurally controlled basins, are the principal ground water reservoirs within the hydrologic study area. Aquifer testing for the alluvium in the vicinity of the tailings facility indicates a geometric mean hydraulic conductivity of 130 feet per day, a transmissivity range from 3.1×10^4 to 8.2×10^4 feet squared per day, and a storage coefficient range from 0.00002 to 0.015 (Baker Consultants, Inc. 1997a). Aquifer testing in the early 1990s on well CM-23 and D2A reported transmissivities of 18,500 and 334,000 feet squared per day and hydraulic conductivities of 74 and 830 feet per day, respectively. Additionally, D2A aquifer tests also indicated a storativity of 0.00064 and a specific storage of 1.6×10^{-6} ft^{-1} (Simon Hydro-Search 1993b).

Regional Fault Zone

Ground water flow pathways are influenced by major faults that offset and displace rock units and older alluvial deposits. Depending on the physical properties of the rocks involved, faulting may create either barriers or conduits for ground water flow. For example, faulting of softer, less competent rocks typically forms zones of crushed and pulverized rock material that behaves as a barrier to ground water movement. Faulting of hard, competent rocks often creates conduits along the fault trace, resulting in zones of higher ground water flow and storage capacity compared to the unfaulted surrounding rock. The increase in hydraulic conductivity caused by faulting is an important component in the study area.

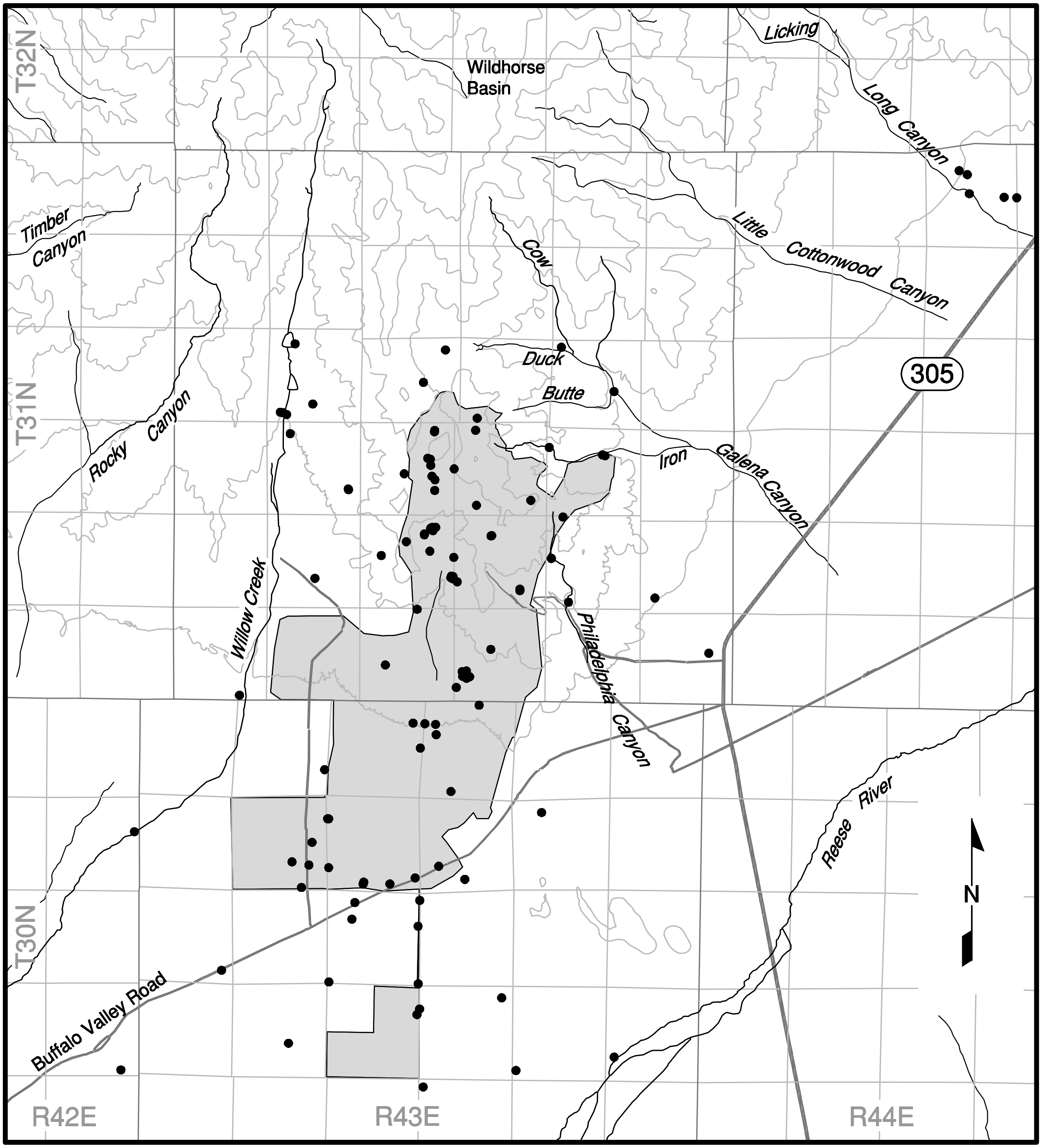
Major regional fault structures are shown in ***Figure 3.1-4.*** Based on apparent discontinuities in the water table surface or changes in hydraulic gradient, Baker Consultants, Inc. (1997a) has identified three major faults that appear to behave as low-permeability barriers to ground water movement:

- The Copper Canyon fault located on the western flank of Copper Canyon
- The Virgin fault, which extends from the vicinity of Antler Peak to the mouth of Copper Canyon
- The Plumas fault, which extends from Galena Canyon in the north to Philadelphia Canyon in the south

Baker Consultants, Inc. (1997a) also encountered other localized faults that appear to behave as barriers or conduits to flow in the area. One localized fault filled with a granodiorite dike was encountered in a borehole at a depth of approximately 440 feet. No ground water was encountered in the borehole above the fault. However, after completing a piezometer through the fault with a screen below this feature, ground water rose 455 feet in the well to above the ground surface (reflecting an artesian condition).

Water Levels

Ground water elevations in 49 on-site and off-site wells, piezometers, and perennial springs were monitored on a quarterly basis during 1996 (Baker Consultants, Inc. 1997a). The four monitoring events took place during March, June, September, and December. The locations of these monitoring sites are shown in ***Figure 3.2-8***. Additional ground water elevation monitoring was conducted during the third and fourth quarters of 1997 and the second and fourth quarters of both 1998 and 1999 (Baker Consultants, Inc. 2000a). The June 1996 ground water elevations were selected as a baseline for comparison since they represent a period of relatively stable ground water conditions compared to subsequent months and years (Baker Consultants, Inc. 2000a). These relatively stable conditions resulted from the fact that for several months prior to June 1996 dewatering operations at the Fortitude Pit had maintained a nearly constant pit lake elevation. After June 1996, active dewatering consistently lowered the Fortitude Pit lake resulting in rapid lowering of ground water levels around the pit. In addition, the precipitation and recharge patterns during the winter and spring months preceding the June 1996 water level measurement were not affected by any unusual precipitation events. However, unusually high precipitation during the spring of 1998 resulted in anomalously high recharge rates and rising ground water levels in some areas in the summer, fall, and winter of 1998. These areas of elevated ground water levels then experienced decline during 1999 after a period of more normal



Explanation

- Drainage
- Road
- Project Facility Boundary
- Existing Wells and Piezometers

Source: Baker Consultants 2000a

Phoenix Project

Figure 3.2-8

Location of Wells Used for Water Level Monitoring recharge. The combined result is that ground water elevations in the vicinity of the Phoenix Project were generally more stable in June 1996 than in subsequent monitored periods. (Baker Consultants, Inc. 2000a). The ground water elevations that existed in June 1996 are presented in ***Figure 3.2-9***.

