3.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES FOR WATER MANAGEMENT OPERATIONS

This chapter describes the environmental baseline conditions in the area potentially affected by Barrick's ground water pumping and water management activities and the regional study area analyzed in the CIA report (BLM 2000b). The environmental baseline information summarized in this chapter was obtained from published and unpublished materials; interviews with local, state, and Federal agencies; and field and laboratory studies in the project area.

The analysis of impacts from Barrick's water management operations assumes the implementation of existing mitigation commitments and other environmental protection measures by Barrick; these measures are described in Section 1.6 of this SEIS. Most of these committed measures were developed by Barrick and the BLM as part of the Betze Project Record of Decision (BLM 1991d) based on the analyses in the Betze Project Final EIS (BLM 1991b). They encompass a range of short- and long-term monitoring programs and associated mitigation in the event that surface water resources and associated riparian vegetation were affected by Barrick's ground water drawdown. The environmental protection measures include monitoring programs along the Humboldt River, at the Humboldt Sink, and at Barrick's future pit lake for water quality and water quantity issues. The following impact analyses reflect the incorporation of these committed environmental protection measures. Potential additional mitigation and monitoring measures developed in response to anticipated impacts are discussed for each resource in this chapter; these measures could be required by the BLM as stipulations of the Record of Decision. Residual impacts, i.e., those impacts remaining following implementation of the mitigation measures, are identified for each resource. Descriptions of irreversible or irretrievable commitments of resources are provided at the end of each resource section. Cumulative impacts are addressed for each resource in Chapter 5.

This document is a Supplemental EIS; therefore, as stated in 40 CFR 1502.9, this chapter addresses "substantial changes in the proposed action that are relevant to environmental concerns..." and "significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts." The BLM determined that the following resources could potentially be affected by changes in the Barrick's water management operations; therefore, potential impacts to these resources are analyzed in Chapter 3.

- Geology
- Water Resources
- Riparian Vegetation
- Wildlife Resources
- Aquatic Resources
- Threatened, Endangered, Candidate, and Sensitive Species
- Grazing Management

The BLM's NEPA Handbook (H-1790-1) requires that all EISs address certain Critical Elements of the Human Environment. These critical elements are presented below along with the location in this chapter where the element is discussed. If the element does not occur within the project area or would not be affected, this is indicated below, and the element is not discussed further in the SEIS. This elimination of nonrelevant issues follows the Council on Environmental Quality guidelines as stated in 40 CFR 1500.4.

- Air Quality - would not be affected.
- Areas of Critical Environmental Concern - would not be affected.
- Cultural Resources - would not be affected.
- Drinking Water/Ground Water Quality - refer to Section 3.2.
- Environmental Justice - refer to Section 3.8.

- Floodplains - refer to Section 3.2.

- Hazardous or Solid Wastes - would not be affected.

- Invasive Non-native and Noxious Plant Species - refer to Section 3.3.2 for riparian vegetation.

- Native American Religious Concerns – refer to Section 3.9; refer to Section 5.9 for potential cumulative impacts of mine dewatering.

- Paleontological Resources - would not be affected.

- Prime or Unique Farmlands - would not be affected.

- Threatened, Endangered, Candidate, or Sensitive Species - refer to Section 3.6.

- Wetlands and Riparian Zones - refer to Section 3.3.

- Wild and Scenic Rivers - would not be affected.

- Wilderness - would not be affected.

Numerous technical reports were used as support documents to this SEIS. Copies of these technical reports are available for review at the following location:

- BLM Elko Field Office
  3900 East Idaho Street
  Elko, Nevada 89801

A complete list of the reference documents used in preparing this SEIS is included in Chapter 8.0.

3.1 Geology

3.1.1 Affected Environment

The geologic conditions in the vicinity of the Goldstrike Mine were summarized in the Betze Project Draft EIS (BLM 1991a). The information provided in this section is intended to supplement the geologic information provided in the original Betze Project Draft EIS. The geologic conditions discussed below provide the information necessary to characterize the hydrogeologic conditions discussed in Section 3.2, Water Resources and Geochemistry.

3.1.1.1 Physiographic and Topographic Setting

The topography and physiographic features of the regional study area for geology and minerals are shown in Figure 3.1-1. The regional study area for geology is coincident with the hydrologic model area described in Water Resources and Geochemistry (Section 3.2). The regional study area includes the Boulder Creek, Rock Creek, Willow Creek, Marys Creek, Maggie Creek, and Susie Creek drainage basins. All of these basins are tributary to the Humboldt River, which forms the southern boundary of the study area. Major mountain ranges within the study area include the Sheep Creek Range and portions of the Tuscarora Mountains, Independence Range, and Adobe Range. The elevation ranges from approximately 8,700 feet above mean sea level (amsl) in the Tuscarora Mountains near the central portion of the study area to 4,500 feet amsl along the Humboldt River in the southwest corner of the study area.

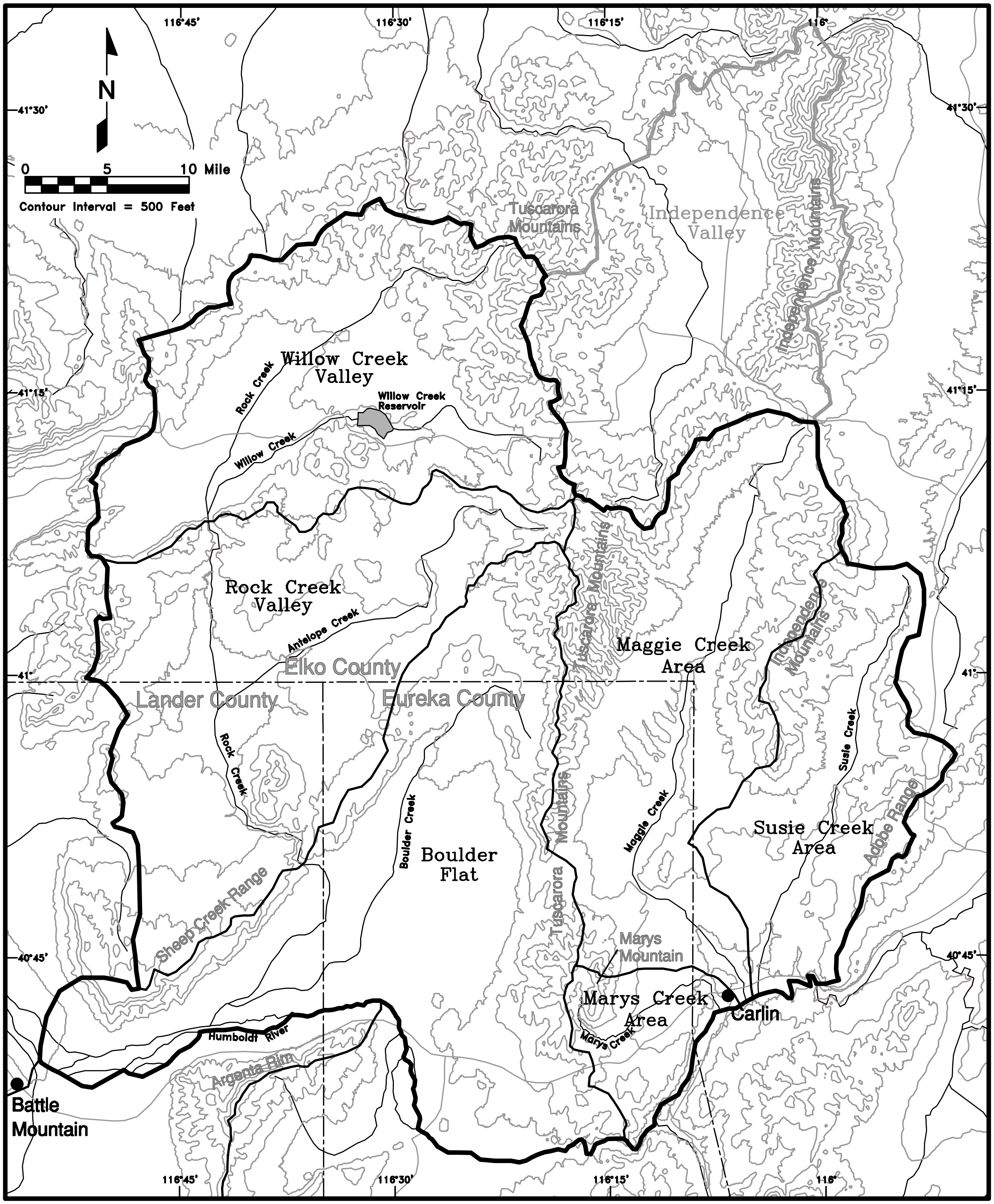
The project area is located within the Great Basin region of the Basin and Range physiographic province and is characterized by a series of generally north-trending mountain ranges separated by broad basins. The Basin and Range physiography has developed from normal faulting that began approximately 17 million years ago and continues to the present (Stewart 1980). The extensional block faulting uplifted the mountains, which consist of Precambrian to Tertiary age bedrock units. The basins are filled with thick accumulations of unconsolidated and consolidated sediments that are derived from erosion of the adjacent mountain ranges.

3.1.1.2 Regional and Geographic Setting

The regional geologic conditions are presented in Figure 3.1-2, and the regional geologic cross sections are shown in Figure 3.1-3. Both the regional geologic map and cross sections are based on information presented by Maurer et al. (1996). Maurer et al. (1996) simplified the complex geology of the region into six regional map units. From oldest to youngest, these regional units include marine carbonate rocks, marine clastic rocks, intrusive rocks, volcanic rocks, older basin-fill deposits, and younger basin-fill deposits. Table 3.1-1 summarizes the age range, lithologic description, maximum estimated thickness, and lists the formations and other localized map units included within each of these six regional geologic map units.

The study area has undergone a complex geologic history, resulting in variable stratigraphic and structural geologic conditions. During the Early Paleozoic Era, marine clastic and carbonate rocks were deposited on the sea floor along the western continental margin of North America. The marine clastic rocks were deposited farther west, in a deep ocean setting, while the carbonate rocks were deposited in a shallow water setting adjacent to the land mass. The marine carbonate rocks consist of limestone and dolomite with minor shale, siltstone, sandstone, and quartzite. The marine siliciclastic rocks include interbedded metasedimentary mudstones, shale, chert, siltstone, quartzite, and greenstone (Stone et al. 1991). A transitional assemblage lies between the two sedimentary assemblages (Stewart 1980; Schull 1991). In the vicinity of the Carlin Trend, the transitional assemblage consists predominantly of limestones and siltstones. In an attempt to simplify the stratigraphy of this region, Maurer et al. (1996) combined these transitional assemblage rocks with the carbonate assemblage.

During the Late Devonian or Early Mississippian time, marine deposition was interrupted, and the Paleozoic sediments were uplifted, folded, and thrusted by the Antler Orogeny (orogeny is a geologic term for mountain building event) .



