QUALITY OF GROUND WATER IN SOUTHERN BUCHANAN COUNTY, VIRGINIA

By Stanley M. Rogers and John D. Powell

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QUALITY OF GROUND WATER IN SOUTHERN
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ABSTRACT

In seven small contiguous stream basins in the coal area of southwest Virginia, ground water is predominantly bicarbonate in anion composition, with calcium as the major cation in the ridges and sodium the major cation in the lower altitudes. Sulfate is the major anion in water associated with coal seams and in stream water draining areas extensively disturbed by mining. Water from a major linear feature in the Big Prater Creek valley and water from deep wells in Levisa Fork basin contain chloride as the predominant anion. Hydrogen ion activities (pH) in the ground water range from 5.2 to 8.4. Total iron concentrations as high as 24,000 micrograms per liter are present in domestic wells. The chemical composition of most streams changes with diminishing discharge and at base flow is similar to the composition of local ground water. At high flows, streams draining mined areas are enriched in sulfate.

INTRODUCTION

Quality of ground water in the coal area of southwest Virginia is vulnerable to the effects of past and present coal mining. The ridges within these basins include actively mined and mined-out surface and underground coal deposits. The seven small contiguous stream basins along the Levisa Fork and Russell Fork in southern Buchanan County (plate 1) were selected for study in order to include the effects of both surface and subsurface mining. Sulfate loading and low-flow discharge of streams in these basins indicate that coal mining adversely affects some basins more than others (Rogers and Hufschmidt, 1980). This present study describes the quality of ground water throughout the area, identifies and discusses water-quality problems, and examines the relation of ground-water and surface-water composition. The quality of stream water during base flow, when all streamflow is contributed by ground-water sources, is considered to be representative of local ground-water quality.

Streams were sampled at or near base flow and at a higher flow to identify trends in chemical composition as discharges approached base flow. Water samples were collected from 77 wells and 17 springs for analysis by the U. S. Geological Survey Central Laboratory, Atlanta, Georgia. Well depths ranged from 11 to 420 feet below land surface, with a median depth of 82 feet. Within each individual basin, water samples were collected from wells finished in all stratagraphic units. Stream-water and ground-water analyses are presented in appendix 1 and appendix 2, respectively.

GEOLOGY OF STUDY AREA

Rocks of the Lee, Norton, and Wise formations of the Pennsylvanian Period are present in Buchanan County. These formations are nearly flat-lying beds of sandstone, siltstone, clay, and coal. Sandstone composes slightly more than half the rock; siltstone composes most of the remainder. The sandstones are fine to coarse grained, micaceous, and many contain carbonate cement; weathered surfaces are coated with a brown iron stain.

A mantle of weathered material covers the vertically fractured bedrock (Hinds, 1918). Many lineaments have been mapped throughout the area by the Virginia Division of Mineral Resources. The more pronounced lineaments commonly extend along stream courses, but in places cross topographic divides (plate 1). The effect of these lineaments upon water composition is not known. The underlying structures may serve as conduits along which more mineralized waters may migrate from depth.

X-ray-diffraction analyses of rock samples indicate the presence of minerals responsible for the chemical composition of the ground water (table 1). The influence of each mineral upon water composition is related to reactivity and availability of the mineral. Other important factors include grain-size distribution, porosity, hydraulic conductivity of the rock, and length of contact time between the minerals and the water.

Table 1.-- Minerals identified as possible contributors to water chemistry.

Minerals	Weathering products contributed to ground-water composition
Silicates	
Plagioclase	Na^+, Ca^{2+}, HCO_3^-, SiO_2
Muscovite	K^+, HCO_3^-, SiO_2
Chlorite	Mg^{2+}, OH^-, SiO_2
Microcline	K^+, HCO_3^-, SiO_2
Carbonates	
Calcite	Ca^{2+}, HCO_3^-,
Dolomite	Ca^{2+}, Mg^{2+}, HCO_3^-
Siderite	Fe^{2+}, HCO_3^-,
Sulfides	
Pyrite	Fe^{2+}, SO_4^{2-}

COMPOSITION OF GROUND WATER

The classification and distribution of water sampled are shown in the water-analysis diagrams in figures 1 and 2. Bicarbonate water is dominant. Seventy-eight percent of the samples analyzed are bicarbonate rich. At higher altitudes along the ridges, calcium is the dominant cation, whereas at lower altitudes and along valley bottoms, sodium is dominant (fig. 3). The reason for these differences is not completely understood. The differences may result from cation exchange on clay and organic compounds associated with coal seams as the water moves downward through the rock material. Mineral analyses indicate that plagioclase feldspar and carbonates are the likely source of calcium in the water.

Sulfate water is found at scattered points throughout the area, with calcium being the dominant cation associated with the sulfate ion (fig. 3). Magnesium is also present, but never exceeds calcium in concentration. Springs flowing from coal seams are sulfate-rich. Wells that penetrate a coal-seam aquifer may contain sulfate-rich water. Shallow dug wells that receive water from weathered surficial material more commonly contain sulfate-rich water than the deeper drilled wells. This may be caused by weathering of pyritic material in the overburden. Gypsum ($CaSO_4 \cdot 2H_2O$) is not available as a source of calcium or sulfate ions.

Chloride-rich water is present in the Levisa Fork (figs. 13, 14, 15) and Big Prater Creek (figs. 10, 11, 12) basins.

Along the Russell Fork (fig. 19), one well (13E1) containing chloride water is found at the intersection of Hurricane Creek and Russell Fork Fault (Plate 1). This chloride-rich water may be rising from depth along structural features indicated by lineaments.

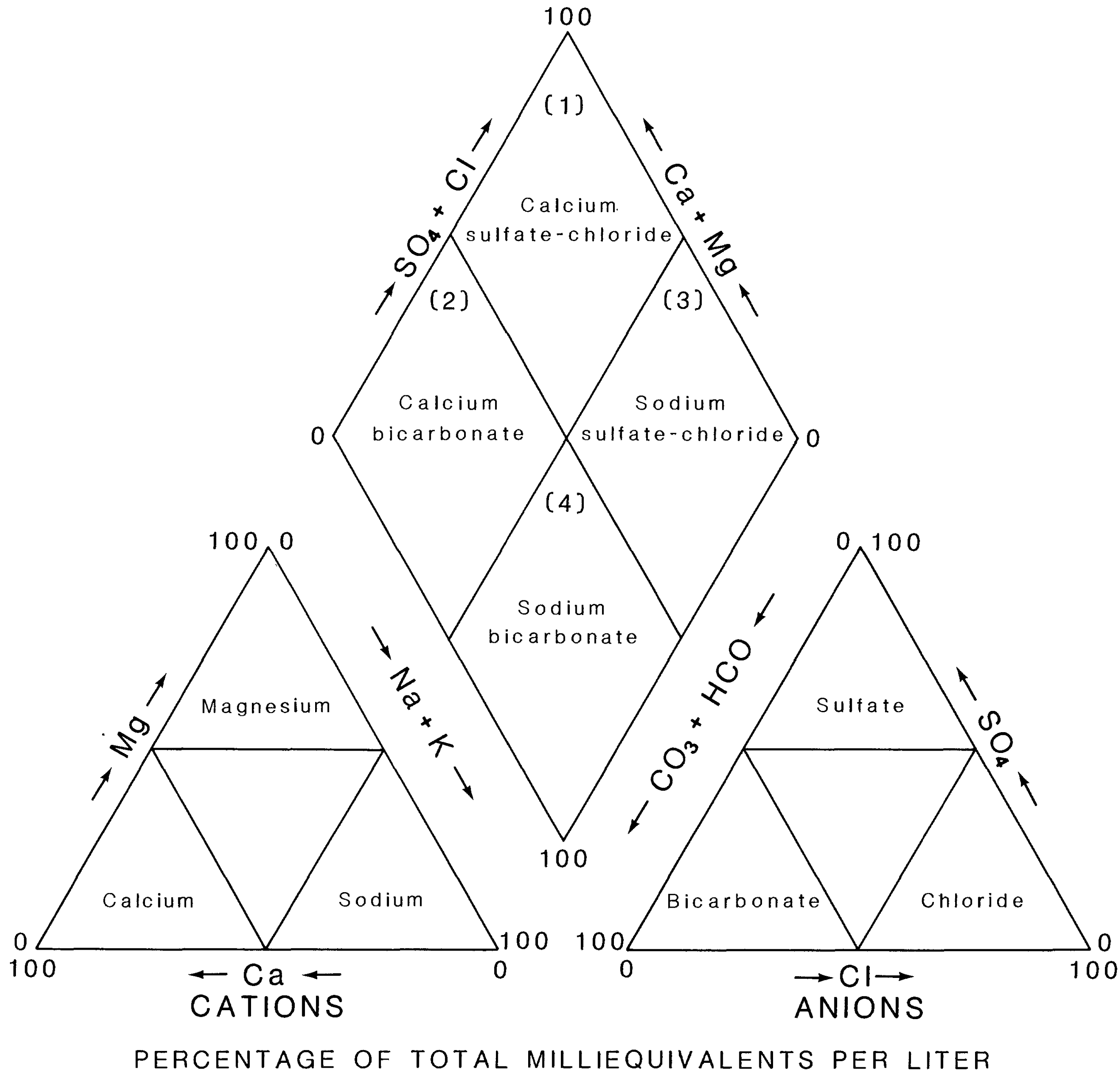

Figure 1.--Classification and nomenclature of water. (After Piper, 1944)

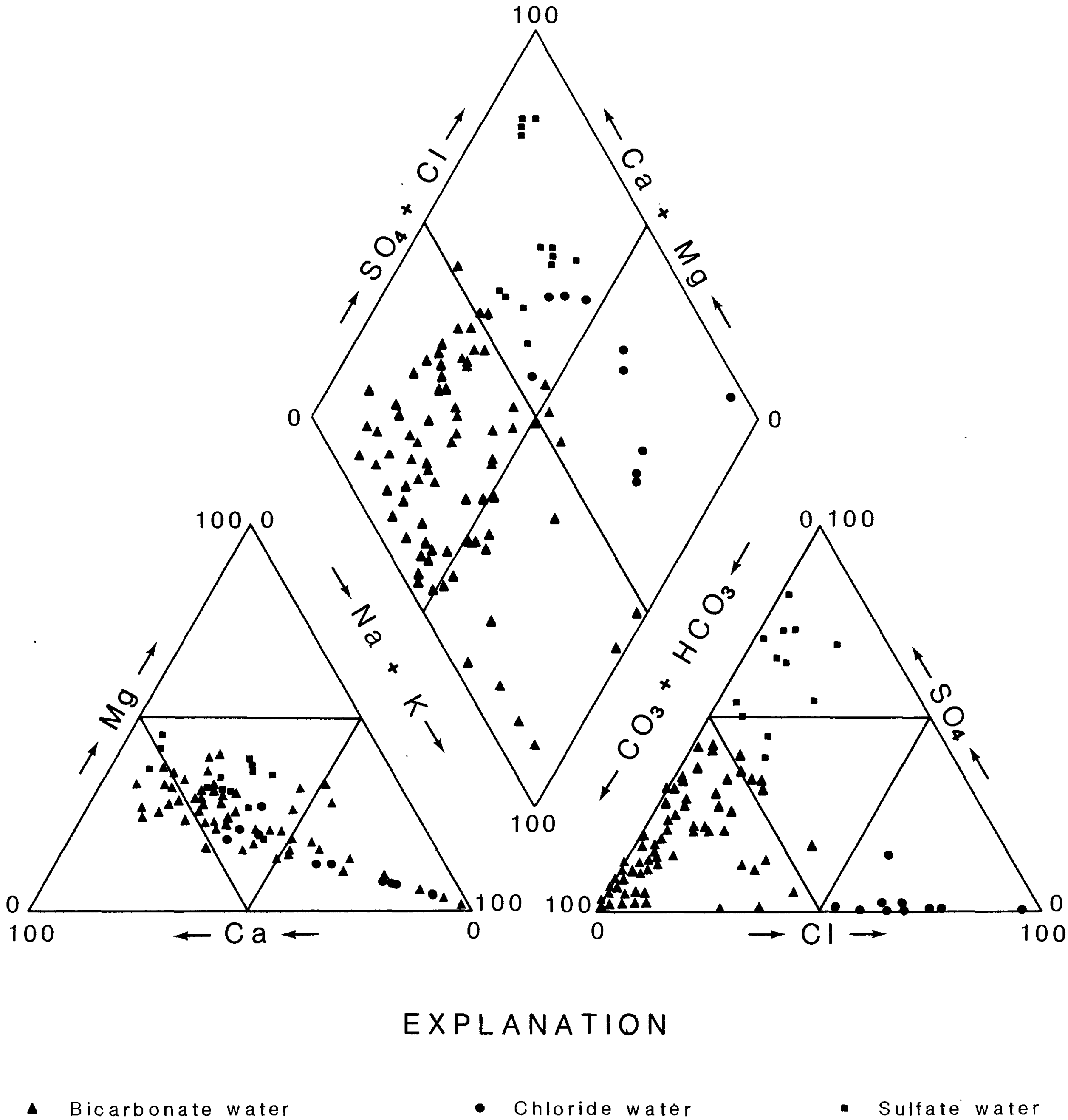

Figure 2.--Chemical composition of ground water in the study area.

