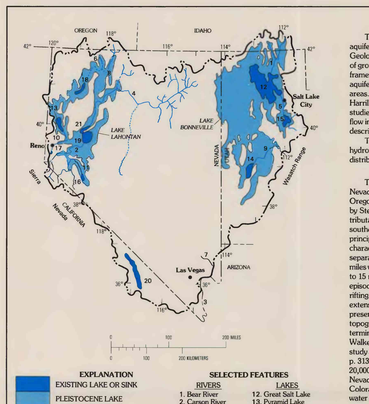


EXPLANATION

EXISTING LAKE OR SINK
PLEISTOCENE LAKE
RIVER—Dotted where ephemeral
STUDY-AREA BOUNDARY

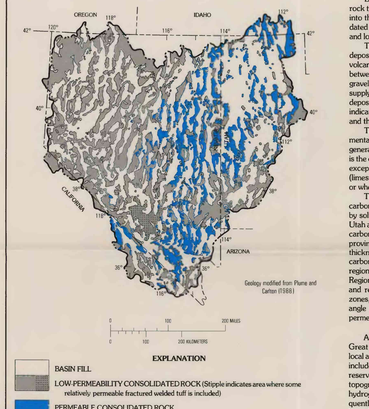
SELECTED FEATURES

RIVERS
1. Bear River
2. Carson River
3. Colorado River
4. Humboldt River
5. Jordan River
6. Kings River
7. Muddy River
8. Quinn River
9. Sevier River
10. Truckee River
11. Walker River

LAKES
12. Great Salt Lake
13. Pyramid Lake
14. Sevier Lake
15. Utah Lake
16. Walker Lake
17. Washoe Lake

TERMINAL SINKS
18. Black Rock Desert
19. Carson Sink
20. Death Valley
21. Humboldt Sink

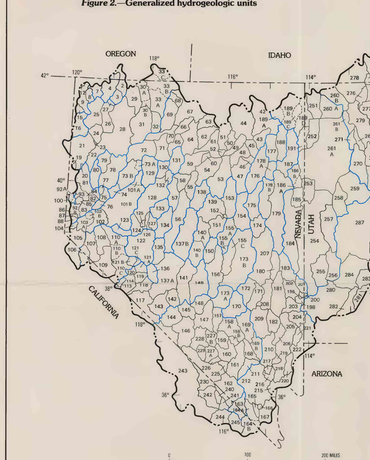
Figure 1.—Location of the study area and principal geographic features within the study area



EXPLANATION

BASIN FILL
LOW PERMEABILITY CONSOLIDATED ROCK (Stipple indicates area where some relatively permeable fractured welded tuff is included)
PERMEABLE CONSOLIDATED ROCK
STUDY-AREA BOUNDARY

Figure 2.—Generalized hydrogeologic units



EXPLANATION

HYDROGRAPHIC-AREA BOUNDARY—Numbers correspond to those used in the adjacent list. Numbers for areas in Nevada are those generally used by State agencies to identify specific areas. Numbers for areas outside of Nevada are index numbers assigned only for purposes of this report. In accompanying list, hydrographic areas are grouped by flow system. Parenthetical flow-system numbers are those shown in figure 6. Asterisk indicates a hydrographic area with subareas in more than one major flow system.
HYDROGRAPHIC-SUBAREA BOUNDARY
MAJOR FLOW-SYSTEM BOUNDARY
STUDY-AREA BOUNDARY

