INTRODUCTION

Since Nevada's territorial days, mining has taken place in the Humboldt River Basin (fig. 1). In the last decade, however, the basin has undergone a mining boom. At present (1994), the expansion of existing mines and the exploration for new mineral deposits continue throughout the basin. The discovery and successful development of extensive, low-grade gold deposits have resulted in nearly 40 active gold-mining operations in the basin. Of these operations, 15 are large-scale, open-pit mines, which together produced more than 5 million ounces of gold and about 19 million ounces of silver in 1993 (Nevada Bureau of Mines and Geology, 1994). Both the concentration of so many large-scale mining operations and the volume of mine dewatering in the basin may be unprecedented in the United States.

As of 1994, ground-water withdrawals for mining purposes amounted to more than 200,000 acre-ft/yr, and the projected completion depth of several open-pit mines is below the altitude of the Humboldt River. Water withdrawals are anticipated to increase as the number of mining operations increases and as pit depths increase. Because the disturbance of one resource—such as rock—can affect another resource—such as water, local managers and residents are concerned about potential adverse effects on water resources from mining activity. Their concerns include not only local effects in the vicinity of each major mining operation, but also the combined or regional-scale effects that all the mining operations may have on the hydrologic regime of the entire Humboldt River Basin.

A study was made by the U.S. Geological Survey (USGS), at the request of and in cooperation with the Bureau of Land Management (BLM), to develop an initial assessment of the generalized extent and magnitude of potential changes in selected hydrologic characteristics or features resulting from mining activities. This report presents the findings of that assessment. The report describes effects that might be expected in the basin in the next 5 years as a result of the current or planned mining activity.

On the basis of drainage patterns within the basin, the USGS has assigned nine hydrographic cataloging units to the Humboldt River Basin (Seaber and others, 1987). For management purposes, the Nevada Division of Water Resources has further separated these nine units into 34 hydrographic areas (fig. 2; Rush, 1968). (Hydrographic areas are the basic units usually used by State and local agencies for planning and management of water resources.)

For this study, a set of rankings was developed that reflects potential effects of mining on seven water-related characteristics and features: ground-water levels, springs, perennial streams, shallow ground-water areas, sediment transport, agricultural irrigation, and fish and wildlife habitat. For each of the seven characteristics or features, the 34 hydrographic areas in the basin were ranked by relative activity or potential effect.

The author would like to acknowledge the assistance of personnel of the Bureau of Land Management and the Nevada Division of Water Resources in providing data for this study.

Figure 1. Location of Humboldt River Basin study area.