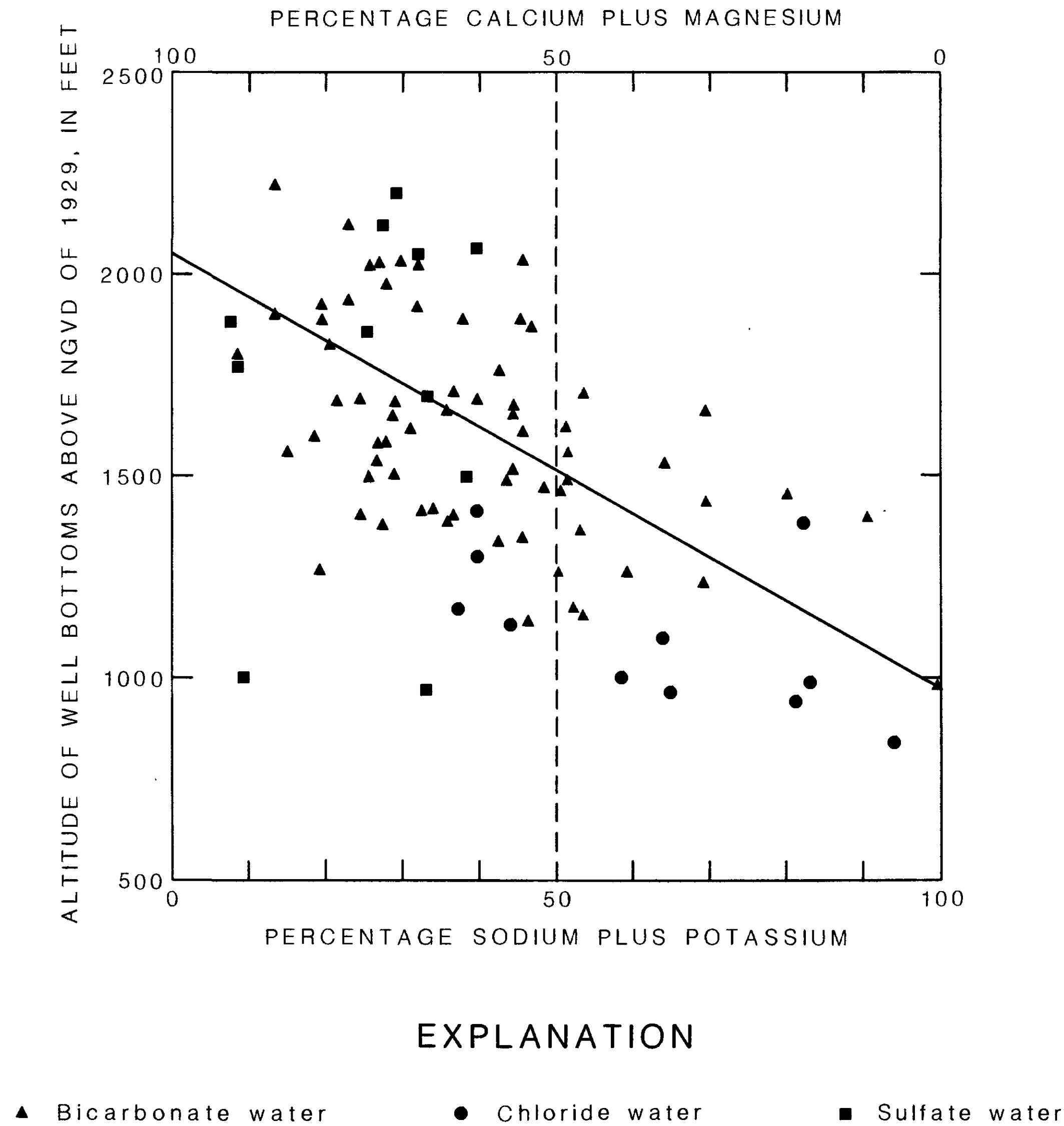

Figure 3.--Relation between altitude and water composition.

GROUND-WATER QUALITY PROBLEMS

Undesirable concentrations of several constituents (National Academy of Sciences and National Academy of Engineering, 1974) were found in some ground-water samples. Each water-quality problem identified is discussed below.

1. Dissolved-solids concentrations range from 200 to 1,100 mg/L. Nine samples exceed the upper limit (500 mg/L) recommended for domestic use. High concentrations of dissolved solids can cause scale deposition in water lines and on plumbing fixtures.

2. Calcium magnesium hardness ranges from 2 to 431 mg/L. The median value of 68 mg/L is in the lower range of moderately hard water (Durfor and Becker, 1964). Calcium and magnesium ions in hard water complex with the organic molecules in soap to form curds, so that much more soap is required for cleaning.

3. Hydrogen-ion activities, range from pH 5.2 to pH 8.4. Springs generally yield lower pH waters, whereas drilled wells yield higher pH waters. This is due primarily to longer residence time for water in aquifers tapped by drilled wells. Springs are found in sandstones capping ridges and are more influenced by recent exposure to carbon dioxide dissolved in rain water. The pH of pure water exposed to carbon dioxide in the atmosphere is 5.6. Low-pH

waters can dissolve copper from copper tubing used in water lines and lead from solder used in connecting segments of copper water lines.

4. One water sample, 420 mg/L, exceeds the recommended limit (250 mg/L) for sulfate concentration. High sulfate levels in water may result in a laxative effect on the user.

5. Chloride concentrations range from 1 to 505 mg/L. Five water samples exceed the recommended limit (250 mg/L). Chloride concentrations greater than the recommended limit impart a salty taste to drinking water.

6. Total iron concentrations range from 0 µg/L to 24,000 µg/L. Thirty-nine water samples exceed the recommended limit (300 µg/L) for dissolved iron. The presence of iron in water can stain clothing, plumbing fixtures, and cookware.

7. Total manganese concentrations range from 0 µg/L to 1,750 µg/L. Forty-seven samples exceed the recommended limit (50 µg/L) for dissolved manganese. The presence of manganese in water can stain clothing, plumbing fixtures, and cookware.

8. Fetid waters are reported by residents. These waters are cased off by drillers, and none were available for ana-

lysis. Hydrogen sulfide (H_2S) is a poisonous gas, gives the odor of rotten eggs to water, is highly soluble in water, and is particularly offensive to users. Its presence accounts for the "sulfur water" reported by residents.

WATER QUALITY WITHIN INDIVIDUAL BASINS

A discussion of water quality within each of the seven small basins includes the following: 1) water-analysis diagram showing water classes and trends* in composition from high flow to base flow, 2) longitudinal cross section showing altitudes of well bottoms relative to the streambed, 3) map showing location of sampling sites, water composition, and areas affected by surface mining, and 4) a brief explanation of the water chemistry.

* In addition to classifying a water, the water-analysis diagram may be used to show trends of change in water quality. Lines connecting points representing stream composition at high flow and at base flow demonstrate a trend toward the composition of that stream's ground-water sources. If no change occurs in the chemical composition of the stream, then that stream is considered stabilized with respect to its ground-water sources.

LEVISA FORK BASIN ABOVE OAKWOOD, VA.

Nine wells were sampled along the Levisa Fork upstream from Oakwood, Va. All ground water except the highest in altitude is bicarbonate water. The highest well contains a sulfate water and is presumably associated with a coal seam. Above 1,600 feet in altitude the water is calcium water. At altitudes less than 1,600 feet, the ground water is predominantly sodium water.

The Levisa Fork near its confluence with Grassy Creek is a calcium bicarbonate water both at high flow and at base flow. Downstream from Grassy Creek, both high flow and base flow are calcium sulfate water. The sulfate in the stream likely originates from extensive land disturbance by mining activities in the basin between Oakwood, Va. and Grassy Creek.

The chemical composition of the water at the upstream sampling site trends toward that of the natural ground-water source. At the downstream site, the composition of the stream water trends toward that of anthropogenic sources high in sodium and chloride.

 (page 16 follows)

GARDEN CREEK BASIN

Eleven wells were sampled in the Garden Creek basin. All wells except one contained bicarbonate water. The one well water is probably associated with a coal seam and contains a sulfate water. Except for two lower altitude wells, characterized by sodium water, wells of the Garden Creek basin are calcium water.

Stream water in both the main stem and the Right Fork is calcium sulfate water at both high flow and base flow. Mining is extensive in the Garden Creek basin and the presence of sulfate water is probably associated with these mining activities.

The chemical composition of Right Fork at base flow trends toward that of the ground-water source. The chemical composition of the main stem remains unaltered as it approaches base flow.

 (page 18 follows)

BIG PRATER CREEK BASIN

Fifteen wells and two springs were sampled in the Big Prater Creek basin. One spring contains a bicarbonate water and is probably associated with sandstone. The other spring contains a sulfate water and is probably associated with a coal seam. Above an altitude of 1,400 feet, wells contain primarily calcium bicarbonate water. Below 1,400 feet in altitude a majority of the wells contain chloride water. Remaining wells contain predominantly sodium bicarbonate water.

Big Prater Creek is a chloride water at both high flow and at base flow. This indicates a strong connection between the local chloride ground-water regime and the stream-water composition even at the higher flow. The source of the chloride is not known. However, Big Prater Creek lies along a major lineament which may be serving as a conduit for water rising from depth.

 (page 20 follows)

LEVISA FORK BASIN BETWEEN VANSANT, VA. AND OAKWOOD, VA.

Seven wells were sampled along the Levisa Fork downstream from Oakwood, Va. Above 1,000 feet in altitude the well water is sulfate and bicarbonate. Below 1,000 feet in altitude the wells contain sodium chloride water which exceeds 250 mg/L chloride. This water, classified as "salt water", demonstrates the quality of water within the deeper stratigraphic units and may be representive of deeper water underlying the entire study area.

No surface-water quality data are available and no trends with flow are identified.

 (page 22 follows)

BALL CREEK BASIN

Twenty wells and 11 springs were sampled in the Ball Creek basin. Most of the wells contain bicarbonate water. Two have sulfate water. Springs draining the sandstone ridges are bicarbonate waters, while those springs associated with coal seams are sulfate water. Most wells in the Ball Creek basin are characterized by calcium water. Two wells at the lower altitudes, however, contain sodium water.

The chemical composition of Ball Creek near its mouth is calcium sulfate at base flow. Base flows in Grissom Creek and Nance White Creek, which drain unmined areas are bicarbonate water. In the upper Ball Creek and the Barton Fork basins, which contain extensive amounts of land disturbed by surface mining, base flows are sulfate water. Chemical data for Ball Creek near Council are not available for high flows and therefore no trend with change in flow is presented for Ball Creek.

 (page 24 follows)

RUSSELL FORK BASIN ABOVE DAVENPORT, VA.

Six wells were sampled along the Russell Fork upstream from Davenport, Va.. Five wells contain bicarbonate water. The sixth well contains a chloride water.

The Russell Fork near Davenport, Va. contains sulfate water at both high and base flow. The trend in composition at base flow is toward that of the bicarbonate well water. The ground water along the main-stem Russell Fork does not appear to make as significant a contribution to the chemistry of the stream water as do tributaries, such as Ball Creek, which drain basins affected by surface mining activities.

 (page 26 follows)

HURRICANE CREEK BASIN

Seventeen wells and three springs were sampled throughout the Hurricane Creek basin. All wells and two springs contain bicarbonate water. The remaining spring contains a sulfate water and is probably associated with a coal seam. Well water is calcium enriched except for two wells along the main stem. These wells penetrate to lower altitudes and contain sodium-enriched water.

The Left Fork of Hurricane Creek contains sulfate water at both high and base flow. The main stem of Hurricane Creek is sulfate water at high flow but is bicarbonate at base flow. Stream water in lesser mined tributary basins is bicarbonate water. Water contributed by heavily mined tributary basins is sulfate water.

The chemical composition of ground water in the Hurricane Creek basin appears unaffected by mining activities.

 (page 28 follows)

SUMMARY AND CONCLUSIONS

Ground water in southern Buchanan County is diverse in chemical character and composition. Bicarbonate is the dominant water type. Sulfate water is found at all altitudes, but chloride water is limited to aquifers at lower altitudes and in valley bottoms near lineaments.

Some ground water exceeds recommended limits for drinking water in dissolved solids, chloride, sulfate, iron, and manganese. Hydrogen sulfide odors are reported by residents as well. Based on data from within the study area, there is no evidence that mining has caused any area wide degradation of ground-water quality. Intensive surface mining may, however, affect ground-water quality locally.

With diminishing flow, the composition of stream water trends toward the composition of the local ground water. In basins relatively undisturbed by man, stream water is predominantly bicarbonate at both high flow and base flow. Most streams whose basins have been disturbed by mining carry calcium sulfate water at higher flows.