As shown in ***Figure 3.2-9***, the ground water surface tends to mimic the topography with steep gradients in the mountain ranges and gentler gradients in the basins. The water level contours also indicate that for the upper aquifers, the ridge located between the Virgin and Plumas faults behaves as a ground water divide with ground water flowing away form the ridge crest west-southwest into the Buffalo Valley hydrographic basin and east-southeast into the Reese River system. The ground water elevation contours also steepen in the vicinity of the Virgin and Plumas faults, indicating that these structures are acting as partial barriers to ground water flow. Hydraulic head losses of hundreds of feet from one side of the faults to the other occur in these areas. In addition, dewatering activities in the Fortitude Pit have caused local ground water to flow toward the pit area.

Ground water extraction wells have a strong seasonal influence on the ground water system in the area directly beneath and to the south of the tailings disposal area. These wells typically are continuously pumped during the spring, summer, and autumn months, which causes flow to move from the tailings area to the southwest toward the wells. The ground water system in this area also is influenced by a basalt unit that acts as an aquitard, restricting ground water movement between the overlying alluvium and underlying tuffaceous sediments.

Aquifer Recharge and Discharge

The existing inflow and outflow from the ground water system were estimated to determine a baseline water balance for the hydrologic study area. The estimated average annual ground water budget (existing conditions) is presented in ***Table 3.2-6***. Existing ground water inflow components include precipitation recharge, irrigation, mine dust control recharge, and ground water inflow from adjacent areas outside the hydrologic study area. Ground water outflow components include evapotranspiration from phreatophyte areas and the Buffalo Valley playa, subsurface outflow leaving the hydrologic study area, ground water pumping at the Battle Mountain Complex, and ground water extracted from pumping of ranch irrigation wells.

Using the Maxey and Eakin (1949) methodology, an estimated 1,500 acre-feet/year is received as recharge in the Lower Reese River Valley portion of the study area, and 2,400 acre-feet/year of recharge is received in the Buffalo Valley portion of the study area.

The primary sources of aquifer recharge are precipitation and stream runoff from snowmelt. As is typical in Nevada, the higher elevations generally receive more rain and snow. This increase in precipitation at higher elevations recharges the bedrock aquifers and local perched systems through fractures in the bedrock outcrops or where bedrock is a sedimentary or volcanic unit that is porous. Where streams emerge from the mountains, a percentage of the stream flow is lost as water infiltrates and recharges the alluvium.

Recharge to the ground water system from direct precipitation was estimated using an empirically derived relationship between precipitation, recharge, and altitude (Maxey and Eakin 1949). This method assumes that a percentage of total precipitation within a specified altitude zone becomes ground water recharge. Using this method, Baker Consultants, Inc. (1997a) determined that the resulting distribution of recharge applied to the study area is as follows:

- 3.15 inches per year above 7,000 feet amsl
- 1.43 inches per year between 6,000 feet and 7,000 feet amsl
- 0.46 inch per year between 5,000 feet and 6,000 feet amsl
- 0.10 inch per year between 4,700 feet and 5,000 feet amsl
- 0.00 inch per year below 4,700 feet amsl

Additional ground water recharge may occur from irrigation, dust control, and ground water inflow from surrounding areas (***Table 3.2-6***).

Table 3.2-6
Estimated Annual Ground Water Budgets for the Reese River Valley and Buffalo Valley Ground Water Systems Within the Hydrologic Study Area

Budget Component	Reese River Valley Ground Water System (acre-feet/year)	Buffalo Valley Ground Water System (acre-feet/year)	Total
Inflow			
Precipitation Recharge	1,500	2,400	3,900
Ranch Irrigation Recharge	7,000	----	7,000
Mine Dust Control Recharge	----	300	300
Ground Water Inflow (Total)	52,000	23,000	75,000
Total Inflow	60,500	25,700	86,200
Outflow			
Evapotranspiration			
Phreatophyte Areas	30,000	10,000	40,000
Playa Area	----	14,000	14,000
Ground Water Outflow	25,000	700	26,000
Ground Water Pumpage:			
Battle Mountain Mine	----	1,300	1,300
Ranch Irrigation	14,000	----	14,000
Total Outflow	69,000	26,000	95,300
Outflow Minus Inflow	8,500	300	9,100

Source: Baker Consultants, Inc. 1997a.

Note: Estimated water balance values presented in the source document were converted to acre-feet/year and then rounded to the nearest hundred for presentation in the EIS.

Ground water in the hydrologic study area discharges by several mechanisms, including evapotranspiration, stream and spring discharge, and pumping. In areas where the depth to ground water is relatively shallow (less than 20 feet), water is lost from the water table surface through evapotranspiration. Ground water discharge by evapotranspiration includes losses from bare soil evaporation and transpiration from phreatophytic vegetation. Based on soil and vegetation surveys and depth to ground water, the southern portion of the hydrologic study area, including the Buffalo Valley and Lower Reese River Valley, was delineated as an area of substantial ground water discharge through evapotranspiration.

Flow in perennial streams and springs is dependent in part on discharge from the ground water system. Discharge of ground water into streams also increases flows in Willow Creek and Reese River within the hydrologic study area.

Other identified springs represent discharge of ground water that may or may not be connected to the regional ground water system.

Ground water is withdrawn from the hydrologic study area for mining and agriculture. Most of the pumped water is consumed; however, some infiltrates and recharges the ground water system.

The overall water balance values presented in ***Table 3.2-6*** are estimates based on available regional information. There is uncertainty regarding the actual flow rates, particularly the amount of recharge, evapotranspiration, and ground water inflow and outflow that occurs at the boundaries of the hydrologic study area. Assuming that these values represent reasonable estimates, the overall ground water balance for the Reese River Valley system suggests that this region is experiencing on the order of 14 percent more outflow than inflow. This apparent imbalance is