Legend

- Study Area
- Ground Water Basin Boundary
- Stream
- County

Figure 3.1-1

Regional Topographic Map

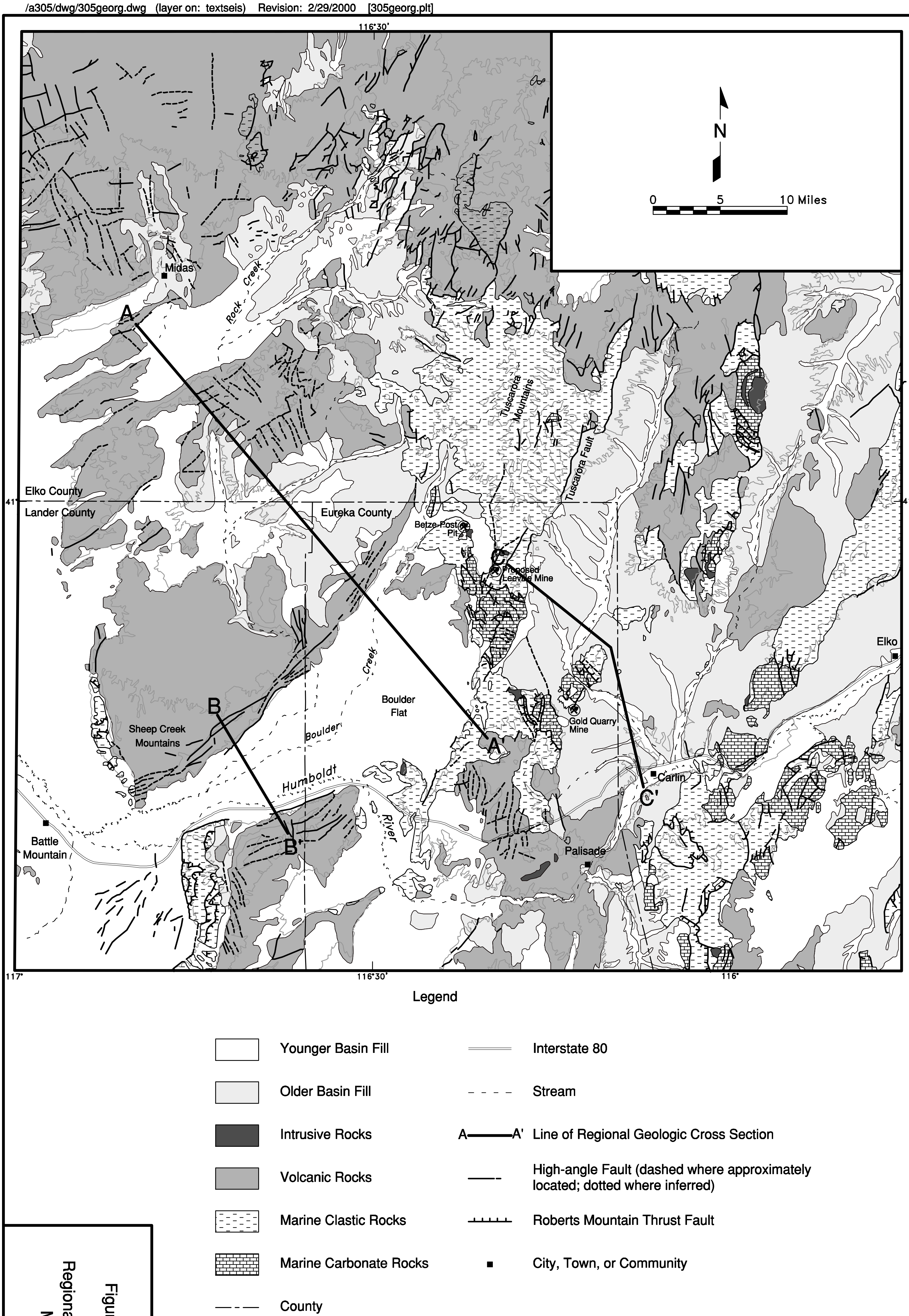


Figure 3.1-2

Regional Geologic Map

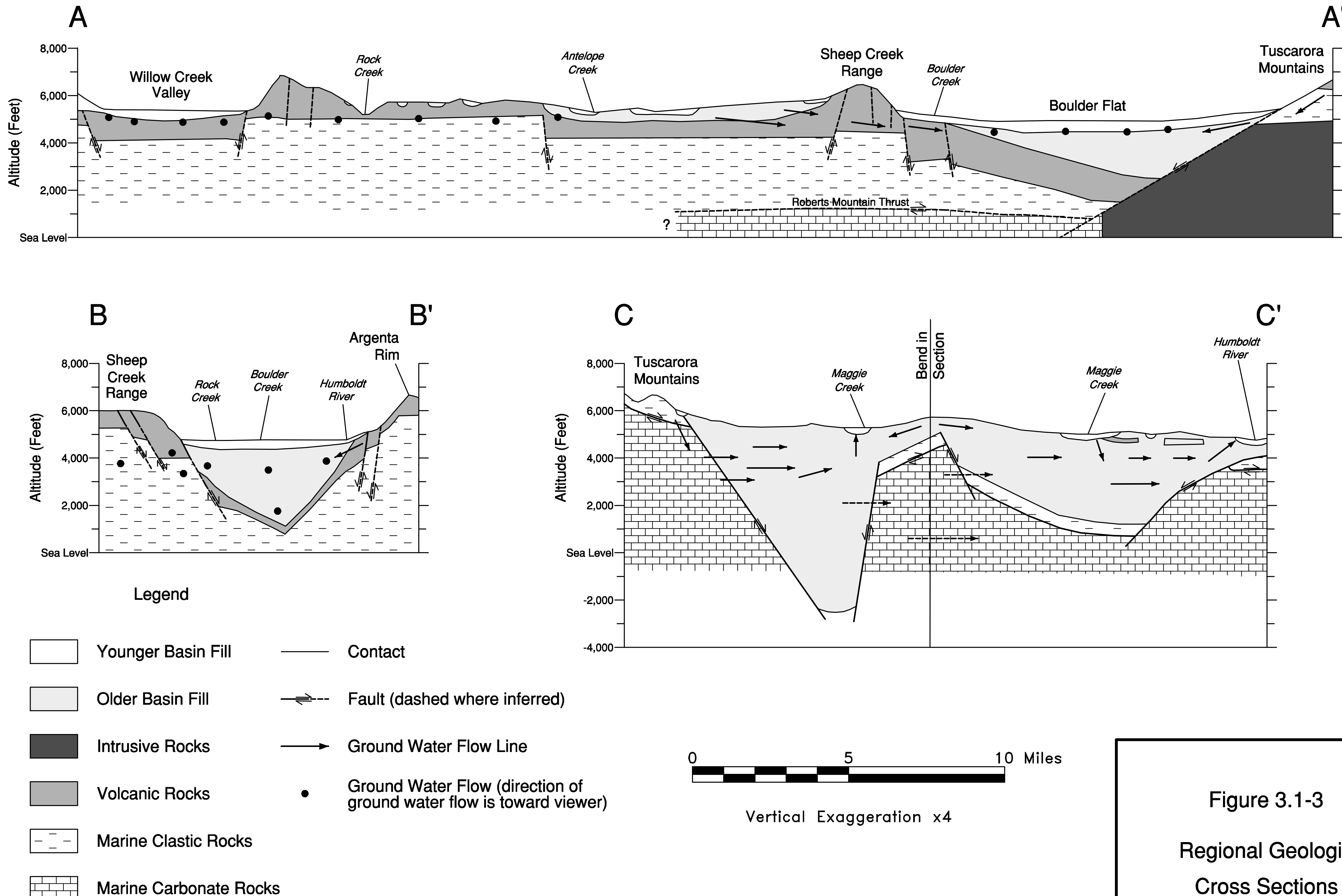


Figure 3.1-3

Regional Geologic Cross Sections

Table 3.1-1
Generalized Description of the Regional Geologic Map Units

Hydrogeologic Unit	Geologic Age	Lithology	Rock or Stratigraphic Unit[1]	Maximum Thickness (feet)
Younger basin-fill deposit	Quaternary and Tertiary	Deposits of alluvial fans, basin lowlands, and stream flood plains	Includes unnamed deposits and Hay Ranch Formation of Regnier (1960)	1,600
Older basin-fill deposit	Tertiary and Cretaceous	Shale, claystone, siltstone, limestone, conglomerate, and sandstone; locally tuffaceous	Upper part of Raine Ranch Formation of Regnier (1960); Carlin Formation of Regnier (1960); Humboldt Formation (restricted) of Smith and Ketner (1976); Elko Formation, limestone, conglomerate, and cherty limestone of Smith and Ketner (1976); Rand Ranch Formation of Regnier (1960); Newark Canyon Formation	7,600
Volcanic rocks	Tertiary and Jurassic	Felsic flows, domes, and ash-flow tuffs; inter-mediate lava flows, pyroclastic rocks, and air-fall tuffs; mafic volcanic rocks; and ash	Big Island Formation, Banbury Formation, Palisade Canyon Rhyolite of Regnier (1960); Rhyolitic welded tuff of Smith and Ketner (1976); Safford Canyon Formation and lower part of Raine Ranch Formation of Regnier (1960); Indian Well Formation, mafic to intermediate units of Smith and Ketner (1976); and Frenchie Creek Rhyolite	13,000
Intrusive rocks	Tertiary and Jurassic	Plutons, dikes, and minor plugs of felsic to intermediate composition	Quartz monzonite plutons of Swales and Lone Mountains; also includes large plutons inferred from aeromagnetic data to underlie Marys Mountain and west part of Sheep Creek Range	--
Marine siliciclastic rocks	Paleozoic (Devonian to Ordovician)	Sandstone, chert, shale, and siltstone	Valmy Formation, Vinini Formation, Silurian rocks of Marys Mountain, Elder Sandstone, Woodruff Formation, and Slaven Chert	23,000
Marine carbonate rocks	Paleozoic (Permian to Mississippian; Devonian to Cambrian)	Mudstone, siltstone, quartzite, limestone, shale, and sandstone	<u>Permian to Mississippian</u>: Tripon Pass Limestone, Webb Formation, argillite of Lee Canyon, Chainman Shale, Diamond Peak Formation, Moleen Formation, Tomera Formation, Carlin Sequence (amended), sandstone and siltstone of Horse Mountain, and Edna Mountain Formation (part of the Antler Sequence)[2]	26,000
		Limestone, dolomite, limy siltstone, sandy dolomite, claystone, chert, and quartzite	<u>Devonian to Cambrian</u>: Hamburg Dolomite, Pogonip Group, Eureka Quartzite, Hansen Creek Formation, Ordovician rocks of Marys Mountain, Roberts Mountains Formation, Lone Mountain Dolomite, Popovich Formation, Rodeo Creek unit of Ettner (1989), Nevada Formation, Devils Gate Limestone, and Wenban Limestone	19,000

Source: Maurer et al. 1996.
[1]Stratagraphic units defined in Regnier 1960; Roberts et al. 1967; Smith and Ketner 1975, 1976; Stewart and McKee 1977; Stewart 1980; Radtke 1985; Coats 1987; and Ettner 1989.
[2]The Permian to Mississippian rock or stratigraphic units are included with the marine siliciclastic rocks in Stewart 1980, and Ekburg and Rota 1987. Roberts et al.
1967 states the Diamond Peak Formation is composed principally of siltstone, sandstone, and conglomerate.