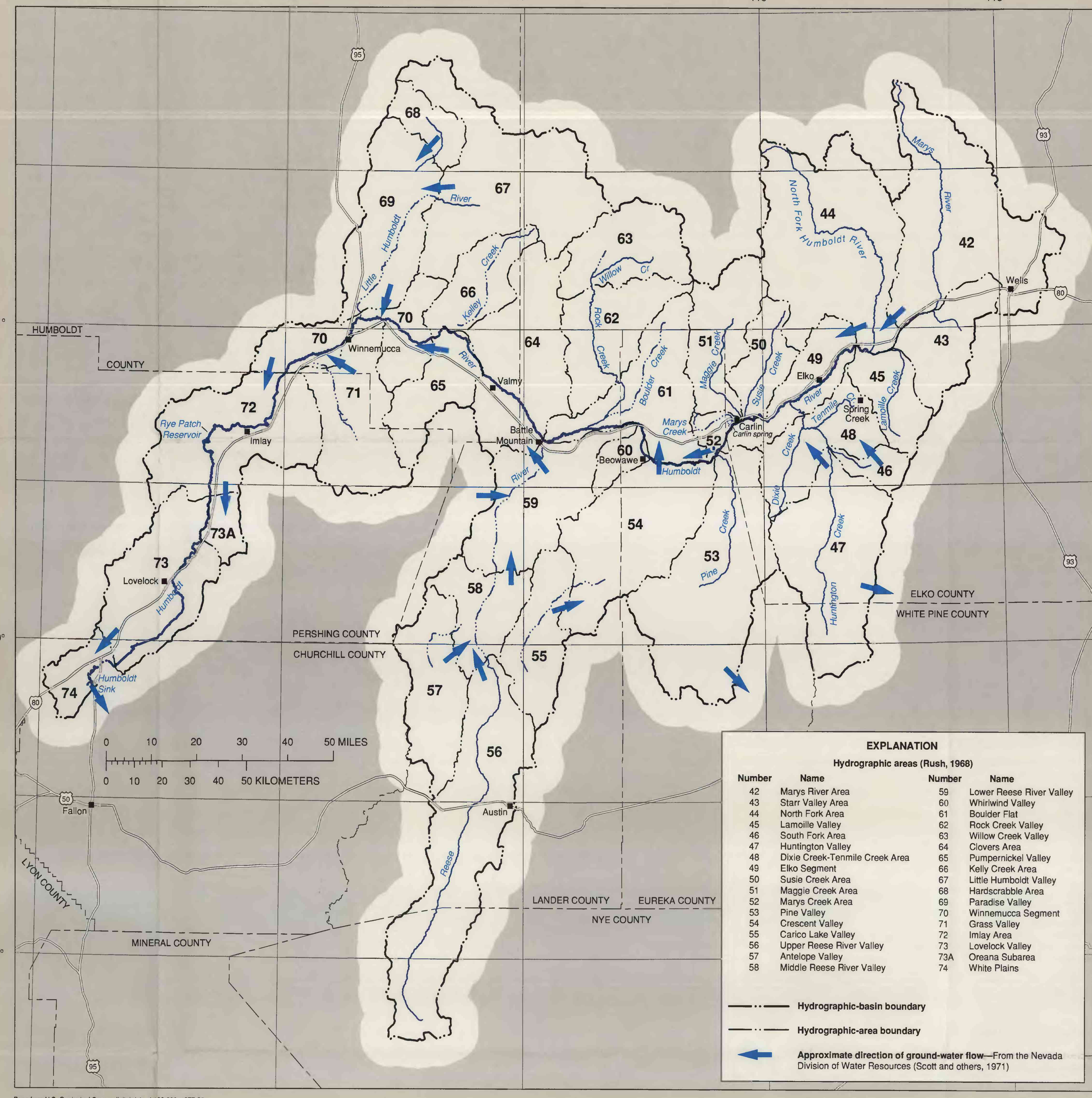

Figure 2. Hydrologic features and hydrographic areas.

