COMPILATION OF GEOHYDROLOGIC DATA COLLECTED AS PART OF THE AREAL APPRAISAL OF GROUND-WATER RESOURCES NEAR BRANSON, MISSOURI

By Jeffrey L. Imes

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CONVERSION FACTORS

To aid those readers who are interested in the International System of Units (SI), the factors for converting from the inch-pound units used in this report to metric units are given below:

Multiply inch-pound unit	By	To obtain metric (SI) unit
mile	1.609	kilometer
foot	0.3048	meter
million gallons per month	3,785	cubic meter per month

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ABSTRACT

A rapidly developing retirement community and tourist industry in the Branson, Missouri area has created an increased demand for potable water, especially in the summer months. The rapid pace of residential and business expansion has created concerns regarding the future ground-water availability and quality. Water levels measured in the Ozark aquifer during the summer of 1988 and March 1989 show water levels increasing in 22 wells, decreasing in 2 wells, and remaining the same in 1 well. The water-level increases ranged from 1 to 111 feet. These measurements and similar measurements during the summer of 1989 will be used to calibrate a three-dimensional model of groand-water flow in the Branson area and estimate the long-term effect of large ground-water withdrawals during the summer tourist season.

A reconnaissance of water quality in 34 wells that are open to the Ozark aquifer shows specific conductance ranging from 347 to 841 microsiemens per centimeter at 25 °Celsius and no fecal coliform bacteria present in any well. Chloride and nitrate concentrations in all wells were well below the Missouri Department of Natural Resources recommended maximum concentrations of 250 mg/L and 10 mg/L respectively. Analyses of 5 water samples for 33 volatile organic compounds failed to detect any concentrations in excess of the detection limits.

INTRODUCTION

Because of the increased popularity of the Table Rock Lake area (fig. 1) as a recreation attraction and retirement center, the populations of Taney and Stone counties about doubled from 1960 to 1980. According to the 1980 census, the population of Taney County was 20,500 and the population of Stone County was 15,600. The population increase is most evident in Branson, a small community located on the shore of Lake Taneycomo about 8 mi (miles) downstream from Table Rock Dam. Although the permanent resident population of Branson only increased by 35 percent from 1960 to 1980 (1,887 to 2,550), the number of business establishments in the city have increased markedly to accommodate the large increase in the number of tourists that visit the area annually. The annual influx of tourists during the warmer summer season exceeds the permanent resident population of the area.

The demand for potable water in the city and surrounding area has increased with the population. The city of Branson recently acquired three additional water-supply wells and several recreational industries have drilled large capacity supply wells. Smaller communities around Branson are experiencing similar increased demands for water. Many shallow wells have been drilled to provide rural residences with water. One consequence of the increased demand for water is a lowering of the potentiometric surface of the Ozark aquifer, the aquifer that supplies almost all of the ground water in the area. Because much of the increased water demand occurs during the summer tourist season, water levels are lowered substantially in the summer and recover during the winter. It is the purpose of this study to determine whether water levels in the Ozark aquifer are recovering fully during winter months when less water is used, or are in a state of continued long-term decline resulting from cumulative effect of the large demand for water during summer months. The 2-year cooperative study with the city of Branson and the Missouri Department of Natural Resources, Division of Environmental Quality includes measurement of water levels near Branson during two summer seasons and one winter season. The study will conclude with the construction and calibration of a digital model of ground-water flow in the Branson area and preparation of a comprehensive interpretive report. Because of the boundary condition requirements of the model, the boundaries of the study area are extended beyond the

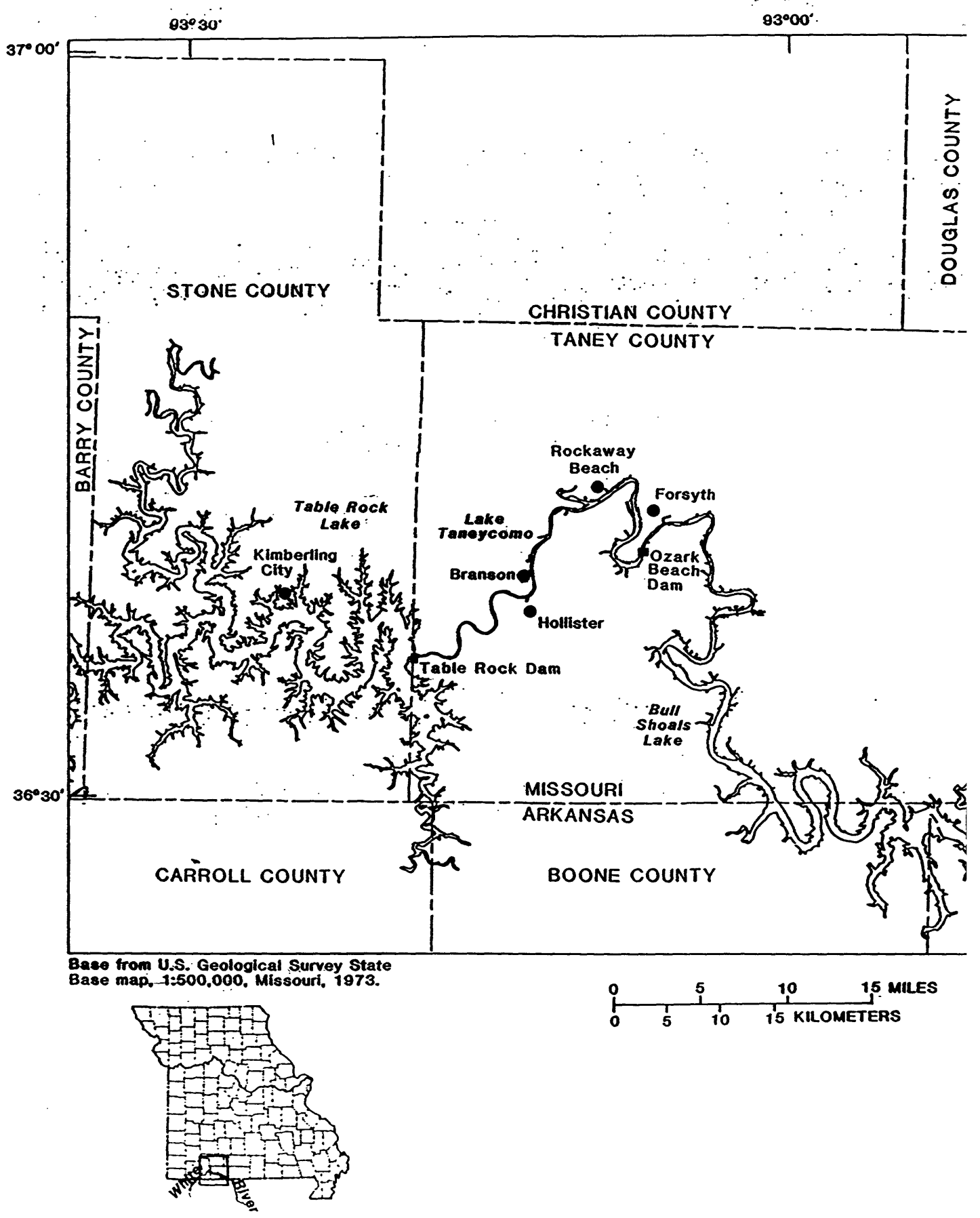

Figure 1.--Location of the study area.

vicinity of Branson. However, data collection efforts have been concentrated near Branson. The purpose of this interim report is to present water-level, water-quality, and water-use data collected during the first year of the study.