During the Antler Orogeny, the siliciclastic rocks were thrust over the carbonate rocks along the Roberts Mountain Thrust (Roberts 1966; Stewart 1980), a major structural feature within the regional study area. The clastic rocks form the upper plate, while the carbonate rocks form the lower plate of the thrust. The marine carbonate rocks underlie the siliciclastic assemblage throughout the study area. Stewart (1980) notes the clastic rocks in the upper plate have been displaced to the east by as much as 90 miles and are composed of interleaved broad, thin thrust sheets that are oriented sub-parallel to the bedding.

The Antler Orogeny also created a highland that persisted during much of the Mississippian period and perhaps during parts of the Pennsylvanian and Permian periods (Stewart 1980). During the Late Paleozoic Era, sediments shed from the highland resulted in deposition of clastic and carbonate rocks (Antler Sequence). These rocks are grouped by Maurer et al. (1996) with the Paleozoic marine carbonate rocks (Table 3.1-1), although the rocks are primarily siliciclastic.

During the Mesozoic and Early Cenozoic Eras, the area was subjected to compression, which resulted in the Tuscarora Mountain anticline and may have fractured the rocks in the vicinity of the anticline, providing pathways for mineral-bearing fluids and ground water. Intrusive igneous activity accompanied this compression. The Marys Mountain intrusive complex, long postulated on the basis of geophysics and recrystallization (Evans 1974), is composed of rocks that span from Jurassic through Tertiary: the outcropping Goldstrike granodiorite is dated at 154-162 million years (Arehart 1992), the outcropping Richmond Mountain quartz monzonite is dated at 106 million years (Evans 1974), and the outcropping Welches Canyon granodiorite is dated at 37 million years (Evans 1974).

Beginning in the late Cenozoic Era, the area was block-faulted by a series of normal and listric faults that created the Basin and Range topography that characterizes the region. Broad valleys in the regional study area, such as Boulder Valley and the Maggie Creek basin, were formed as down-dropped blocks between uplifted mountain ranges. As shown on the project area geologic map, Figure 3.1-4, (Maurer et al. 1996; McDonald Morrissey Associates, Inc. 1998) major normal faults bound the southeast flank of the Sheep Creek Range, the east flank of the Tuscarora Mountains, and the north side of the Argenta Rim. These normal faults drop the basin side down relative to the mountain side, may have displacements of thousands of feet, and are usually at high angles (McDonald Morrissey Associates, Inc. 1996b). Major normal faults within the study area (Figure 3.1-4) are listed below:

- Post Fault, which trends north-northwest
- Fault zone along the southeast margin of the Sheep Creek Range
- Little Boulder Basin Fault, located in the Tuscarora Mountains
- Tuscarora Fault, located on the eastern margin of the Tuscarora Mountains (HCI 1999b)
- Soap Creek fault, located on the western margin of the Independence Mountains (HCI 1999b)

In addition, the Siphon and Boulder Narrows faults were identified by Barrick’s hydrogeologic studies (McDonald Morrissey Associates, Inc. 1998).

Uplift and subsequent erosion of the mountains during the late Cenozoic Era have partially filled the basins with poorly consolidated to unconsolidated silty clay, silt, clayey sand, sand, gravel, and boulders deposited primarily as a series of coalescing alluvial fans. These basin-fill deposits are mapped as two types: (1) older basin-fill deposits and (2) younger basin-fill deposits (Maurer et al. 1996).

The older basin-fill deposits are Miocene to Pliocene in age and consist of fluvial and lacustrine sediments, volcaniclastic rocks, and volcanic rocks. In Boulder Flat, the older basin-fill deposits may be as thick as 3,000 feet (McDonald Morrissey Associates, Inc. 1996b), while in the Maggie Creek basin the older basin-fill deposits may be in excess of 5,000 feet (McDonald Morrissey Associates, Inc. 1998).

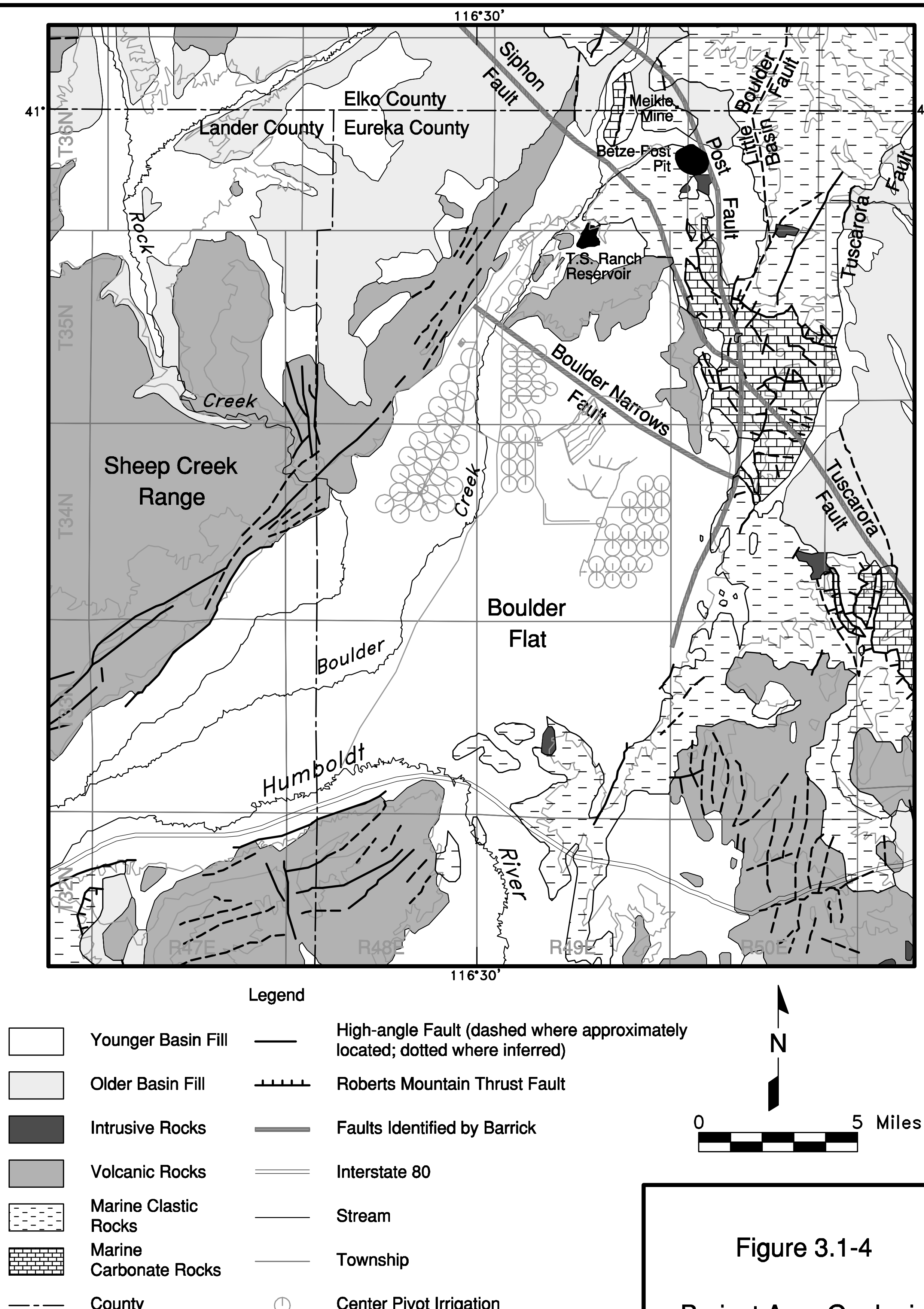


Figure 3.1-4

Project Area Geologic Map

The younger basin-fill deposits (alluvium) consist of unconsolidated alluvium deposits that underlie present-day streams, flood plains, and associated stream terraces. These deposits are highly variable and consist of silty clay, sandy clay, silty sand, clayey sand, gravel sand, and conglomerate (McDonald Morrissey Associates, Inc. 1998). The thickness ranges from a few tens of feet in the mountains (Stone et al. 1991) to 1,000 feet in the southern part of Boulder Flat (McDonald Morrissey Associates, Inc. 1996b). Table 3.1-2 presents the characteristics of the basins in the study area.

Structure and Secondary Geologic Processes

The geologic structures discussed above and associated secondary geologic processes affect the permeability and porosity of the rock in the regional study area as reported by McDonald Morrissey Associates, Inc. (1996b) (Table 3.1-3).

Project Area Geologic Conditions

The project area encompasses the Betze-Post Pit, Meikle Mine, TS Ranch Reservoir, injection and infiltration areas, and the water management activities in Boulder Valley. The geology in the vicinity of the Betze-Post Pit is described in the Betze Project Draft EIS (BLM 1991a), and the Meikle Mine subsurface geology is described in the Meikle Mine Development EA (BLM 1993a).

Most of the water management facilities are located in Boulder Flat. As stated previously, Boulder Flat is underlain by younger and older basin-fill deposits that have a combined thickness of up to several thousand feet near the central and lower portions of the basin. As illustrated on cross section A-A' (Figure 3.1-3), in the northwest part of the valley the basin-fill deposits overlie volcanic rock, while in the southeast part of the valley the basin-fill deposits overlie intrusive rock. Boulder Flat is bounded on both sides by high-angle faults (Figure 3.1-4). Volcanics and marine clastic rocks bound the northern portion of Boulder Flat. The Boulder Narrows Fault (inferred from drilling data; McDonald Morrissey Associates, Inc. 1998) is marked by an increase in depth to bedrock and corresponding increase in thickness of the basin-fill deposits southwest of the fault. The TS Ranch Reservoir is situated on a thin, younger basin-fill deposit overlying volcanic rocks. In early 1991 in the southern portion of the reservoir, soil-piping in the basin-fill deposits opened a conduit to a fracture in the underlying volcanic rock. This fracture became the primary outlet for TS Ranch Reservoir water (McDonald Morrissey Associates, Inc. 1998).

3.1.1.3 Faulting and Seismicity

The project area is located in a region that is characterized by active and potentially active faults and a relatively high level of historic seismicity. For the purposes of this evaluation, an active fault is one that shows evidence of displacement during the Holocene period (last 10,000 years), and a potentially active fault is one that shows evidence of surface displacement during the late Quaternary period (last 150,000 years). Historically, surface displacement along faults occurred in Nevada during major earthquakes in 1869, 1903, 1915, 1932, and three events in 1954 (Stewart 1980). All of these events occurred along a north-trending zone called the Nevada Seismic Belt, located over 40 miles southwest of the project area (Figure 3.1-5) (Dohrenwend et al. 1995). Surface fault rupture typically occurs along active fault traces. A review of maps of potentially active faults (Dohrenwend and Moring 1991a, b; Dohrenwend et al. 1995) indicates that no historic faulting has occurred within the study area. The closest known historic surface fault displacement to the regional study area was in 1915, approximately 60 miles to the southwest. As shown in Figure 3.1-6 (Dohrenwend et al. 1995; National Earthquake Information Center Database), inferred Holocene to late Pleistocene faults occur along the southeastern edge of the Sheep Creek Range, in the central part of Boulder Valley, along the southeastern edge of Boulder Valley, and along the northern edge of the Argenta Rim.