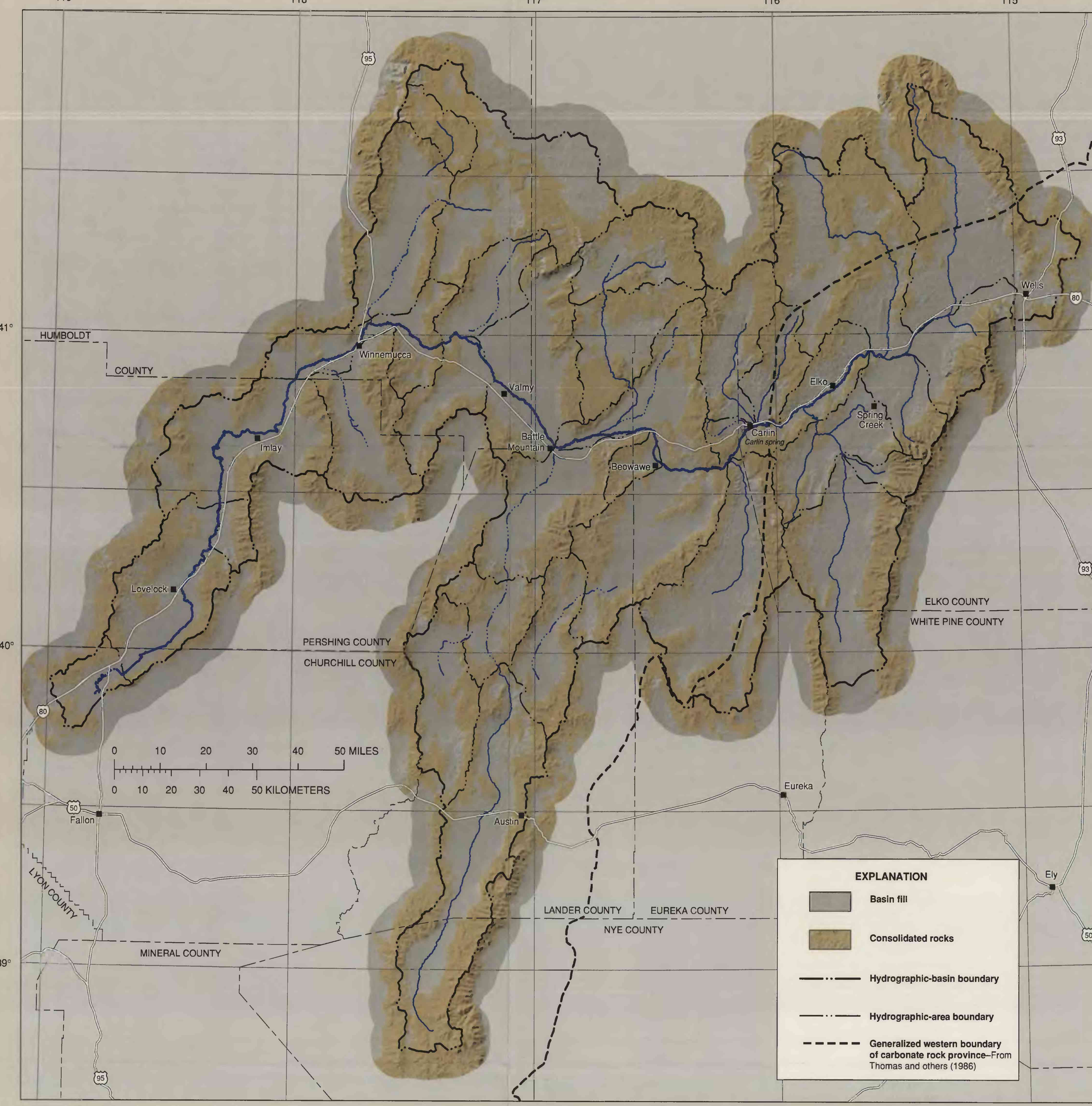

Figure 3. Approximate extent of basin fill and consolidated rocks.

HYDROGEOLOGY OF STUDY AREA

The Humboldt River Basin is a closed basin that drains to the Humboldt Sink and lies entirely within Nevada; it encompasses an area of about 16,800 mi^2 in the northern part of the State (fig. 1). During infrequent periods of unusually high runoff, the Humboldt Sink overflows to the Carson Sink, the terminus of the Carson River. The Humboldt River Basin is within the Basin and Range physiographic province, which is characterized by long and narrow, generally north-south trending mountain ranges separated by broad, relatively flat valleys. Altitudes in the basin range between 3,900 and 11,800 ft above sea level.

Most hydrographic areas contain a basin-fill ground-water reservoir and include the drainage area in adjacent mountains. Commonly, the hydrologic boundaries correspond to topographic and geologic features that constitute the geographic boundaries of hydrographic areas. In many places, however, both shallow and deep interbasin ground-water flow take place.

Because the geologic history of the Humboldt River Basin is complex, a wide variety of rock types and structural features is present. For the purposes of this initial assessment, the geology in the area was grouped into two categories—valleys filled with alluvial and lacustrine deposits (basin fill) of moderate to high permeability, and mountain ranges underlain by consolidated rocks of generally low to moderate permeability (fig. 3).

The basin fill consists primarily of unconsolidated and weakly consolidated deposits of gravel, sand, silt, and clay derived from the adjacent mountains. Volcanic sediments also are included in the fill. Thickness of the basin fill generally ranges between 2,000 and 5,000 ft, but exceeds 10,000 ft in the deepest parts.