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APPENDIX 1

Appendix I.--Chemical analyses of stream water sampled at high and base flow. All constituent concentrations are in milligrams per liter.

Station identification		Discharge (ft^3/s) High	Discharge (ft^3/s) Base	Dissolved solids	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Water classification
03207210	Levisa Fork near			137	22	6.4	9.1	1.9	67	38	8.8	Calcium bicarbonate
	Grimsleyville		.70	194	38	11	14	2.3	110	49	12	Calcium bicarbonate
03207223	Levisa Fork at	47		200	26	12	18	1.9	57	100	7.0	Calcium sulfate
	Oakwood		4.6	623	65	25	89	3.9	131	250	93	Calcium sulfate
03207225	Garden Creek at	18		172	23	13	5.5	1.9	43	87	1.5	Calcium sulfate
	Mount Vernon		1.4	529	66	32	21	3.9	127	240	4.9	Calcium sulfate
03207228	Right Fork at	26		107	14	6.2	7.5	1.6	36	43	3.4	Calcium sulfate
	Mount Vernon		1.1	324	49	18	28	3.5	148	120	13	Calcium sulfate
03207390	Big Prater Creek	9.9		320	25	8.2	59	2.0	54	39	100	Sodium chloride
	near Vansant		1.5	509	57	18	98	4.8	126	100	170	Calcium chloride
03208034	Grissom Creek near Council		.02	130	19	8.1	8.3	2.4	90	6.9	9.5	Calcium bicarbonate
03208036	Barton Fork near Council		.08	225	31	14	12	2.1	65	75	8.2	Calcium sulfate
03208039	Ball Creek near Council		.22	258	39	18	11	3.1	95	110	6.4	Calcium sulfate
03208040	Russell Fork			92	13	5.7	4.6	1.6	33	35	5.1	Calcium sulfate
	at Council		1.4	149	25	11	6.6	2.1	79	45	5.7	Calcium bicarbonate
03208043	Russell Fork	24		98	11	5.9	4.2	1.4	27	38	3.8	Calcium sulfate
	at Davenport		1.6	211	30	14	8.1	2.9	87	76	8.2	Calcium sulfate
03208046	Hurricane Creek	11		70	8.4	3.8	3.2	1.2	29	25	1.3	Calcium sulfate
	near Davenport		.59	145	23	8.3	8.1	2.7	78	40	6.0	Calcium bicarbonate
03208048	Left Fk Hurricane	9.1		106	12	6.1	2.9	1.3	25	41	1.2	Calcium sulfate
	Creek nr Davenport		.63	199	36	15	6.6	2.8	78	85	3.6	Calcium sulfate
370435082022701	Ball Creek below Barton Fork		.22	283	41	20	11	3.0	89	130	5.7	Calcium sulfate
370438082034701	Russell Fork above Ball Creek		.26	111	16	43	11	1.9	71	11	15	Calcium bicarbonate
370445082021901	Ball Creek above Grissom Creek		.14	398	58	30	10	2.9	105	190	4.0	Calcium sulfate
370512082020501	Ball Creek above Nance White Branch		.13	462	63	35	9.1	2.7	91	180	1.8	Calcium sulfate
370513082020701	Nance White Branch		.005	156	26	11	10	2.3	134	8.3	11	Calcium bicarbonate

APPENDIX 2

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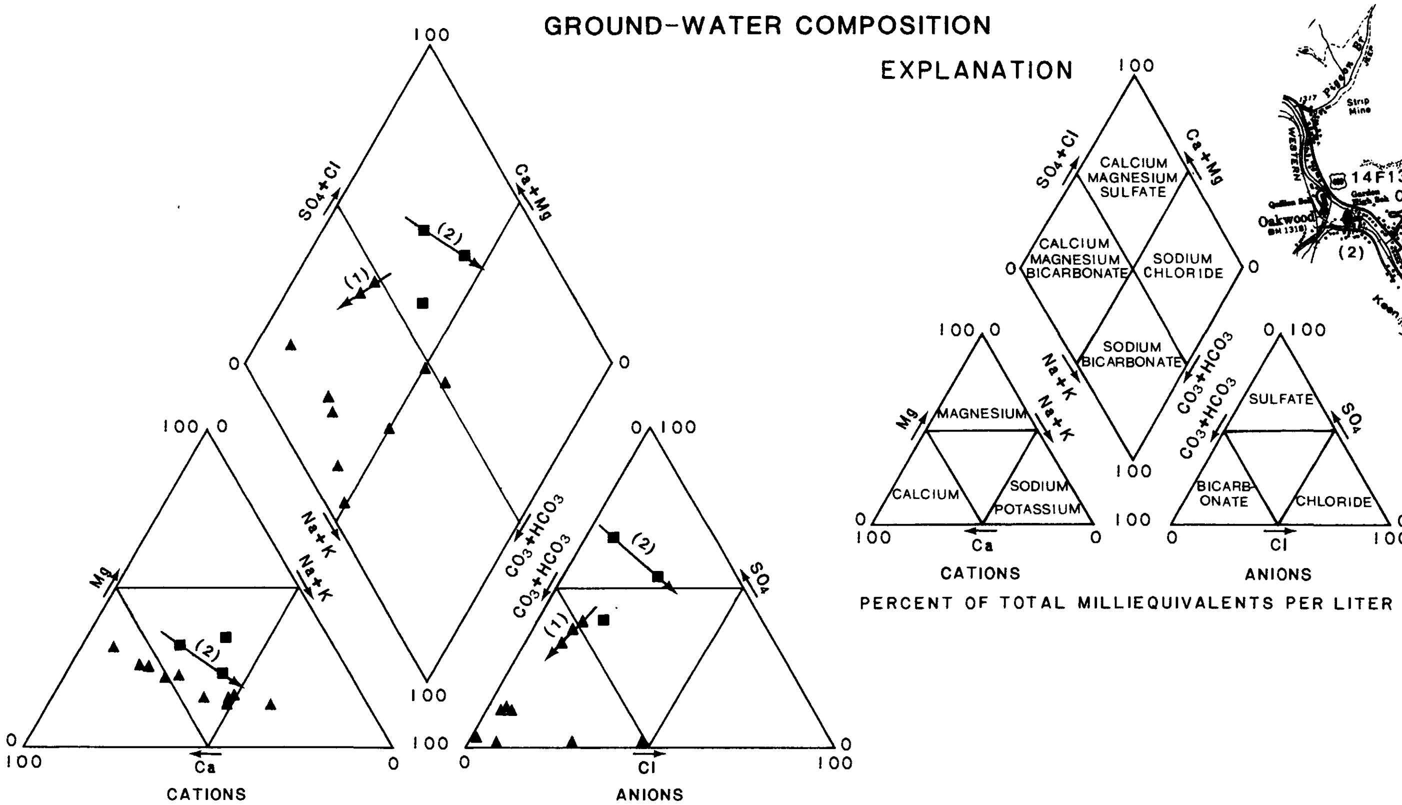

Figure 4.--Chemical composition of ground water and trends in stream-water composition.

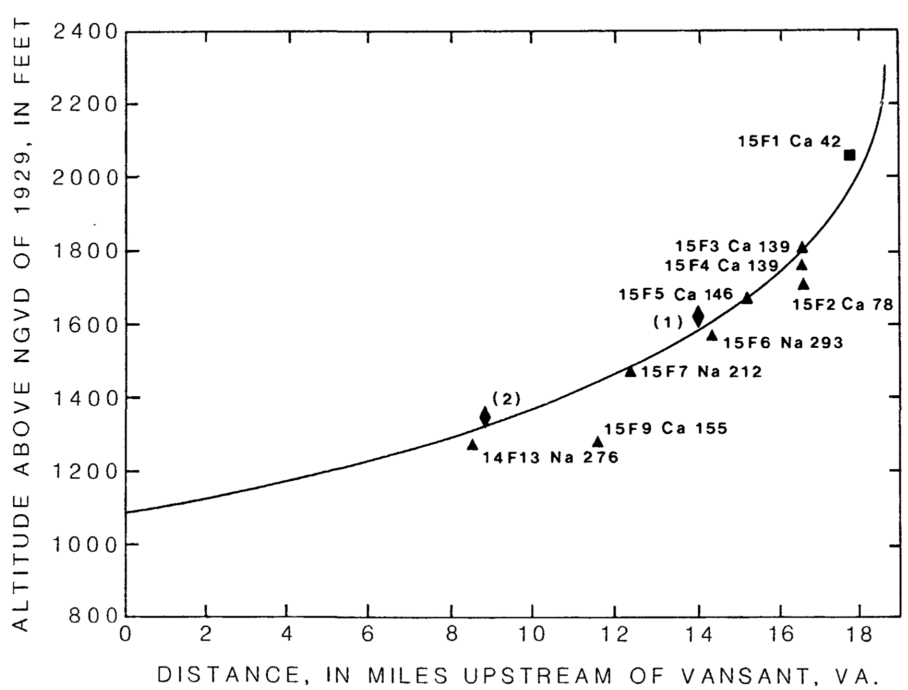

Figure 5.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

◆ 03207210	Streamflow and water-quality sampling site and number
(1) →	Trend in water quality from high flow to low flow at streamflow site
▲	Well or spring containing bicarbonate water
●	Well or spring containing chloride water
■	Well or spring containing sulfate water
15F1	Well number
15FS1	Spring number
Ca	Cations more than 50 percent calcium
Na	Cations more than 50 percent sodium
139	Dissolved solids, in milligrams per liter

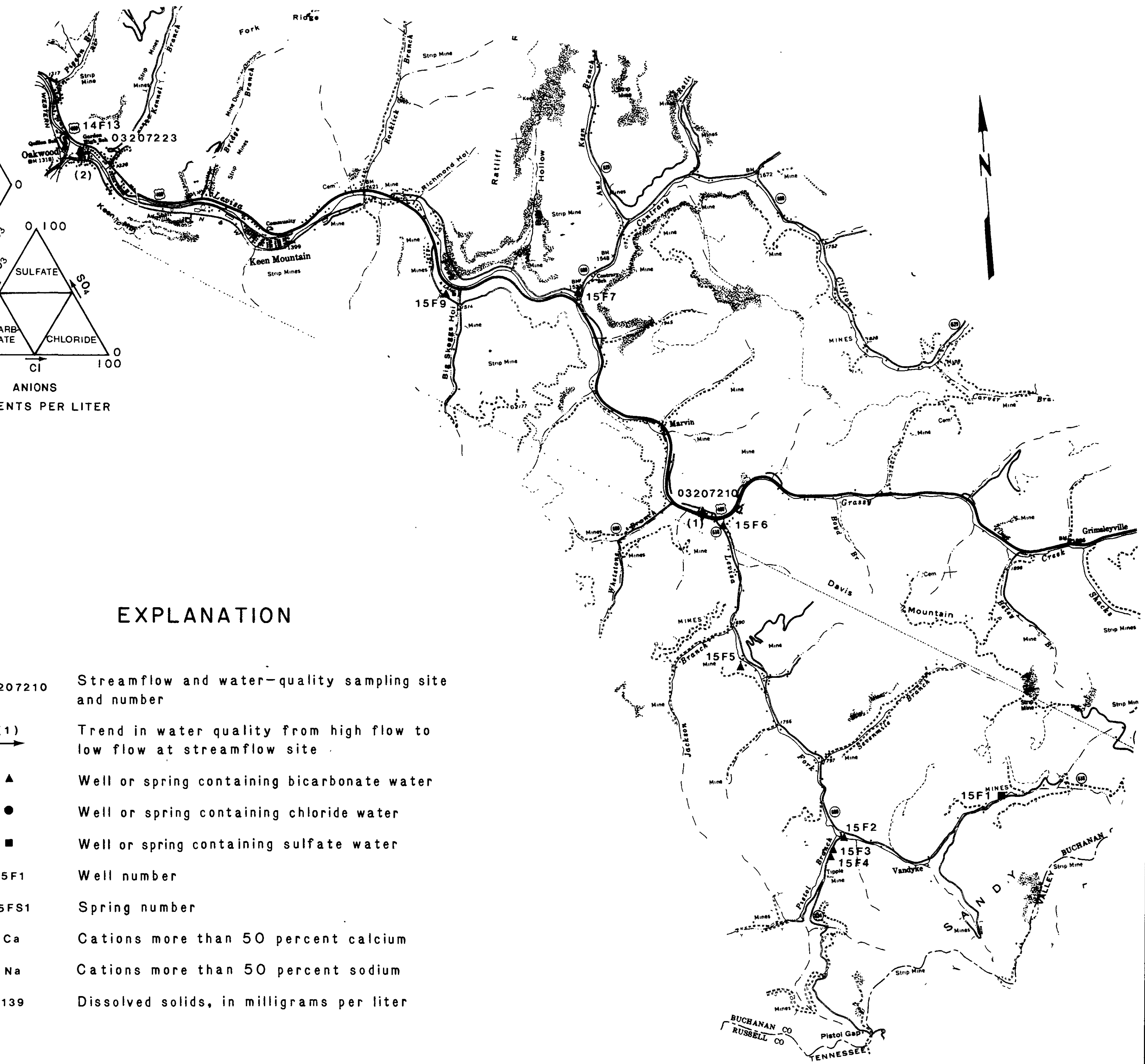

Figure 6.--Sampling sites in Levisa Fork basin above Oakwood, Virginia.