The project area is located in a region that has experienced moderate seismic activity in historic time. Earthquake records indicate that three earthquakes have been recorded within the regional study area (Figure 3.1-6). These earthquakes generated a Richter magnitude of

Table 3.1-2
Basin Characteristics

Basin	Thickness of Basin-fill Deposits (feet)	Structural Characteristics	Bedrock
Upper Maggie Creek Area	7,000 to 8,000	Deepest basin that is formed by down-faulted rocks	Paleozoic clastic rock that overlies carbonate rock
Lower Maggie Creek (LMC) and Susie Creek Area	LMC - 3,000 to 4,000; Susie Creek - 2,000	Broad structural basin	Paleozoic clastic rock thrust by the Roberts Mountain thrust over the carbonate rock
Willow Creek Valley	< 500	A relatively narrow basin oriented northeast to southwest	Basin underlain by volcanic rocks on top of Paleozoic clastic rocks
Rock Creek Valley	800 to 2,000	A relatively shallow, bowl-shaped depression	Basin underlain by volcanic rocks that lie on top of Paleozoic clastic rocks
Boulder Flat	Over 2,500; the southwest part of the basin (north of Argenta Rim) is estimated to be 3,500 to 5,000	Bound by range-front faults	Underlain by 500 feet of volcanic rock, which overlies Paleozoic clastic rocks

Source: Maurer et al. 1996.

Table 3.1-3
Effects of Geologic Events on Rock Properties

Event	Effect on Rock
Antler Orogeny (eastward thrust faults and deformed upper plate)	• Increased horizontal permeability sub-parallel to the bedding of the formation, compared to the vertical permeability.
Tuscarora Mountain anticline	• The upper plate rocks dip gently westward; fracturing due to the folding allows fluid pathways.
Mesozoic and Cenozoic igneous activity	• Intrusive rocks are not extensively fractured, resulting in an impermeable boundary. • Volcanic rocks may contain extensive fracturing (e.g., rhyolite in the northern part of Boulder Flat) and are highly permeable.
Cenozoic high angle normal faults	• Locally high angle faults may create barriers to fluid movement; low porosity and permeability in fault. • Cenozoic normal faults locally offset entire sections of the Paleozoic sedimentary rocks causing juxtaposition of rock types.
Hydrothermal fluids and associated pressure	• Increased fracturing and permeability.
Associated mineralization and alteration	• Decarbonatization – locally increases porosity. • Silicification – decreases porosity of host rocks. • Argillization – decreases permeability. • Dolomitization – may result in formation of pores and fissures. • Dissolution by hot mineral-bearing fluids - increases permeability in carbonate rocks.

Sources: McDonald Morrissey Associates, Inc. 1996b, 1998.

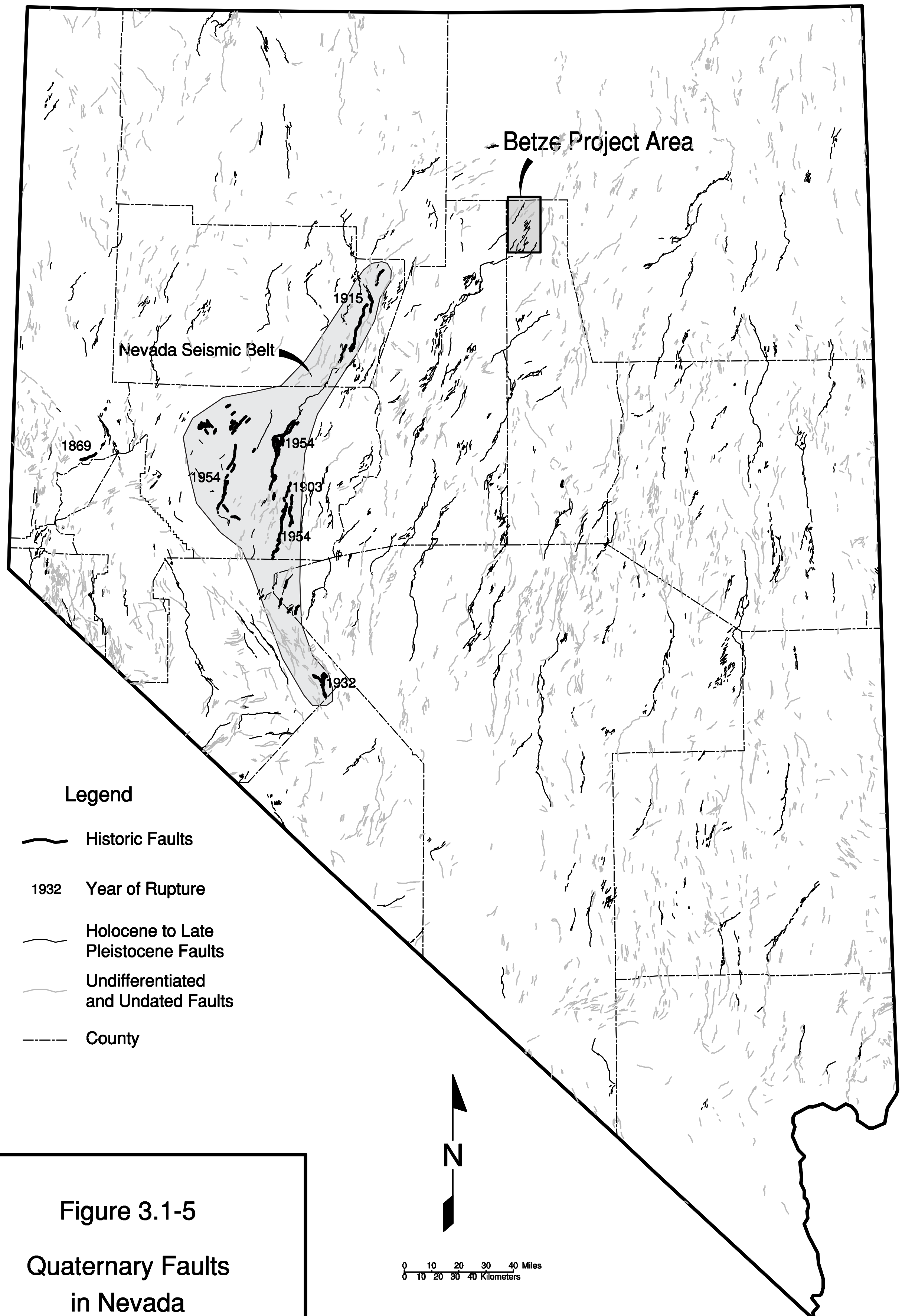
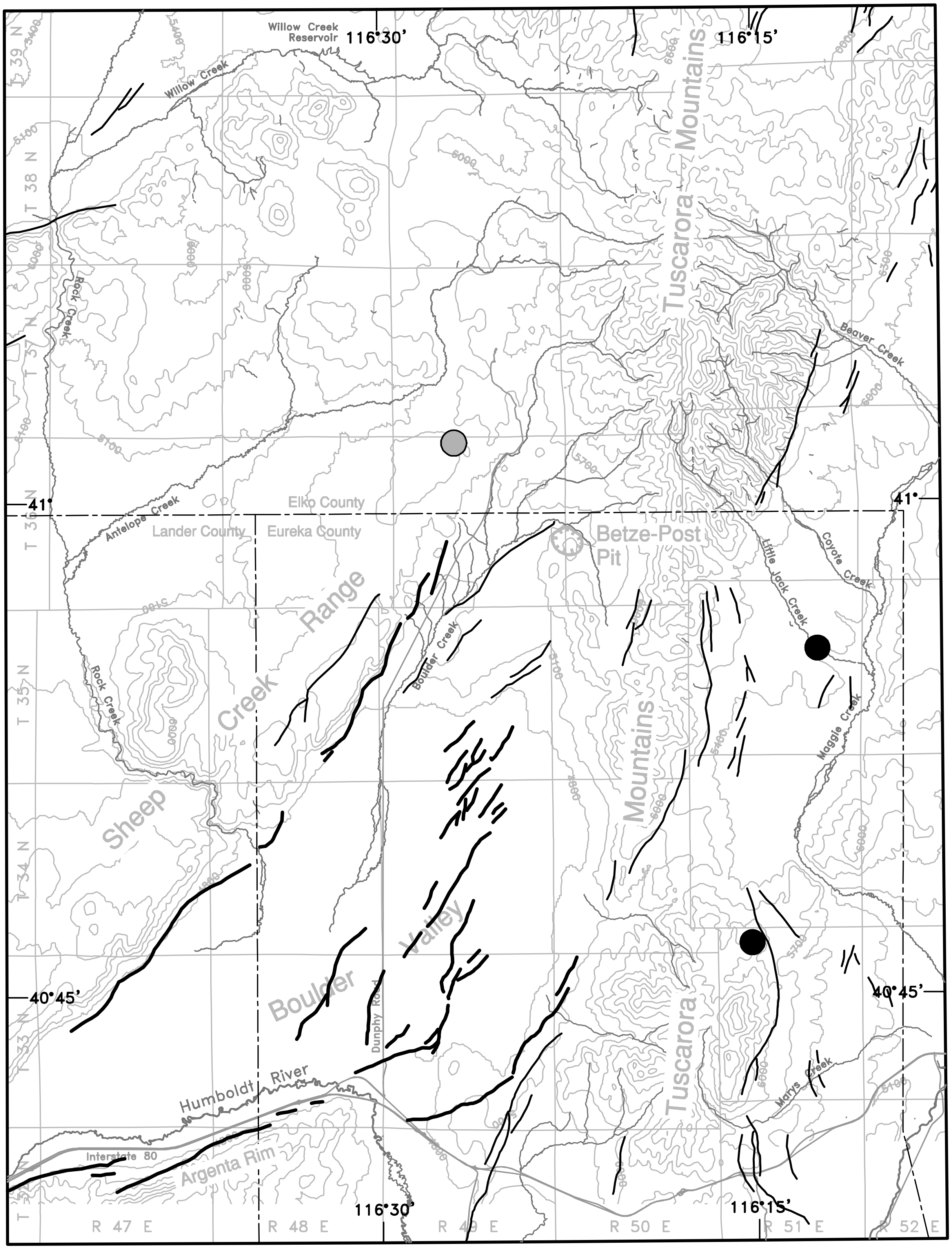


Figure 3.1-5

Quaternary Faults in Nevada



N

0 1 2 3 4 5 Miles

300' Contour Interval

Source for Fault Traces: Dohrenwend et al. 1995
Source for Seismic Events: National Earthquake Information Center Data Base

Legend

- Holocene to Late Pleistocene Faults
- Undifferentiated and Undated Faults
- Seismic Event Pre-1970 Magnitude 4.0 -4.9
- Seismic Event Post-1970 Magnitude 4.0 -4.9

Figure 3.1-6

Quaternary Faults and Seismic Events

4.0 to 4.9 (U.S. Geological Survey [USGS] Earthquake Database).