The consolidated rocks in the mountain ranges and underlying the basin fill include clastic sedimentary rocks, intrusive and extrusive igneous rocks, and metamorphic rocks that generally do not transport water readily unless they are extensively fractured. Where the consolidated volcanic and carbonate rocks are highly fractured and permeable, water yields readily to wells. The carbonate rocks form a regional aquifer system underlying the eastern part of the Great Basin and including the part of the Humboldt River Basin that is mainly east of Carlin (fig. 3). This regional flow system consists of several interrelated local flow systems (Plume and Carlton, 1988). In addition, structural features—such as some faults—may act as barriers to ground-water flow, and aquifers may be compartmented by barriers that inhibit regional-scale flow of water through rock (Prudic and others, 1993). These barriers commonly coincide with the mountain ranges that bound the hydrographic areas in the basin.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
ounce, troy	31.035	gram
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

LAND AND WATER USE

Within the basin, the BLM is responsible for managing more than 9,700 mi^2 of land—about 57 percent of the basin (fig.4; Larry Steward, Bureau of Land Management, oral commun., 1994). Many of the private land holdings were obtained in a checkerboard pattern in the late 1860's along a 20-mi swath on either side of the transcontinental railroad line, which closely parallels the Humboldt River through much of the basin. Nearly all human activities require water. In prehistoric times, natural streams and springs in the Humboldt River Basin were used for personal needs. Since development of irrigated agriculture in the mid-1800's, people have diverted rivers and streams and tapped ground water to meet their needs.

The two largest land uses in the basin, by acreage, are livestock grazing and irrigated agriculture. The largest water uses in the basin, by amount withdrawn, are irrigation, mining, public supply, and electric-power generation. These land and water uses are briefly discussed below; estimated areas and quantities listed herein are based on information compiled for Nevada by this author and reported by Solley and others (1993).

Livestock grazing, mostly on open range, is the most widespread land use in the basin. Primarily cattle, and some sheep, are raised. The water required for livestock is minimal in the basin; in 1990, an estimated 1,700 acre-ft of water, mostly surface water, was used for livestock.

Irrigation for agriculture uses the most water in the basin. Agriculture is common along the Humboldt River, as well as in Grass, Paradise, and middle and upper Reese River Valleys. The predominant crops are grass and alfalfa for animal forage. Flood irrigation is the most common method of applying the water to fields. In 1990 (a drought year), an estimated 234,000 acres were irrigated with nearly 1,000,000 acre-ft of water, about 75 percent of which was surface water. Most of the surface water in the Humboldt River and its tributaries was appropriated before 1900. Since the mid-1940's, the amount of ground water used for irrigation has steadily increased.

Mining, like grazing and agriculture, was active in the basin prior to Statehood in 1864. The first mining boom was for gold in the Austin area (fig. 3) in the mid-1860's. The second boom began with the discovery of copper deposits south of Battle Mountain (fig. 3) in the 1950's and lasted until the early 1980's. A third mining boom began north of Carlin (fig. 3) in 1965 with the discovery of low-grade gold deposits. At many of the gold mines, silver also is recovered during the ore processing. Industrial minerals mined in the basin include barite and tungsten; non-minerals mined are sand and gravel and limestone. Diatomite is mined just outside the basin, but the processing plant is within the basin. Mining is a growing water use in the basin because of more and larger mining operations. Mining activities that use water include mining the ore, processing the ore, and pit dewatering. Some water-use accounting methods do not include pit dewatering as a mine water use; for this analysis, however, pit dewatering is included. In 1990, an estimated 32,000 acre-ft of water, mostly ground water, was used for mining activities. In 1993, the use was an estimated 200,000 acre-ft.

Seven towns in the basin have a population of 1,000 or more; most of these towns are along the Humboldt River. These towns (fig. 3) and their 1990 populations (U.S. Bureau of the Census, 1992) are Elko (14,736), Winnemucca (6,134), Spring Creek (5,866), Battle Mountain (3,542), Carlin (2,220), Lovelock (2,069), and Wells (1,256). The population of the entire basin in 1990 was estimated at 48,800. A public water-supply facility serves each of the towns in the basin with a population of 1,000 or more. Some of the other towns and communities that have water-supply facilities are Austin, Imlay, and Valmy (fig. 3). In 1990, an estimated 15,000 acre-ft of water, mostly ground water, was used for public supply. Approximately 87 percent of the people in the basin received their domestic water from public-supply facilities. The remaining 13 percent of the people were self supplied and used about 800 acre-ft of water, mostly from wells.