CONTINENTAL LAKE SYSTEM (1)
2 Continental Lake Valley
A. Upper & Lower Valley Areas
4 VIRGIN VALLEY (2)
7 SWAN LAKE VALLEY (3)
LONG VALLEY SYSTEM (4)
8 Massacre Lake Valley
9 Long Valley
12 Mosquito Valley
15 Boulder Valley
16 DUCK LAKE VALLEY (5)
BLACK ROCK DESERT SYSTEM (6)
19 Dry Valley
20 Sano Valley
21 Smoke Creek Desert
22 San Emidio Desert
23 Granite Basin
24 Hualapai Flat
25 High Rock Lake Valley
26 Mud Meadows
27 Summit Lake Valley
28 Black Rock Desert
29 Pine Forest Valley
30 Kings River Valley
A. Rio King Subarea
B. Sod House Subarea
31 Desert Valley
32 Silver State Valley
33 Quinn River Valley
A. Orovada Subarea
B. McDermitt Subarea
C. Oregon Canyon Subarea
HUMBOLDT SYSTEM (7)
42 Marys River Area
43 Starr Valley Area
44 North Fork Area
45 Lamoille Valley
46 South Fork Area
47 Huntington Valley
48 Franklin Lake Area
49 Elko Segment
50 Susie Creek Area
51 Maggie Creek Area
52 Marys Creek Area
53 Rock Creek Area
54 Crescent Valley
55 Carico Lake Valley
56 Upper Reese River Valley
57 Antelope Valley
58 Middle Reese River Valley
59 Lower Reese River Valley
60 Whirlwind Valley
61 Boughs Flat
62 Rock Creek Valley
63 Willow Creek Valley
64 Clovers Area
65 Pumpernickel Valley
66 Kelly Creek Area
67 Little Humboldt Valley
68 Hardscrabble Area
69 Paradise Valley
70 Winnemucca Segment
71 Grass Valley
72 Imlay Area
73 Lovelock Valley
A. Oreana Subarea
B. Upper & Lower Valley Areas
74 White Plains
131 BUFFALO VALLEY (8)
129 BUENA VISTA VALLEY (9)
GRANITE SPRINGS SYSTEM (10)
78 Granite Springs Valley
79 Kumiva Valley
80 WINNEMUCCA LAKE VALLEY (11)
TRUCKEE SYSTEM (12)
81 Pyramid Lake Valley
82 Dodge Flat
83 Tracy Segment
84 Warm Springs Area
85 Spanish Springs Valley
86 Sun Valley
87 Truckee Meadows
88 Pleasant Valley
89 Washoe Valley
LEMMON VALLEY (13)
92 Lemmon Valley
A. Western Part
B. Eastern Part
93 Antelope Valley
100 COLD SPRING VALLEY (14)
FERNLEY SINK SYSTEM (15)
75 Bradys Hot Springs Area
76 Fernley Area
77 Fireball Valley
CARSON SYSTEM (16)
101 Carson Desert
A. Packard Desert
B. Labontan Valley
102 Churchill Valley
103 Dayton Valley
A. Carson Plains
B. Stagecoach Valley
104 Eagle Valley
105 Carson Valley
WALKER SYSTEM (17)
106 Antelope Valley
107 Smith Valley
108 Mason Valley
109 East Walker Area
110 Walker Lake Valley
A. Schurz Subarea
B. Lake Subarea
C. Hawthorne Whiskey Flat
121 Soda Spring Valley
B. Western Part
C. Central Part
DIXIE VALLEY SYSTEM (18)
124 Fairview Valley
125 Stingaree Valley
126 Cowkick Valley
127 Eastgate Valley Area
128 Dixie Valley
130 Pleasant Valley
132 Jersey Valley
133 EDWARDS CREEK VALLEY (19)
134 SMITH CREEK VALLEY (20)
123 RAWHIDE FLATS (21)
122 GABBS VALLEY (22)
136 MONTE CristO VALLEY (23)
SOUTH-CENTRAL MARSHES (24)
113 Fish Lake Valley
114 Teels Marsh Valley
117 Fish Lake Valley
118 Columbus Salt Marsh Valley
119 Rhodes Salt Marsh Valley
120 Garfield Flat
121 Soda Spring Valley *
B. Eastern Part
135 Lone Valley
137 Big Smoky Valley *
A. Tonopah Flat
B. Northern Part
141 Ralston Valley
142 Alkali Spring Valley
143 Clayton Valley
149 Stone Cabin Valley
138 GRASS VALLEY (25)
NORTHERN BIG SMOKY VALLEY (26) *
DIAMOND VALLEY SYSTEM (27)
139 Kobeh Valley
140 Monitor Valley
A. Northern Part
B. Southern Part
151 Antelope Valley (Eur & Nye)
152 Stevens Basin
153 Diamond Valley
DEATH VALLEY SYSTEM (28)
144 Lida Valley
145 Stonewall Flat
146 Sarcobatus Flat
147 Gold Flat
148 Cactus Flat
157 Kawich Valley
158 Emigrant Valley
A. Groom Lake Valley
B. Papoose Lake Valley
159 Yucca Flat
160 Frenchman Flat
161 Indian Springs Valley
162 Pahrump Valley
168 Three Lakes Valley (Northern Part)
169 Tikapoo Valley
A. Northern Part
B. Southern Part
173 Railroad Valley *
A. Southern Part
211 Three Lakes Valley (Southern Part)
225 Mercury Valley
226 Rock Valley
227 Fortymile Canyon
A. Jackass Flats
B. Buckboard Mesa
228 Oasis Valley
229 Crater Flat
230 Amargosa Desert
240 Chicago Valley
241 California Valley
242 Lower Amargosa Valley
243 Death Valley
244 Valjean Valley
245 Shadow Valley
NEWARK VALLEY SYSTEM (29)
154 Newark Valley
155 Little Smoky Valley *
A. Northern Part
B. Central Part
RAILROAD VALLEY SYSTEM (30)
150 Little Fish Lake Valley
155 Little Smoky Valley*
C. Southern Part
156 Hot Creek Valley
173 Railroad Valley *
B. Northern Part
170 PENOYER VALLEY (31)
INDEPENDENCE VALLEY SYSTEM (32)
177 Clover Valley
188 Independence Valley
RUBY VALLEY SYSTEM (33)
176 Ruby Valley
178 Butte Valley *
A. Northern Part
B. Southern Part
COLORADO SYSTEM (34)
164 Ivanpah Valley
A. Southern Part
B. Northern Part
165 Jean Lake Valley
166 Hidden Valley (South)
167 Eldorado Valley
171 Coal Valley
172 Garden Valley
174 Jakes Valley
175 Long Valley
180 Cave Valley
181 Dry Lake Valley
182 Delamar Valley
183 Lake Valley
198 Dry Valley
199 Rose Valley
200 Eagle Valley
201 Spring Valley
202 Patterson Valley
203 Panaca Valley
204 Clover Valley
205 Lower Meadow V Wash
206 Kane Springs Valley
207 White River Valley
208 Pahroc Valley
209 Pahranagat Valley
210 Coyote Spring Valley
212 Las Vegas Valley
215 Black Mountains Area
216 Garnet Valley
217 Hidden Valley (North)
218 California Wash
219 Muddy River Springs Area
220 Lower Moapa Valley
221 Tule Desert
222 Virgin River Valley
GOSHUTE VALLEY SYSTEM (35)
178 Butte Valley *
B. Southern Part
179 Steptoe Valley
187 Goshute Valley
163 MESQUITE VALLEY (36)
GREAT SALT LAKE DESERT SYSTEM (37)
251 Grouse Creek Valley
252 Pilot Valley
253 Deep Creek Valley
254 Snake Valley
255 Pine Valley
256 Wah Wah Valley
257 Tule Valley
258 Fish Springs Flat
259 Dugway-Government Creek Valley
260 Park Valley *
A. West Park Valley
261 Great Salt Lake Desert *
A. West Part
184 Spring Valley
185 Tippett Valley
186 Antelope Valley
A. Southern Part
B. Northern Valley
189 Thousand Springs Valley
A. Herrell-Brush Creek
B. Toano-Rock Spring
C. Rocky Butte Area
D. Montello-Contenden
191 Pilot Creek Valley
GREAT SALT LAKE SYSTEM (38)
260 Park Valley *
B. East Park Valley
261 Great Salt Lake Desert *
B. East Part
262 Tooele Valley
263 Rush Valley
264 Cedar Valley
265 Utah Valley Area
A. Goshen Valley
B. Southern Utah Valley
C. Northern Utah Valley
266 Northern Juab Valley
267 Salt Lake Valley
268 East Shore Area
269 West Shore Area
270 Skull Valley
271 Sink Valley
272 Cache Valley
273 Malad-Lower Bear River Area
274 Pocatello Valley
275 Blue Creek Valley
276 Tremont & the Rozel Flat
277 Promontory Mtns Area
278 Curlew Valley
279 Great Salt Lake
SEVIER LAKE SYSTEM (39)
280 Beryl-Enterprise Area
281 Parowan Valley
282 Cedar City Valley
283 Beaver Valley
284 Milford Area
285 Leamington Canyon
286 Pavant Valley
287 Sevier Desert