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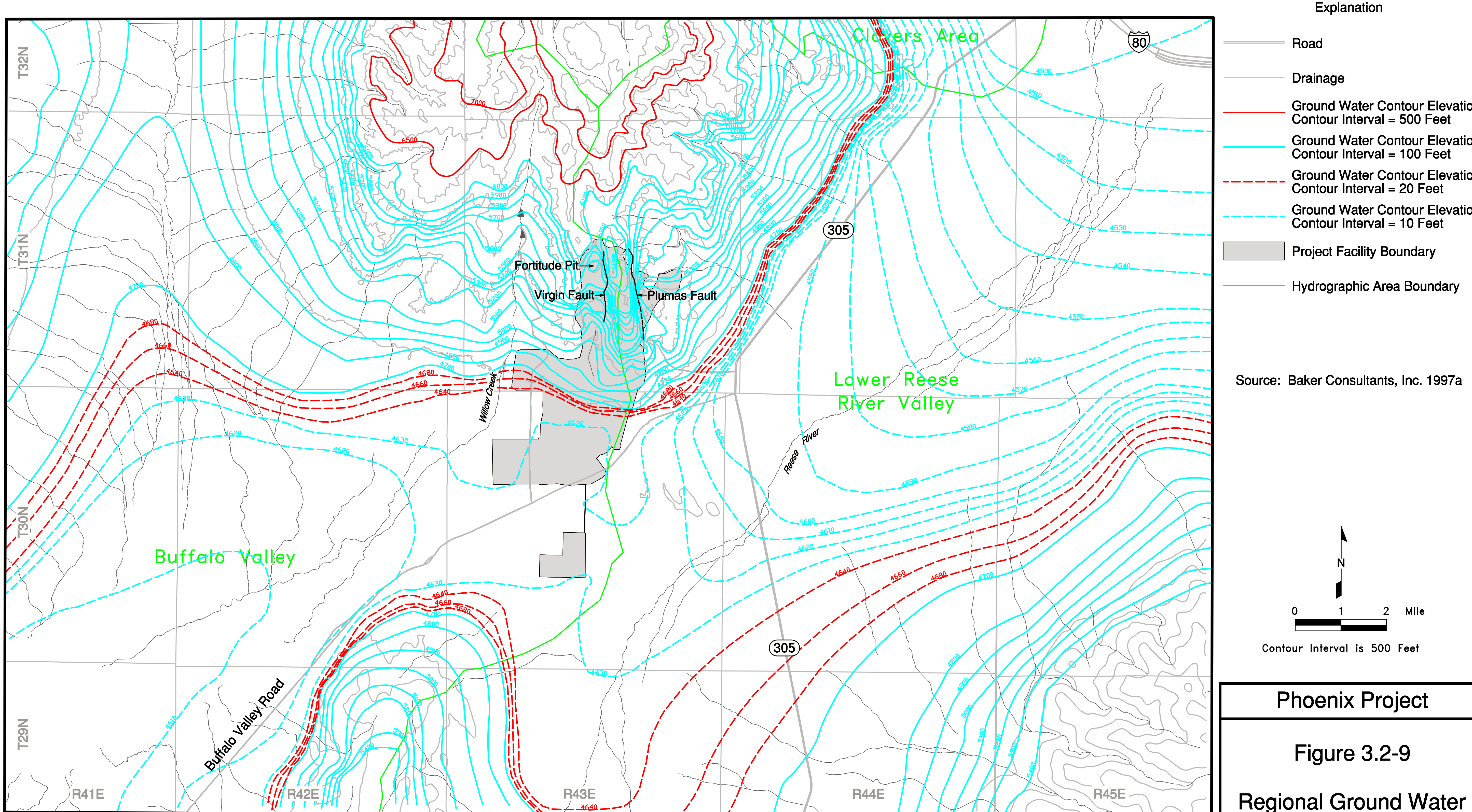


Phoenix Project

Figure 3.2-9

Regional Ground Water Elevation Map, June 1996 probably attributable to extensive ground water withdrawal for ranch irrigation. This type of imbalance would suggest that ground water extraction for irrigation is probably resulting in drawdown of ground water levels within the basin fill sediments in the Reese River Valley. The water balance for Buffalo Valley suggests that this portion of the hydrologic study area is in a state of equilibrium with outflows essentially equal to inflows.

Ground Water Rights and Applications for Ground Water Rights

Water rights and applications for water rights were reviewed and summarized by Brown and Caldwell 1998b and SEA Incorporated (1995). For this inventory, all rights and applications owned or controlled by BMG were excluded. Of the 37 water rights and application for water rights, 23 were associated with ground water sources. **Table 3.2-7** summarizes these ground water rights and applications for ground water rights; the point of diversion locations listed for the water right are shown in ***Figure 3.2-10***. Since water rights are not necessary for most domestic wells, this inventory (based on information on file at the Nevada Division of Water Resources) does not include all domestic or stock watering wells that may exist within the study area. The primary uses for water are irrigation, stock, mining, milling, and domestic.

Ground Water Quality Standards

Standards for protecting ground water used as a drinking water source have been adopted by the Nevada Bureau of Health Protection Services. Specifically, Nevada Administrative Code 445A.453 establishes primary standards in the form of maximum contaminant levels, and Nevada Administrative Code 445A.455 establishes secondary standards also as maximum contaminant levels. Primary maximum contaminant levels are established to protect human health from potentially toxic substances in drinking water, while secondary maximum contaminant levels are established to protect aesthetic qualities of drinking water, such as taste, odor, and appearance. Since ground water in the vicinity of the proposed project is used or is potentially usable as a drinking water source, Nevada primary and secondary maximum contaminant levels listed in ***Table 3.2-3*** apply to protecting area ground waters. In addition, Nevada's regulations governing mining facilities specifically state that ground water quality cannot be degraded beyond established maximum contaminant levels (Nevada Administrative Code 445A.424).

Ground Water Quality

Baseline ground water quality has been characterized by analyzing samples from wells located throughout the Phoenix Project study area (PTI 1997a,c; Exponent 1999) (***Figure 3.2-11***). These wells include 20 operational wells located near previous and current mining operations that have been sampled on a quarterly basis and 43 baseline wells, most of which have been sampled once or twice through April 1997 as part of the baseline characterization (PTI 1997a,c). Selected operational and baseline wells also were monitored from May 1997 through December 1998 (Exponent 1999).

Ground water samples were analyzed for most of the standard water quality indicators, including pH, alkalinity, major cations and anions, and metals for which drinking water standards exist. Analyses for the operational wells generally did not determine the concentrations of aluminum, boron, cobalt, lithium, molybdenum, and tin, although concentrations of these constituents were generally determined in samples from the baseline wells.

The chemical composition of the ground water shows less variability than observed for the surface waters. The bulk of the pH determinations are between 5 and 8.5, with extremes at 3.1 for two samples from the Midas Pit and 10.3 for one sample from Copper Canyon (***Figure 3.2-12***). Other areas with pH outside of the drinking water standard range of 6.5 to 8.5 include the Copper Leach Area (pH=5.03 to 5.22), the proposed Phoenix Pit (pH = 5.25 to 7.3), Philadelphia Canyon (pH = 5.58 to 6.1), and the West Copper Pit (pH = 5.04 to 6.88).

Ground water concentrations of total dissolved solids exceeded the secondary drinking water standard of 500 milligrams per liter in samples collected throughout the study area, including monitoring wells in Buffalo Valley that have not been impacted by mining. In general, the concentrations of total dissolved solids in ground water showed a tendency to increase at lower pH, similar to the trend seen for the surface waters, although there is more scatter in the data. The ground water samples with the lowest pH values from near the Midas Pit also generally exceeded drinking water standards for sulfate. Ground water samples from the Gold Tailings Facility, in

Table 3.2-7
Ground Water Rights and Applications for Ground Water Rights[1]

Map #	Application Number	Status[3]	Certfi-cate #	Well Location					Cubic Feet/ Second	Acre feet	Use	Owner
G1	20146	CER	7470	NW	NE	14	29n	43E	4.460	1485.81	Irrigation	Henry Filippini
G2	20147	CER	7471	NE	NE	13	29n	43E	4.640	1545.79	Irrigation	Henry Filippini
G3	22990	CER	7593	SE	SE	9	31n	43E	0.716	168.9 MGA	Milling	Frank W. Lewis
G4	23448	CER	7698	SE	SE	24	30n	43E	3.400	357.48	Irrigation & Domestic	R.E. & W.B. Chiara
G5	23927	CER	8130	SE	NE	24	31n	43E	2.000	67.39	Mining, Milling & Domestic	R.E. & W.B. Chiara
G6	24496	CER	665	SW	SW	11	31n	43E	0.0022	1440 gpd	Domestic	Frank W. Lewis
G7	25039	CER	8350	SW	SW	16	29n	43E	2.720	613.60	Irrigation	Henry A. & Marian Filippini
G8	33139	CER	12372	SE	NE	13	29n	43E	3.560	2010.76	Irrigation	Henry Filippini, Jr.
G9	35215	CER	11624	SE	NE	11	29n	43E	2.670	516.48	Irrigation	Henry Filippini, Jr.
G10	44755	CER	1347	SE	SE	23	30n	42E	0.010	6.58 MGA	Stock	BLM, Battle Mountain
G11	48899	CER	11909	NW	NW	16	29n	43E	2.197	508.32	Irrigation	Henry Filippini, Jr.
G12	49038[2]	RFP	---	NW	NW	19	31n	44E	2.000	---	Mining, Milling & Domestic	Hart Resources, Inc.
G13	49039[2]	RFP	---	NW	NW	19	31n	44E	2.000	---	Mining, Milling & Domestic	Hart Resources, Inc.
G14	49053[2]	RFP	---	SE	NE	24	31n	43E	2.000	---	Mining, Milling & Domestic	Hart Resources, Inc.
G15	49141[2]	RFP	---	SE	SE	9	31n	43E	3.000	---	Mining, Milling & Domestic	Frank W. Lewis
G16	49142[2]	RFP	---	NE	NE	16	31n	43E	3.000	---	Mining, Milling & Domestic	Frank W. Lewis
G17	54230	PER	---	SW	SE	17	32n	44E	1.000	---	Mining, Milling & Domestic	Bamco Exploration, Inc.
G18	54231	PER	---	NE	NW	20	32n	44E	1.000	32.25 MGA	Mining, Milling & Domestic	Bamco Exploration, Inc.
G19	57442	PER	---	SW	SW	29	32n	43E	0.110	60.00	Mining Exploration	Sante Fe Pacific Mining, Inc.