GROUND-WATER COMPOSITION

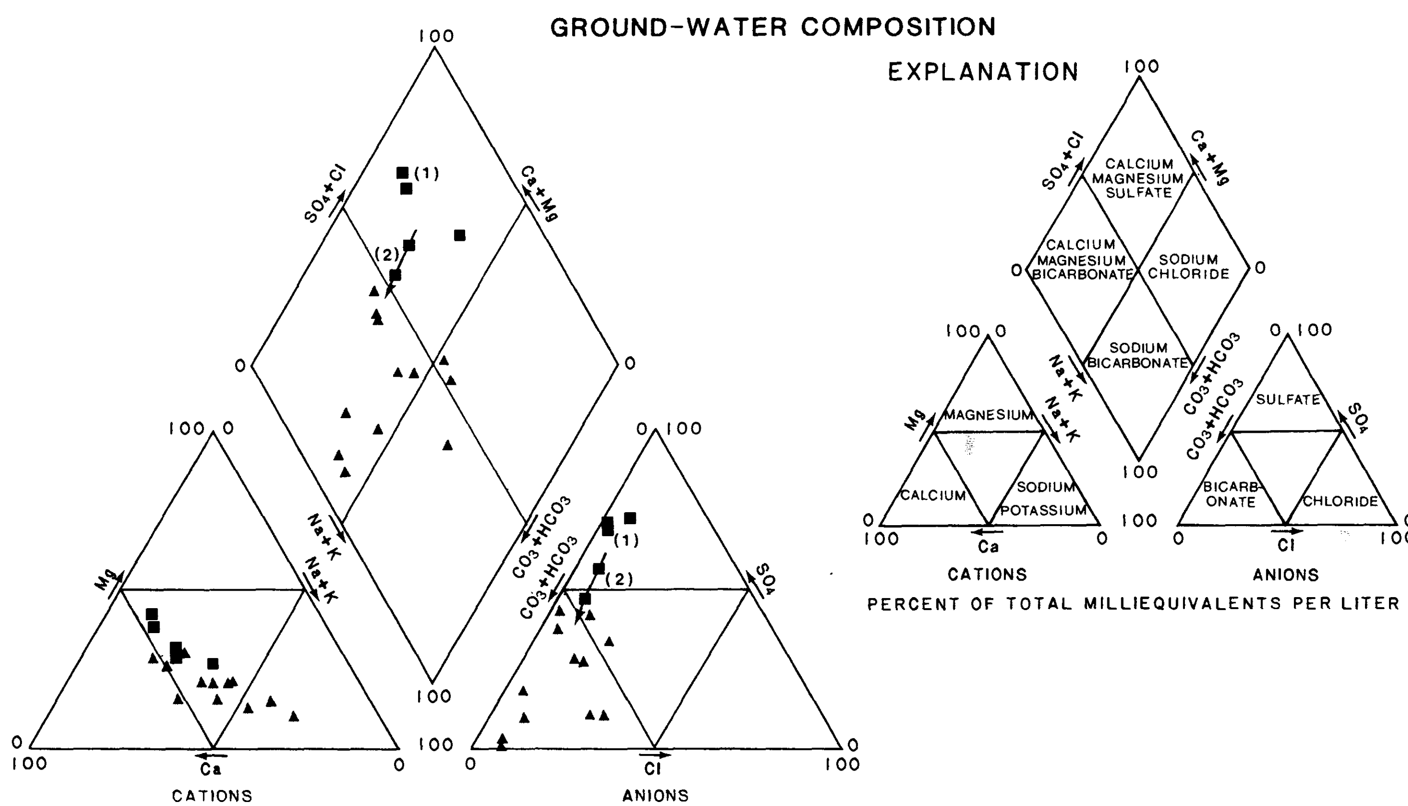

Figure 7.--Chemical composition of ground water and trends in stream-water composition.

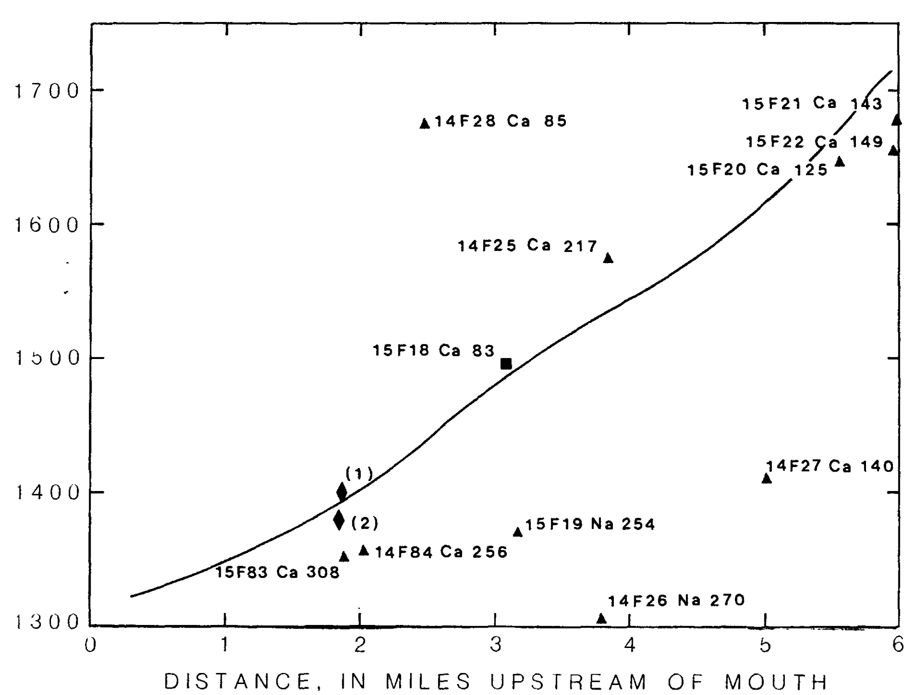

Figure 8.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

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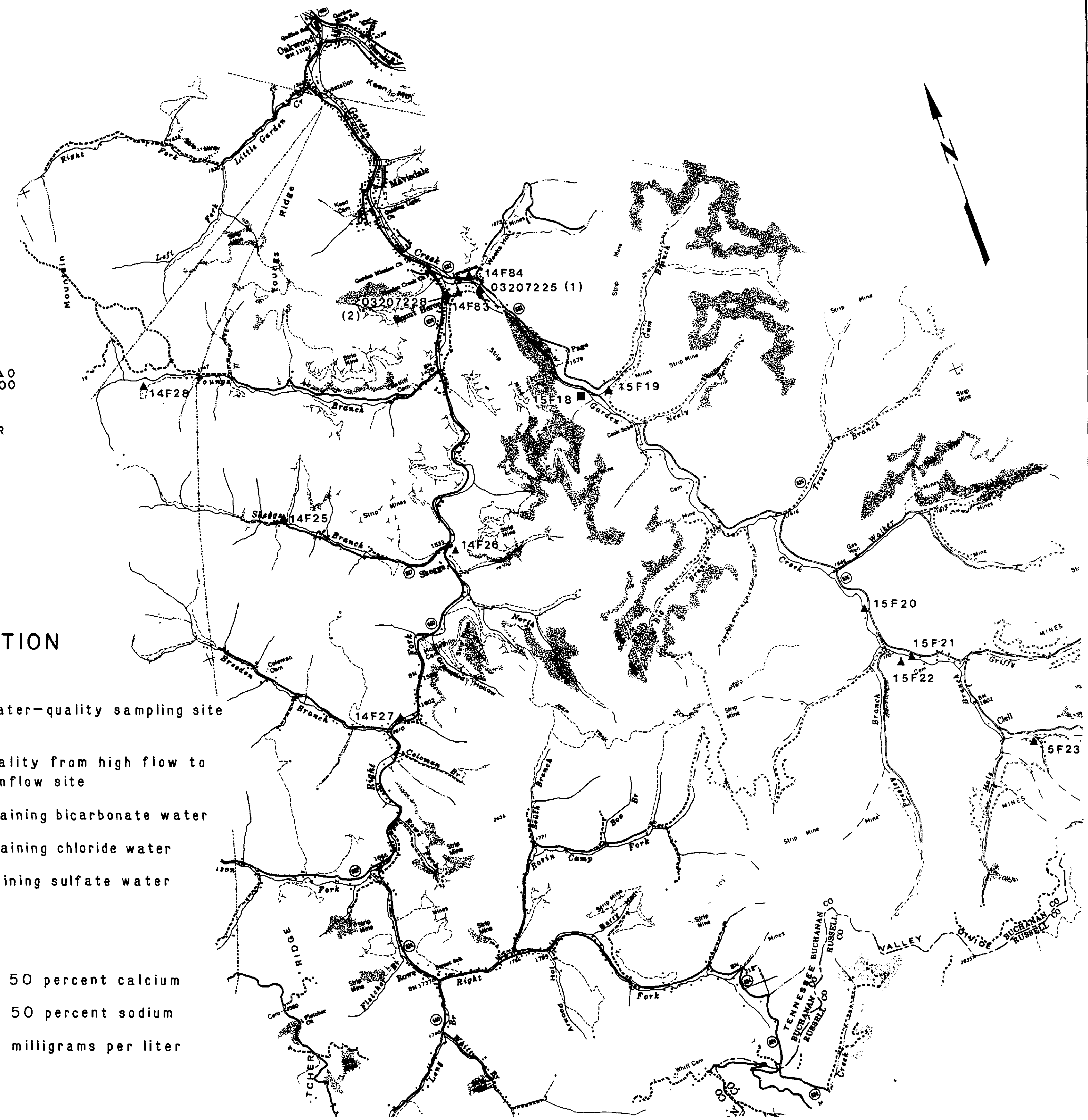

Figure 9.--Sampling sites in Garden Creek basin.

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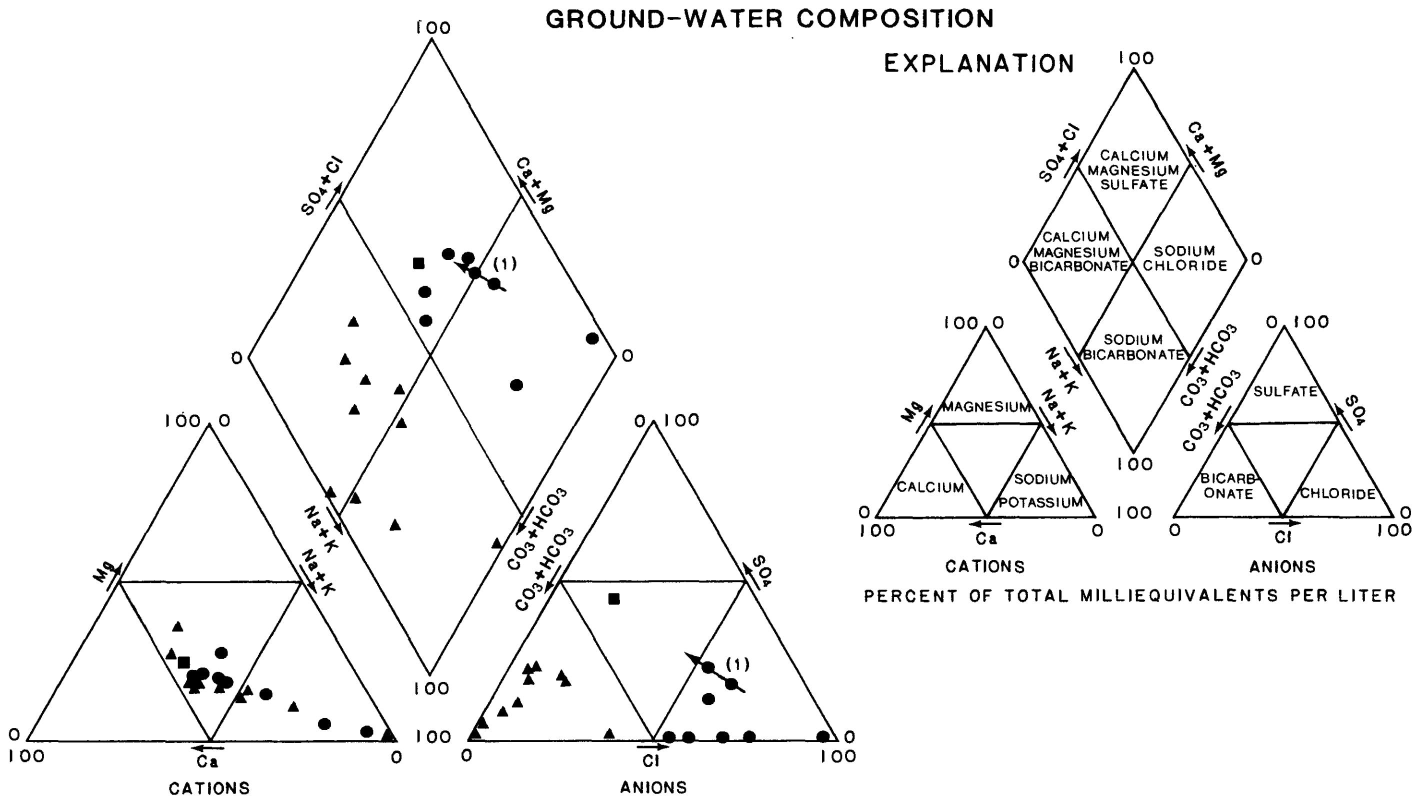

Figure 10.--Chemical composition of ground water and trends in stream-water composition.