Figure 3.—Hydrographic areas

INTRODUCTION

This atlas is one of several reports that are products of an analysis of regional aquifer systems in the Great Basin of Nevada, Utah, and adjacent States. The Geological Survey program of regional aquifer-system analyses is a nationwide study of ground-water systems on a regional scale. The program is intended to establish a framework of geologic, hydrologic, and geochemical information for each regional aquifer system studied. As of 1985, studies have been started or completed in 19 areas. The scope of the Great Basin Regional Aquifer-System Analysis is outlined by Harrill and others (1983). The purpose of this report is to bring the findings of several studies together into a map report that discusses regional aspects of ground-water flow in the Great Basin, delineates the major ground-water flow systems, and briefly describes some of their characteristics.

This atlas is Chapter C of a three part series. Chapter A delineates and describes hydrogeologic units in the Great Basin region, and Chapter B shows the generalized distribution of hydraulic potential.

THE STUDY AREA

The Great Basin region discussed herein includes about 140,000 mi², largely in Nevada and Utah, but with smaller components in Arizona, California, Idaho, and Oregon (fig. 1). The study area generally conforms to the Great Basin region as shown by Stewart (1980, p. 7); however, it includes an area of southeastern Nevada that is tributary to the Colorado River, and it excludes some of the Great Basin parts of southeastern California and southern Oregon and the headwater areas of some of the principal drainages in the Sierra Nevada and Wasatch Range. The study area is characterized by generally north-trending mountain ranges more than 50 miles long, separated by alluvial and fluviolacustrine basins. Most mountain ranges are 5 to 15 miles wide and more than 1,000 to 5,000 feet above adjoining basins; basins are also 5 to 15 miles wide. The area has had a complex geologic history that includes major episodes of sedimentation, igneous activity, orogenic deformation, and continental rifting. Major tectonic activity beginning about 17 million years ago involved extensional faulting that formed the major basins and ranges which characterize the present physiography (Stewart, 1980, p. 5). Many of the structural basins are topographically closed; however, others are intercepted by river systems, which terminate in major lakes or sinks. The Great Salt Lake of Utah and Pyramid and Walker Lakes of Nevada are remnants of two large lakes that occupied much of the study area from more than 26,000 years ago to about 11,000 years ago (Benson, 1978, p. 313, and Arnow, 1984, p. 2). Lake Bonneville covered a maximum area of about 20,000 mi² in Utah, and Lake Lahontan covered a maximum of about 8,000 mi² in Nevada. About 12,000 mi² in the southeast part of the study area drains to the Colorado River; however, most of this drainage is in the form of interbasin ground-water flow rather than streamflow.