Table 3.2-7 (Continued)

Map #	Application Number	Status[3]	Certfi-cate #	Well Location					Cubic Feet/ Second	Acre feet	Use	Owner
G20	59100	PER	---	SE	SW	36	36n	43E	2.500	451.00	Irrigation & Domestic	Henry A. FIlippini
G21	59101	PER		NW	NE	6	29n	44E	4.000	1220.80	Irrigation & Domestic	Henry A. FIlippini
G22	59102	PER		Lot	1	6	29n	44E	5.400	1440.00	Irrigation & Domestic	Henry A. FIlippini
G23	59876	PER		SW	SW	22	30n	44E	0.0155	3.65 MGA	Stock & Domestic	Julian Tomer Ranches, Inc.

Sources: SEA Incorporated 1995, Brown and Caldwell 1998b.

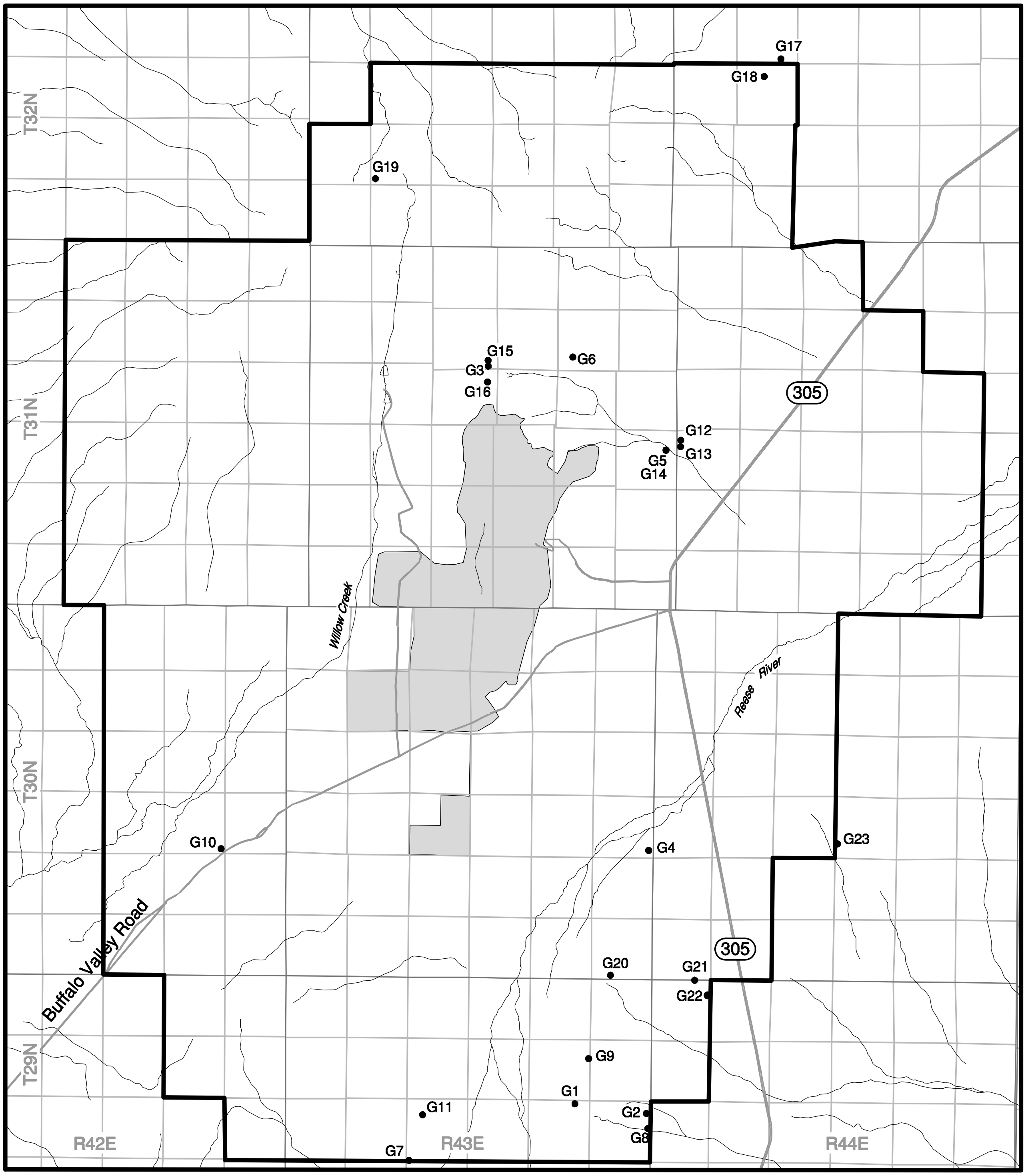
[1]Excludes water rights owned or controlled by BMG.

[2]Protested.

[3]Status: CER = Certificate
PER = Permit
RFP = Ready for Action (protested)

[4]Map numbers refer to locations shown in ***Figure 3.2-10***.

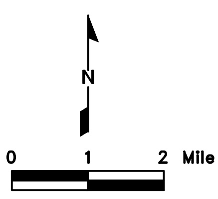
\A325\DWG\325WATRT.DWG (Layer on: WATERRIGHTGROUND) REVISION: 1/3/2001



Explanation

- Road
- Drainage
- Limits of Research
- Project Facility Boundary
- G8• Water Right on File at State Engineer's Office

