U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

HYDROLOGIC INVESTIGATIONS ATLAS HA–694–E
Schaefer, D.H., 1996, Distribution of oil and natural-gas wells in relation to
ground-water flow systems in the Great Basin region of Nevada, Utah, and adjacent States

CONVERSION FACTORS

Multiply	By	To obtain
barrel (bbl)	0.1590	cubic meter
barrel (bbl)	43.23	gallon
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

INTRODUCTION

This map publication is one of several in a series concerning various aspects of the ground-water hydrology of the Great Basin in Nevada, Utah, and adjacent States. One report in the series describes the hydrogeologic framework of the Great Basin (Plume and Carlton, 1988). Another shows the ground-water levels for the aquifer systems of the Great Basin (Thomas and others, 1986). A third report in the series describes the regional ground-water flow patterns in the Great Basin (Harrill and others, 1988).

The Great Basin as discussed here includes about 140,000 mi^2, largely in Nevada and Utah but with smaller components in Arizona, California, Idaho, and Oregon (fig. 1). The study area, identical to the area described by Harrill and others (1988), is characterized by generally north-trending mountain ranges more than 50 mi long, separated by alluvial and fluviolacustrine basins. Most mountain ranges are 5 to 15 mi wide and rise 1,000 to 5,000 ft above adjoining basin floors. Many of the structural basins are topographically closed; however, others are interconnected by several river systems that terminate in major lakes or sinks. The area has had a complex geologic history that includes major episodes of sedimentation, igneous activity, orogenic deformation, and continental rifting.

The area includes several oil-producing fields in Nevada and Utah. Oil production in Nevada was approximately 3.4 million bbl in 1991 (Nevada Bureau of Mines and Geology, 1993). Several studies in recent years have shown a relation between ground-water movement and the occurrence of hydrocarbons. An early report by Hubbert (1953) and more recent reports by Tóth (1980, 1988) and by Garven (1989) indicate that ground-water flow may act as the driving force behind oil migration in certain areas. Garven describes conditions where regional flow in Upper Devonian carbonate rock and Lower Cretaceous sandstone in a western Canada sedimentary basin may have been responsible for the formation of an oil field containing more than 2,700 billion bbl of oil. In this conceptual model, ground water descends vertically from the recharge area. Soluble hydrocarbons are leached near deeply buried source rocks and transported by ground-water flow through regional aquifers. The hydrocarbons then accumulate in the discharge area of the flow system. Several key factors, such as the presence of heat sources and of forms of hydrocarbons capable of migration, must be in effect for this sequence of events to take place (Tóth, 1988, p. 485). Knowing that the occurrence and movement of hydrocarbons in some areas of the Great Basin can be due to regional ground-water flow could prove useful in future hydrocarbon exploration.

The objective of the study described herein is to illustrate the possible relation between ground-water flow and the location of oil and natural gas within the regional flow systems of the Great Basin. The study area for this project is the Great Basin of Nevada and western Utah; however, much of the data collection was concentrated in Railroad Valley, in east-central Nevada. This valley, the most productive oil area of the State, yielded about 2.86 million bbl of oil in 1991 (Nevada Bureau of Mines and Geology, 1993).

This study included compiling all available data on hydrocarbon exploration and production wells drilled in the Great Basin and on hydrocarbon shows detected while drilling other wells. Garside and others (1988) compiled an extensive collection of hydrocarbon-related data for the State of Nevada. Other data were obtained in 1992 from State agencies (Nevada Bureau of Mines and Geology and Nevada Department of Minerals). Well data for Nevada were current as of April 1992. Well-location and well-status data for Utah were collected by Brady (1984) and were current as of 1982. Also collected was information on the locations of oil seeps in the study area and water wells that had an indication of hydrocarbons. The hydrocarbon data were integrated with hydrologic and geologic information to construct a map that shows the spatial relation of hydrocarbon exploration and production wells to regional and local ground-water flow systems. The question of whether ground-water flow is the motive force behind oil and gas migration in the Great Basin is not addressed further herein, but future directions of research to test this theory may become apparent.