GEOHYDROLOGIC DESCRIPTION OF THE STUDY AREA

The study area includes most of Taney County and Stone County, the southern one-half of Christian County, and a small part of northern Arkansas. The deeply entrenched White River, a primary discharge area for regional ground-water flow in southern Missouri and northern Arkansas, flows eastward through the study area. The river flows on Ordovician bedrock, primarily the Cotter and Jefferson City Dolomites. Upland areas north and south of the river generally are capped by Mississippian cherty limestone, usually represented by the Burlington and Keokuk Limestones.

Geohydrologic units in the Branson area previously were identified and mapped as part of a regional study of the Ozark Plateaus aquifer system (Imes and Emmett, in press). The units are defined on the basis of regional geohydrologic properties. Six units are present in the Branson area. From the stratigraphically youngest to oldest, the units are (1) the Springfield Plateau aquifer, (2) the Ozark confining unit, (3) the Ozark aquifer, (4) the St. Francois confining unit, (5) the St. Francois aquifer, and (6) the Basement confining unit. A seventh and stratigraphically higher unit, the Western Interior Plains confining system, is present in a small isolated area located in the northwestern corner of the study area. Thin Quaternary alluvial deposits of small areal extent are present along the larger stream valleys. The relation between geohydrologic units and stratigraphic units within the study area is shown in table 1. The Ozark aquifer is the only aquifer important to this study. Many of the stratigraphically higher geologic formations that form the Ozark aquifer are not present in the area. Within the study area, the uppermost formation of the Ozark aquifer generally is the Cotter Dolomite or Jefferson City Dolomite; however, the Everton Formation, Smithville Formation, and Powell Dolomite also are present and can be the uppermost formation of the aquifer along the southern margins of the study area. The permeability of formations that comprise the Ozark aquifer in the area differ sufficiently enough that the aquifer can be divided into two reasonably distinct zones. The upper, less permeable zone includes the Jefferson City Dolomite and overlying formations of the aquifer, and the lower, more permeable zone includes the four formations of the aquifer that underlie the Jefferson City Dolomite (the Roubidoux Formation, Gasconade Dolomite, Eminence Dolomite, and Potosi Dolomite).

The top of the St. Francois aquifer, the lowermost aquifer in the Ozark Plateaus aquifer system, ranges from about 1,500 ft to 2,000 ft (feet) below land surface. Because of the depth of the St. Francois aquifer and because adequate quantities of ground water for municipal and industrial supply exist in the overlying Ozark aquifer, water-supply wells in the study area are not open to the St. Francois aquifer.

GROUND-WATER LEVELS IN THE OZARK AQUIFER

Water levels in 77 wells that are open to the Ozark aquifer were measured in June and July 1988, during the peak of the tourist season, and water levels in 25 wells were measured in March 1989, after a decrease in water demand during the winter months (fig. 2). The water-level data are presented in table 2 with the results of water-level measurements made during summer 1987 by the Missouri Department of Natural Resources, Division of Geology and Land Survey (Brown, in press) and water levels measured in August 1987 in wells located in Arkansas that are part of data entered into the U.S. Geological Survey Ground-Water Site Inventory file at Little Rock, Arkansas.

A comparison of water levels measured in the same wells during the summers of 1987 and 1988 shows that water levels increased in five wells and decreased in three wells. It is difficult to make meaningful conclusions about the summer 1987 to summer 1988 water-level changes because no water-use data are available to relate changes in water levels to changes in water-use patterns. Because many measurements were made in different wells, a more accurate assessment of whether long-term water-level declines are occurring will be available later from interpretations of potentiometric maps that include all

Table 1.--Generalized correlation of stratigraphic to geohydrologic units in the Branson area

Regional geohydrologic system	Regional geohydrologic unit	Principal stratigraphic unit(s)	Time-stratigraphic unit
Ozark Plateaus Aquifer System	Springfield Plateau aquifer	St. Louis Limestone, Salem Limestone, Warsaw Limestone, Boone Formation, St. Joe Limestone Member of Boone Formation, Keokuk Limestone, Burlington Limestone, Elsey Formation, Reeds Spring Formation, and Pierson Formation	Mississippian
	Ozark confining unit	Northview Shale, Sedalia Limestone, Compton Limestone, and Chattanooga Shale	Lower Mississippian and Upper Devonian
	Ozark aquifer	Clifty Limestone, Penters Chert, Lafferty Limestone, St. Clair Limestone, Brassfield Limestone, Cason Shale, Fernvale Limestone, Kimmswick Limestone, Plattin Limestone, Joachim Dolomite, St. Peter Sandstone, Everton Formation, Smithville Formation, Powell Dolomite, Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconade Dolomite, Van Buren Formation, Gunter Sandstone Member of Van Buren Formation, Eminence Dolomite, and Potosi Dolomite	Middle Devonian through Uppermost Cambrian
	St. Francois confining unit	Doe Run Dolomite, Derby Dolomite, and Davis Formation	Upper Cambrian
	St. Francois aquifer	Bonneterre Dolomite, Reagan Sandstone, and Lamotte Sandstone	Upper Cambrian
	Basement confining unit	Mostly igneous and metamorphic rock	Precambrian