Electric power is generated at two sites in the basin: a fossil-fuel electric plant near the Humboldt River at Valmy, and a geothermal electric plant at Beowawe. Both plants use only ground water and, in 1990, withdrew approximately 9,800 acre-ft of water.

METHODS OF STUDY

This study estimated the effects that current (1994) active mining and potential mining during the next 5 years may have on seven water-related characteristics or features for each of the 34 hydrographic areas. These characteristics are ground-water levels, springs, perennial streams, shallow ground-water areas, sediment transport, agricultural irrigation, and fish and wildlife habitat. Because of the lack or limited nature of the available data on two other characteristics— land subsidence and water quality—the effects of changes were not evaluated for each hydrographic area, but are discussed briefly below.

Land subsidence commonly accompanies extensive ground-water drawdowns over a large area of unconsolidated aquifers. Typically, areas of fine-grained materials, such as silt and clay, are more susceptible than areas of coarse-grained materials, such as sand and gravel. Information on the composition of the basin-fill material and the location and extent of the various aquifers is insufficient for estimating potential subsidence in the study area.

Although few data are available to assess the water quality in the basin, any type of activity that changes the natural flow of water also could change the physical, chemical, and biological composition of the water. The excavation of a mine pit that permits the mixing of water from different aquifers, the oxidation of material, the transfer of ground water to the surface, the leaching of material, and the seeping of surface water into the ground are examples of the activities that could cause a change in the water quality. Until a monitoring network is established to sample the water that is to be transferred and the water in the intended receiving area, any changes in water quality will be unknown.

Active mines, active explorations, and potential exploration sites considered for this study are shown in figure 4 and listed in table 1. These operations were listed in either the 1993 Directory of Nevada Mine Operations (Nevada Division of Industrial Relations, 1994) or supplied by the BLM (written commun., 1993). Potential exploration sites are areas that mining companies have indicated as being considered for exploration. Such sites are herein limited to those that involve at least some BLM lands; information on potential exploration sites solely on private land was unavailable. Each site location in figure 4 represents the approximate center of operations that may actually cover many square miles. Land-ownership information is based on digital data supplied by BLM, which updates land ownership on 1:100,000-scale maps (BLM, written commun., 1994). The nine maps for the Humboldt River Basin were last updated between 1974 and 1979. Since then, land ownership has changed little.

The seven water-related characteristics or features were evaluated using available information. Each was assigned a series of rankings for relative potential effect of mining activity that was tailored to that characteristic (table 2, sheet 2). The number of ranks for evaluating each characteristic ranges from 1 to 4, with 1 being the highest potential effect of activity compared to pre-mining conditions.

The BLM also has inventoried the springs and streams, as well as other characteristics discussed in this report. Those BLM studies were not used as the basis for this analysis, however, because they are limited to only BLM lands and, therefore, would not provide a uniform level of detail across the entire basin.

Each of the seven characteristics or features was evaluated for at least two distances— *local* and *areal*—from each major mining activity in the hydrographic area. The *local* area is defined, for the purposes of this study, as the area within a 2-mi radius of the mining activity. The *areal* distance is defined as a 4-mi-wide band that extends from 2 mi to 6 mi from the mining activity. Ground-water levels also were evaluated at a *regional* distance, which is that part of the basin that is more than 6 mi away from the mining activity.

A single value was assigned to represent the potential change in each hydrographic area for each characteristic or feature at each distance evaluated. The rank for the most severe effect expected near any one mine within the hydrographic area was used as the value for the entire hydrographic area. In many places, only a small segment of the area being evaluated might be affected to the degree to which the entire area is ranked. The rankings were then tallied and summarized for each hydrographic area, as shown in table 3 (sheet 2).