HYDROGEOLOGIC UNITS

The Great Basin has had a complex geologic history resulting in a variety of rock types and structural features (Jennings, 1977; Walker, 1977; Bond, 1978; Stewart and Carlson, 1978; Hintze, 1980). Surficial geology in the area comprises three categories: basin fill characterized by mostly moderate to high permeability, consolidated rocks characterized by generally low permeability, and consolidated rocks characterized by moderate and locally high permeability.

The basin fill consists primarily of unconsolidated and semiconsolidated deposits of gravel, sand, silt, and clay derived from adjacent mountain ranges. Thickness of the basin fill generally ranges from 2,000 to 5,000 ft but exceeds 10,000 ft in the deeper basins. The basin fill has mostly moderate to high permeability. Information on the hydrologic properties of the deeper basin-fill deposits is limited, although the deeper deposits generally are assumed to have lower permeabilities and poorer water quality than the shallower deposits. In most basins, the uppermost 1,500 ft of basin fill forms the most productive aquifer.

The consolidated materials of generally low permeability include clastic sedimentary rocks, intrusive and extrusive igneous rocks, and metamorphic rocks, generally none of which transmit water readily unless extensively fractured. Basalt can have localized zones characterized by high permeability. Carbonate rocks, such as limestone and dolomite, generally have low permeability where they are unfractured or where fractures enlarged by solution are uncommon or not interconnected.

Bedrock characterized by moderate to locally high permeability includes 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 known as the carbonate-rock province, where thick sequences of carbonate sediments were deposited in Paleozoic and early Mesozoic time. In this province, the Paleozoic and early Mesozoic sequence ranges in aggregate thickness from 20,000 to 30,000 ft and consists mostly of carbonate rocks. The carbonate-rock province is typified by complex interbasin systems of regional ground-water flow that include both basin-fill and carbonate-rock aquifers. Regional structural features that may account for significant local fracturing and resultant secondary permeability include overthrust zones, strike-slip shear zones, and low-angle fault zones (detachment surfaces). Locally, high-angle normal or listric faults may also cause significant fracturing and resultant permeability. The overall distribution of hydrogeologic units throughout the Great Basin is shown on Plume and Carlton's (1988) map, and the hydrogeology also was described by Dettinger and others (1990, 1995) and by Plume (1996).

GROUND-WATER FLOW SYSTEMS

Large ground-water flow systems are driven by hydraulic gradients that are continuous over long distances. These large systems are of either the regional or intermediate type (Harrill and others, 1988). A major flow system is considered to be local, intermediate, or regional depending upon what percentage of an area's ground water it conveys. Where consolidated rocks are permeable enough to allow hydraulic continuity on a regional scale, the local and intermediate flow systems are considered to be subsystems of the regional flow system. Where consolidated rocks have a low permeability and where no interbasin flow is evident from flow-system budgets, local and intermediate ground-water flow systems are thought to predominate.

Harrill and others (1988) delineated 39 flow systems in the Great Basin that range in area from 30 to 18,000 mi^2. Of these, 16 are single-basin systems and 23 are multibasin systems. One of the multibasin systems includes as many as 34 hydrographic areas and subareas. Large, multibasin flow systems outside the carbonate-rock province are generally coincident with major river systems.

A good example of a regional ground-water flow system in the Great Basin is the White River system (figs. 1 and 2), described by Thomas (1988) and Dettinger (1989). Much of the ground water in the White River system is recharged in the Ely area of eastern Nevada (fig. 2). Additional recharge feeds the system near the center and also in the southern part. Ground water discharges at various locations throughout the flow system but primarily at several regional springs in White River and Pahranagat Valleys; some recharge is consumed by evapotranspiration in many parts of the White River system. Ground water ultimately discharges in Moapa Valley through springs along the Muddy River, in the southern part of the flow system.