PREVIOUS WORK

Several investigators have delineated regional ground-water flow systems in parts of the Great Basin. The most extensive work has been in southern Nevada (Winograd, 1962; Winograd and Eakin, 1965; Blankennagel and Weir, 1973; and Winograd and Thordarson, 1975). Eakin (1966) described the White River flow system in southeast Nevada using ground-water budget techniques and hydraulic gradients. Mifflin (1968) evaluated flow systems throughout Nevada and identified 136 systems, separating them into two groups on the basis of the presence or absence of interbasin flow. Mifflin's work was augmented by Rush and others (1971) who prepared a map summarizing interbasin flows for 232 hydrographic areas in Nevada. Winograd and Friedman (1972) demonstrated that ratios of the isotopes deuterium (hydrogen-2) and hydrogen-1 in ground water are useful tools for tracing regional flow in the Great Basin. Gates and Kruer (1981) described areas thought to be associated with regional ground-water flow in western Utah. Bedinger, Harrill, and Thomas (1984) and Bedinger, Gates, and Stark (1984) have prepared flow-system maps of the Basin and Range Province in Nevada and Utah, which delineate the shallowest observed or local flow systems on the basis of the water-table configuration. Bedinger, Reed, and Langer (1984) delineated regional flow systems using a rationale devised for mapping the hydraulic head for regional ground-water flow.

HYDROGEOLOGIC UNITS

Because the Great Basin has had a complex geologic history, a wide variety of rock types and structural features are present. All rocks in the area can be grouped into three categories: basin fill with mostly moderate to high permeability, consolidated rocks with generally low permeability, and consolidated rocks with moderate and locally high permeability (fig. 2).

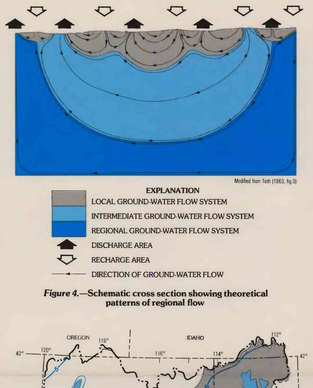
The basin fill consists primarily of unconsolidated and weakly consolidated deposits of gravel, sand, silt, and clay derived from adjacent mountains. Some volcanic rocks also are included in the fill. Thickness of the basin fill is generally between 2,000 and 5,000 feet, but exceeds 10,000 feet in the deepest basins. Sand and gravel deposits to depths of about 1,500 feet are the most productive aquifers, and supply almost all water withdrawn by existing major water users. The deep basin-fill deposits are unexplored in most places; however, the sparse information available indicates that they generally do not yield water as readily as the shallower deposits, and that some may contain water of poor quality.

The consolidated materials of generally low permeability include clastic sedimentary rocks, intrusive and extrusive igneous rocks, and metamorphic rocks, which generally do not transmit water readily unless they have been extensively fractured, as is the case for the area in figure 2 that includes highly fractured welded tuff. Another exception is basalt, which locally can be highly permeable. Carbonate rocks (limestone and dolomite) also can have a low permeability where they are unfractured or where fractures enlarged by solution are not common and not interconnected.

The bedrock of moderate to locally high permeability includes primarily carbonate rocks within which secondary permeability has been developed, probably by solution enlargement of fractures. These rocks underlie a large area in western Utah and eastern Nevada—the carbonate-rock province—where thick sequences of carbonate sediments were deposited in Paleozoic and early Mesozoic time. In this province, geologic formations of Paleozoic and early Mesozoic age range in aggregate thickness from 20,000 to 30,000 feet, and much of this sequence is composed of carbonate rocks. The carbonate-rock province is typified by complex interbasin regional flow systems that include both basin-fill and carbonate-rock aquifers. Regional structural features that might lead to the formation of significant fracturing and resultant secondary permeability include overthrust faulting, strike-slip shear zones, and low-angle extensional fault zones (detachment surfaces). Locally, high-angle normal or listric faults may also cause significant fracturing and resultant permeability.