3.1.2 Environmental Consequences

Environmental issues related to geology and minerals include: (1) the potential for karst development from ground water infiltration and injection, (2) potential surface subsidence caused by cavern collapse (sinkholes) from ground water discharge, (3) the potential for minerals todissolve and metals to be released as a result of dewatering and water management operations, and (4) dewatering-induced surface subsidence

3.1.2.1 Impacts from Mine Dewatering and Localized Water Management Activities

Karst Development and Other Solution Features

Karst refers to solution features that occur in some areas underlain by limestone or carbonate rocks. Karst-type features include solution cavities and sinkholes that form with the dissolution of calcium carbonate. Areas affected by dissolution processes can experience occasional rapid (localized) subsidence where the solution cavities are located near the surface. The solution process may be accelerated by man-made changes in ground water conditions, including: (1) discharging excessive water into geologic materials susceptible to karst development and (2) lowering the water table, which can both increase vertical seepage rates and cause collapse of near-surface caverns that were buoyed by the water table.

Most younger sinkholes are caused by a collapse process. The development of sinkholes can pose a hazard to livestock, humans, and wildlife. If the sinkhole develops in the area of buildings, roads, and other structures, damage to these structures may result.

Accelerated sinkhole development caused by mine dewatering has been documented worldwide (Brink 1984; Kath et al. 1995; Wagner and Day 1984). One well-documented sinkhole problem caused by mine dewatering occurs in the dolomites of South Africa. The dolomites are above the gold-bearing conglomerates that were dewatered to enable mining. Hundreds of sinkholes have developed since the 1960s; several of these sinkholes have been very large causing loss of life and damage to buildings and other structures (Brink 1984; Wagner and Day 1984). Additional sinkhole development has occurred from dewatering of limestone quarries in the southeastern United States (Kath et al. 1995).

Several different processes can cause sinkhole or doline development. A doline is a basin or funnel-shaped hollow in limestone and does not imply a specific genesis. The processes that cause dolines are shown schematically in Figure 3.1-7 (Ogden 1984). The top two block diagrams in Figure 3.1-7 show dolines that occur when carbonate rocks are at the ground surface or are covered by a thin layer of soil. These dolines form either by collapse of an underground cavity near the ground surface (collapse doline) or slow preferential dissolution of rock along fractures (solution doline). The bottom two block diagrams depict limestone covered by soil or loosely consolidated rock material. These dolines form either by gradual subsidence caused by vertical erosion or piping of the cover material into subterranean voids (subsidence dolines) or collapse of the overlying material into underlying cavities (subjacent karst collapse dolines).

Karst Development in the Region. In the carbonate province of Nevada, caves and caverns have been documented in the limestone (Hess 1992). The only known caves or caverns identified in the cumulative study area occur in the carbonate rocks encountered in Barrick's Meikle Mine (part of the Goldstrike Project). The cavities encountered in the Meikle Mine range up to an estimated 100 to 150 feet wide, 30 to 50 feet high, and several hundreds of feet long. In the Meikle Mine, these caverns are characterized by having a massive rind of coarse calcite and barite crystals up to several feet thick. To-date, none of the cavities encountered during mining have shown evidence of collapse during dewatering or present any stability concerns for the mining operations.

Two sinkholes have been documented to-date in the area affected by dewatering at the Goldstrike

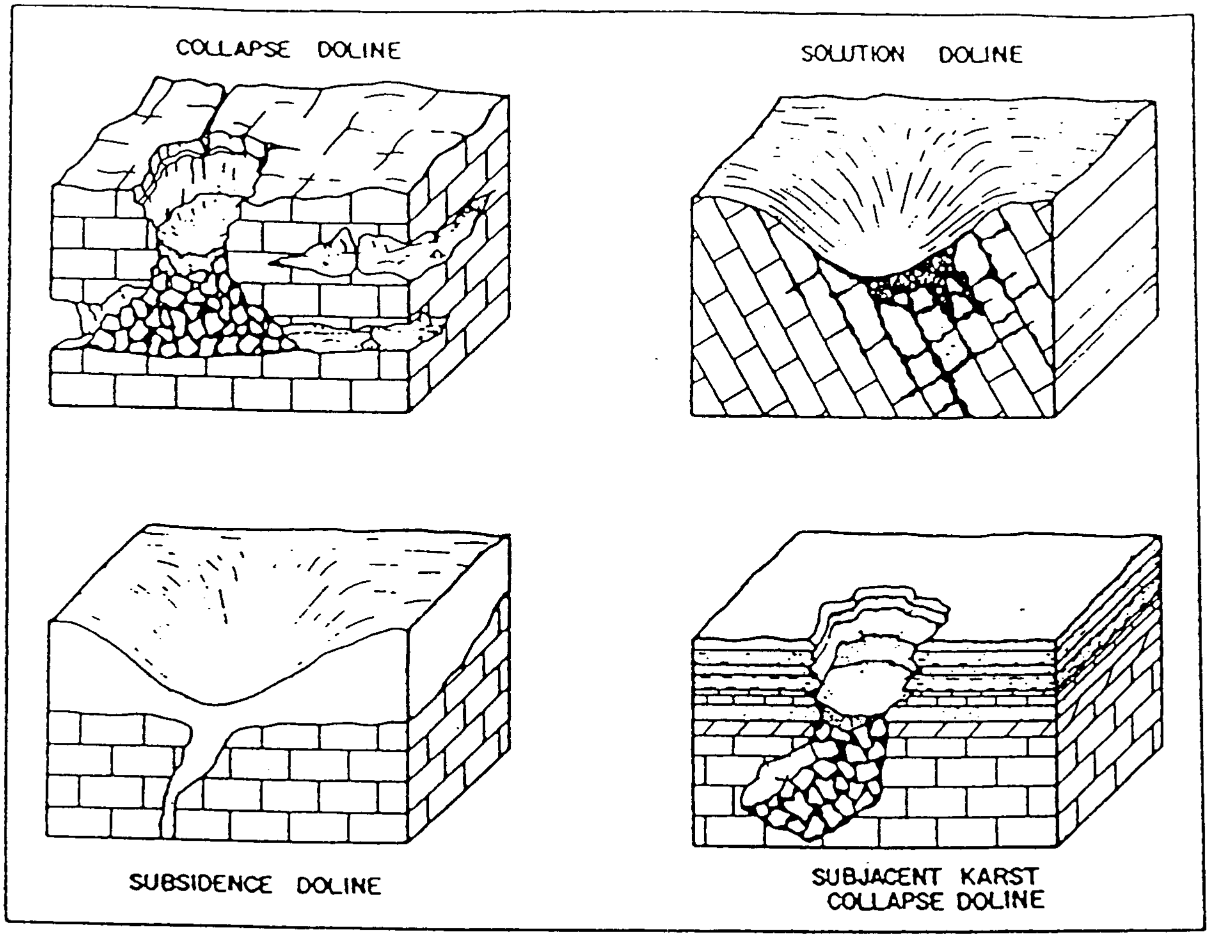


Figure 3.1-7

Block Diagrams of Sinkhole Development

Mine: (1) a sinkhole approximately 3.5 miles northwest of the center of the Betze-Post Pit, and (2) a sinkhole approximately 2.8 miles west of the center of the Betze-Post Pit located near spring 6. The locations of these features are shown in Figure 3.1-8 (BLM 1998b, 1993c; Adrian Brown Consultants, Inc. 1997, 1998) and are described below.

1. The sinkhole 3.5 miles northwest of the Betze-Post Pit was reported to be approximately 80 feet long, 60 feet wide, and 40 feet deep on September 29, 1993 (BLM 1993c). Barrick has filled the sinkhole by pushing material into the hole. The actual site-specific conditions in the vicinity of this collapse feature are not known. It is inferred that a cavity existed in this area prior to dewatering. The sinkhole development appears to have resulted from dewatering activity.

2. Adrian Brown Consultants, Inc. (1997, 1998) reported a circular sinkhole approximately 4 feet deep and 30 feet across located near spring 6. Dewatering of the Betze-Post Pit had lowered the water table in this area by approximately 1,100 feet at the end of 1996, causing the hydrostatic pressure to drop. Since this spring is located approximately 1 mile south of sinkhole 1, it is possible the mechanisms for sinkhole development are similar to those suggested above; however, the mechanism for development is not known.

TS Ranch Reservoir Fracture. An open fracture was discovered in the bottom of the south-central portion of TS Ranch Reservoir in the summer of 1990. The general location of this feature is shown in Figure 3.1-8. This fracture can be traced on the surface for several hundred feet south of the reservoir. The fracture occurs in Tertiary Rhyolite and is open, with the width of the void space along the fracture ranging up to several inches. This fracture presumably existed prior to reservoir development; however, piping and/or dissolution of the fracture-filling material occurred after the reservoir was used to store water. Initially, a fraction of the water stored in the reservoir flowed out of the reservoir through the fracture. In the last several years, a series of dikes have been constructed in the reservoir to isolate and control flow out of the reservoir through the fracture.

Areas Susceptible to Future Sinkhole Development. Predicting sinkhole development from mining activities requires consideration of site-specific geology, hydrology, topographic information, and climate. Sinkhole development is most likely in areas where carbonate rocks are at or sufficiently near the ground surface. These conditions would allow for the collapse of subsurface cavities, or piping (washing out of granular material) of the overlying soils into those cavities. Either of these processes would result in enough displacement of the cover materials to impact the surface topography. If the cavities occur within deep carbonate deposits overlain by thick consolidated material, a collapse would be unlikely to impact the surface topography.

To delineate areas that could potentially be susceptible to future sinkhole development, the following were considered:

1. Areas where mine dewatering and water management activities are predicted to result in either lowering the water table and/or increasing the amount of infiltration (in areas where excess water is discharged).

2. Areas where soluble carbonate rock units exist at or near the ground surface

3. The depth to the carbonate rock below the ground surface

Several scenarios of soil cover, depth to ground water, and carbonate rock depth were evaluated to develop criteria for use in identifying areas that could potentially be susceptible to sinkhole (or doline) development. For the purpose of this evaluation, it was assumed that the dimensions of the largest cavity that could potentially be encountered in the subsurface was 150 feet in width and approximately 50 feet high (based on observations in the Meikle Mine). These dimensions were used to predict the maximum thickness of the overburden material (soil or rock) required to completely contain any stoping or dome fallouts that could occur without breaking through to the ground surface.