Source: Brown and Caldwell 1998b



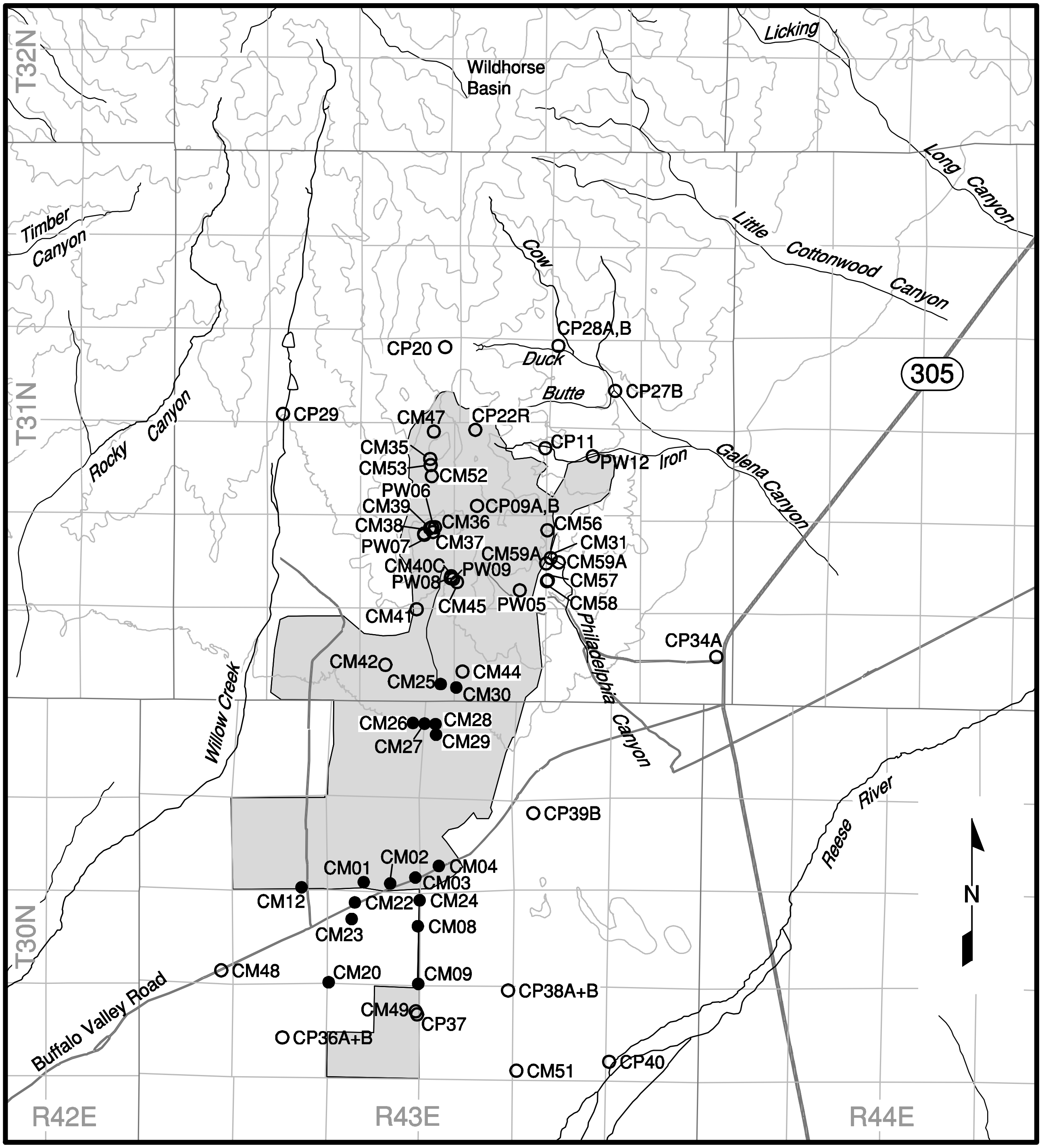
Note: Water rights owned or controlled by BMG are excluded.

Phoenix Project

Figure 3.2-10

Ground Water Rights and Applications for Ground Water Rights on File at the State Engineer's Office

\A325\DWG\325GWLOC.DWG REVISION: 1/3/2001



Explanation

Drainage

Road

CM20 Operational Well for Ground Water Quality Sampling

CM51 Baseline Well for Ground Water Quality Sampling

Project Facility Boundary

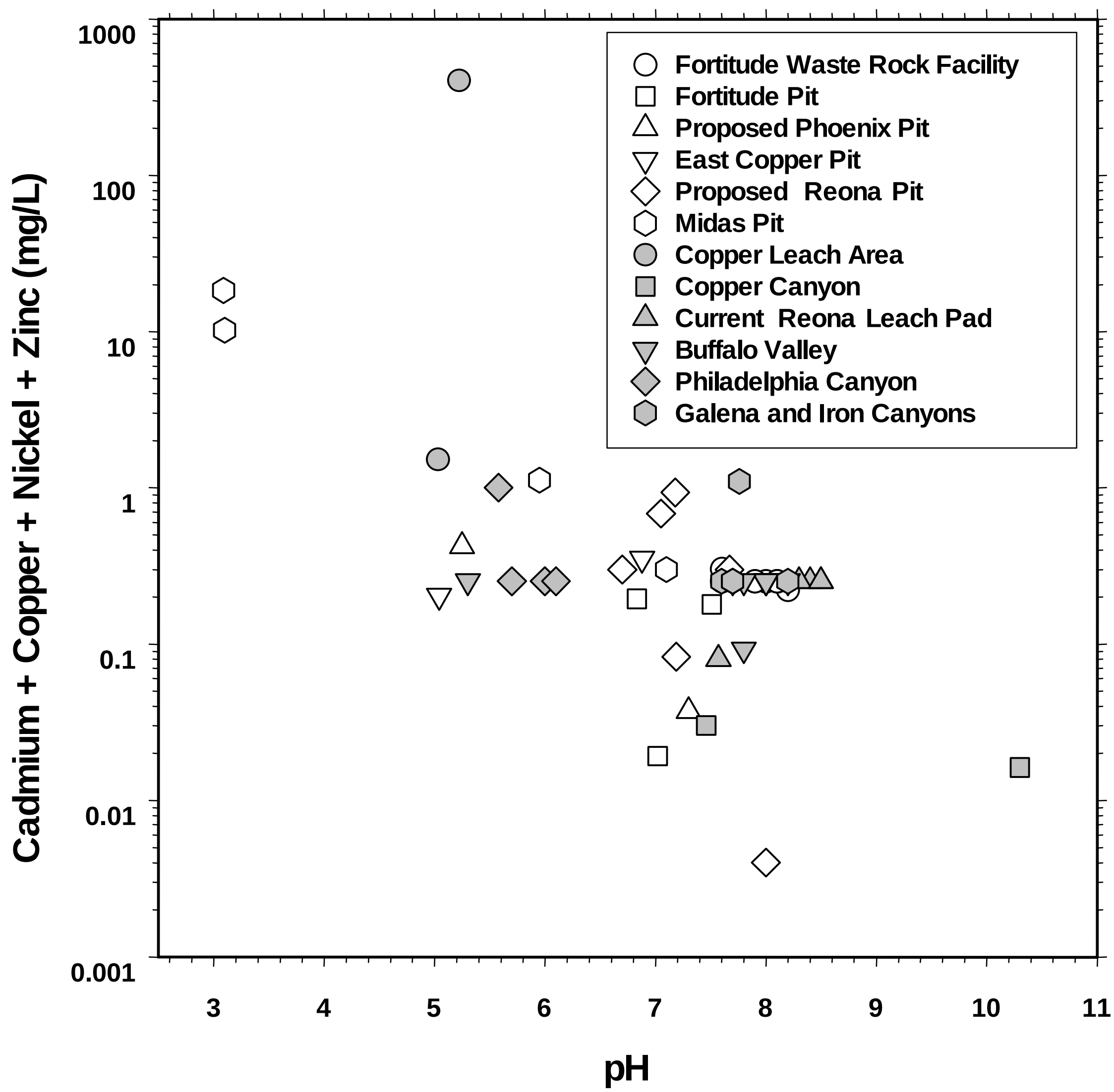
Source: BMG 1996b through 1996e

0 1 2 Mile

Phoenix Project

Figure 3.2-11

Ground Water Quality Sampling Locations



Phoenix Project

Figure 3.2-12

Sum of Cadmium, Copper, Nickel, and Zinc Concentrations with pH for Ground Water particular, deviate from the general trend, showing elevated total dissolved solids concentrations at pH 7.6 to 8.2 because of high concentrations of chloride. Overall, the highest total dissolved solids concentrations occur in ground water samples from areas near the Gold Tailings Facility and the Copper Leach Waste Area (***Figure 2-2***). Specific ground water monitoring and/or mitigation requirements are applicable to both of these areas pursuant to the Battle Mountain Complex Water Pollution Control Permit.