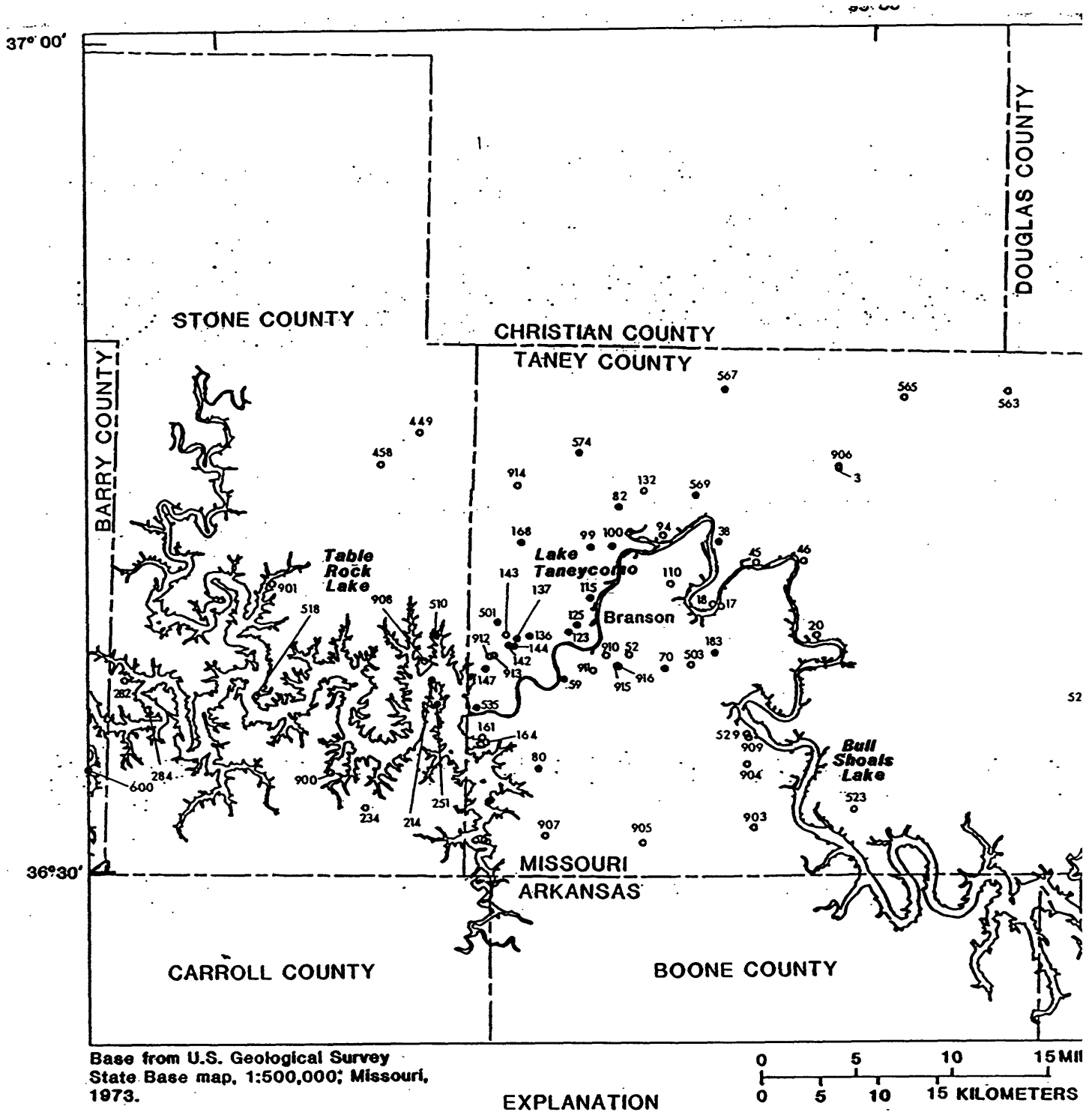

Figure 2.--Location of wells in which water levels were measured in June and July 1988 and in March 1989.

Table 2.--Water levels measured in selected deep and shallow wells

[ft, feet; PWSD, public water supply district; --, no data; MHP, mobile home park; >, greater than]

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
3	Taneyville PWSD-1	1,075	1,000	435	--	310	--	Or-Ce
17	Valley View Village South	926	585	376	--	266	--	Ojc-Og
18	Empire Electric Ozark Beach #2	739	360	--	--	100	--	
20	Dale Wyatt	749	200	32	--	97	--	Ojc
35	JimWade (old well)	980	568	42	240	--	--	--
38	Forsyth City #4	930	1,020	575	--	271	262	Or-Ce
45	Forsyth School Rockwell (old 1)	785	325	201	--	158	--	Ojc-Or
46	Lakeway#1,Taneyville	985	722	480	--	315	--	--
52	Holiday Hills Resort #1	870	1,023	425	--	160	--	
59	School of the Ozarks	926	1,125	305	--	254	233	Ojc-Ce
68	Ernest Goodall	940	505	84	257	--	--	
70	Kirbyville School (old)	1,000	525	303	--	264	230	Oc-Ojc
76	L.C. Stacy	1,040	685	84	310	--	--	
80	AT&T	1,345	655	407	--	469	430	Oc-Ojc
82	Meadowbrook Estates MHP	922	385	300	--	132	119	Or
94	Rockaway Beach City #2 Northwest	902	600	214	--	214	--	Ojc-Og
99	Missouri Department of Conservation	1,008	275	8	--	238	220	Oc
100	Joe P. Gott	968	327	14	--	209	225	Oc-Ojc
110	John Holcomb	990	383	20	--	261	--	
115	Branson City #5, New Well	900	1,520	530	235	222	212	Oc-Cd

Table 2.--Water levels measured in selected deep and shallow wells --Continued

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
122	Monte Shell	960	465	84	200	--	--	
123	Branson City #3, Crosby	986	1,085	460	391	357	357	Or-Ce
125	Branson City #4, Michel	845	1,002	393	210	195	179	Or-Ce
132	Missouri Highway Department Taney County	1,047	540	--	--	298	--	O
134	Calvert	943	308	35	--	31	--	Oc-Ojc
135	Estes Snowden	953	285	36	--	53	44	Oc-Ojc
136	Branson #8	970	1,315	452	350	299	217	Or-Ce
137	Branson #7	960	1,242	410	290	314	203	Or-Ce
142	Branson #6	1,065	1,190	414	395	396	309	Ojc-Ce
143	White Water	1,045	775	425	360	367	--	Ojc-Og
144	Gateway Subdivision	1,022	360	23	--	279	262	Oc-Ojc
147	Tri-State Utilities	1,200	1,602	502	--	443	395	--
161	Table Rock State Park #2	975	437	284	--	127	--	Ojc-Or
164	Table Rock State Park #3	989	475	275	--	91	--	Ojc-Or
168	Charley Rantz	1,120	465	100	--	269	262	--
178	Silver Slipper Motel	1,090	545	--	320	--	--	--
180	Richard Combs MHP	1,340	825	84	462	--	--	--
183	Taney County PWSD-2 (#2)	1,000	1,420	474	--	311	289	Ojc-Ce
190	Virgil Mcgough	880	568	21	240	--	--	--
195	Perry Hunsley	1,140	565	84	275	--	--	--

Table 2.--Water levels measured in selected deep and shallow wells --Continued

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
196	Marvin Puett	960	405	84	50	--	--	--
197	Devils Pool Guest Ranch	1,020	800	42	120	--	--	Oc-Og
199	Oakmont Motel Well #1	1,090	830	260	220	--	--	--
200	Oakmont Shores (old)	980	365	20	72	--	--	--
204	Long Creek Lodge	1,060	410	101	150	103	--	Oc
205	Long Creek Lodge Backup	1,043	485	188	--	168	--	Oc
206	Corps of Engineers-Long Creek Boat Dock	965	500	--	--	69	--	
211	Indian Trails Resort	980	405	150	100	--	--	--
214	Corps of Engineers-Coombs Ferry	937	375	250	--	32	--	Ojc-Or
230	Bill Thomas	1,380	605	84	400	--	--	--
234	Lev Anderson	1,315	540	42	--	385	--	Mgf-Oc
251	Toby M. Perkins	991	150	15	--	84	80	Oc
282	Mark Twain National Forest	1,096	360	225	--	227	--	Ojc-Or
284	Corps of Enineers-Campbell Point	948	355	273	--	91	--	Ojc-Or
449	Leo Wallace	1,430	595	130	--	418	--	Mrs-Ojc
458	Reeds Spring City	1,349	1,005	365	--	287	--	Oc-Oug
501	Ozark Auto Show, Jim Lane	1,107	410	18	--	400	327	Oc-Ojc
502	Gerald Combs	1,300	505	42	260	--	--	--
503	Taney County PWSD-2 (#1)	1,085	1,212	440	--	282	--	Ojc-Ce
510	J.D. Fullerton	957	345	37	--	174	98	Oc-Or