In the Great Basin, deep ground water flows through the carbonate-rock aquifer and discharges through regional springs (Mifflin, 1968). These springs result from the combined influence of topography and geologic factors such as rock type and structure. Several regional springs in the White River Valley apparently are related to structural constriction of the carbonate-rock aquifer, which forces ground-water flow to the surface. Plume (1988) used aeromagnetic modeling to support this interpretation.

OIL AND NATURAL-GAS WELLS AND GROUND-WATER FLOW

In the White River flow system, several of the hydrocarbon test wells are just upgradient from some of the regional springs. Compared to the overall distribution of test wells in the White River flow system, hydrocarbon shows tend to be concentrated at these locations (fig. 1). This distribution may result from a restriction in the ground-water flow system that not only aids in the formation of the regional springs but may also act as a barrier to hydrocarbon migration. Plume's (1988) aeromagnetic modeling indicated that the ground water can be affected by geologic barriers, but no definitive proof exists for the possible constriction of hydrocarbon migration in this area.

Several large, producing oil fields are on the east edge of Railroad Valley (fig. 1). At depth the Grant Range is composed primarily of crystalline basement rock, which acts as a barrier to easterly ground-water flow and possibly to easterly oil migration. Railroad Valley itself is the location of numerous springs that form a terminal discharge zone for the Railroad Valley regional flow system.

REFERENCES CITED

Bond, J.G., compiler, 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.

Brady, B.T., 1984, Selected geologic and hydrologic characteristics of the Basin and Range Province, Western United States—Coal, oil and gas wells, seeps and tar sandstone occurrences: U.S. Geological Survey Miscellaneous Investigations Map I–1522–E, scale 1:2,500,000.

Dettinger, M.D., 1989, Distribution of carbonate-rock aquifers in southern Nevada and the potential for their development—Summary of findings, 1985–88: Carson City, Nev., Program for the Study and Testing of Carbonate-Rock Aquifers in Eastern and Southern Nevada, Summary Report no. 1, 37 p.

Dettinger, M.D., Harrill, J.R., and Schmidt, D.L., 1995, Distribution of carbonate-rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah: U.S. Geological Survey Water-Resources Investigations Report 91–4146, 100 p.

Dettinger, M.D., Schaefer, D.H., and Thomas, J.M., 1990, Tertiary-age extensional patterns as a geologic framework for interpreting regional ground-water flow in the eastern Great Basin, Nevada and Utah [abs.], in Flanigan, D.M.H., Garside, L.J., and Hansen, Mike, eds., Oil fields and geology of the Pine Valley, Eureka County area, Nevada: Reno, Nev., Nevada Petroleum Society Inc., 1990 Fieldtrip Guidebook, p. 55.

Garside, L.J., Hess, R.H., Fleming, K.L., and Weimer, B.S., 1988, Oil and gas developments in Nevada: Nevada Bureau of Mines and Geology Bulletin 104, 136 p.

Garven, Grant, 1989, A hydrogeologic model for the formation of the giant oil sands deposit of the western Canada sedimentary basin: American Journal of Science, v. 289, p. 105–166.

Harrill, J.R., Gates, J.S., and Thomas, J.M., 1988, Major ground-water flow systems in the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Hydrologic Investigations Atlas HA–694–C, 2 map sheets, scale 1:1,000,000.

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 82–455, 49 p.

Hintze, L.F., compiler, 1980, Geologic map of Utah: Utah Geological and Mineral Survey, scale 1:500,000.

Hubbert, M.K., 1953, Entrapment of petroleum under hydrodynamic conditions: American Association of Petroleum Geologists Bulletin 37, p. 1954–2026.

Jennings, C.W., compiler, 1977, Geologic map of California: California Division of Mines and Geology Geologic Data Map 2, scale 1:750,000.