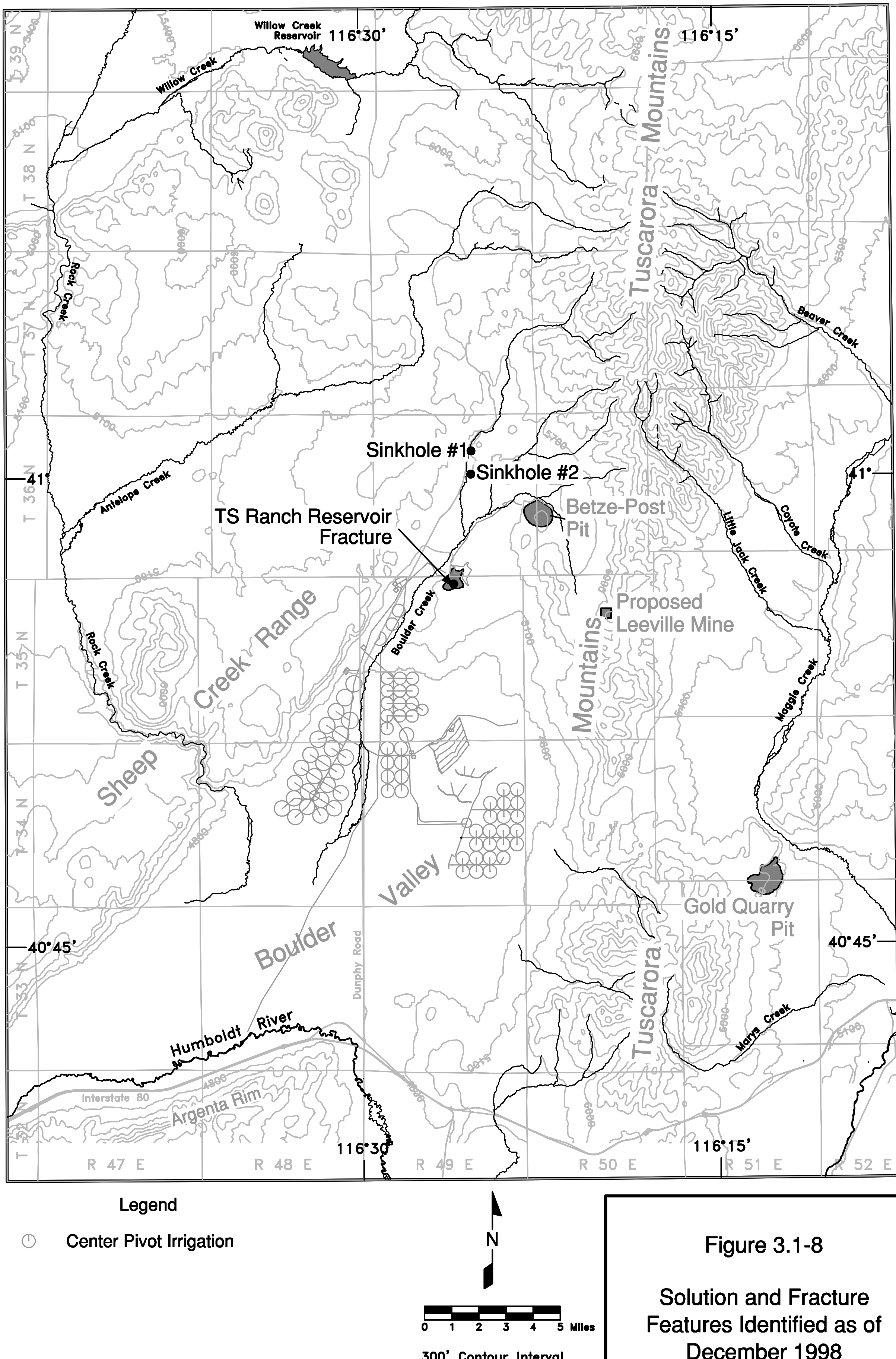


Figure 3.1-8

Solution and Fracture Features Identified as of December 1998

Several criteria were established to define areas that could be susceptible to sinkhole development under changing ground water conditions (increased infiltration and/or lowering of the water table). In summary, areas where the carbonate rocks are located either at the ground surface or at depths of less than 250 feet and covered by unconsolidated (e.g., alluvial or colluvial) materials are susceptible to sinkhole development. Areas where the carbonate rock is overlain by consolidated, insoluble layers less than approximately 50 feet thick also are considered susceptible to sinkhole development. Conversely, areas where carbonate rocks are overlain by more than approximately 50 feet of consolidated, insoluble rock materials, and/or are deeper than approximately 250 feet below the ground surface are considered to have low risk of sinkhole development.

The criteria described previously were combined with available information on the geology in the region (including location of carbonate outcrop areas and materials above the carbonate rocks) and prediction of ground water drawdown (presented in Section 3.2) to develop a map illustrating areas that could potentially be susceptible to sinkhole development. The areas where carbonate rocks are located at or near surface and assumptions of overburden materials (alluvium or insoluble bedrock) were determined based on available regional geologic information (Maurer et al. 1996; Newmont 1998). The general depth to the carbonate rocks was based on available well completion logs for monitoring wells completed by Barrick and Newmont. As illustrated in Figure 3.1-9, areas potentially susceptible to sinkhole development include the large area underlain by carbonate rock located between the Betze-Post Pit and Gold Quarry Pit, and the area northwest of the Betze-Post Pit.

The results of this evaluation delineate several areas that could potentially be susceptible to sinkhole development. These areas contain few buildings, major roads, or other infrastructures. Critical mine-related facilities such as waste rock storage facilities, heap leach pads, and mill and tailings facilities are not located within these areas. A segment of a power line associated with the Carlin Mine occurs within an areas that could be susceptible to karst development. Other non-mine-related features of note located within these areas include a 1-mile segment of Boulder Creek, a 1-mile segment of Sheep Creek, several springs and intermittent streams, a corral, and several unpaved dirt roads.

It is important to note that information on the depth to carbonate rock and thickness of cover materials is based on limited subsurface information. The site-specific risk of sinkhole development will depend, in part, on site conditions including depth to carbonate rocks, mineralogical and hydrological characteristics of the carbonate rock, size of new or pre-existing voids in the carbonate rock, properties of the overlying materials, and hydrologic changes induced by the cumulative mine dewatering and water management activities.

Potential for Mineral Dissolution

The potential for minerals to dissolve and metals to be released as a result of dewatering and water management operations is related to the temperature and chemical properties of the water. The infiltration and injection areas of the water management operations are dominated by younger basin fill and volcanic rocks. Minerals that dissolve in water (in order of solubility) include halite, gypsum, and calcite; and minerals that could release elements into the ground water and absorb elements from the ground water include zeolites. Evaporites (halite and gypsum) form when water evaporates. Localized evaporate deposits are common throughout the Basin and Range region, and likely occur in the younger basin fill found in the valleys of the study area. This is supported by considerable variation in water chemistry over time for the Green Spring water (see Figure 3.2-32). No large-scale evaporite deposits are likely to exist in the study area because no Pleistocene lakes are documented in any of the study area valleys (Stewart 1980).

Calcite occurs as a secondary mineral in alluvium and may occur as fracture/vug fillings in the volcanic deposits. The volcanic deposits may also contain zeolites that fill voids and vugs. Continued infiltration and injection activities would likely result in local mineral dissolution. Impacts to water quality associated with infiltration and injection are addressed in Section 3.2.2.2.

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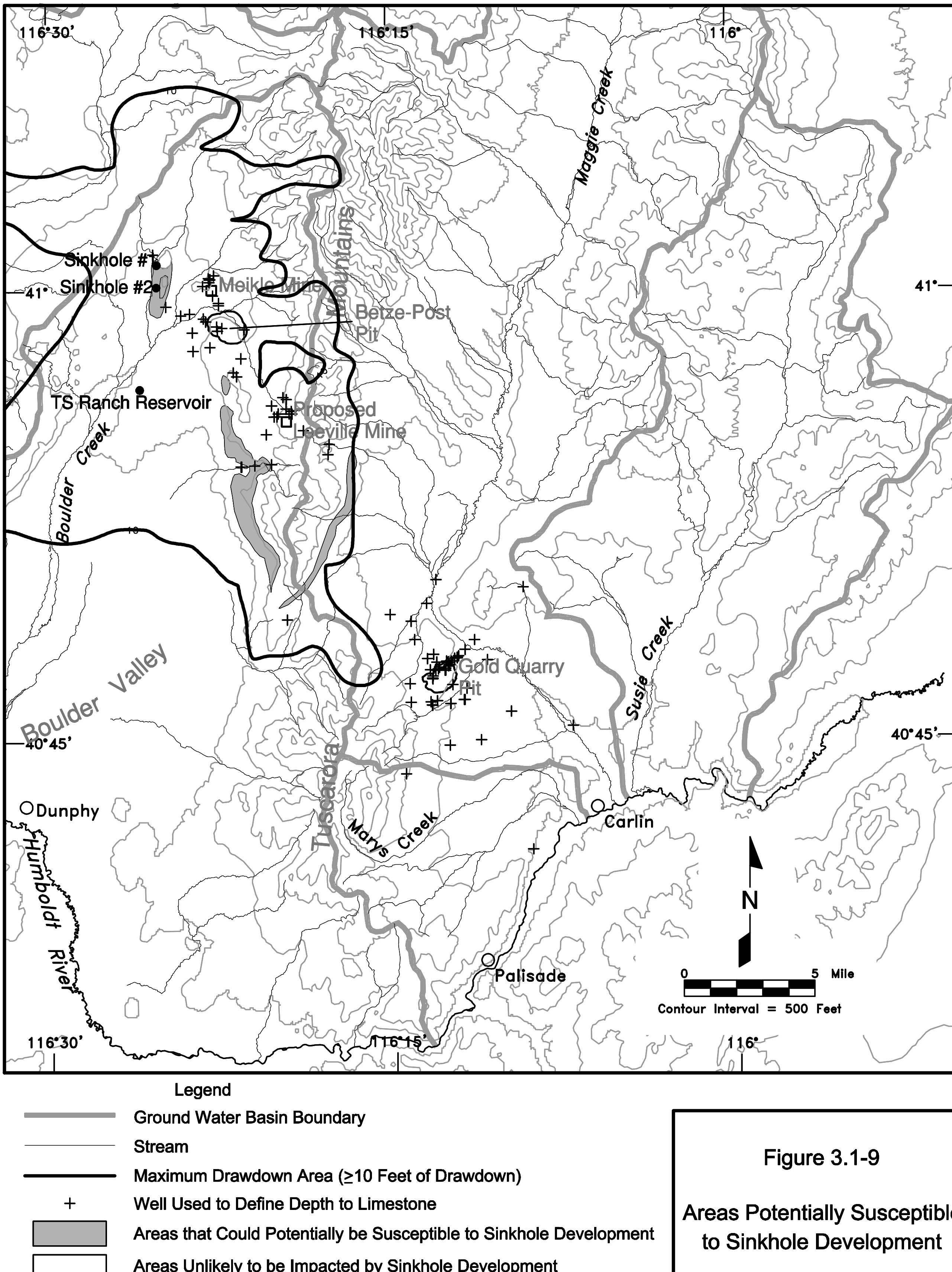


Figure 3.1-9

Areas Potentially Susceptible to Sinkhole Development

Dewatering-induced Surface Subsidence

Dewatering-induced subsidence occurs when ground water is withdrawn in valleys filled with unconsolidated to poorly consolidated alluvial sediments. This is an issue where ground water extraction is occurring in alluvial valleys throughout the southwestern United States (Poland et al. 1984). Dewatering at the Goldstrike Mine primarily occurs in consolidated bedrock material. Therefore, regional subsidence resulting from ground water withdrawal is not anticipated in the vicinity of the Goldstrike Mine.

3.1.2.2 Impacts to the Humboldt River

No impacts to geologic or mineral resources are anticipated to the Humboldt River as a result of water management activities at the Goldstrike Mine because the Humboldt River is not associated with any identified geologic features that would potentially be affected by mining operations. Potential impacts to the river from mining and water management activities, such as stream erosion, sedimentation, and channel geometry, are addressed in Section 3.2.2.2.