Table 2.--Water levels measured in selected deep and shallow wells --Continued

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
518	Corps of Engineers-Joe Bald	950	350	251	--	95	--	Ojc
523	Charlie Guinn	896	89	8	--	46	--	Oc
526	Protem School R-8	1,072	675	460	--	254	--	Ojc-Or
529	S.R. Johnson	964	437	--	--	285	--	Ojc
535	Shepherd of the Hills Hatchery	839	545	227	--	14	-1	Ojc-Or
551	Duane Hense	970	580	405	240	--	--	Ojc-Or
563	Bradleyville High School	838	500	350	--	41	--	Og
565	Missouri Highway Department	1,120	425	--	--	253	--	Ojc
567	Mark Gideon	1,010	200	9	--	28	24	Oc-Ojc
569	Richard Scott Subdivision	1,060	720	500	--	360	391	Or-Og
574	Bill Stone	1,207	480	62	--	367	349	Oc-Ojc
575	Al Evans	732	320	6	--	91	--	Oc-Ojc
591	Knobhill Acres Subdivision	1,043	768	300	--	154	--	Or-Og
596	Greenwood Subdivision	978	578	310	--	146	--	Ojc-Og
598	Emerald Beach Estates	1,038	421	375	--	125	--	Ojc-Or
600	Corps of Engineers	950	300	275	--	44	--	Or
900	Delbert Tibbets	1,110	580	--	--	192	--	--
901	Aunt's Creek 1st Addition	1,080	--	--	--	195	--	--
902	Leonard Daugherty	1,100	300	--	--	84	--	--
903	Mincy Public Hunting Area	760	--	--	--	33	--	

Table 2.--Water levels measured in selected deep and shallow wells --Continued

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
904	Kelley Daniels	900	--	--	--	161	--	
905	Double J Ranch, Beauchamp	1,325	1,013	--	--	470	--	--
906	Sullenger	1,070	--	--	--	42	--	--
907	Oakmont Country Club #1	1,370	1,008	--	--	>500	--	--
908	Colman Motel	980	240	--	--	127	--	--
909	S.R. Johnson	925	--	--	--	188	--	
910	Hollister City #2	966	1,125	375	--	357	--	
911	Hollister City #1	818	990	285	--	210	--	
912	Dale Bowen	973	305	--	--	26	--	--
913	Merle Pew	940	276	--	--	36	--	--
914	Richard Combs	1,345	564	40	--	466	--	--
915	P.B. Pattison	945	525	21	--	270	234	
916	P.B. Pattison	945	310	--	--	269	--	
1095	--	1,300	--	--	166	--	--	Oc
1096	--	1,380	700	--	435	--	--	Oc
1097	Gary Matlock	1,030	425	--	110	--	--	Oc
1098	Floyd Butel	1,210	645	--	386	--	--	Oc
1099	Paul Bilty	940	250	--	104	--	--	Oc
1100	Real Estate Office	1,360	--	--	254	--	--	Oc
1101	--	1,040	405	--	118	--	--	Oc

Table 2.--Water levels measured in selected deep and shallow wells --Continued

Well number (fig. 2)[1]	Owner or contact	Altitude of land surface (ft)	Well depth (ft)	Casing depth (ft)	Depth to water (ft)[2] Summer 1987	June-July 1988	March 1989	Well opening or primary producing formation[3]
1102	Table Rock Park	1,030	--	--	121	--	--	Oc
1103	--	1,140	--	--	224	--	--	Oc
1104	--	1,540	--	--	290	--	--	Oc
1105	Tysons Farm	1,030	100	--	75	--	--	Oc
1107	--	1,.250	--	--	130	--	--	Oc
1113	Solomon Potts	1,240	590	--	170	--	--	Oc
1114	Clifford Story	1,350	485	--	287	--	--	Oc
1115	Dean Huffman	1,280	375	--	237	--	--	Oc
1116	George Jones	1,330	600	--	238	--	--	Oc
1118	Herb Edwards	1,530	--	--	390	--	--	Oc

[1]Wells shown in figure 2 include only those that were measured in June-July 1988 and March 1989.

[2]Negative depth to water indicates water level is above land surface.

[3]Or, Roubidoux Formation; Og, Gasconade Dolomite; Ojc, Jefferson City Dolomite; Oc, Cotter Dolomite; Mgf, Grand Falls Formation; Mrs, Reeds Spring Formataion; Oug, Upper Gasconade Dolomite; Ce, Eminence Dolomite; Cd, Davis Formation.

measured water levels. A similar comparison of water levels measured in the summer of 1988 and March 1989 shows water levels increased in 23 wells, decreased in 2 wells, and remained the same in 1 well. Water-level increases in the 23 wells ranged from 4 ft to 111 ft, with the larger increases occurring in the city of Branson municipal wells.

GROUND-WATER MONITORING

From the inception of this project, it was determined that several wells in the study area needed to be monitored on a regular basis to provide information on the seasonal fluctuations of water levels in the Ozark aquifer. After completion of a well inventory and the first mass water-level measurements during the summer of 1988, seven wells were selected as suitable candidates for water-level monitoring wells. Permission to measure water levels monthly could be obtained for only two deep wells; well 59 (School of the Ozarks), and well 125 (city of Branson "Michel" well); and one shallow well, well 144 (Gateway Subdivision) (fig. 3). It was not possible to locate and gain permission to use paired shallow and deep wells to monitor hydraulic head differences between the shallower and deeper rocks of the Ozark aquifer. The city of Branson began monitoring water levels in the three wells in late September 1988, but soon discontinued wells 59 and 144 because of time and personnel constraints. A hydrograph of water-level data for well 125 (fig. 4) shows water levels rising 21 ft from late September 1988 to early December 1988 and remaining relatively stable from December 1988 through March 1989.