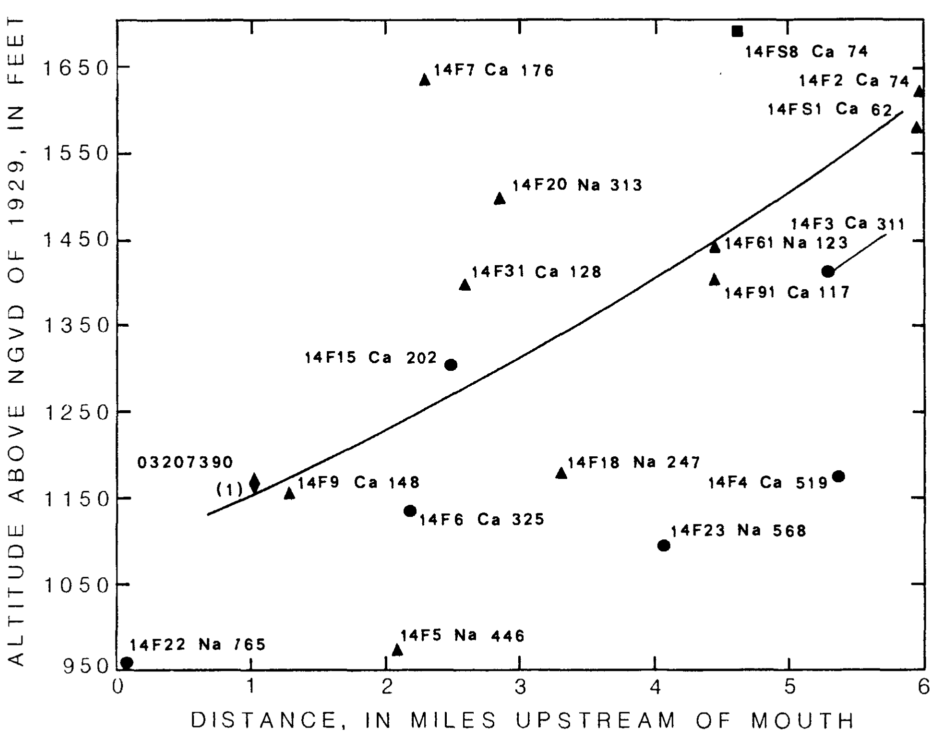

Figure 11.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

♦ 03207210	Streamflow and water-quality sampling site and number
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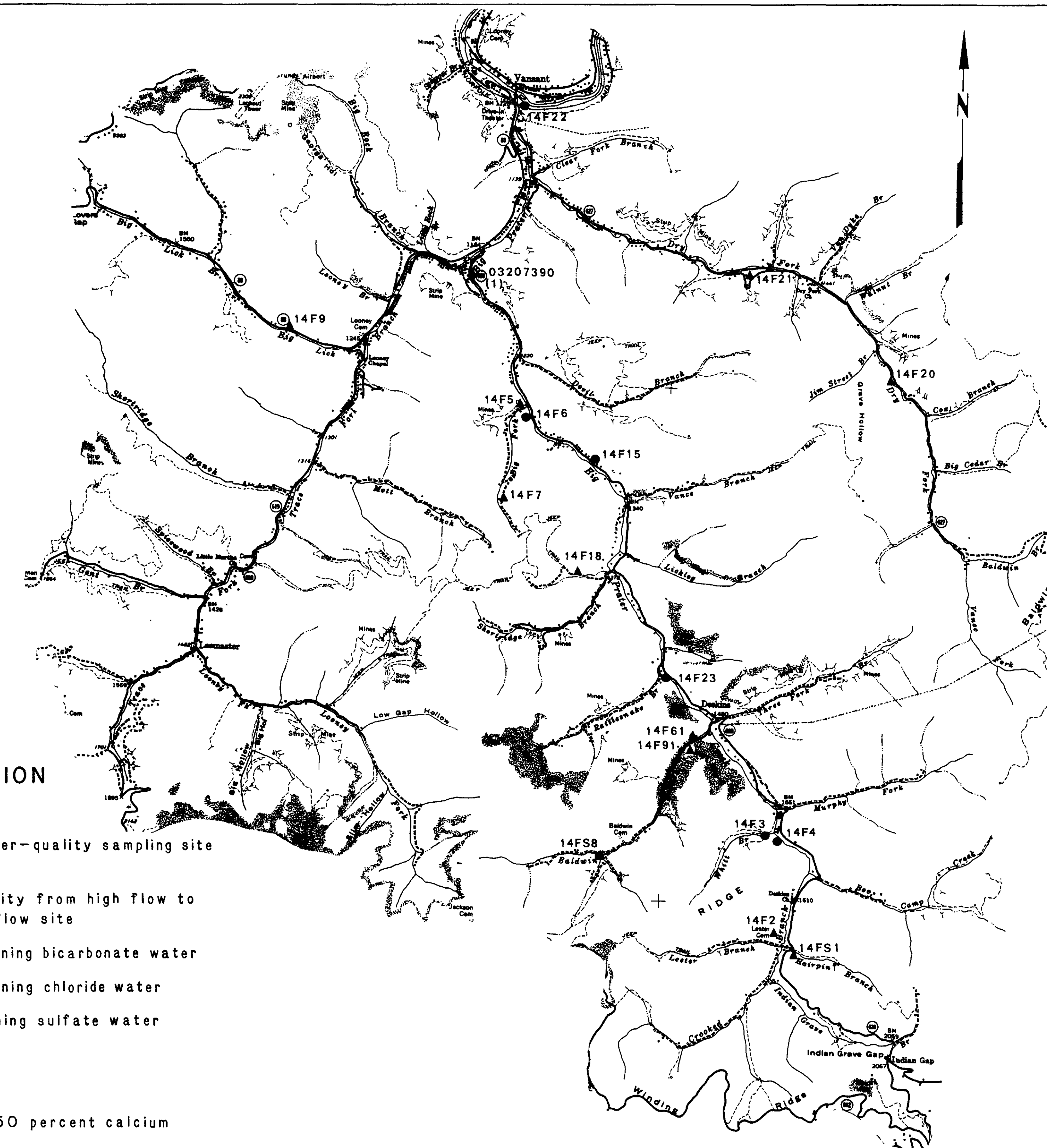

Figure 12.--Sampling sites in Big Prater Creek basin.

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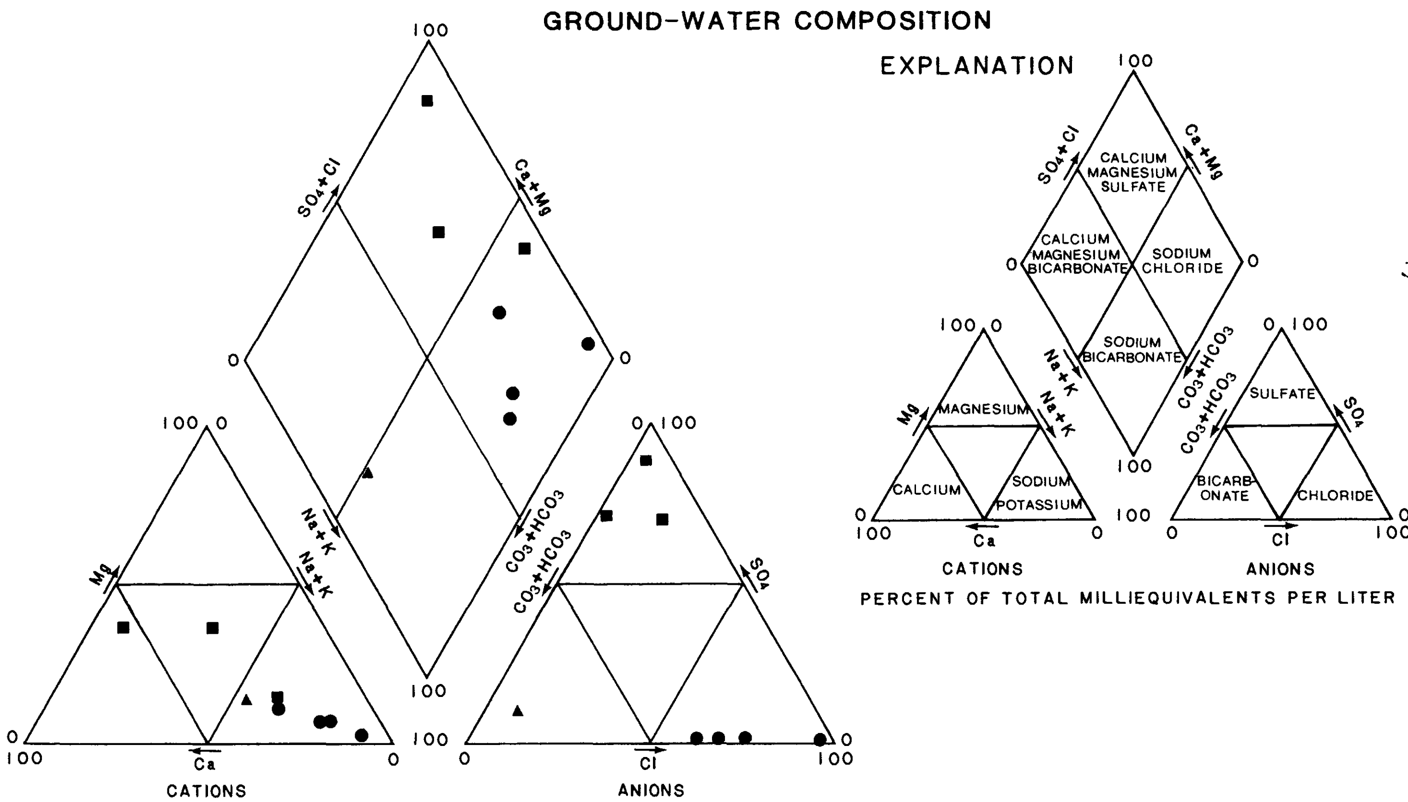

Figure 13.--Chemical composition of ground water and trends in stream-water composition.