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: University of Nevada Desert Research Institute Technical Report Series H–W, no. 4, 112 p.

Nevada Bureau of Mines and Geology, 1993, The Nevada mineral industry 1992: University of Nevada Mackay School of Mines Special Publication MI–1992, 52 p.

Plume, R.W., 1988, Use of aeromagnetic data to define boundaries of a carbonate-rock aquifer in east-central Nevada, in Subitzky, Seymour, ed., Selected papers in the hydrologic sciences: U.S. Geological Survey Water-Supply Paper 2330, p. 1–10.

-----1996, Hydrogeologic framework of the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Professional Paper 1409–B, 64 p.

Plume, R.W., and Carlton, S.M., 1988, Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Hydrologic Investigations Atlas HA–694–A, scale 1:1,000,000.

Stewart, J.H., and Carlson, J.E., compilers, 1978, Geologic map of Nevada: U.S. Geological Survey, scale 1:500,000.

Thomas, J.M., 1988, Delineation of regional ground-water flow systems in southern Nevada using isotopic and chemical data [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A363.

Thomas, J.M., Mason, J.L., and Crabtree, J.D., 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 map sheets, scale 1,000,000.

Tóth, Jozsef, 1980, Cross-formational gravity-flow of groundwater—A mechanism of the transport and accumulation of petroleum (the generalized hydraulic theory of petroleum migration), in Roberts, W.H., and Cordell, R.J., eds., Problems of petroleum migration: American Association of Petroleum Geologists, Studies in Geology 10, p. 121–167.

-----1988, Ground-water and hydrocarbon migration, in Back, W., Rosenshein, J.S., and Seaber, P.R., eds., Hydrogeology: Geological Society of America, The Geology of North America, v. O–2, p. 485–502.

Walker, G.W., compiler, 1977, Geologic map of Oregon east of the 121st meridian: U.S. Geological Survey Miscellaneous Investigations Map I–902, scale 1:500,000.

Base from U.S. Geological Survey digital data, 1:100,000, 1987
Lambert Conformal Conic projection
Standard parallels 33° and 45°, central meridian –117°

Table 1.—**Hydrographic areas**

[Numbers and names correspond to those used by Harrill and others (1988) and are used to label the areas in figure 1]