GROUND-WATER QUALITY IN SELECTED WELLS

To address concerns about the quality of water in the Ozark aquifer near Branson, water-quality samples were collected in 34 wells, located primarily between Branson and Forsyth (fig. 5). The specific conductance of each sample and a count of fecal coliform bacteria in 25 ml (milliliters) and 100 ml of sample was determined in the field. Laboratory analyses for chloride, total nitrite plus nitrate [mg/L (milligrams per liter) of nitrogen], and total nitrite (mg/L of nitrogen) were made for each sample, and total nitrate (mg/L of nitrogen) was calculated from results of the laboratory analyses (table 3). Analysis for these inorganic species was made because they are indicators of contamination from sewage effluent, a primary concern in the area. Specific conductance of the samples ranged from 347 to 841 µS/cm (microsiemens per centimeter at 25 °Celsius), and no samples contained fecal coliform. Chloride concentrations in samples from five wells exceeded the detection limit of 5 mg/L. Water from well 101 had the largest chloride concentration (81 mg/L); however, this concentration is considerably less than the Missouri Department of Natural Resources (1987) recommended maximum concentration of 250 mg/L. Nitrate concentrations in 27 wells were below the detection limit, 1 sample container was damaged in transit and the sample was lost, and 6 samples contained measurable concentrations of nitrite plus nitrate or nitrite. The maximum concentration of nitrate determined for the samples was 0.6 mg/L, well below the Missouri Department of Natural Resources (1987) recommended maximum concentration of 10 mg/L.

In addition to analyzing ground-water samples for inorganic species, samples from 5 wells (fig. 5) were analyzed for selected volatile organic compounds. None of the analyses detected the presence of any of the 33 volatile organic compounds in excess of the detection limits for the compounds (table 4).

GROUND-WATER USE BY MUNICIPALITIES, PUBLIC WATER-SUPPLY DISTRICTS, AND SELECTED BUSINESSES

Because it is necessary to have accurate water-use data to properly calibrate a ground-water flow model, the primary ground-water users (fig. 6) were contacted in September 1988 and were requested to measure their water use monthly for the next one and one-half years and report the water-use data each month to the U.S. Geological Survey. Generally, response to this request was favorable, although in practice an occasional reminder is necessary to actually obtain the data. Monthly water-use information collected to date is listed in table 5.

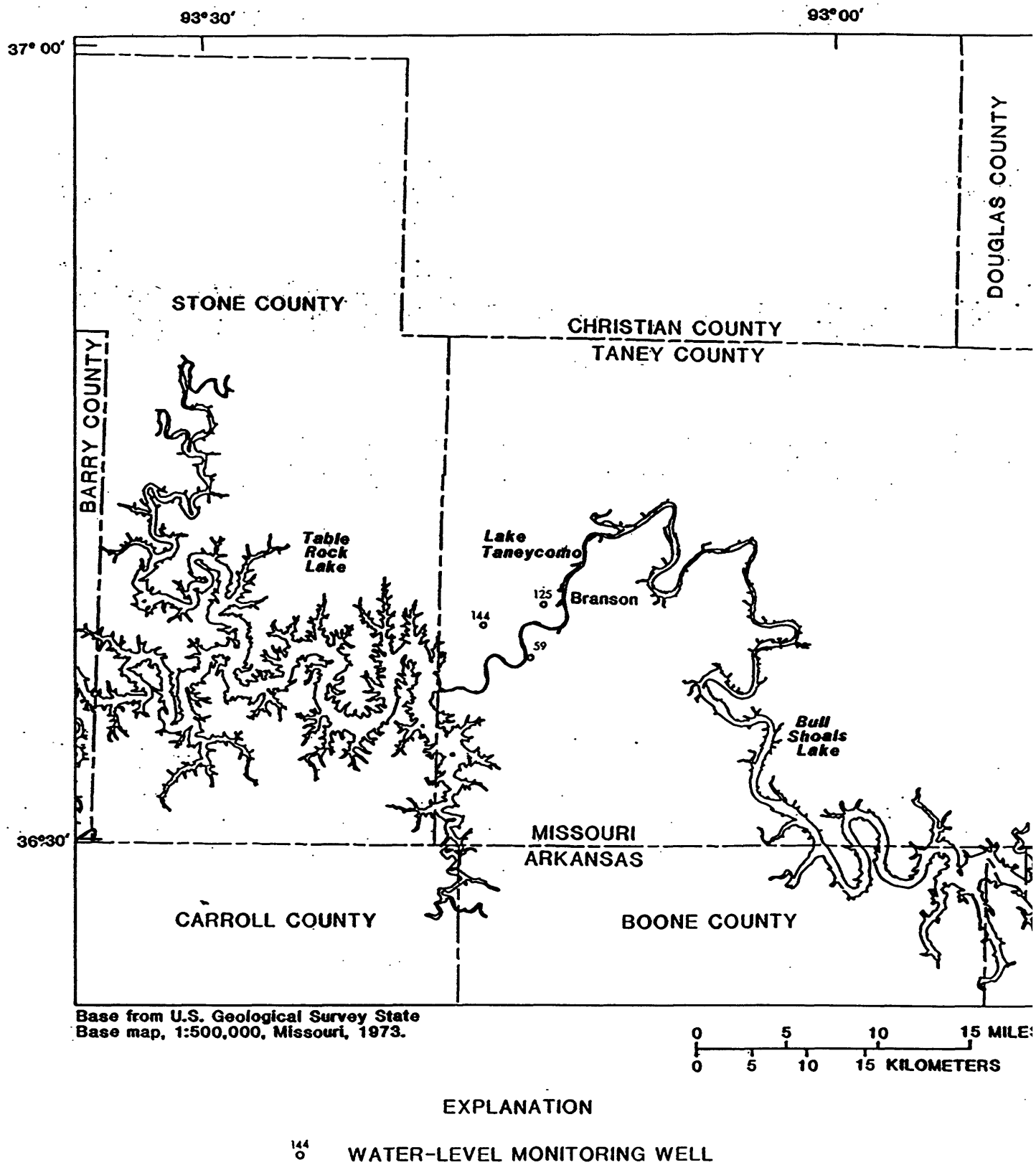

Figure 3.--Location of water-level monitoring wells.