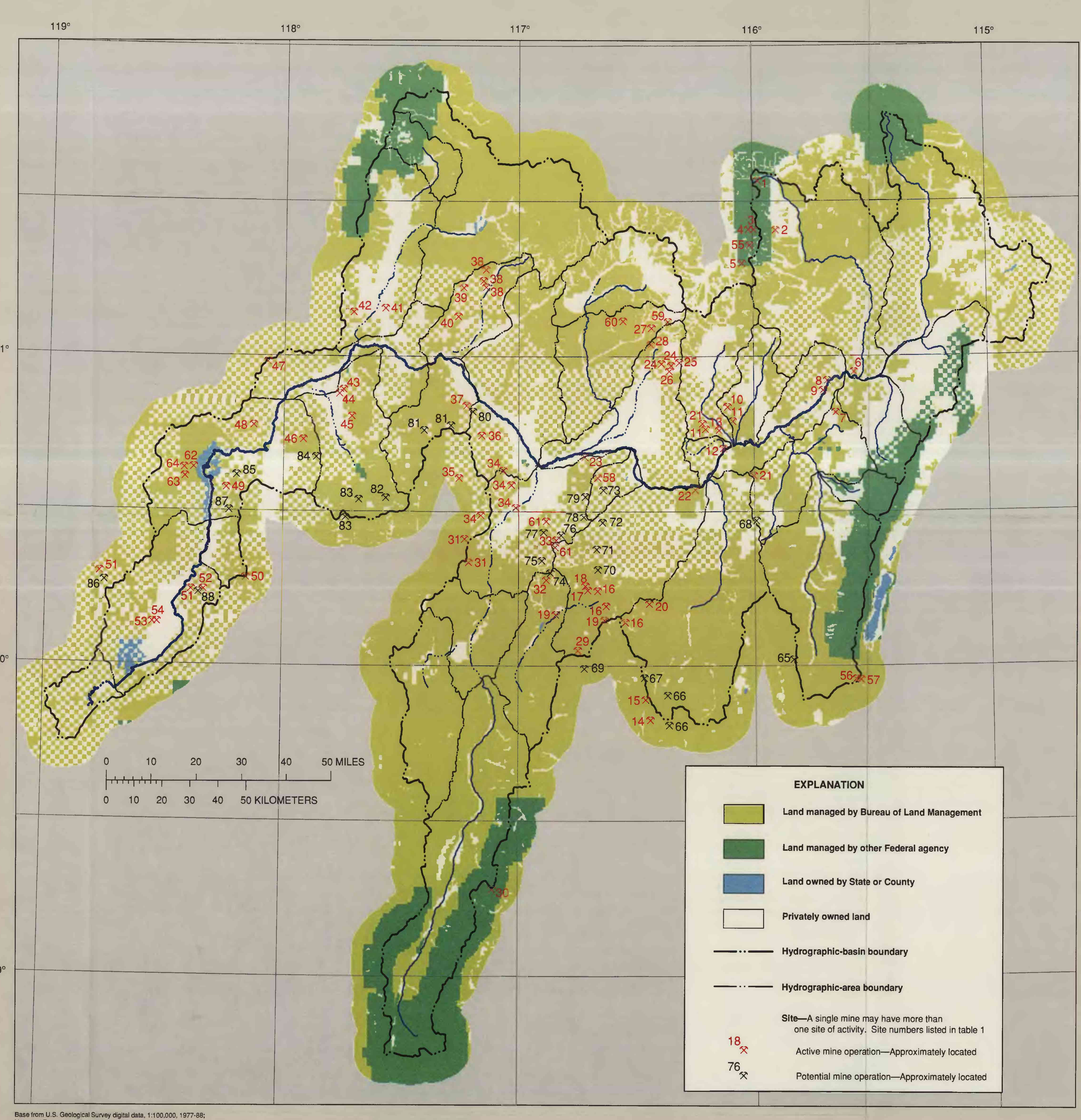

Figure 4. Delineation of public and private land ownership, 1974-79, and approximate location of active and potential mining operations, 1993. Land-ownership information from the Bureau of Land Management (BLM), management status maps, 1974-79, 1:100,000; mine-operations information from BLM (written commun., 1993) and Nevada Division of Industrial Relations (1994). See table 1 for more information on mines.