HYDROGRAPHIC AREAS

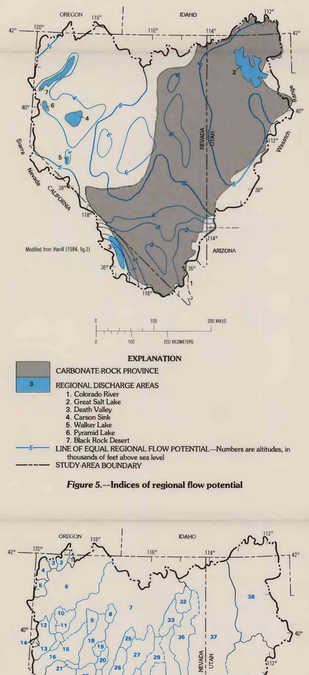
A total of 260 hydrographic areas or subareas are presently recognized within the Great Basin region (fig. 3). These areas usually are the basic units used by State and local agencies for planning and management of water resources, and they commonly include only one topographic basin. Most areas contain a basin-fill ground-water reservoir and include the drainage area in the adjacent mountains. Generally, the topographic and geologic features that constitute the geographic boundaries of hydrographic areas and subareas correspond to hydrologic boundaries; consequently, boundaries of larger ground-water flow systems generally correspond to boundaries of either hydrographic areas or subareas.



EXPLANATION

LOCAL GROUND-WATER FLOW SYSTEM
INTERMEDIATE GROUND-WATER FLOW SYSTEM
REGIONAL GROUND-WATER FLOW SYSTEM
DISCHARGE AREA
RECHARGE AREA
DIRECTION OF GROUND-WATER FLOW

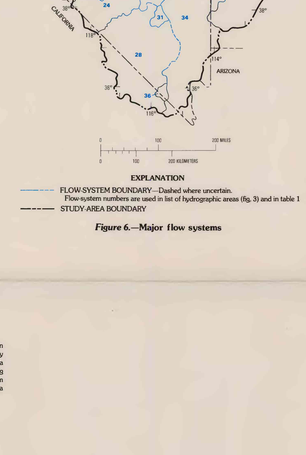
Figure 4.—Schematic cross section showing theoretical patterns of regional flow



EXPLANATION

CARBONATE-ROCK PROVINCE
3 REGIONAL DISCHARGE AREAS
1. Colorado River
2. Great Salt Lake
3. Death Valley
4. Carson Sink
5. Walker Lake
6. Pyramid Lake
7. Black Rock Desert
5 LINE OF EQUAL REGIONAL FLOW POTENTIAL—Numbers are altitudes, in thousands of feet above sea level
STUDY-AREA BOUNDARY

Figure 5.—Indices of regional flow potential



EXPLANATION

FLOW-SYSTEM BOUNDARY—Dashed where uncertain.
Flow-system numbers are used in list of hydrographic areas (fig. 3) and in table 1
STUDY-AREA BOUNDARY

Figure 6.—Major flow systems

BASIS FOR DEFINING FLOW SYSTEMS

Theoretical aspects of ground-water flow systems were examined in the 1960's by Toth (1962, 1963) and Freeze and Witherspoon (1966, 1967), who modeled hypothetical systems along vertical sections. Toth (1963, p. 4807) used a system of uniform permeability to demonstrate that, if the potential on the surface of the system differed from a linear gradient, circulation cells would form in response to local areas of recharge and discharge that corresponded with areas of localized high and low potential, respectively. Toth was able to identify three types of flow systems—local, intermediate, and regional—on the basis of the length of flow lines and whether flow passed beneath local areas of high or low potential. These types of systems are illustrated in figure 4. His findings that are most applicable to the Great Basin are (1) the concept that deep regional flow can pass beneath shallow local areas of high potential (ground-water divides) and (2) the example that variations in permeability within the system can cause appreciable discharge upgradient from the hydraulic terminus of the system.

Freeze and Witherspoon (1967, p. 626–632) evaluated the theoretical effects of subsurface permeability variations on regional ground-water flow. They developed a number of two-dimensional vertical sections that illustrate the diversity of possible regional flow patterns. One conclusion from their work is that when permeability in the deeper part of the system is increased, deep circulation of flow increases, discharge becomes concentrated near the terminus of the system, the vertical component of flow in the shallower parts of the system is increased, and circulation cells representing local or intermediate systems are less likely.

POTENTIAL FOR REGIONAL GROUND-WATER FLOW

Large ground-water flow systems are driven by hydraulic gradients that are continuous over long distances. These large systems generally are either the regional or intermediate types described in the preceding section. Bredehoeft and others (1982) reviewed the development of concepts relating to regional ground-water flow. One of the principles they listed as governing regional ground-water flow was that "differences in hydraulic head produced by topographic relief on the boundaries of the system are, in most instances, the driving force for the flow." This principle was used to evaluate the potential for regional flow in the Great Basin. The approach taken was to determine the lowest water-level altitude in the basin-fill deposits of each valley (which generally is only slightly below the topographically lowest point in the basin), and then to draw smooth contours through the point altitudes for each valley. Figure 5 shows indices of the regional flow potential obtained using this method. If deposits and rocks are sufficiently permeable, regional flow would be toward the Colorado River or major sinks. More detailed information on regional hydraulic gradients is presented by Thomas and Mason (1986). Bedinger, Reed, and Langer (1984) developed a rationale for mapping hydraulic head for regional flow and applied it to the Bonneville region of the Basin and Range Province. The resulting contours (Bedinger, Reed, and Langer, 1984, pl. 2) are quite similar to the indices of regional flow potential shown in figure 5.