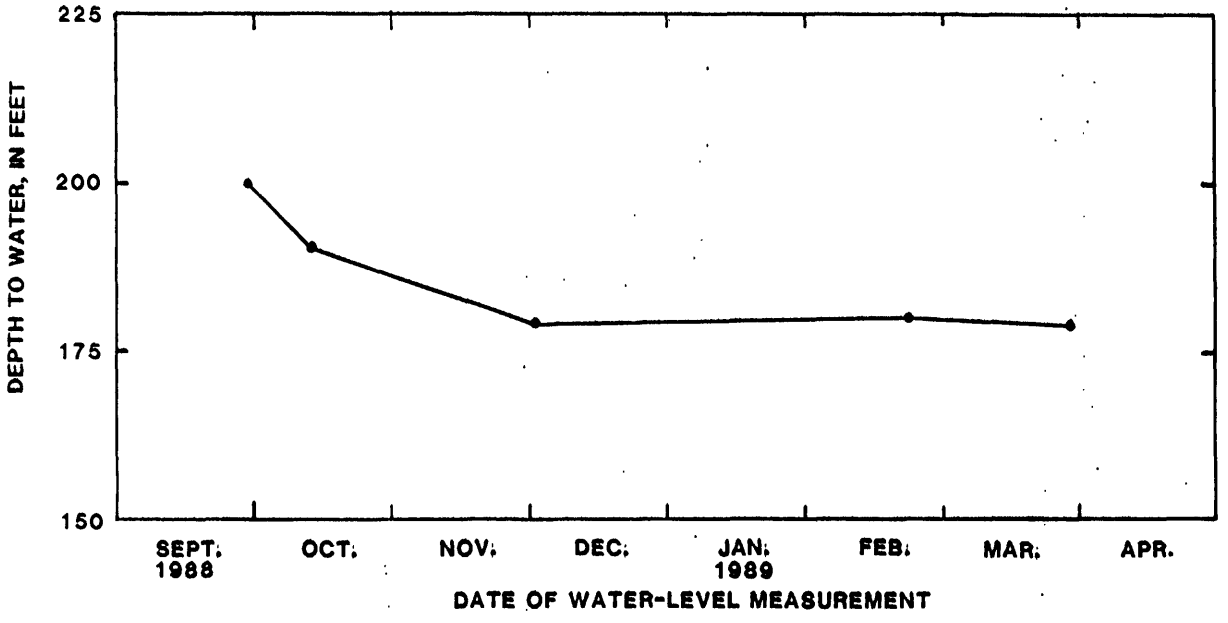

Figure 4.--Hydrograph of water levels in well 125 (city of Branson "Michel" Well).

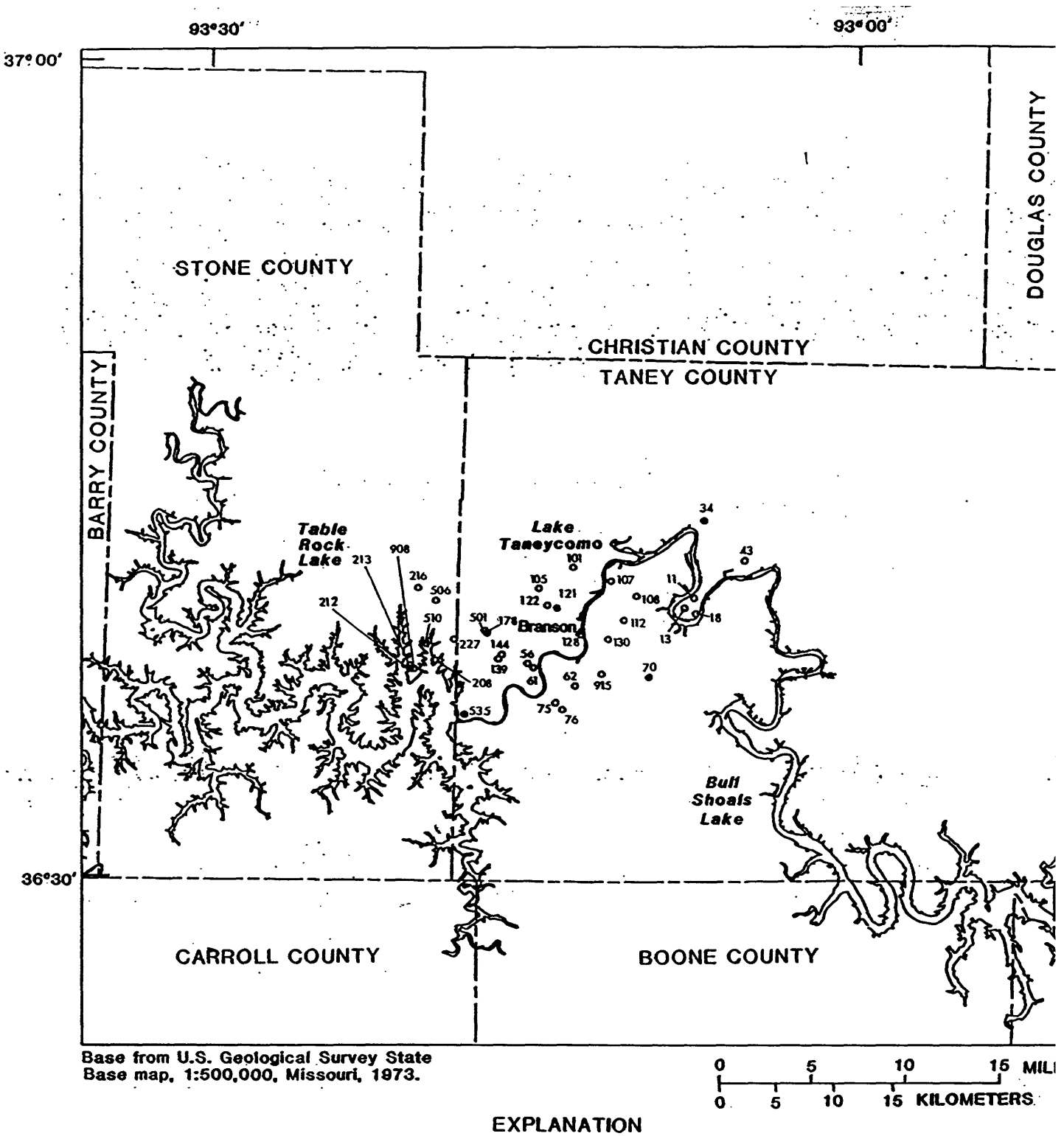

Figure 5.--Location of wells in which water-quality samples were collected and analyzed for selected inorganic constituents and volatile organic compounds.

Table 3.--Results of specific conductance measurements, fecal coliform bacteria count, and analyses of water samples for selected inorganic species

[µS/cm, microsiemens per centimeter at 25 °Celsius; mg/L, milligrams per liter; <, not detected in concentrations exceeding the stated detection limit; --, no data]

Well number (fig. 5)	Identification number[1]	Specific conductance, µS/cm	Fecal coliform, colonies per 100 milliliters	Chloride, dissolved as Cl, mg/L	Nitrite, total mg/L as NO_2	Nitrite plus Nitrate, total as N mg/L	Nitrate, total, calculated mg/L as NO_3
11	88-7160	604	0	6	<0.010	<0.100	--
13	88-7161	590	0	<5	<.010	.200	0.200
18	88-7159	534	0	6	<.010	<.100	--
34	88-7186	536	0	<5	<.010	.600	.600
43	88-7187	597	0	<5	<.010	.200	.200
56	88-7179	557	0	<5	<.010	<.100	--
61	88-7178	556	0	<5	<.010	<.100	--
62	88-7173	634	0	<5	<.010	<.100	--
70	88-7190	528	0	<5	<.010	<.100	--
75	88-7162	530	0	<5	<.010	<.100	--
76	88-7158	619	0	<5	<.010	<.100	--
101	88-7181	841	0	81	<.010	.500	.500
105	88-7195	550	0	<5	<.010	<.100	--
107	88-7174	644	0	<5	<.010	<.100	--
108	88-7189	667	0	<5	<.010	<.100	--
112	88-7192	522	0	<5	--	--	--
121	88-7182	496	0	<5	<.010	<.100	--
122	88-7183	681	0	<5	<.010	<.100	--
128	88-7185	627	0	<5	<.010	<.100	--
130	88-7151	659	0	<5	.010	<.100	<.100