2	Continental Lake Valley	147	Gold Flat
3	Gridley Lake Valley	148	Cactus Flat
4	Virgin Valley	149	Stone Cabin Valley
7	Swan Lake Valley	150	Little Fish Lake Valley
8	Massacre Lake Valley	151	Antelope Valley (Eureka and Nye)
9	Long Valley	152	Stevens Basin
12	Mosquito Valley	153	Diamond Valley
15	Boulder Valley	154	Newark Valley
16	Duck Lake Valley	155	Little Smoky Valley[1]
19	Dry Valley	156	Hot Creek Valley
20	Sano Valley	157	Kawich Valley
21	Smoke Creek Desert	158	Emigrant Valley[1]
22	San Emidio Desert	159	Yucca Flat
23	Granite Basin	160	Frenchman Flat
24	Hualapai Flat	161	Indian Springs Valley
25	High Rock Lake Valley	162	Pahrump Valley
26	Mud Meadow	163	Mesquite Valley
27	Summit Lake Valley	164	Ivanpah Valley[1]
28	Black Rock Desert	165	Jean Lake Valley
29	Pine Forest Valley	166	Hidden Valley (South)
30	Kings River Valley[1]	167	Eldorado Valley
31	Desert Valley	168	Three Lakes Valley (Northern Part)
32	Silver State Valley	169	Tikapoo Valley[1]
33	Quinn River Valley[1]	170	Penoyer Valley
42	Marys River Area	171	Coal Valley
43	Starr Valley Area	172	Garden Valley
44	North Fork Area	173	Railroad Valley[1]
45	Lamoille Valley	174	Jakes Valley
46	South Fork Area	175	Long Valley
47	Huntington Valley	176	Ruby Valley
48	Tenmile Creek Area	177	Clover Valley
49	Elko Segment	178	Butte Valley[1]
50	Susie Creek Area	179	Steptoe Valley
51	Maggie Creek Area	180	Cave Valley
52	Marys Creek Area	181	Dry Lake Valley
53	Pine Valley	182	Delamar Valley
54	Crescent Valley	183	Lake Valley
55	Carico Lake Valley	184	Spring Valley
56	Upper Reese River Valley	185	Tippett Valley
57	Antelope Valley	186	Antelope Valley[1]
58	Middle Reese River Valley	187	Goshute Valley
59	Lower Reese River Valley	188	Independence Valley
60	Whirlwind Valley	189	Thousand Springs Valley[1]
61	Boulder Flat	191	Pilot Creek Valley
62	Rock Creek Valley	198	Dry Valley
63	Willow Creek Valley	199	Rose Valley
64	Clovers Area	200	Eagle Valley
65	Pumpernickel Valley	201	Spring Valley
66	Kelly Creek Area	202	Patterson Valley
67	Little Humboldt Valley	203	Panaca Valley
68	Hardscrabble Area	204	Clover Valley
69	Paradise Valley	205	Lower Meadow Valley Wash
70	Winnemucca Segment	206	Kane Springs Valley
71	Grass Valley	207	White River Valley
72	Imlay Area	208	Pahroc Valley
73	Lovelock Valley[1]	209	Pahranagat Valley
74	White Plains	210	Coyote Spring Valley
75	Bradys Hot Springs Area	211	Three Lakes Valley (Southern Part)