MAJOR FLOW SYSTEMS IN THE GREAT BASIN

The general concepts outlined above were helpful in delineating the major flow systems in the study area. The "major flow system" is herein considered to be the local, intermediate, or regional system that is dominant—usually the one conveying the largest percentage of ground water in the area. Where consolidated rocks are permeable enough to afford significant identifiable hydraulic continuity on a regional scale, the local and intermediate types of systems were considered to be subsystems within major regional-flow systems. Where consolidated rocks have only low permeability and where water-budget studies do not indicate interbasin flow, regional flow was considered insignificant and the local and intermediate types of systems were considered to be the major flow systems. Where several basins are traversed by a major stream, and continuity between the basins is provided primarily by the stream, these interconnected basins are considered to constitute a complex regional-scale major flow system involving substantial interaction between ground water and surface water. The Humboldt, Truckee, Carson, and Walker River basins of Nevada are examples of this situation. A basic premise is that each flow system terminates in a discharge area. Consequently, if all of the terminal discharge areas are identified, the task of delineating a flow system is reduced to identifying areas that contribute flow toward the specified discharge area. For local systems consisting of only one basin or of a discharge area and one or more tributary basins, the task is simple, providing adequate hydrologic data are available; however, some of the larger regional systems extend for more than 100 miles and have flow paths that traverse as many as seven basins. In most instances, some water discharges at intermediate points along this path from local or intermediate flow systems; consequently, only some of the water flows all the way to the regional discharge area. Boundaries between systems are only generally defined; some may represent physical barriers to flow such as masses of intrusive rocks and others represent ground-water divides or divisions where an area of parallel flow ultimately diverges downgradient. Again, adequate hydrologic data are needed to precisely define flow-system boundaries. For much of the Great Basin, these data are not yet available.

A delineation of the major flow systems was made using the general procedures outlined in the preceding paragraphs and information published through 1984 on hydraulic heads, water budgets, and interbasin flows. This information was developed from data based toward the shallower parts of the system. Consequently, the boundaries of deeper major flow systems are delineated primarily on the basis of inference from information regarding the shallower part of the systems. The 39 major flow systems delineated are shown in figure 6 and, in detail, on sheet 2; some of their general characteristics are summarized in table 1.

The 39 flow systems identified in table 1 range in area from 30 to 18,000 mi². Sixteen are single-basin systems, the remainder are multibasin systems which may include as many as 34 hydrographic areas or subareas. Large multibasin flow systems outside of the carbonate-rock province are generally coincident with major river systems. Large multibasin systems within the carbonate-rock province typically have little surface flow; instead, they may contain ground-water flow paths more than 100 miles long that traverse several basins. Discharge from these systems is typically from large springs. This discharge generally is consumed by evapotranspiration in the vicinity of the spring. Altitudes of terminal discharge areas range from about 5,800 feet in high parts of central Nevada to a low of about 200 feet below sea level in Death Valley.

An alternate interpretation of the data for Utah is possible. The Sevier Lake, Great Salt Lake Desert, and Great Salt Lake systems could have been grouped into a large system with its terminus at the Great Salt Lake. There is some geologic and hydrologic evidence for regional continuity between these areas, but significant hydraulic gradients between the areas are virtually nonexistent; consequently, the volume of subsurface flow is relatively small. Moreover, each of the three areas has a distinctive hydrologic character. Consequently, this part of the region is described as three major flow systems with three terminal discharge areas.

In southern Nevada, the hydrologic character of parts of the western boundary of the Colorado system is not well understood and its location is uncertain. Additional information probably will allow significant refinement of this boundary.

REFERENCES CITED

Arnow, Ted, 1984, Water level and water quality changes in the Great Salt Lake, Utah, 1847–1983: U.S. Geological Survey Circular 913, 22 p.

Bedinger, M.S., Gates, J.S., and Stark, J.R., 1984, Maps showing ground-water units and withdrawal, Basin and Range Province, Utah: U.S. Geological Survey Water-Resources Investigations Report 83–4122–A, 2 sheets, scale 1:500,000.

Bedinger, M.S., Harrill, J.R., and Thomas, J.M., 1984, Maps showing ground-water units and withdrawal, Basin and Range Province, Nevada: U.S. Geological Survey Water-Resources Investigations Report 83-4119-A, 2 sheets, scale 1:500,000.

Bedinger, M.S., Reed, J.E., and Langer, W.H., 1984, Ground-water hydrology, *in* Bedinger, M.S., Sargent, K.A., and Langer, W.H., eds., Studies of geology and hydrology in the Basin and Range Province, southwestern United States, for isolation of high-level radioactive waste—characterization of the Bonneville region, Utah and Nevada: U.S. Geological Survey Open-File Report 84–744, p. 69–102.