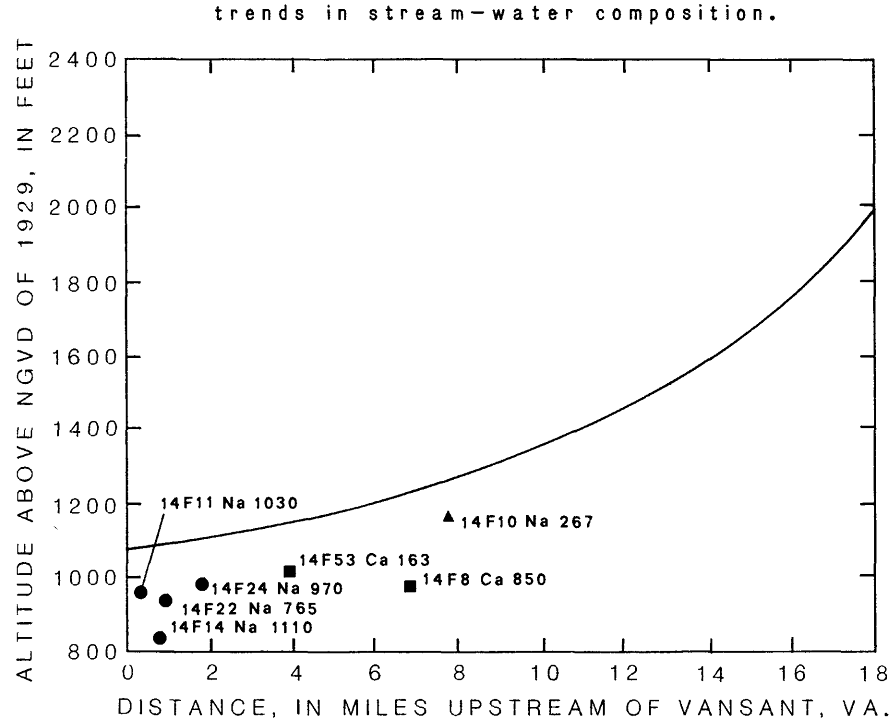

Figure 14.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

♦ 03207210	Streamflow and water-quality sampling site and number
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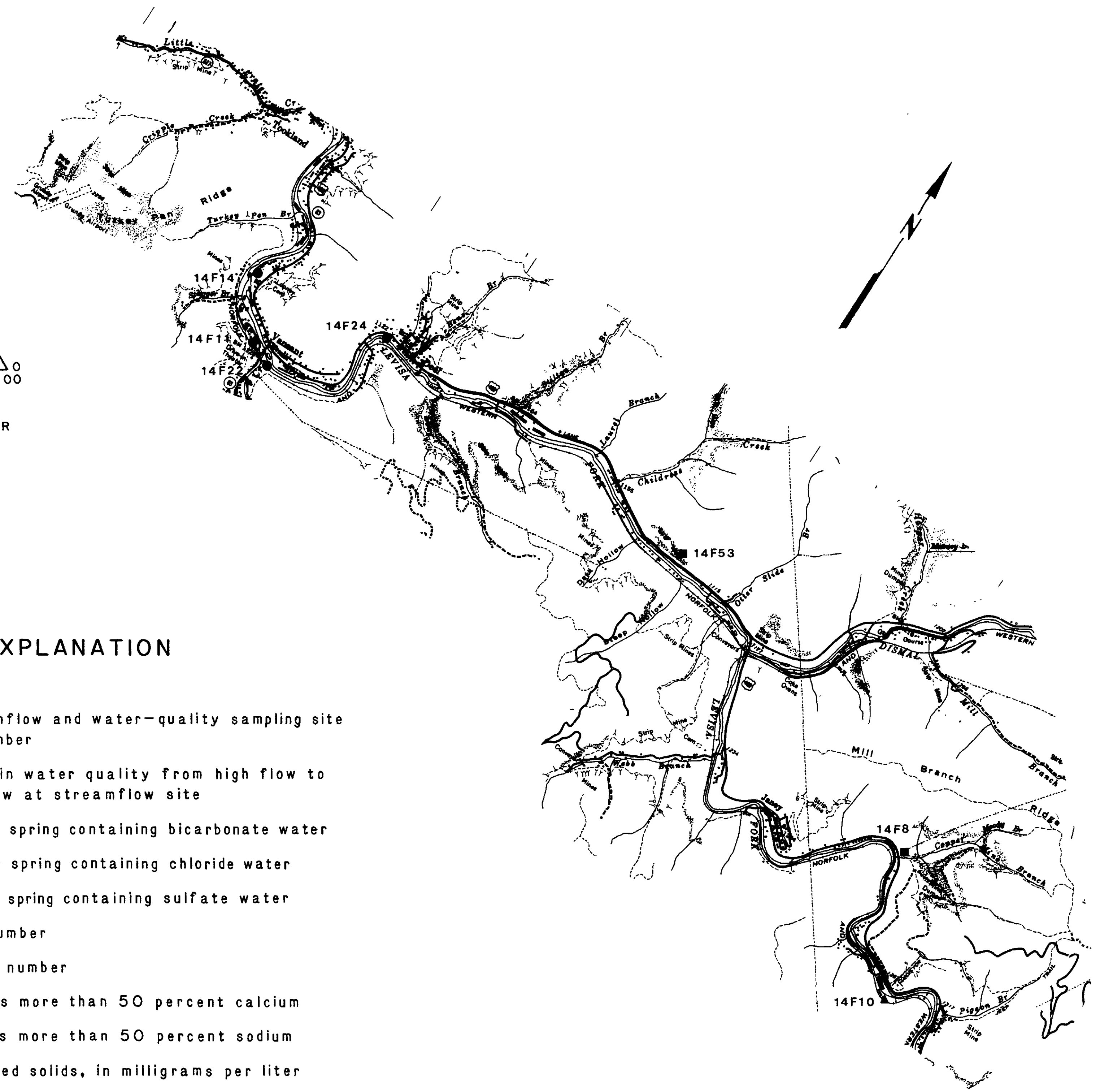

Figure 15.--Sampling sites in Levisa Fork basin between Vansant and Oakwood, Virginia.

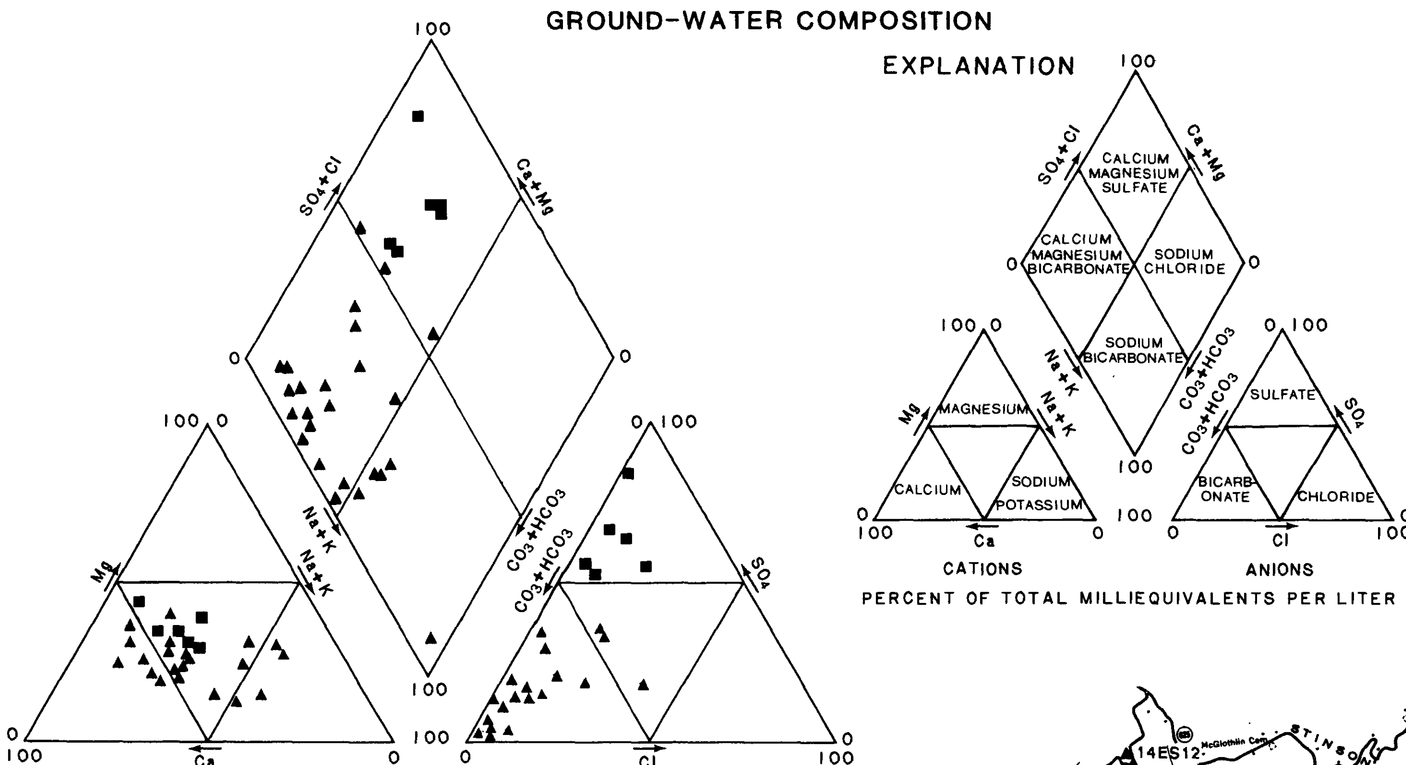

Figure 16.--Chemical composition of ground water.

EXPLANATION

♦ 03207210	Streamflow and water-quality sampling site and number
(1) →	Trend in water quality from high flow to low flow at streamflow site
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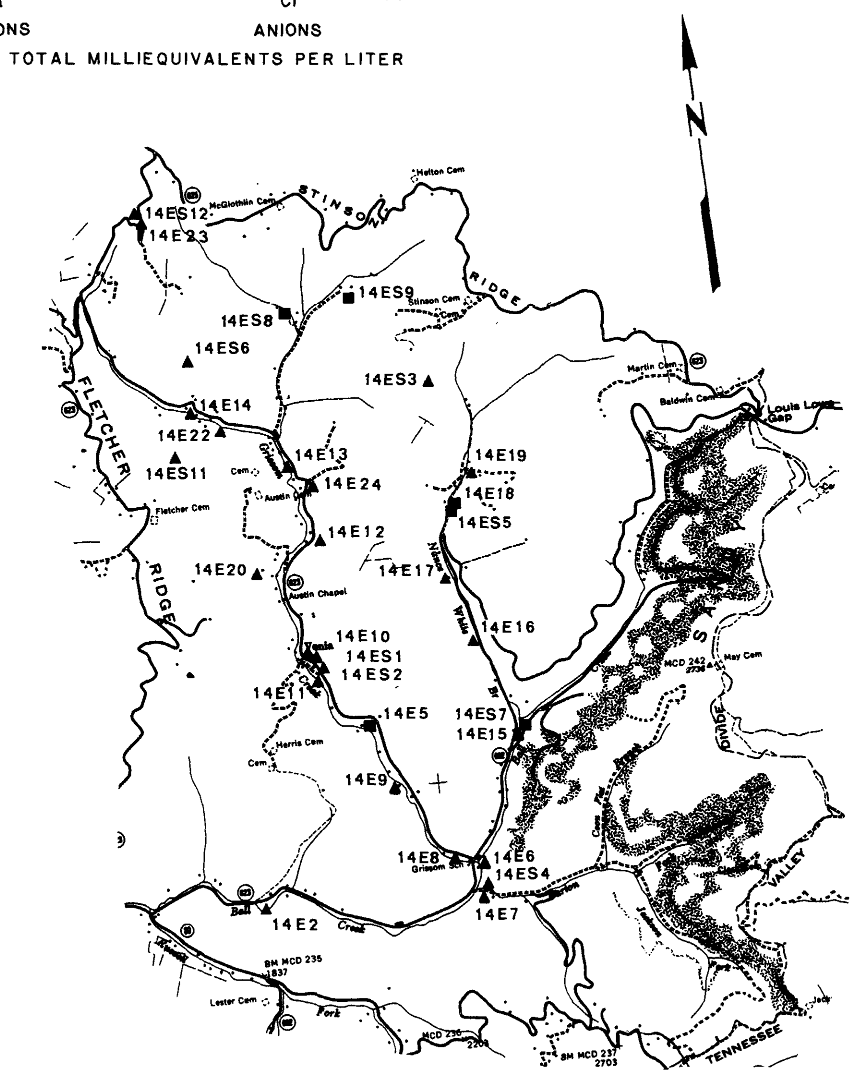

Figure 18.--Sampling sites in Ball Creek basin.

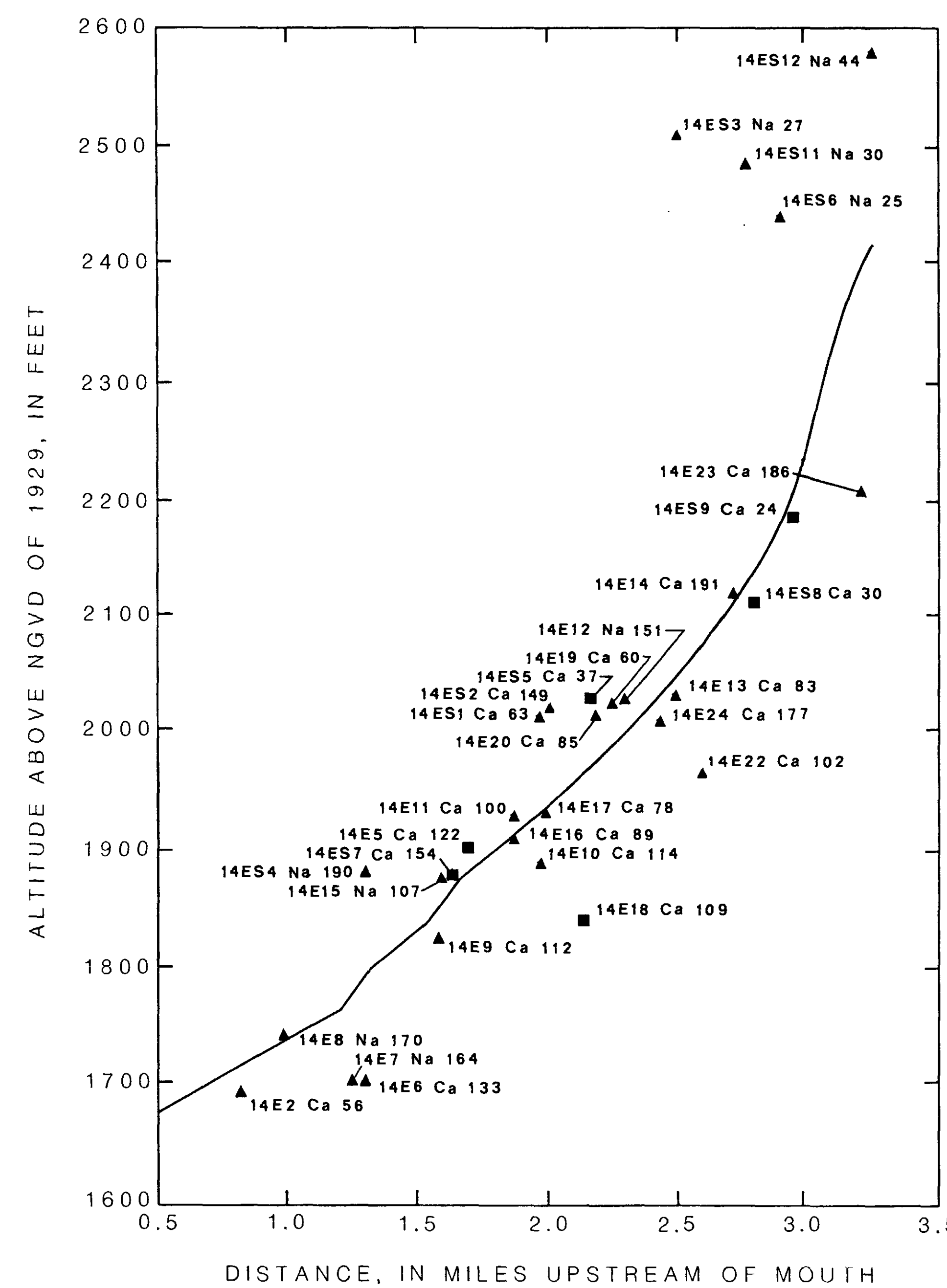

Figure 17.--Stream-bed profile showing altitudes of springs and well bottoms.