Table 1. Active and potential mining operations, commodity mined, and land ownership or management[1]

[Abbreviations: BLM, Bureau of Land Management; OFA, other Federal agency; P, private]

Site number (figure 4)	Mining operation	Commodity mined	Land ownership or management
	Active operations		
1	Big Springs	Gold	OFA
2	Jerritt Canyon	Gold	BLM
3	Independence Gold Mine	Gold	OFA
4	Enfield Bell Mine	Gold	OFA
5	Mill Creek	Gold	BLM
6	Elburz Pit	Sand, gravel	P
7	Stitzel Pit	Sand, gravel	BLM
8	Pardo Quarry	Railroad ballast	P
9	Osino Pit	Sand, gravel	BLM/P
10	Boehler Pit	Sand, gravel	BLM
11	Gold Quarry	Gold	BLM/P
12	Elko Sand and Gravel	Sand, gravel	BLM
13	Jones Pit	Sand, gravel	BLM/P
14	Gold Bar Mine	Gold	BLM
15	Tonkin Springs Mine	Gold	BLM
16	Horse Canyon Mine	Gold	BLM
17	Crescent Mine	Gold	BLM
18	Pipeline Project	Gold	BLM
19	Cortez Gold Mine	Gold	BLM
20	Buckhorn Mine	Gold	BLM
21	Rain Mine	Gold	BLM
22	Nevada Barth Iron Mine	Magnetite, iron	BLM/P
23	Argenta Mine	Barite	P/OFA
24	Gold Strike Mine	Gold	BLM/P
25	Post Mine	Gold	BLM/P
26	Genesis Mine	Gold	P
27	Rossi Mine	Barite	BLM
28	Dee Mine	Gold	BLM
29	Saddle Deposit	Gold	BLM
30	Klondike Mine	Gold, silver	OFA
31	Cove-McCoy Mine	Gold	BLM
32	Greystone Mine	Barite	BLM
33	Dean Pilot Plant	Gold, silver	P
34	Copper Canyon Mine	Gold	BLM/P
35	Buffalo Valley Mine	Gold	BLM
36	Marigold Mine	Gold	BLM/P
37	Lone Tree Mine	Gold	BLM/P
38	Twin Creeks	Gold	BLM/P
39	Getchell Mine	Gold	BLM/P
40	Pinson Mine	Gold	BLM/P
41	Paridise Hill Pit	Sand, gravel	BLM
42	Dun Glen Mine	Limestone	BLM
43	Sonoma Gravel	Sand, gravel	P
44	Thomas Creek Pit	Sand, gravel	BLM/P
45	Sexton Mine	Limestone	P
46	Dun Glen Mine	Gold	BLM/P
47	Main Plant Pit	Sand, gravel	BLM
48	Sutton II Mine	Tungsten	P
49	Florida Canyon Mine	Gold	BLM/P
50	Rochester Mine	Gold, silver	BLM/P
51	Colado Mine	Diatomite	BLM/P
52	Willard Mine	Gold	BLM/P
53	DeBraga Pit No. 1	Sand, gravel	P
54	Perth Pit West Gravel	Sand, gravel	BLM/P
	Active explorations		
55	Burnes Basin	Gold	BLM
56	Bald mountain Project	Gold	BLM
57	White Pine Mine	Gold	BLM
58	Mule Canyon	Gold	BLM
59	North Bootstrap	Gold	BLM/P
60	Hollister Mine	Gold	BLM
61	Dean Mine	Gold	BLM
62	Dusty Mine	Gold	BLM
63	Imlay Canyon	Gold	BLM
64	Saundra Lee and Phase II Mines	Gold, silver	BLM
	Potential exploration sites (Mine operation name and commodity to be mined are undetermined)		
65	--	--	BLM
66	--	--	BLM
67	--	--	BLM
68	--	--	BLM
69	--	--	BLM
70	--	--	BLM
71	--	--	BLM/P
72	--	--	BLM/P
73	--	--	BLM/P
74	--	--	BLM
75	--	--	BLM
76	--	--	BLM/P
77	--	--	BLM/P
78	--	--	BLM/P
79	--	--	BLM/P
80	--	--	BLM/P
81	--	--	BLM/P
82	--	--	BLM
83	--	--	BLM/P
84	--	--	BLM
85	--	--	BLM/P
86	--	--	BLM
87	--	--	BLM/P
88	--	--	BLM

[1] Information from Bureau of Land Management (written commun., 1993) and Nevada Division of Industrial Relations (1994).

POTENTIAL HYDROLOGIC EFFECTS OF MINING IN THE HUMBOLDT RIVER BASIN, NORTHERN NEVADA

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