Bensen, L.V., 1978, Fluctuation in the level of pluvial Lake Lahontan during the last 40,000 years: Quaternary Research, v. 9, p. 300–318.

Blankennagel, R.K., and Weir, J.E., Jr., 1973, Geohydrology of the eastern part of Pahute Mesa, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Professional Paper 712-B, 35 p.

Bredehoeft, J.D., Back, W., and Harshaw, B.B., 1982, Regional ground-water flow concepts in the United States: historical perspective, *in* Narasimhan, T.N., ed., Recent trends in hydrogeology: Geological Society of America Special Paper 189, p. 297–316.

Eakin, T.E., 1966, A regional interbasin ground-water system in the White River area, southeastern Nevada: Water Resources Research, v. 2, no. 2, p. 251–271.

Freeze, A.R., and Witherspoon, P.A., 1966, Theoretical analysis of regional ground-water flow: 1. Analytical and numerical solutions to the mathematical model: Water Resources Research, v. 2, no. 4, p. 641–656.

_____ 1967, Theoretical analysis of regional groundwater flow: 2. Effect of water-table configurations and subsurface permeability variation: Water Resources Research, v. 3, no. 2, 623–634.

Gates, J.S., and Kruer, S.A., 1981, Hydrologic reconnaissance of the southern Great Salt Lake Desert and summary of the hydrology of west central Utah: Utah Department of Natural Resources, Technical Publication 71, 55 p.

Harrill, J.R., 1984, Great Basin aquifer systems, Nevada–Utah—an overview, *in* Replogle, J.A., and Renard, K.G., eds., Water today and tomorrow: Specialty Conference, Irrigation and Drainage Division, American Society of Civil Engineers, July 1984, Proceedings, p. 590–597.

Harrill, J.R., Welch, A.H., Prudic, D.E., Thomas, J.M., Carman, R.L., Plume, R.W., Gates, J.S., and Mason, J.L., 1983, Aquifer systems in the Great Basin Region of Nevada, Utah, and adjacent states—a study plan: U.S. Geological Survey Open-File Report 82-445, 49 p.

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: University of Nevada, Desert Research Institute Technical Report H-W 4, 89 p.

Plume, R.W., and Carlton, S.C., (1988), Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic Investigations Atlas HA–694–B, 2 sheets.

Rush, F.E., Scott, B.R., Van Denburgh, A.S., and Vasey, B.J., compilers, 1971, State of Nevada water resources and inter-basin flows: Nevada Division of Water Resources map, scale 1:750,000.

Stewart, J.H., 1980, Geology of Nevada—a discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Thomas, J.M., and Mason, J.L., (1986), Ground-water levels in the Great Basin Region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic Investigations Atlas HA–694–B, 2 sheets.

Toth, J., 1962, A theory of groundwater motion in small drainage basins in central Alberta, Canada: Journal of Geophysical Research, v. 67, no. 11, p. 4375–4387.

_____ 1963, A theoretical analysis of groundwater flow in small drainage basins: Journal of Geophysical Research, v. 68, no. 16, p. 4795–4812.

Winograd, I.J., 1962, Interbasin movement of ground water at the Nevada Test Site, Nevada, *in* Short papers in the geologic and hydrologic sciences: U.S. Geological Survey Professional Paper 450-C, p. C108–C111.

Winograd, I.J., and Eakin, T.E., 1965, Interbasin movement of ground water in south-central Nevada—the evidence in Abstracts for 1964: Geological Society of America Special Paper 82, p. 227.

Winograd, I.J., and Friedman, Irving, 1972, Deuterium as a tracer of regional ground-water flow, southern Great Basin, Nevada and California: Geological Society of American Bulletin, v. 83, no. 12, p. 3691–3708.

Winograd, I.J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada–California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712-C, 126 p.

CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to International System (metric) units by using the following factors:

Multiply	By	To obtain
Feet (ft)	0.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi²)	2.590	Square kilometers (km²)

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

TABLE 1—*CHARACTERISTICS OF MAJOR FLOW SYSTEMS*

Map No.: Major ground-water flow systems shown in figure 6.
Ground-water recharge: Natural recharge. Excludes irrigation return flows and other man-induced forms of recharge. Primarily a compilation of published estimates. Where information was not available, rough estimates were made for this compilation.
Ground-water storage: Represents water stored in basin-fill reservoirs. Number is the amount of water (in acre-feet) that would be released from storage if the water table in a given area were uniformly lowered 1 foot. Storage for a given interval of dewatering can be estimated by multiplying the per-foot values by the total interval, in feet, to be dewatered. Volumes estimated may include some water of poor quality. Does not include water stored in consolidated rock. Values are based primarily on published estimates. Where information was not available, rough estimates were made for this compilation using approximate areas of saturated basin fill and an average specific-yield value of 10 percent.
References: Letters refer to report series; number indicates the specific report number (see accompanying list). B, Water-Resources Bulletin, Nevada Department of Conservation and Natural Resources; OF, Open-File Report, U.S. Geological Survey; P, Professional Paper, U.S. Geological Survey; R, Water-Resources Reconnaissance Report, Nevada Department of Conservation and Natural Resources; TP, Technical Publication, Utah Department of Natural Resources; W, Water-Supply Paper, U.S. Geological Survey; WRI, Water-Resources Investigations Report, U.S. Geological Survey. See accompanying list for more complete citation.