GROUND-WATER COMPOSITION

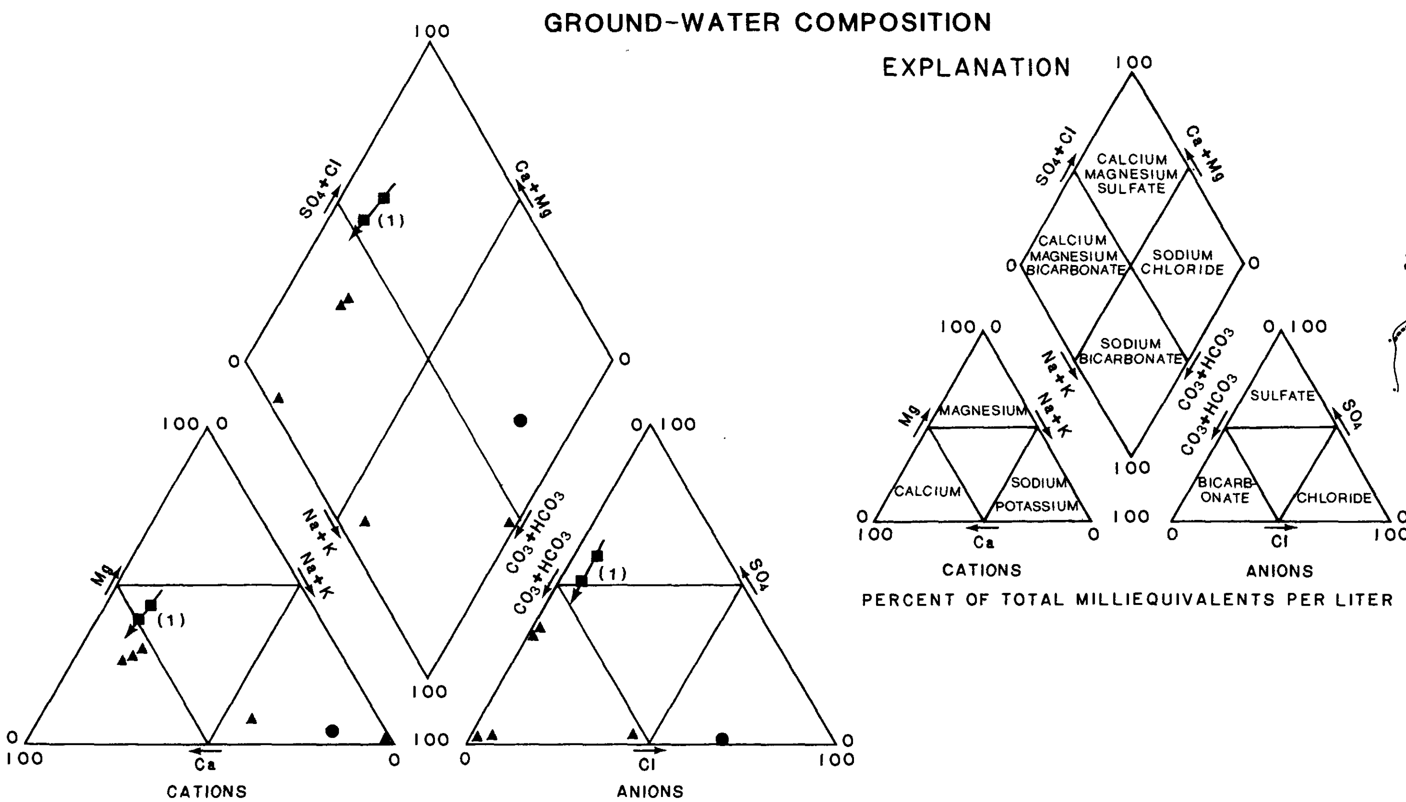

Figure 19.--Chemical composition of ground water and trends in stream-water composition.

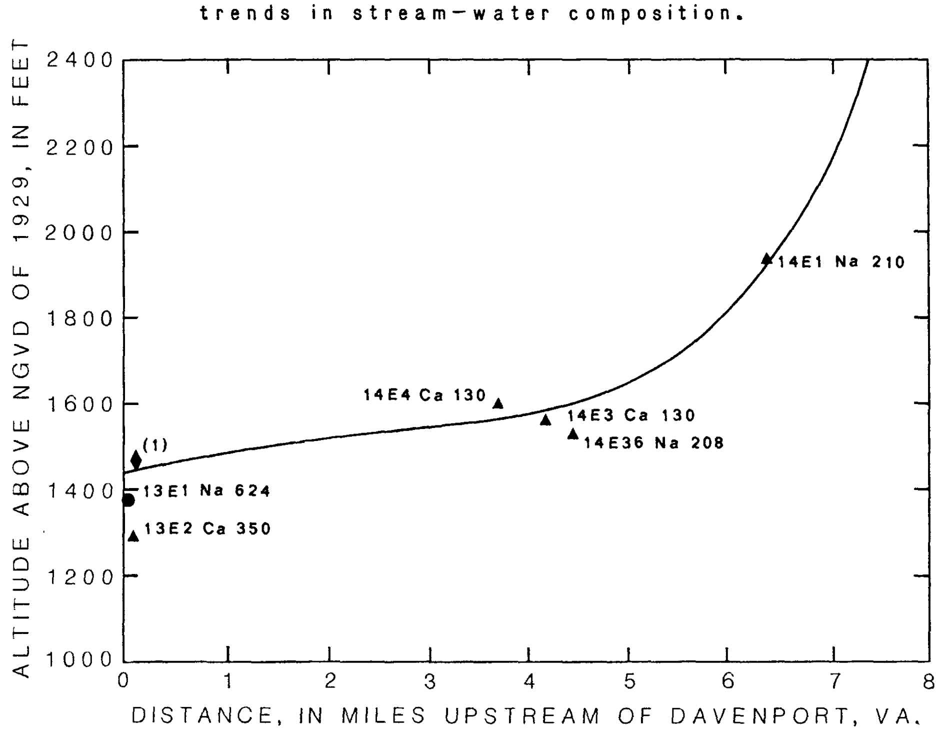

Figure 20.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

◆ 03207210	Streamflow and water-quality sampling site and number
(1) →	Trend in water quality from high flow to low flow at streamflow site
▲	Well or spring containing bicarbonate water
●	Well or spring containing chloride water
■	Well or spring containing sulfate water
15F1	Well number
15FS1	Spring number
Ca	Cations more than 50 percent calcium
Na	Cations more than 50 percent sodium
139	Dissolved solids, in milligrams per liter

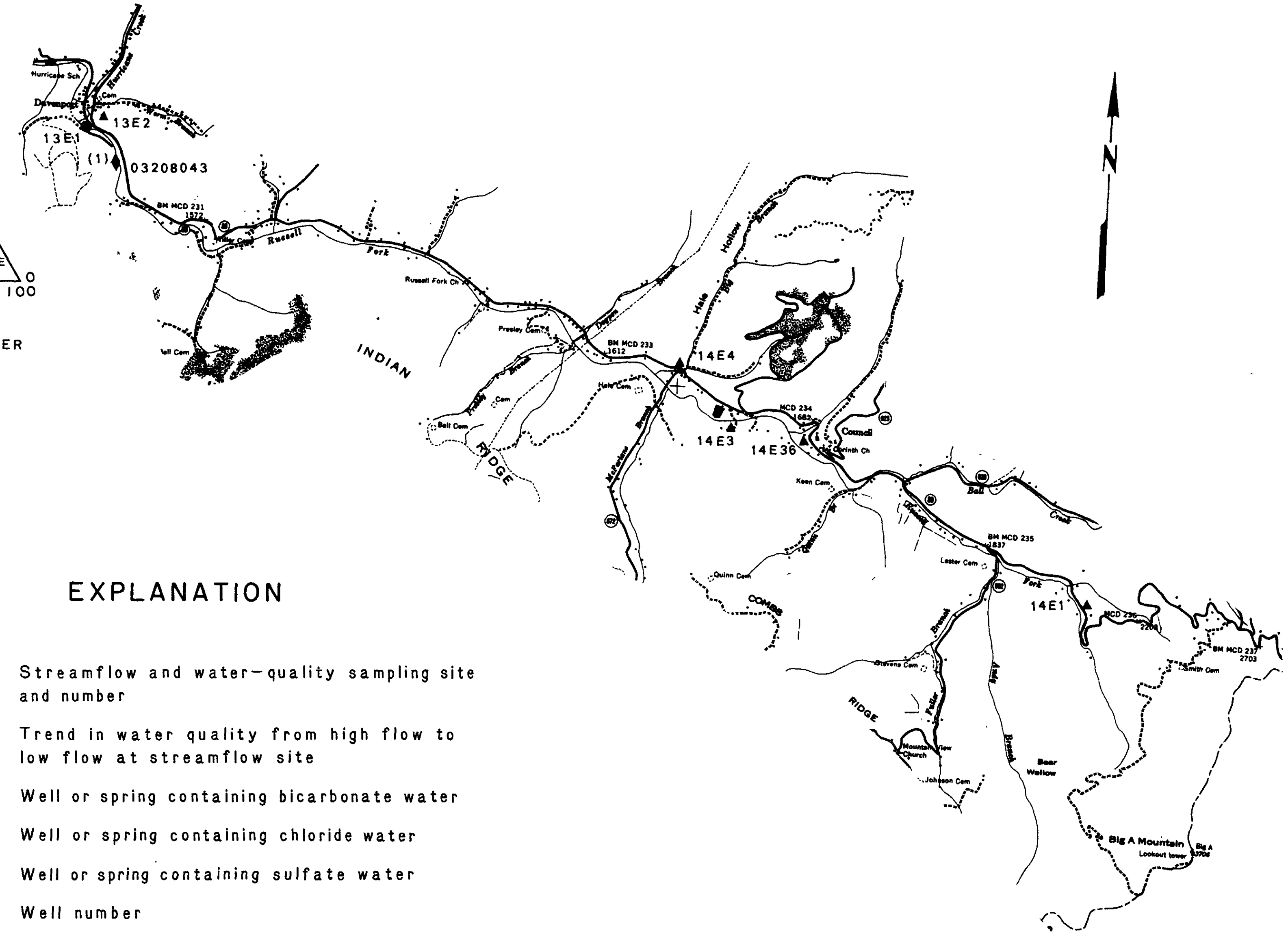

Figure 21.--Sampling sites in Russell Fork basin above Davenport, Virginia.