3.1.3 Monitoring and Mitigation

Hazards associated with karst solution features or sinkhole development could be mitigated as follows:

1. Report any suspected subsidence feature or possible evidence of sinkhole development (on BLM land) to the BLM authorized officer within 24 hours of detection to determine significance and coordinate development of a monitoring program and remedial action plan.

2. Develop site-specific remedial measures or a mitigation plan for approval by the BLM that may include, as necessary, plans to arrest the subsidence, stabilize the land, and restore surface conditions.

3. Implement approved remedial measures or mitigation plan.

3.1.4 Residual Impacts

Residual impacts were described in the Betze Project Final EIS. No additional unavoidable adverse impacts to geology are anticipated.

3.1.5 Irreversible and Irretrievable Commitment of Resources

Irreversible and irretrievable commitments of geologic resources were described in the Betze Project Final EIS. No irreversible or irretrievable geologic impacts are anticipated from Barrick's continued water management activities.

3.2 Water Resources and Geochemistry

Baseline water quantity and quality in the vicinity of the Goldstrike Mine were described in the Betze Project Draft EIS (BLM 1991a). Since 1991, considerable additional water resources and geochemistry information has been collected throughout the project area. Subsection 3.2.1, Affected Environment, includes an updated description of the premining conditions. Subsection 3.2.2, Environmental Consequences, provides an evaluation of impacts to date (1991 through 1998) and projected future impacts to water resources associated with groundwater pumping and water management operations at Barrick's Goldstrike Mine.

3.2.1 Affected Environment

3.2.1.1 Introduction

The Goldstrike Mine is located within the Humboldt River basin in north-central Nevada. The entire basin covers an area of nearly 17,000 square miles; upstream of the project facilities, the river drainage occupies approximately 7,500 square miles. The Humboldt River flows within an enclosed basin, having no external drainage to a larger flow system. The river flows westward and terminates by evaporation and infiltration in the Humboldt Sink south of Lovelock, Nevada.

For water resources, the affected environment consists of two study areas: (1) a hydrologic study area for mine dewatering (and localized water management activities), and (2) a Humboldt River study area for evaluating the potential effects associated with the discharge of excess mine water to the river system.

The hydrologic study area for mine dewatering occupies approximately 2,060 square miles and includes six designated ground water basins established by the Nevada Division of Water Resources (Figure 3.2-1) (Riverside Technology, inc. [RTi] 1994; McDonald Morrissey Associates, Inc. 1998; AATA International, Inc. 1998a, 1997; Nevada Division of Wildlife 1998b, 1996b, 1978; Valdez et al. 1994). These ground water basins, their state identification numbers, and their land surface areas are listed in Table 3.2-1.

These ground water basins drain southward to the Humboldt River. The hydrologic study area for mine dewatering is bounded by the Tuscarora Mountains on the north, the Adobe Range and Independence Mountains on the east, and the Humboldt River on the south. As shown in Figure 3.2-1, the western boundaries of the Willow Creek and Rock Creek ground water basins form the western boundary of the hydrologic study area. Elevations within the study area range from approximately 8,800 feet in the Tuscarora Mountains to 4,500 feet on the Humboldt River near the town of Battle Mountain. The affected environment for the hydrologic study area for mine dewatering is described in Section 3.2.1.2.

For this study, the streams have been subdivided into three types of reaches that define the general character of the reach: (1) perennial, (2) discontinuous flowing, or (3) intermittent or ephemeral. Perennial stream reaches have some measurable flow year round. Discontinuous flowing stream reaches are characterized as a series of generally short (tens of feet to hundreds of feet in length) perennial segments separated by intermittent segments (defined below). Intermittent segments tend to go dry in late summer to early fall in most years, and ephemeral stream reaches only flow in response to precipitation events. The perennial, discontinuous flowing, and intermittent or ephemeral stream reach segments presented in Figure 3.2-1 are based on the baseline water resource information presented in AATA International, Inc. 1997, 1998a; JBR 1990a; Newmont Gold 1991, 1992a, b; Nevada Division of Wildlife 1978, 1996b, 1998b; Riverside Technology, inc. (RTi) 1994; and Valdez et al. 1994.

The Humboldt River study area consists of the Humboldt River and its floodplain, extending from the USGS gage at Carlin to the Humboldt Sink downstream of Lovelock. Quantitative assessments have been conducted for the river from Carlin to the gage at Comus, approximately 9 miles east of Golconda (Figure 1-6). Semi-quantitative or qualitative assessments have been conducted from Comus to the sink. This approach was used because of the locations of mining discharge, the availability of data, and the increasing influence of irrigation practices and evapotranspiration losses in the downstream

Table 3.2-1
Major Subregions Within the Hydrologic Study Area

Nevada Designated Ground Water Basin	Basin Number	Approximate Land Area (square miles)
Susie Creek	50	220
Maggie Creek	51	410
Marys Creek	52	60
Boulder Flat	61	560
Rock Creek Valley	62	450
Willow Creek Valley	63	420

Source: Nevada State Engineer's Office 1992; Maurer et al. 1996.

direction. The affected environment for the Humboldt River Study Area is described in Section 3.2.1.3.

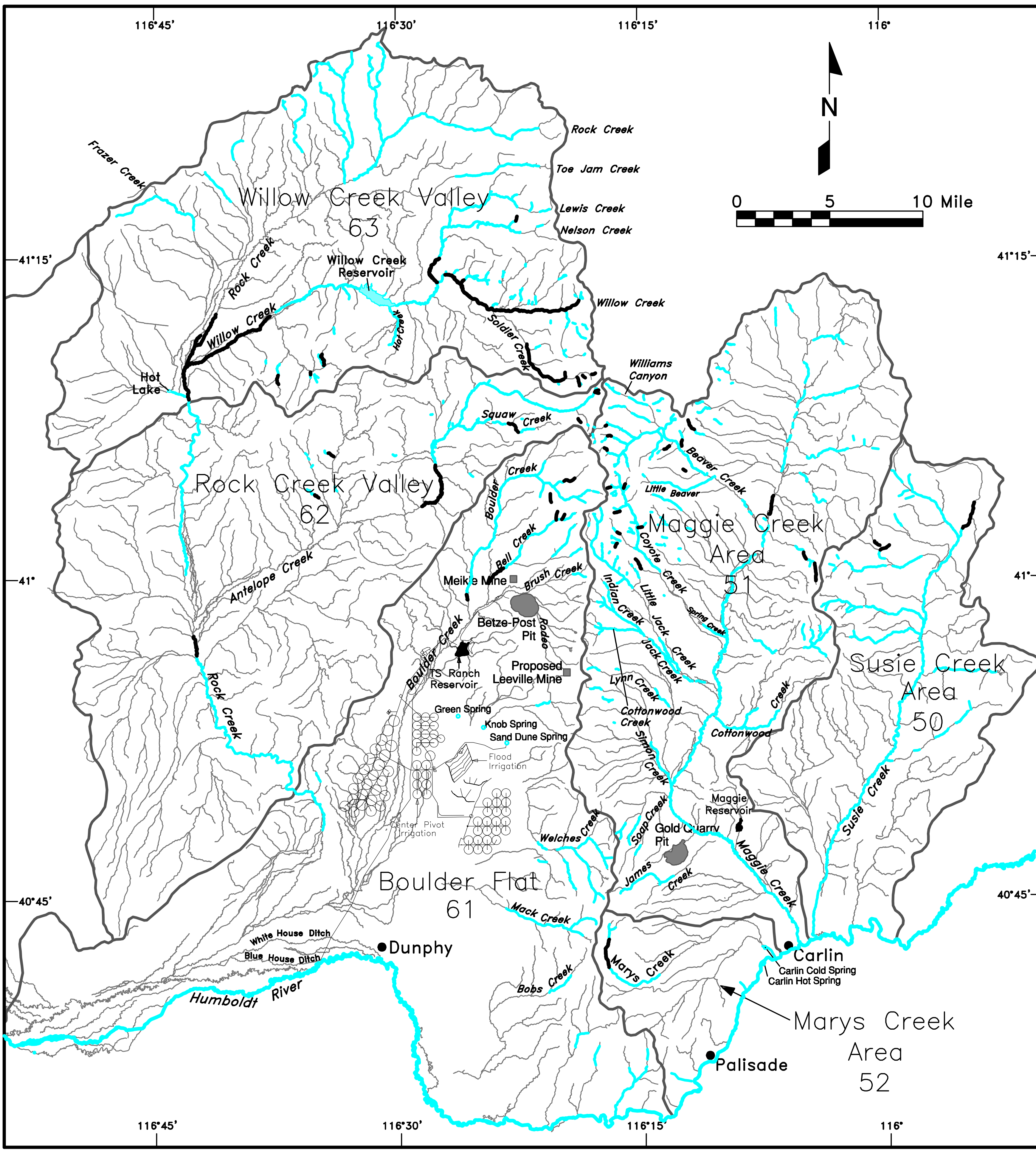
Hydrometeorology

Average annual precipitation varies widely within the region but generally increases with elevation (Figure 3.2-2) (Plume 1995). Most precipitation falls as snow in the mountains as a result of frontal storms between November and May. Total annual precipitation ranges from 5 to 8 inches on Boulder Flat and 15 to 20 inches at higher elevations in the Tuscarora Mountains. The mean annual snowfall is over 40 inches at places in the Tuscarora Mountains (McDonald Morrissey Associates, Inc. 1996b). Average monthly precipitation values for approximately 50 years of record at Elko and Battle Mountain are shown in Figure 3.2-3 (Earthinfo Inc. 1997; National Climatic Data Center 1999). Total annual precipitation has averaged 9.6 inches at Elko and 7.7 inches at Battle Mountain over this period (Figure 3.2-4) (RTi 1998). Precipitation varies along the river, but generally decreases toward the Humboldt Sink. Average annual precipitation is 8.2 inches at Winnemucca and 5.2 inches at Lovelock (National Oceanic and Atmospheric Administration - Cooperative Institute for Environmental Sciences 1999).

The variation in mean annual precipitation for periods of interest to the surface hydrology analysis is compared to the longer historical record (1944 through 1998) in Table 3.2-2. A regional drought affected the area between 1985 and 1993 and is most noticeable in the Elko data shown below. Corresponding to this period of less precipitation at higher elevations, the total flow in the Humboldt River at the Carlin gage in 1987 was approximately 40 percent of normal; in 1992, the total flow at the same site was approximately 20 percent of normal (Maurer et al. 1996). In addition to flow effects from less precipitation in the headwaters, irrigation demands during those dryer years reduced flows in the river. Normal or above normal precipitation rates occurred in most areas of Nevada after 1993 (RTi 1998).

High streamflows may occur in the winter or early spring as a result of rain on snow or frozen ground, but more commonly the annual high flow events occur from snowmelt in the spring. Snowmelt and winter frontal storms can result in sizable runoff volumes and high flood stages over large areas, particularly from rain-on-snow events. Occasionally, isolated flooding may result from intense local thunderstorms, which most often occur from late spring through the fall. These events produce the most intense precipitation in the region, but they are typically limited in duration and extent. As a result, flash floods from thunderstorms generally have larger peak flows than snowmelt events, but they are typically confined to smaller areas and shorter timeframes.