76	Fernley Area	212	Las Vegas Valley
77	Fireball Valley	215	Black Mountains Area
78	Granite Springs Valley	216	Garnet Valley
79	Kumiva Valley	217	Hidden Valley (North)
80	Winnemucca Lake Valley	218	California Wash
81	Pyramid Lake Valley	219	Muddy River Springs Area
82	Dodge Flat	220	Lower Moapa Valley
83	Tracy Segment	221	Tule Desert
84	Warm Springs Area	222	Virgin River Valley
85	Spanish Springs Valley	225	Mercury Valley
86	Sun Valley	226	Rock Valley
87	Truckee Meadows	227	Fortymile Canyon[1]
88	Pleasant Valley	228	Oasis Valley
89	Washoe Valley	229	Crater Flat
92	Lemmon Valley[1]	230	Amargosa Desert
93	Antelope Valley	240	Chicago Valley
100	Cold Spring Valley	241	California Valley
101	Carson Desert[1]	242	Lower Amargosa Valley
102	Churchill Valley	243	Death Valley
103	Dayton Valley[1]	244	Valjean Valley
104	Eagle Valley	245	Shadow Valley
105	Carson Valley	251	Grouse Creek Valley
106	Antelope Valley	252	Pilot Valley
107	Smith Valley	253	Deep Creek Valley
108	Mason Valley	254	Snake Valley
109	East Walker Area	255	Pine Valley
110	Walker Lake Valley[1]	256	Wah Wah Valley
113	Huntoon Valley	257	Tule Valley
114	Teels Marsh Valley	258	Fish Springs Flat
117	Fish Lake Valley	259	Dugway–Government Creek Valley
118	Columbus Salt Marsh Valley	260	Park Valley[1]
119	Rhodes Salt Marsh Valley	261	Great Salt Lake Desert[1]
120	Garfield Flat	262	Tooele Valley
121	Soda Spring Valley[1]	263	Rush Valley
122	Gabbs Valley	264	Cedar Valley
123	Rawhide Flats	265	Utah Valley Area[1]
124	Fairview Valley	266	Northern Juab Valley
125	Stingaree Valley	267	Salt Lake Valley
126	Cowkick Valley	268	East Shore Area
127	Eastgate Valley Area	269	West Shore Area
128	Dixie Valley	270	Skull Valley
129	Buena Vista Valley	271	Sink Valley
130	Pleasant Valley	272	Cache Valley
131	Buffalo Valley	273	Malad–Lower Bear River Area
132	Jersey Valley	274	Pocatello Valley
133	Edwards Creek Valley	275	Blue Creek Valley
134	Smith Creek Valley	276	Hansel and Northern Rozel Flat
135	Ione Valley	277	Promontory Mountains Area
136	Monte Cristo Valley	278	Curlew Valley
137	Big Smoky Valley[1]	279	Great Salt Lake
138	Grass Valley	280	Beryl–Enterprise Area
139	Kobeh Valley	281	Parowan Valley
140	Monitor Valley[1]	282	Cedar City Valley
141	Ralston Valley	283	Beaver Valley
142	Alkali Spring Valley	284	Milford Area
143	Clayton Valley	285	Leamington Canyon
144	Lida Valley	286	Pavant Valley
145	Stonewall Flat	287	Sevier Desert
146	Sarcobatus Flat		