The major components that make up total dissolved solids show a general shift from predominantly bicarbonate in ground water with low total dissolved solids to mostly sulfate in samples with high total dissolved solids. This shift is similar to that observed for the surface water. The primary exception to this trend is ground water from the Gold Tailings Facility (wells CM-1, CM-22, CM-24, PW-1, PW-4), where chloride is a major component of total dissolved solids. The elevated concentrations of chloride, sodium, and sulfate in this area are a result of a solute plume originating from the Gold Tailings Facility. This plume is a result of an unlined disposal area that was used for copper and gold tailings intermittently from 1966 to 1993. The chloride plume is currently being managed under the State of Nevada Water Pollution Control Permit.

The concentrations of minor metals in the ground water generally are low over most of the study area, but drinking water standard exceedences for cadmium, copper, nickel, and zinc do occur (PTI 1997a,e; Exponent 1999). In general, metals concentrations tend to increase with decreasing pH (***Figure 3.2-12***), hence exceedences are most common in the most acidic ground waters. This trend is similar to that seen for surface water (***see Figure 3.2-7***). The constituent with the greatest number of exceedences of its drinking water standard was cadmuim, which was above the 0.005 milligram per liter standard in the Copper Leach Area, Fortitude Pit, Midas Pit, proposed Reona Pit, and West Copper Pit. A single exceedence of the drinking water standard of 1.3 milligrams per liter for copper occurred in well CM-31 near the Copper Leach Area. Nickel concentrations exceeded the drinking water standard of 0.1 milligram per liter in ground water samples from wells at the Copper Leach Area, Midas Pit, Iron Canyon, Philadelphia Canyon, proposed Phoenix Pit, and proposed Reona Pit.

Concentrations of zinc in exceedence of the secondary drinking water standard of 5 milligrams per liter occurred in wells at the Copper Leach Area and Midas Pit. Additionally, concentrations of mercury slightly exceeded the drinking water standard of 0.002 milligram per liter in ground water samples from wells located near the Northeast Extension Pit (0.00239 milligram per liter), the West Copper Pit (0.0206 milligram per liter), the proposed Reona Pit (0.00218 milligram per liter), and Copper Canyon (0.00355 milligram per liter).

Arsenic concentrations exceeded the drinking water standard of 0.05 milligram per liter in a number of samples and did not show a strong dependence on pH as did the other metals. Specific instances of arsenic exceedences occurred in ground water from Copper Canyon, the current Reona Leach Pad, the Fortitude Pit, Galena Canyon, the Midas Pit, the proposed Phoenix Pit, the proposed Reona Pit, and the West Copper Pit. Additionally, two ground water samples from Copper Canyon and the East Copper Pit showed exceedences of the drinking water standard for selenium of 0.05 milligram per liter.

Other exceedences of drinking water standards for minor metals that occurred in isolated wells include beryllium (drinking water standard = 0.004 milligram per liter) at concentrations of 0.0083 and 0.0044 milligram per liter in the Midas Pit wells and 0.028 milligram per liter at well CM-31 at the Copper Leach Area. Well CM-31 at the Copper Leach Area also had a thallium concentration of 0.002 milligram per liter, which equals the drinking water standard for this metal. The sample from well CM-31 also had the only lead concentration that exceeded the drinking water standard at 0.87 milligram per liter.

In general, concentrations of the major metals (aluminum, iron, and manganese) are higher in the lower pH ground water samples, much like the pattern observed for cadmium, copper, nickel, and zinc (see ***Figure 3.2-12***). Iron concentrations were highest in ground water samples from the Copper Leach Area and the Midas Pit, reaching 1,500 and 180 milligrams per liter, respectively. However, ground water samples throughout the study area had iron concentrations that exceeded the secondary drinking water standard of 0.6 milligram per liter, including the Copper Leach Area, Fortitude Pit, Galena Canyon, Iron Canyon, Midas Pit, Philadelphia Canyon, proposed Phoenix Pit, proposed Reona Pit, and West Copper Pit. Manganese concentrations show a pattern similar to iron, reaching their highest level of 190 milligrams per liter at the Copper Leach Area and showing widespread exceedences of the secondary drinking water standard of 0.1 milligram per liter over the entire study area, including Buffalo Valley, Copper Leach Area, Fortitude Pit, Fortitude Waste Rock Facility, Galena Canyon, Iron Canyon, Midas Pit, Philadelphia Canyon, proposed Phoenix Pit, proposed Reona Pit, and East Copper Pit. Aluminum concentrations exceeded the secondary drinking water standard of 0.2 milligram per liter in ground water samples from the Midas Pit and the proposed Phoenix Pit, although aluminum was not determined for all samples.

3.2.1.4 Waste Rock Characterization

Mining operations bring mineralized rocks from depth, where they are geochemically stable, to the surface, where they react with air and water and potentially release metals and other solutes. Sulfide minerals, in particular, undergo oxidation reactions, resulting in acid sulfate and metal-bearing solutions, commonly referred to as acid rock drainage. The assessment of surface water quality discussed in Section 3.2.1.2 indicates the presence of acid rock drainage in some portions of the study area, primarily in Iron and Butte canyons. Acid rock drainage in these areas is indicated by elevated concentrations of sulfate and metals.

To evaluate the extent to which reactions between air, water, and rocks may result in future releases of metals and other solutes, a series of standard geochemical tests was conducted with rocks from the study area. These tests included acid-base accounting from static testing, kinetic testing, and meteoric water mobility testing (Exponent 2000a). In addition to the standard tests, a series of field measurements of the rate of oxidation of sulfide minerals in existing waste rock and pit benches was conducted.

<u>Acid-base Accounting</u>

Acid-base accounting often is used as a screening tool for discriminating rocks with the potential to generate acid by reacting with air and water from rocks that have the potential to consume acid. Acid-base accounting is based on determinations of the acid-generating potential, which is a function of the amount of sulfide minerals in a rock, and the acid-neutralizating potential, which is a function of the amount of carbonate minerals in a rock. The acid-neutralizating potential and acid-generating potential are determined in static tests and are expressed in terms of tons of $CaCO_3$ per kiloton of rock. The difference between the acid-neutralizing potential and the acid-generating potential is called the net neutralization potential.

The BLM's Acid Rock Drainage Policy (BLM 1996b) states that rocks with a ratio of acid-neutralizating potential to acid-generating potential greater than 3 probably will not generate acid through exposure to air and water. For rocks with a ratio less than 3, kinetic tests (described below) also may be conducted to obtain a better measure of the potential for the rocks to generate acid. The criterion used by the State of Nevada for designating waste rock as acid-generating is a ratio of acid-neutralizing potential to acid-generating potential of less than 1.2. Previous studies of rates of acid generation in kinetic tests associated with mine development indicate that a ratio of 1.2 is a reliable and conservative demarcation for classifying rocks as acid neutralizing versus acid generating (BLM 1996b).

For the Phoenix Project, a total of 976 rock samples were subjected to static tests to obtain acid-base accounting data for rocks potentially exposed during the proposed project (Exponent 2000a). An additional 213 samples of rocks from existing waste rock facilities were tested; these samples and testing are discussed separately.