Table 3.--Results of specific conductance measurements, fecal coliform bacteria count, and analyses of water samples for selected inorganic species--Continued

Well number (fig. 5)	Identification number[1]	Specific conductance, µS/cm	Fecal coliform, colonies per 100 milliliters	Chloride, dissolved as Cl, mg/L	Nitrite, total mg/L as NO_2	Nitrite plus Nitrate, total as N mg/L	Nitrate, total, calculated mg/L as NO_3
139	88-7177	594	0	<5	<.010	<.100	--
144	88-7176	705	0	<5	<.010	<.100	--
178	88-7188	563	0	<5	<.010	<.100	--
208	88-7170	676	0	<5	<.010	<.100	--
212	88-7165	534	0	<5	.010	<.100	--
213	88-7156	422	0	<5	<.010	<.100	--
216	88-7172	408	0	<5	<.010	<.100	--
227	88-7169	601	0	<5	<.010	<.100	--
501	88-7175	472	0	<5	<.010	<.100	--
506	88-7166	363	0	<5	<.010	<.100	--
510	88-7157	640	0	18	.021	.200	0.180
535	88-7164	347	0	<5	<.010	<.100	--
908	88-7171	568	0	<5	<.010	<.100	--
915	88-7163	428	0	5	<.010	.200	0.200

[1]Missouri Division of Environmental Quality identification number.

Table 4.--Results of laboratory analyses of ground-water samples for presence of volatile organic compounds

[Well information consists of the following: top number-well number; bottom number-Missouri Department of Natural Resources, Division of Environmental Quality identification number; <, not detected in concentrations exceeding the stated detection limit; all units are micrograms per liter]

Organic compound	Well information 34 88-7355	70 88-7352	121 88-7184	178 88-7354	535 88-7351
Acetone	<20	<20	<20	<20	<20
Benzene	<5.0	<5.0	<5.0	<5.0	<5.0
Bromomethane	<5.0	<5.0	<5.0	<5.0	<5.0
Bromodichloromethane	<5.0	<5.0	<5.0	<5.0	<5.0
Bromoform	<5.0	<5.0	<5.0	<5.0	<5.0
2-Butanone	<20	<20	<20	<20	<20
Carbon disulfide	<5.0	<5.0	<5.0	<5.0	<5.0
Carbon tetrachloride	<5.0	<5.0	<5.0	<5.0	<5.0
Chlorobenzene	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroethane	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroform	<5.0	<5.0	<5.0	<5.0	<5.0
Chloromethane	<5.0	<5.0	<5.0	<5.0	<5.0
Dibromochloromethane	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethane	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloroethane	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethylene	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloroethylene	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloropropane	<5.0	<5.0	<5.0	<5.0	<5.0
Cis-1,3-dichloropropene	<5.0	<5.0	<5.0	<5.0	<5.0
Trans-1,3-dichloropropene	<5.0	<5.0	<5.0	<5.0	<5.0
Ethylbenzene	<5.0	<5.0	<5.0	<5.0	<5.0
2-hexanone	<20	<20	<20	<20	<20
Methylene chloride	<20	<20	<20	<20	<20
4-methyl-2-pentanone	<20	<20	<20	<20	<20
1,1,2,2-tetrachloroethane	<5.0	<5.0	<5.0	<5.0	<5.0

Table 4.--Results of laboratory analyses of ground-water samples for presence of volatile organic compounds--Continued

Organic compound	Well information 34 88-7355	70 88-7352	121 88-7184	178 88-7354	535 88-7351
Tetrachloroethylene	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,1-trichloroethane	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,2-trichloroethane	<5.0	<5.0	<5.0	<5.0	<5.0
Trichloroethylene	<5.0	<5.0	<5.0	<5.0	<5.0
Toluene	<5.0	<5.0	<5.0	<5.0	<5.0
Total xylenes	<10	<10	<10	<10	<10
Vinyl acetate	<20	<20	<20	<20	<20
Vinyl chloride	<5.0	<5.0	<5.0	<5.0	<5.0