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[1] Includes two or more subareas, which may be in different major flow systems.

EXPLANATION

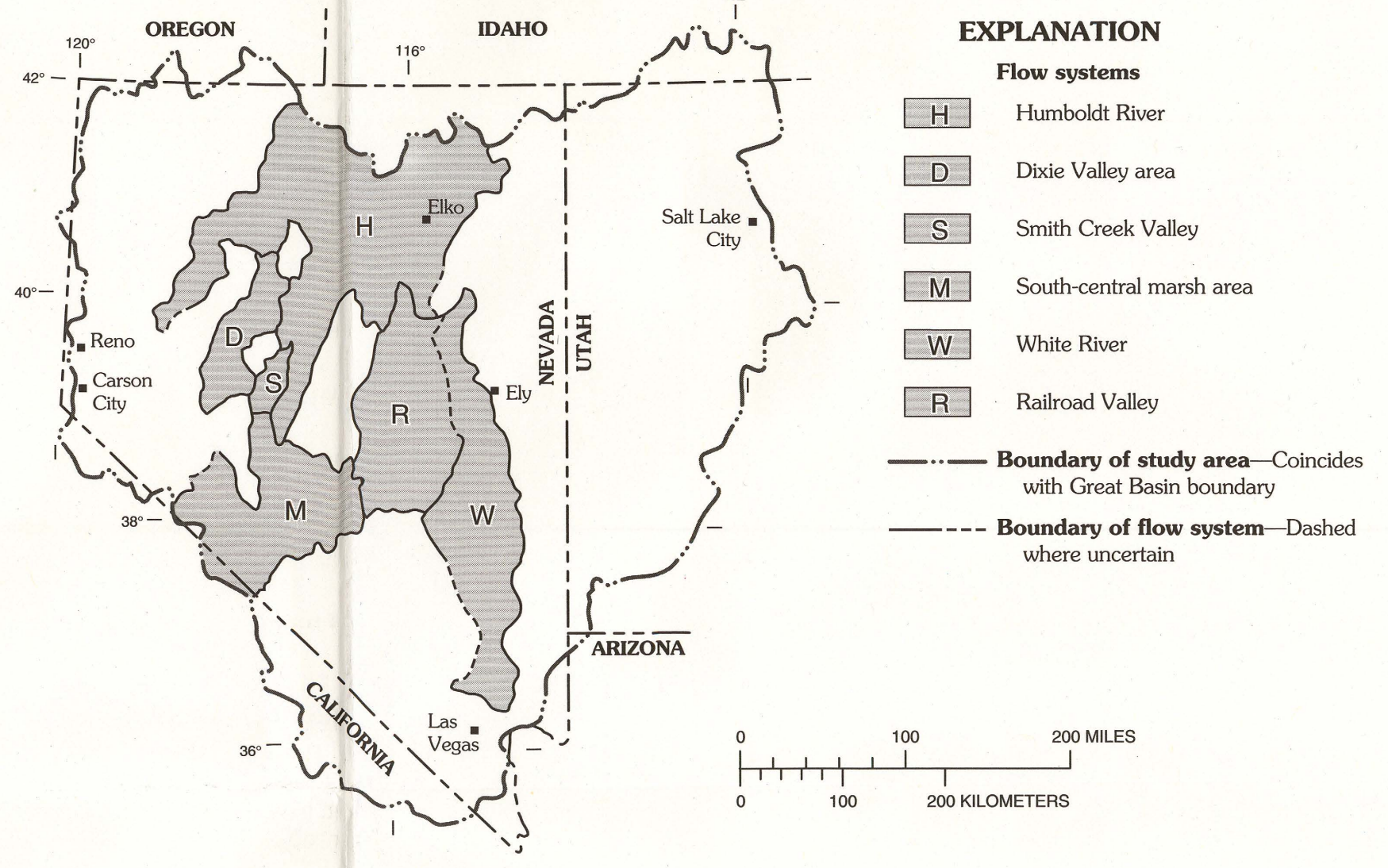
☐	**Basin fill (Quaternary to Tertiary)**—Unconsolidated to consolidated sedimentary deposits. Includes some tuff and interbedded lava flows
▨	**Consolidated rock (Tertiary and older)**
🟥	**Oil field**—Includes many wells not shown individually
— —	**Boundary of carbonate-rock province**
—······	**Major flow-system boundary**—Dotted where uncertain. Coincident with hydrographic-area or -subarea boundary
—··—	**Hydrographic-area boundary within major flow systems**—See table 1 and figure 2
←	**General direction of ground-water flow in basin-fill deposits**
⇐	**Flow across hydrographic-area or -subarea boundary**—Solid arrow indicates flow primarily through basin fill; dashed arrow indicates flow primarily through permeable consolidated rock
—··—	**Boundary of study area**—Coincides with Great Basin boundary
●	**Large spring**—In Utah and most of Nevada, springs having discharge generally greater than 1,000 gallons per minute; in more arid parts of Nevada and in California, regionally significant springs having discharges greater than 200 gallons per minute
●	**Producing oil well**—Approximately located
	Test wells
⊕	No oil or gas shows
⊕	Oil show
☼	Gas show
☼	Oil and gas shows
■	**Oil show in water well or spring**—Approximately located
□	**Oil seep or hydrocarbon occurrence**—Approximately located

SCALE 1:1,000,000

20 0 20 40 60 80 100 MILES

20 0 20 40 60 80 100 KILOMETERS

Figure 1.—Distribution of oil and gas wells in relation to ground-water flow systems.



EXPLANATION

Flow systems

H	Humboldt River
D	Dixie Valley area
S	Smith Creek Valley
M	South-central marsh area
W	White River
R	Railroad Valley
—··—	**Boundary of study area**—Coincides with Great Basin boundary
—---	**Boundary of flow system**—Dashed where uncertain

Figure 2.—Index map, showing examples of ground-water flow systems in study area (modified from Harrill and others, 1983, fig. 3): single-basin system (Smith Creek Valley flow system), multibasin system linked by saturated basin fill (Dixie Valley area and Humboldt River flow system), multibasin system linked by fracture zones (south-central marsh area flow system), and deep regional system with ground water flowing through both basin fill and adjacent and underlying permeable rock (White River and Railroad Valley flow systems).

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Geology modified from Plume and Carlton (1988)

DISTRIBUTION OF OIL AND NATURAL-GAS WELLS IN RELATION TO GROUND-WATER FLOW SYSTEMS IN THE GREAT BASIN REGION OF NEVADA, UTAH, AND ADJACENT STATES

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