Static test samples were selected on the basis of pit designs proposed in the 1994 Plan of Operations. To select rock samples representative of the pit wall surfaces, block models of the pits were developed on the basis of 500x500-foot grids using existing drill-hole data. Five samples then were selected from each block to obtain a coverage of 5 samples per 250,000 feet squared of surface area. Waste rock was sampled at a rate of 1 sample per 432,000 tons of waste rock. This rate of sampling is comparable to the rate of 1 sample for every 500,000 tons of waste rock recommended in BLM guidance (Plumb 1996); therefore, it was expected to provide a complete representation of the rocks in the ultimate pit surfaces and waste rock facilities as proposed in the 1995 Plan of Operations.

Statistical analyses of the static test results yielded a site-wide range for the net neutralization potential of -937 to 874 ton $CaCO_3$/kiloton rock, with a median of –11.5 and an arithmetic mean of - 46.9 ton $CaCO_3$/kiloton rock (***Table 3.2-8***). Based on a cutoff acid-neutralizing potential to acid-generating potential ratio of 3.0 recommended by the BLM, these results indicate that the majority of

Table 3.2-8
Summary of Net Neutralization Potential for Project Area Rocks

Pit	Number of Samples	Net Neutralization Potential (tons $CaCO_3$/kiloton rock)			
		Minimum	Maximum	Average	Median
Iron Canyon	68	-496	3.17	-24.2	-5.94
Midas	372	-371	43.1	-25.5	-3.65
Phoenix	405	-937	874	-82.8	-53.6
Reona	131	-118	4.89	-8.44	0.104
All Pits	976	-937	874	-46.9	-11.5

Source: Exponent 2000a.

the rocks in the pit wall surfaces and waste rock have the potential to generate acid. The area with the greatest potential to generate acid is the Phoenix Pit, with an average net neutralization potential of -82.8 ton $CaCO_3$/kiloton rock. None of the pits have a positive average net neutralization potential.

The static test sampling frequency developed for the 1994 Plan of Operations is considered suitable for characterizing the rocks that would be disturbed under the current Plan of Operations. Under the current Plan of Operations, the proposed 1994 pits have been expanded and deepened, but no new rock types have been encountered that significantly alter the findings obtained from the existing data. The deeper rocks that would be disturbed under the current Plan of Operations are predominantly net acid-generating and are expected to behave similarly to the net acid-generating rocks that were tested for the 1994 Plan of Operations. A block model of the Proposed Action has been developed by BMG based on exploration data and the geochemical testing program, and overall estimates of acid-base accounting are based on the block model. Additional testing would not alter the primary finding that the rocks to be disturbed are predominantly net acid-generating.

Kinetic Testing

Kinetic testing, commonly consisting of humidity cell testing, is designed to represent maximum rates of acid generation from rocks caused by exposure to air and water. The information obtained from these tests is used in geochemical modeling to represent rates of solute release from pit wall rocks into pit lakes and to evaluate waste rock for determining disposal alternatives.

For the Phoenix Project, 82 kinetic tests were conducted on rock samples from the Iron Canyon, Midas, Phoenix and Reona pits and from the Fortitude ore stockpile. Samples from each location were selected to obtain even spatial coverage, representation of major lithologies in the waste rock and pit wall surfaces, and coverage of the range of net neutralization potential values present in the rocks in each area (***Table 3.2-9***).

The procedure used by Exponent (2000a, Appendix A3) for conducting the kinetic tests was slightly different than the commonly used method of Sobek et al. (1978) and followed modifications developed by Lawrence (1990). Briefly, 1,200 grams of rock, crushed to less than 0.25-inch-diameter pieces, was placed in a humidity cell and exposed to a cycle of 3 days of dry air, 3 days of humid air, and rewetting with 10 milliliters of deionized water on the seventh day. At the end of every 2 weeks, 1,200 milliliters of deionized water was added to each cell, allowed to equilibrate for 1 hour, then drained and collected for analyses. Exponent determined pH, specific conductivity, redox potential (Eh), ferrous iron, total iron, sulfate, and alkalinity for every biweekly sample. Exponent also determined fluoride, chloride, sulfate, mercury, and phosphorus at 4-week intervals. Additionally, determinations of metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, copper, iron, lead, lithium, magnesium, manganese, molybdenum, potassium, nickel, silica, selenium, sodium, silver, strontium, thallium, vanadium, and zinc) were conducted on bulk 20-week samples created by compositing 300 milliliter samples collected from the biweekly rinses. This composite sample depicts the cumulative release of solutes over the duration of the kinetic tests. Results for pH from the kinetic tests after 20 weeks indicated that all 13 rock samples with positive net neutralizing potential produced near-neutral to alkaline leachates. A total of 13 rock samples with negative net neutralizing potential produced leachates with pH greater than 4.5. The remaining 56 rock samples with negative net neutralizing potential produced more acidic leachates. Sixteen of the kinetic tests were extended for a period of up to 62 weeks, including 11 cells that

Table 3.2-9
Summary of Rock Samples Used in Kinetic Testing

Location	Number of Tests
Iron Canyon Pit	3
Midas Pit	16
Phoenix Pit	46
Reona Pit	15
Fortitude Ore Stockpile	2
TOTAL	82

Source: Exponent 2000a.

contained negative net-neutralization potential rocks. All of the cells with positive net-neutralization potential rocks remained neutral, and 5 of the 11 negative net-neutralization potential cells remained neutral over the extended period. These results indicate that net neutralizing potential of zero is an appropriate cutoff for distinguishing acid-producing rocks from acid-neutralizing and unreactive rocks. Data compiled from eight other Nevada mines show that it is extremely rare for rocks with positive net neutralization potential to generate acidic leachate (Exponent 2000a, Appendix B1).

The results of the kinetic tests indicate that most of the rocks in the project area directly associated with mining operations (pits and waste rock) have the potential to generate acid rock drainage. This finding is consistent with the observation that surface water and some ground water in the vicinity of existing pits are acidic and have elevated concentrations of sulfate and metals.

Meteoric Water Mobility Procedure Testing

Meteoric Water Mobility Procedure (MWMP) testing is designed to simulate solutes washing off the surfaces of rocks when they are exposed to rain or snow melt. In this test, 5 kilograms of rock fragments less than 5 centimeters in diameter were placed in a plastic column. Five liters of water with a pH from 5.6 to 6.0 were delivered to the column over 24 hours. The water passing through the rocks in the column was collected and analyzed for chemical composition.

For the Phoenix Project, the MWMP tests were applied to oxide rocks that would be used as cover materials for waste rock facilities and would be present in pit walls (Exponent 2000a, Appendix A6). The oxide rocks tested generally had net neutralization potential values greater than zero; therefore, they are less likely to release metals and acid than rock types with negative net neutralization potential values (***Table 3.2-10***). The oxide rocks tested included a total of 33 samples from the Fortitude, Iron Canyon, Midas, Northeast Extension, and Reona pits. Samples were collected from each rock formation included in oxide waste and pit wall rocks in these areas.

The analytical results from the MWMP tests were compared with the maximum contaminant levels allowed for drinking water for Nevada (***Table 3.2-3***). This comparison was made to determine the potential for rain water to leach the oxide rocks at concentrations great enough to exceed established water quality criteria.