Map No.	Flow-system name	Area (square miles)	Number of hydrographic areas or subareas included	Ground-water recharge (acre-feet)	Ground-water storage (acre-feet per foot)	System characteristics	References
1	Continental Lake system	409	2	16,000	6,100	Consolidated rock is primarily volcanic. Flow between basins is primarily in surface streams. Flow in consolidated rock not determined; small if any. Altitude of terminus at Continental Lake about 4,213 ft.	R22
2	Virgin Valley	496	1	7,000	420	Consolidated rock is primarily volcanic. Minor surface-water flow to Continental Lake system, but for purposes of this study, area is considered a single-basin system (lowest point in area is at altitude of about 4,805 ft). Flow in consolidated rock not determined; small if any.	R22
3	Swan Lake Valley	226	1	6,700	1	Consolidated rock is primarily volcanic. Hydrologic system is dominated by surface-water flow. No large basin-fill reservoir is present. Altitude of terminus at Swan Lake Reservoir is about 5,635 ft.	R15
4	Long Valley	729	4	12,000	12,000	Consolidated rock is primarily volcanic. Continuity between areas is primarily by ground-water flow in alluvium and shallow consolidated rock. Altitude of terminus at Massacre Lake is about 5,620 ft.	R15
5	Duck Lake Valley	533	1	9,000	5,600	Consolidated rock is primarily volcanic. In wet years, surface-water flow to adjacent Surprise Valley, Calif. Playa altitude is about 4,680 ft.	R17
6	Black Rock Desert system	9,100	18	170,000	230,000	Consolidated rock is primarily volcanic and intrusive. Black Rock Desert is a regional ground-water sink (playa altitude is about 3,965 ft).	B31, B34, B37, B39, R6, R7, R11, R20, R44
7	Humboldt system	16,800	34	500,000	330,000	Consolidated rock is predominantly volcanic and siliceous sedimentary in lower basin, and clastic sedimentary, metamorphic, volcanic, and carbonate in upper basin. Hydrologic system is dominated by Humboldt River. Eleven basins are along mainstem; remaining basins are tributary areas. Regional discharge is to Humboldt Sink (altitude about 3,890 ft), with surface-water overflow to Carson Sink.	B32, B39, OF81-635, P493-D, R2, R19, R29, R31, B32, R35, B37, W1581, W1754, W1795, W1816, W1816,	
8	Buffalo Valley	504	1	12,000	17,000	Consolidated rock is primarily siliceous sedimentary and volcanic. Is an arid single-basin system (playa altitude about 4,600 ft).	B32
9	Buena Vista	742	1	10,000	24,000	Consolidated rock is primarily fine-grained marine and continental clastic sedimentary, with some volcanic and intrusive. Is an arid single-basin system (playa altitude about 4,035 ft).	B13
10	Granite Springs system	1,300	2	4,500	36,000	Consolidated rock is primarily volcanic, and fine-grained marine and continental clastic sedimentary, with some intrusive. Flow between basins is through fractured non-carbonate consolidated rocks. Discharge area is Granite Springs Valley playa (altitude about 3,698 ft).	R55
11	Winnemucca Lake Valley	371	1	2,900	9,600	Consolidated rock is primarily volcanic and intrusive. Is considered a single-basin system, but when Pyramid Lake was at higher stages this area received intermittent surface-water inflow from Truckee River. Altitude of Winnemucca Lake playa is about 3,770 ft.	R57, W1539-C
12	Truckee system	1,700	9	73,000	36,000	Consolidated rock is primarily volcanic, with some areas of marine and continental metasediments and metavolcanics. System is dominated by the Truckee River, which is supplied by runoff from Sierra Nevada. Interbasin flow is primarily by surface water. Terminus of system is Pyramid Lake, except for water diverted to the Carson system. Lake altitude has fluctuated between a historical high of 3,878 ft in 1891 and a historical low of 3,784 ft in 1967.	OF84–433, OF84–465, R41, B43, R57, W1779–S
13	Lemmon Valley	111	3	1,800	4,100	Consolidated rock is primarily marine and continental metasediments, intrusive, and some volcanics. Flow between basins is controlled by faults. Ground-water outflow occurs, probably through fractured granitic rock. Discharge is primarily by evapotranspiration in and near two playa areas. Altitude of lowest playa is about 4,915 ft.	B42, OF80–1123 B43,
14	Cold Spring Valley	30	1	900	450	Consolidated rock is primarily marine and continental metasediments, with some volcanics. Is a single-basin system. Significant sur