Evaporation, as measured from Class A pan devices, averages about 60 inches per year in the hydrologic study area (National Oceanic and Atmospheric Administration 1982). After accounting for pan characteristics, this converts to a free water surface evaporation rate of about 44 inches per year. This rate approximates the



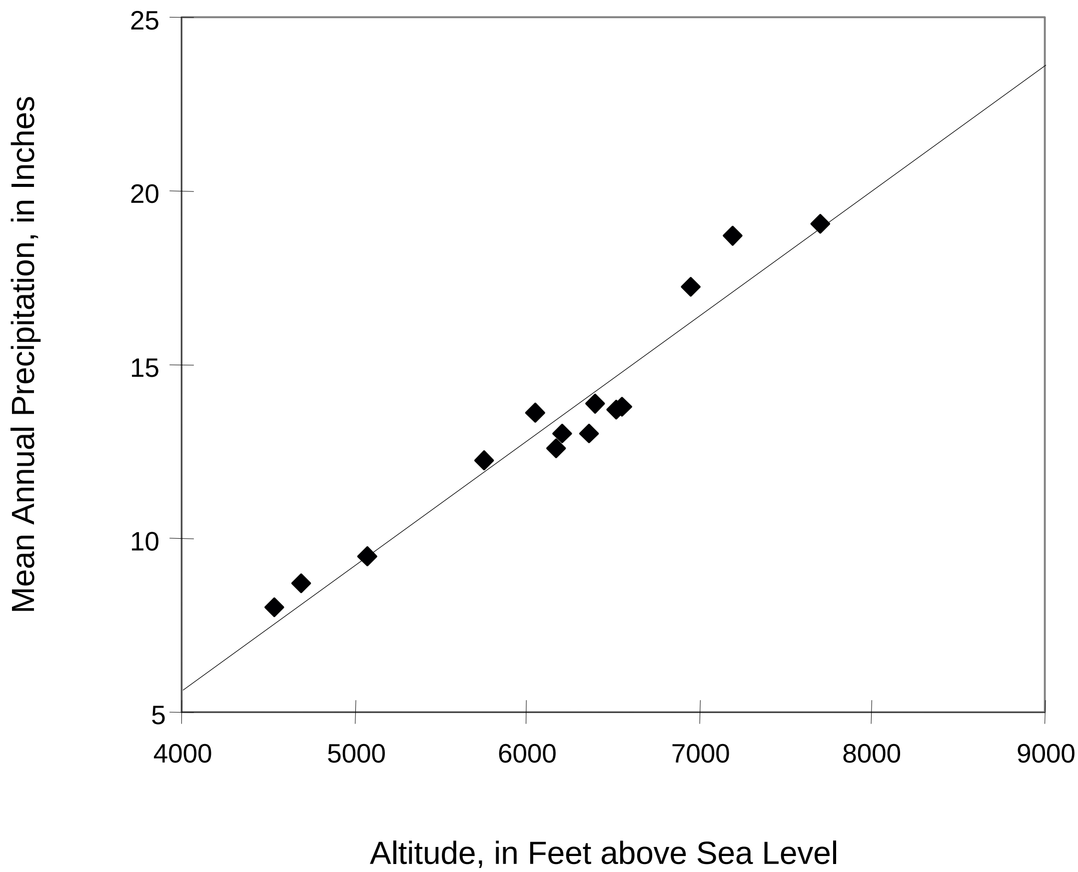
Legend

- Ground Water Basin Boundary
- Stream (Intermittent or Ephemeral)
- Perennial Stream
- Discontinuous Flowing Stream Reach
- Center Pivot Irrigation

Note: Stream locations are taken from USGS line graph database. Hydrographic Area Boundary locations are approximate.

Figure 3.2-1

Hydrologic Study Area for Mine Dewatering and Localized Water Management Activities



Source: Plume 1995

Figure 3.2-2

Relation of Mean Annual Precipitation to Altitude

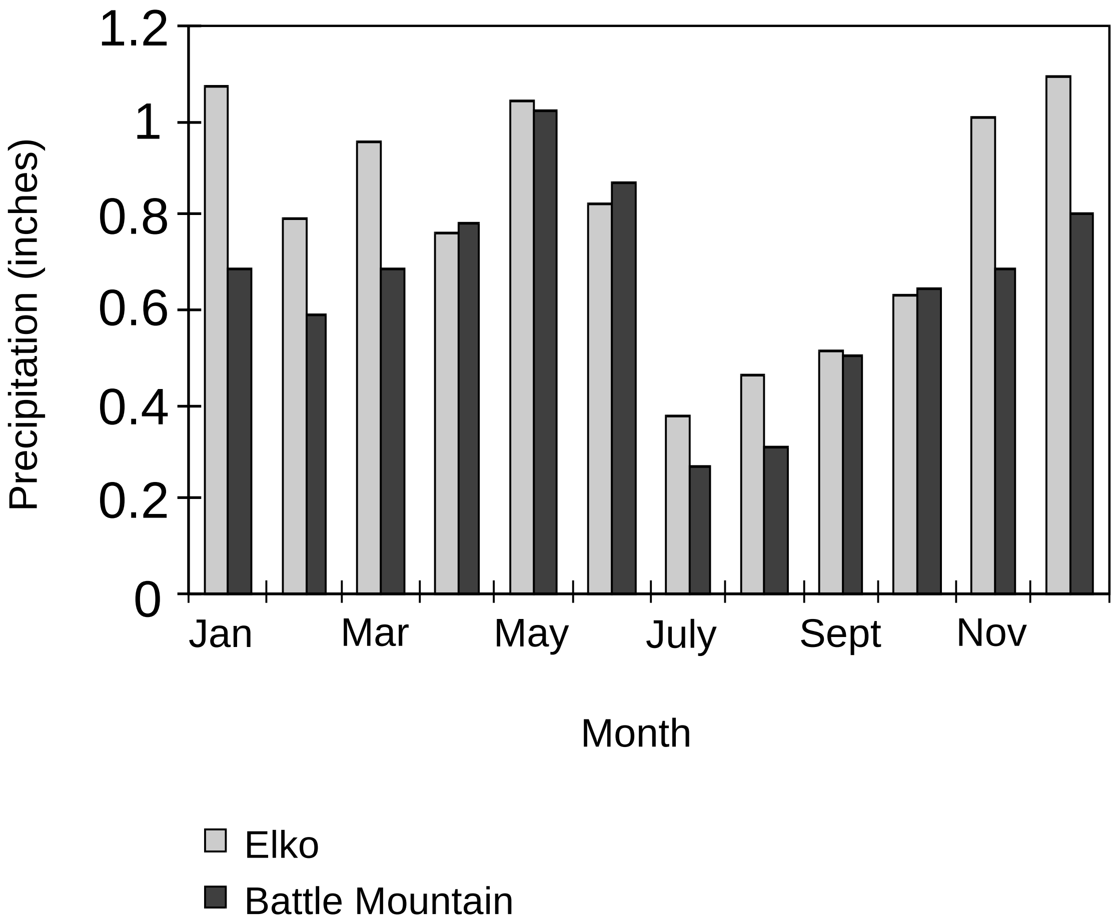


Figure 3.2-3

Average Monthly Precipitation at Elko and Battle Mountain

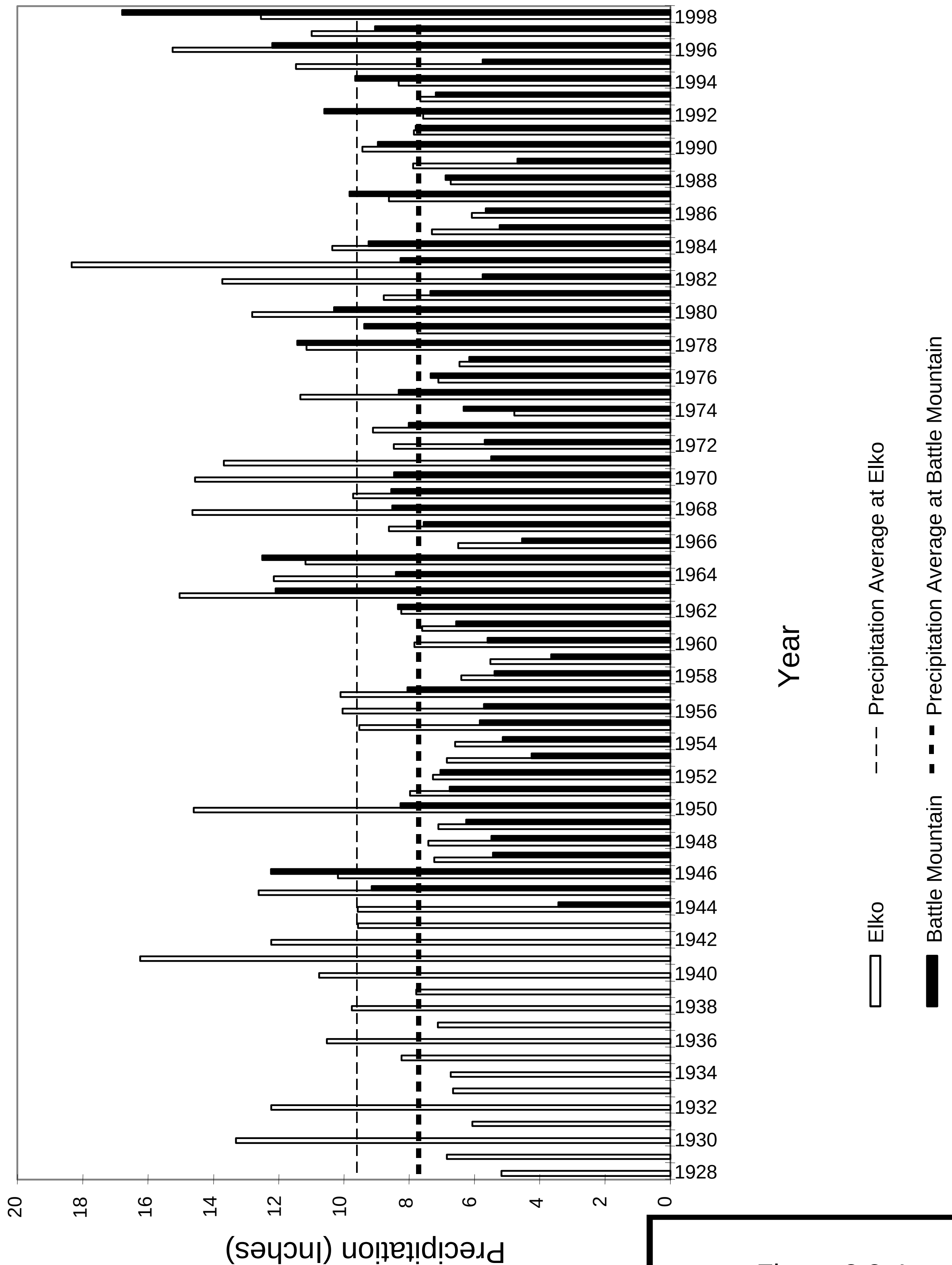


Figure 3.2-4

Annual Precipitation at Elko and Battle Mountain