These comparisons show that arsenic concentrations exceeded drinking water standards in 44 percent of tests on rocks from the Reona Pit and 25 percent of tests on rocks from the Midas Pit (***Table 3.2-11***). The rock types in these two pits that yielded arsenic included the Pumpernickel and Granodiorite Porphyry formations. Exceedences of water quality standards for other analytes occurred sporadically in the test results and could not be linked to specific lithologic units. The analyte that most commonly exceeded drinking water standards was aluminum, occurring in 53 percent of the MWMP testing results for all the pits (***Table 3.2-11***). The only pit not showing aluminum exceedences was the Northeast Extension Pit. Manganese exceedences were observed in 20 percent of the tests overall and occurred only for oxide rocks from the Reona, Iron Canyon, and Northeast Extension pits. Cadmium exceedences occurred in 7 percent of the tests overall, but occurred only for rocks from the Iron Canyon and Northeast Extension pits. Single exceedences for fluoride and nickel occurred in tests on rocks from the Iron Canyon and Reona pits, respectively. Measured pH values were outside the drinking water standard range of 6.5 to 8.5 in 9 of the tests, or 30 percent overall (***Table 3.2-11***). However, 4 of the 9 pH exceedences were determined for Midas Pit rocks and were within 0.1 pH units of the 6.5 lower limit for the drinking water standard.

Table 3.2-10
Summary of Rock Samples Used in Meteoric Water Mobility Procedure Testing

Location	Number of Samples	Average Net Neutralization Potential[1]
Northeast Extension Pit	4	-0.4
Reona Pit	10	0.6
Fortitude Pit	7	0.3
Iron Canyon Pit	4	0.3
Midas Pit	8	0.3
TOTAL	**33[2]**	**0.2**

Source: Exponent 2000a.
[1]Average of rock samples used in Meteoric Water Mobility Procedure tests; not site-wide average.
[2]Includes three samples of non-oxide material.

Table 3.2-11
Summary of Samples Exceeding Drinking Water Standards
(from Meteoric Water Mobility Tests on Oxide Rocks)

Analyte	Fortitude Pit	Iron Canyon Pit	Midas Pit	Northeast Extension Pit	Reona Pit	Site Wide
Number of Tests	7	4	8	2	9	30
Percent Exceedences						
Aluminum	71	75	50	0	44	53
Arsenic	0	0	25	0	44	20
Cadmium	0	25	0	50	0	7
Fluoride	0	0	0	0	11	3
Manganese	0	25	0	100	11	13
Nickel	0	25	0	0	0	3
pH	29	50	50	50	0	30

Source: Exponent 2000a.

In addition to the standard MWMP tests, triple-rinse tests also were conducted on one sample of oxide rock from the Fortitude, Iron Canyon, Northeast Extension, and Reona pits and two samples from the Midas Pit (Exponent 2000a, Appendix A6). A trend of increasing concentrations in consecutive rinses from these tests hypothetically could be evidence that the standard MWMP tests underestimate rates of solute leaching. Conversely, decreasing trends would imply that the standard test overestimates leaching rates. In general, results from the triple-rinse tests did not show marked or systematic increases in metal concentrations for consecutive rinsates. Instead, most metals decreased in concentration in the second and third rinses compared to the first.

Arsenic concentrations were similar in the successive rinses, suggesting a mineral solubility or sorption equilibrium control on the maximum concentration. These results imply that the standard, single rinse MWMP tests provided a conservative description of the potential for metal releases that may occur as rain water washes over oxide rocks.

<u>**Characterization of Existing Facilities**</u>

Waste Rock and Copper Leach Facilities. The potential for rocks located at existing facilities in the project area to generate acid was investigated by acid-base accounting, measurements of paste pH, and measurements of oxygen consumption (Exponent 2000a). The acid-base accounting determinations provide information on the reservoirs of potentially acid-generating rocks already in place at the site. The paste pH values provide an indication of the extent to which reactions between the rocks, air, and water already have initiated acid generation. Rates of oxygen consumption provide an indication of sulfide oxidation at depth in existing waste materials that can be used to calibrate mathematical models and identify potential areas of acid generation. The areas investigated during these various studies include the main Fortitude Waste Rock Facility, the Northeast Extension Waste Rock Facility, reclaimed cover at the Copper Basin Reclamation Area, native ground near the Reona Pit, and native ground near the Fortitude Pit.

The acid-base accounting results indicate that the majority of the waste rock has negative net neutralization potential values (Exponent 2000a; Appendix A4). The results for the paste pH measurement indicated variability within specific waste rock piles and between piles, but the pH values are generally related to the net neutralization potential value of the rock. Rocks with net neutralization potential values less than zero showed acidic pH values in the range of approximately 3 to 5, compared to a range of 5 to 7 for rocks with net neutralization potential values greater than zero. The most acidic paste pH values were found to occur in the upper 10 feet of the South Fortitude, Northeast Extension, and Iron Canyon waste rock facilities.

Determinations of oxygen concentrations at different depths were conducted at 36 locations in the main Fortitute Waste Rock Facility (Exponent 2000a, Appendix A14). In general, the results show rapid decreases in oxygen content between the surface and a depth of 4 feet. This result is consistent with a process of oxygen diffusion into waste rocks and reaction with sulfide minerals to create acid-sulfate leachates (Blowes and Jambor 1990).

Field measurements of the rates of oxygen consumption were determined at the Fortitude, Midas, and Northeast Extension pits and the main Fortitute Waste Rock Facility (Exponent 2000a, Appendix A15). The measurements were made at pit benches and surfaces of waste rock piles and ore stockpiles. The highest oxygen consumption rates were determined for the ore stockpiles. The average rate for the pit benches (4.08 percent sulfide mineral content) was approximately 5 percent of the average rate for the ore stockpile (5.10 percent sulfide mineral content) even though the 2 rock types had comparable sulfide contents. The average rate for the waste rock (0.85 percent sulfide mineral content) was approximately 53 percent of the average rate for the ore stockpile materials.

The lack of a direct relationship between oxygen consumption rates and sulfide mineral contents in the rocks implies that factors, such as mineralogy, porosity, grain size, moisture content, etc., are important for controlling sulfide oxidation rates. However, the measurements of oxygen consumption clearly indicate that oxidation reactions between air, water, and sulfide minerals in the rocks are ongoing processes in existing mining areas. The oxidation of sulfide minerals is the primary cause of acid rock drainage observed in surface and ground water monitoring locations adjacent to existing mines and excavated areas.

At the Copper Leach Facility, paste pH values were near 4.0 and were relatively constant with depth (Exponent 2000a, Appendix A4). The rocks in this facility were acid leached for copper extraction, hence acid pH values were expected. The paste pH values of the alluvium underlying the leached copper ore did not increase back to neutral values but were near 4.0 at depth. These low pH values indicate that percolation of acidic solutions from the copper leaching operations has acidified the underlying native materials.

Runoff and Seep Water Quality. Two water samples were collected from a seep and runoff from the walls of the Fortitude Pit to determine water quality (Exponent 2000a, Appendix A17). This information is useful for providing a guide for the quality of water that could enter the pit after mine closure if it were not backfilled, as well as for comparison against leachates generated in kinetic tests that are designed to simulate acid rock drainage.

Analytical results for the seep and runoff showed strongly acidic pH values of 3.0 and 3.2, sulfate concentrations of 4,180 and 666 mg/L, and total dissolved solids of 5,206 and 1,050 mg/L, respectively. These values are well above State of Nevada maximum contaminant levels (***Table 3.2-3***). Additionally, the solutions also contained concentrations of aluminum, beryllium, cadmium, copper, iron, manganese, nickel, and zinc that exceeded State of Nevada maximum contaminant levels. The low pH values are consistent with those observed in the kinetic tests conducted with rock samples that had net neutralization potential values less than 0.0 ton $CaCO_3$/kiloton rock.

The pit rock from the Fortitude Pit had the highest average net neutralization potential value of all the pits, although the data showed considerable variability. The other pits have lower average net neutralization potential values, indicating that the water quality of their runoff may be similar to or worse than that observed for the Fortitude Pit.