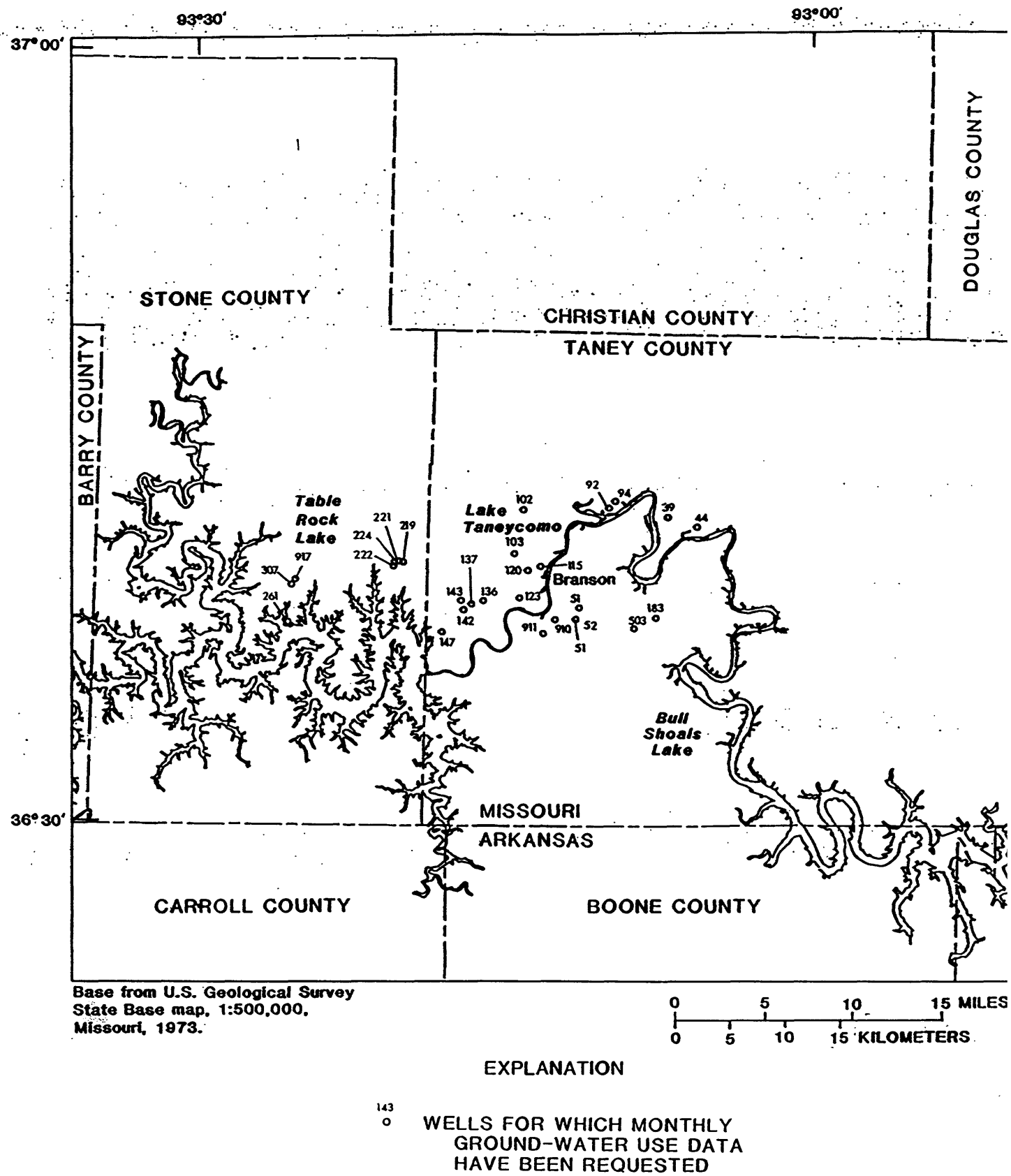

Figure 6.--Location of wells for which monthly ground-water use data have been requested.

Table 5.--Monthly ground-water use by the primary ground-water users in the Branson area

[--, no data available; PWSD, public water supply district; e, estimated]

Well number (fig. 6)	Well Owner	Ground-water use, in million gallons per month (1988-89)								
		1988				1989				
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
39	Forsyth #3	3.9930	3.6860	2.9550	3.4820	1.5998	2.6480	--	--	--
44	Forsyth #1	1.9208	2.2120	1.3490	1.3470	1.3820	1.3150	--	--	--
51	Holiday Hills Resort #2	--	--	--	--	--	--	--	--	--
52	Holiday Hills Resort #1	--	--	--	--	--	--	--	--	--
92	Rockaway Beach #3	1.4200	1.0202	.6830	.8760	.7310	.9220	1.0270	--	--
94	Rockaway Beach #2	.0670	.0380	.0690	.0310	.0130	.0380	.0310	--	--
102	Taney Co PWSD-3 #2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	--
103	Taney Co PWSD-3 #1	3.0720	2.6040	2.6810	2.1980	2.380	2.4170	2.2580	2.8790	--
115	Branson "New Well"	7.1350	6.9650	5.2330	5.8720	5.7390	6.4780	--	--	--
120	Branson North Subdivision 2	.7730	.6670	.6180e	--	--	--	--	--	--
123	Branson "Crosby Well"	8.0000	7.3290	4.7040	10.7990	9.0080	8.0260	--	--	--
136	Branson #8	.8670	3.0840	1.8930	7.6500	12.2100	10.0570	--	--	--
137	Branson #7	18.9080	18.5820	10.3040	3.7550	.0000	.0000	--	--	--
142	Branson #6	3.3670	3.6770	5.2370	2.0070	.0000	2.2420	--	--	--
143	White Water	.1820e	.1820e	.1150	.0970e	.1190e	.1190e	.1190e	--	--
147	Tri-State Utilities	6.9820	6.1740	5.0430	5.6170	5.9290	5.3130	--	--	--
183	Taney Co PWSD-2 #2	2.3230	1.4020	1.3630	4.5880	1.6640	1.4920	1.8540	--	--
221	Silver Dollar City #5	9.7200	9.7200	.0000	.0000	.0000	.0000	4.8600	--	--
222	Silver Dollar City #6	10.8000	10.8000	.0000	.0000	.0000	.0000	5.4000	--	--
224	Silver Dollar City #4	6.4800	6.4800	6.4800	6.4800	6.4800	6.4800	6.4800	--	--
219	Silver Dollar City #7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	--	--
261	Kimberling City Water Company	.7220	.6100	.5360	.5450	.5580	--	--	--	--
307	Kimberling City PWDS-1 #2	1.9850	1.7080	1.7170	.8960	1.2520	2.2830	--	--	--
503	Taney Co PWSD-2 #1	2.1470	2.7650	2.7610	2.9060	2.6130	2.8470	2.8860	--	--
911	Hollister #1	8.8120	6.1850	6.9340	4.4330	8.3810	--	--	--	--

Table 5.--Monthly ground-water use by the primary ground-water users in the Branson area --Continued

Well number (fig. 6)	Well Owner	Ground-water use, in million gallons per month (1988-89)								
		1988				1989				
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
910	Hollister #2	4.8170	4.6900	4.4460	6.2020	4.0690	--	--	--	--
917	Kimberling City PWDS-1 #1	2.3870	1.9630	1.7760	2.9860	2.6650	2.4270	--	--	--

GROUND-WATER FLOW MODEL DEVELOPMENT

A three-dimensional finite-difference model of ground-water flow in the upper and lower zones of the Ozark aquifer has been designed and is being constructed. The U.S. Geological Survey modular model developed by McDonald and Harbaugh (1984) is being used in this analysis. The variable grid model contains 54 rows by 55 columns centered in the Branson area with cell sizes ranging from 2 mi by 2 mi near the corners of the model to 0.5 mi by 0.5 mi near the center of the model. Computerized data bases of geohydrologic and water-use information have been created and are being used to prepare contour maps of the altitude of the top of each important geohydrologic unit and potentiometric surface maps for each zone of the Ozark aquifer. The contour maps will be used to generate aquifer thickness data, saturated rock thickness data, and related information necessary for calibration of the flow model.

SUMMARY AND FOCUS OF FUTURE WORK

Measurements of water levels made during this study show substantial seasonal changes. Comparison of changes in water levels measured in the same wells from the summer of 1987 to the summer of 1988 cannot be used to accurately assess whether long-term water level declines are occurring in the area, because water levels in few wells were measured at both times. However, interpretative potentiometric maps based on all measured water levels during the summers of 1987, 1988, and 1989 should provide sufficient data to make an analysis of water-level trends.

A survey of 34 wells to determine the concentrations of fecal coliform bacteria and inorganic chemicals showed no fecal coliform bacteria present in any well, and no unusually large concentration of inorganic constituents. Chloride and nitrate concentrations in all water samples were less than the Missouri Department of Natural Resources recommended maximum concentrations. An analysis of 5 water samples for a suite of 33 volatile organic compounds failed to detect the presence of any of the compounds.

Water-level measurements will be made during the summer 1989 tourist season, and the monthly water-use data will continue to be updated. The remainder of the project time will be spent analyzing the collected data, completing the construction of the ground-water flow model, and calibrating the model to the available hydrologic data. Upon completion of the data analysis and model calibration, one or two simulations will be prepared to represent the potential effects of continued ground-water withdrawals in the Branson area. Finally, a comprehensive report will be prepared that presents the results of the data analysis and model simulations.

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