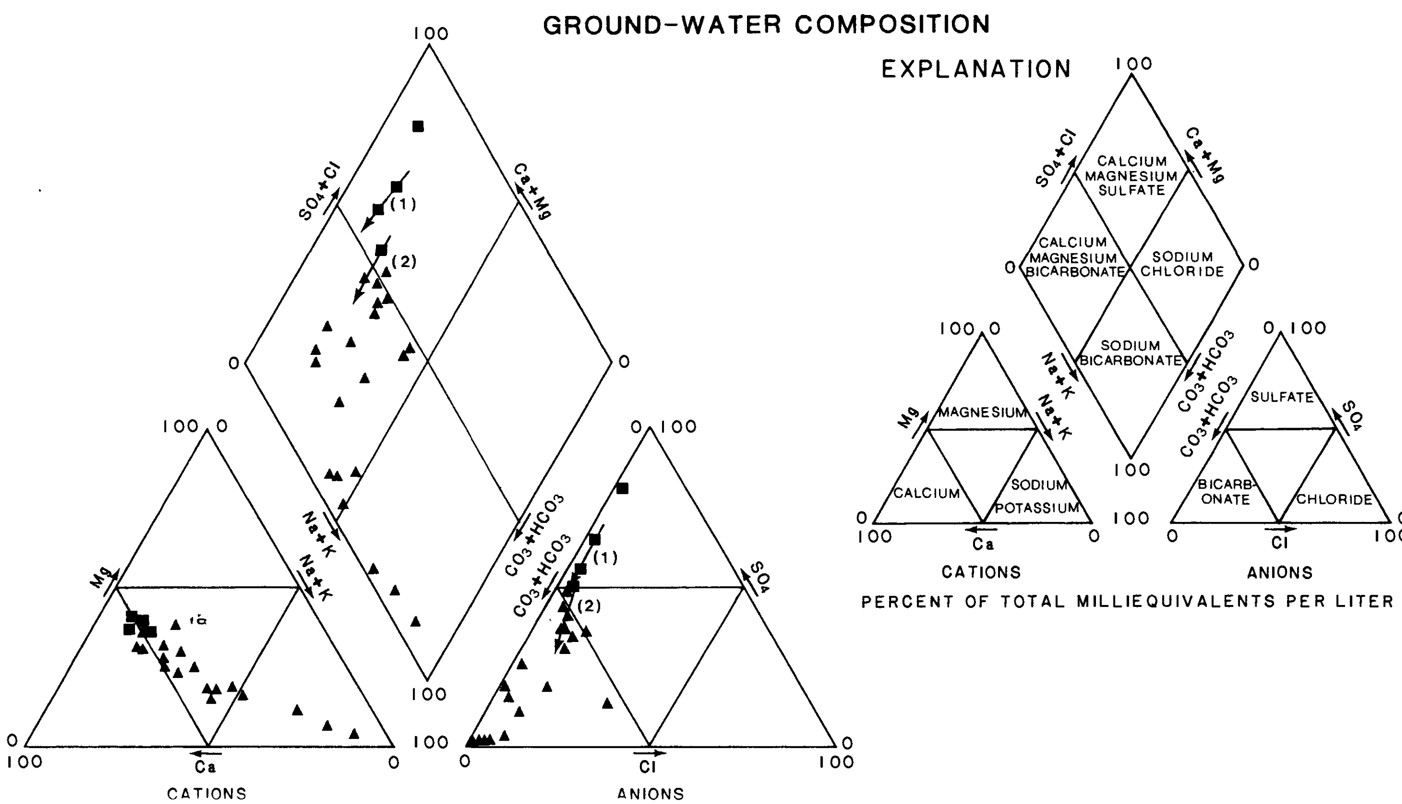

Figure 22.--Chemical composition of ground water and trends in stream-water composition.

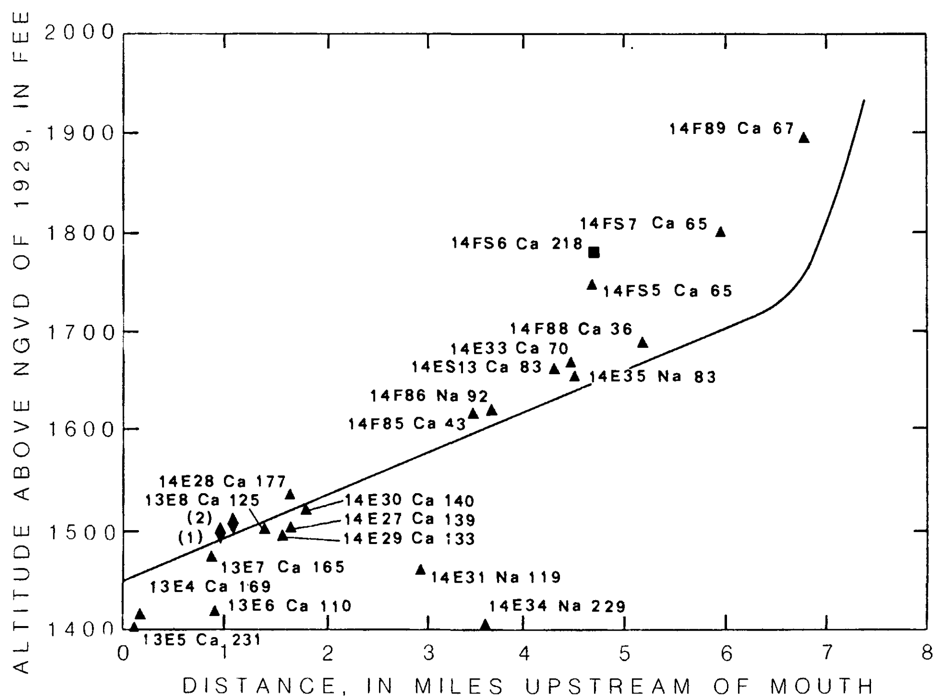

Figure 23.--Stream-bed profile showing altitudes of springs and well bottoms.

EXPLANATION

♦ 03207210	Streamflow and water-quality sampling site and number
(1) →	Trend in water quality from high flow to low flow at streamflow site
▲	Well or spring containing bicarbonate water
●	Well or spring containing chloride water
■	Well or spring containing sulfate water
15F1	Well number
15FS1	Spring number
Ca	Cations more than 50 percent calcium
Na	Cations more than 50 percent sodium
139	Dissolved solids, in milligrams per liter

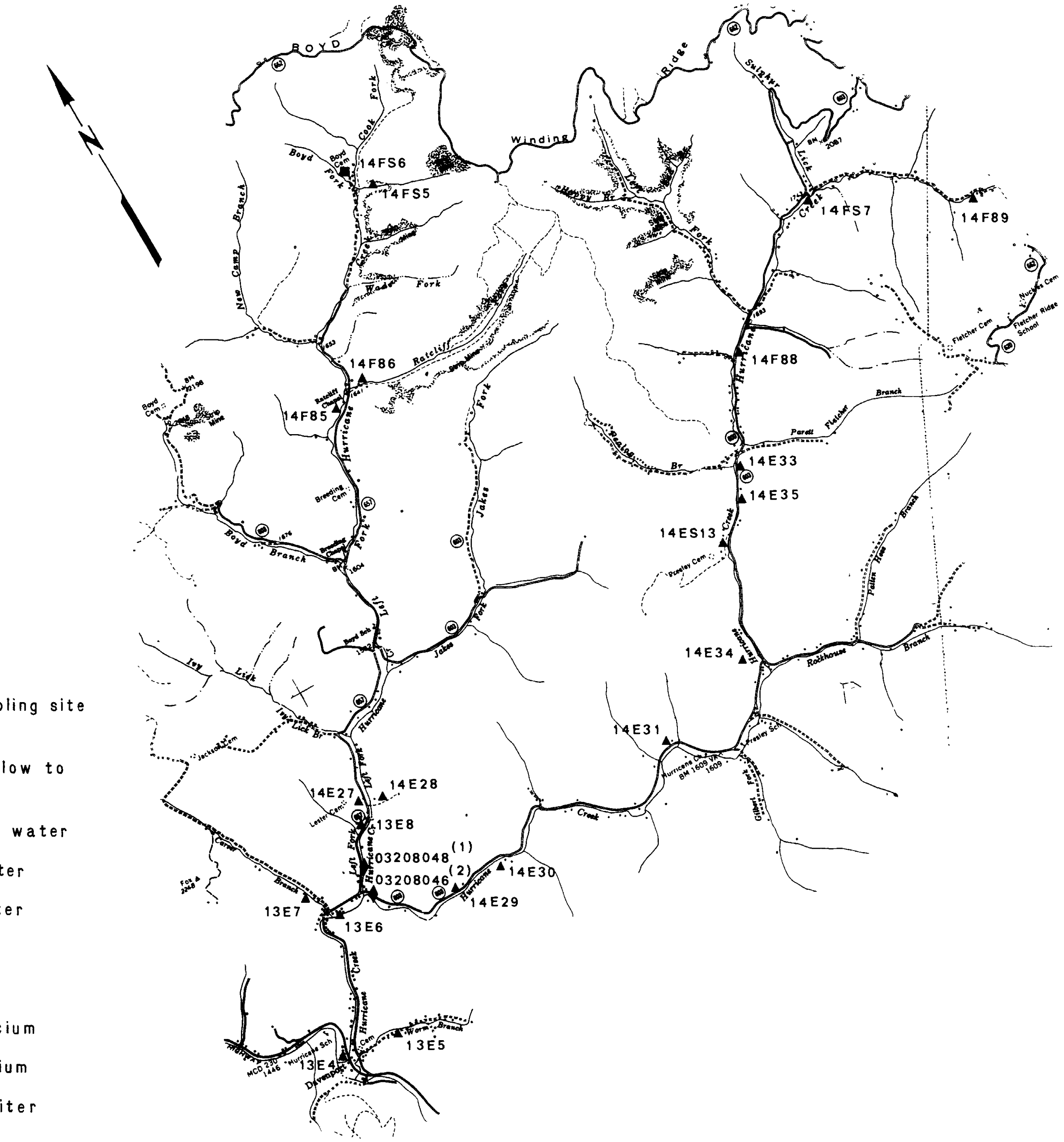

Figure 24.--Sampling sites in Hurricane Creek basin.

Appendix 2.--Chemical analyses of ground water sampled within the study area.

LOCAL IDENTIFIER	LATITUDE	LONGITUDE	SEQ. NO.	ALT. OF WELL BOTTOM DATUM (FT. NGVD)	DEPTH OF WELL, TOTAL (FEET)	DATE OF SAMPLE	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	pH FIELD (UNITS)	HARD-NESS (mg/L AS $CaCO_3$)	HARD-NESS NONCAR-BONATE (mg/L as $CaCO_3$)	CALCIUM, DISSOLVED (mg/L as Ca)	MAGNE-SIUM, DIS-SOLVED (mg/L as Mg)	SODIUM, DIS-SOLVED (mg/L as Na)	POTAS-SIUM DIS-SOLVED (mg/L as K)	IRON, DIS-SOLVED (μg/L as Fe)	ALKA-LINITY (mg/L as $CaCO_3$)	SULFATE DIS-SOLVED (mg/L as SO_4)	CHLO-RIDE DIS-SOLVED (mg/L as Cl)	SILICA, DIS-SOLVED (mg/L as SiO_2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L)	MANGA-NESE, DIS-SOLVED (μg/L as Mn)
LEVISA FORK RIVER BASIN																					
15F 1 Stillwell, Sally	37 08 50	081 54 48	01	2050	30	78-06-05	50	6.5	12	5	2.1	1.6	2.6	1.3	<10	7	6.3	2.2	8.6	42	
15F 3 Wade, Lettie Dug W	37 08 40	081 55 57	01	1802	18	78-06-05	230	6.9	100	21	27	8.6	3.4	2.0	<10	82	10	3.5	4.0	139	
15F 4 Wade, Lettie	37 08 40	081 55 57	02	1760	60	78-06-05	180	6.8	49	U	15	2.9	16	1.0	30	78	1.1	4.2	14	111	
15F 2 Daily Wade Well	37 08 42	081 55 53	01	1695	145	78-06-05	120	6.7	36	0	10	2.7	7.1	1.1	30	49	5.4	2.2	14	78	
15F 5 McNulty, Toy	37 09 41	081 56 25	01	1678	42	78-06-05	245	7.0	82	0	23	6.0	14	1.1	50	98	13	4.4	15	146	
15F 6 Rose, Garland	37 10 23	081 56 27	01	1560	55	78-06-05	520	7.1	120	0	37	6.9	57	1.6	<10	130	.2	89	16	293	
*15F 7 Ike's Ser. Station	37 11 39	081 57 14	01	1472	48	74-08	370	7.5	100		31	6.6	48	0.9		151	0.8	41		212	
*15F 9 Buck Co. Funrl. Hm.	37 11 43	081 58 01	01	1274	206	74-10	225	7.2	88		23	5.0	35	1.0		151	3.0	1.0		155	
*14F 13 Garden Elem. Sch.	37 12 43	082 00 24	01	1270	50	74-08	443	7.0	112		28	9.1	70	1.4		135	92	22		276	
*14F 10 Islnd. Crk. Coal Co.	37 12 59	082 00 47	01	1170	120	75-08	405	8.2	110		32	7.9	57	1.3		184	23	14		267	
14F 53 Jewell Office 1	37 14 10	082 03 18	01	1020	140	81-02-24	270	6.8	100	91	25	10	4.0	1.9	<10	13	79	16	9.6	163	60
14F 52 Isle Crk VPI	37 14 26	082 02 00	01	1007	182	81-02-24	1400	7.1	260	110	75	17	180	2.8	5400	147	11	370	14	835	1300
14F 24 Noah Horn Driller	37 14 18	082 05 25	01	982	140	80-09-23	1600	7.9	160	0	43	11	300	2.1	110	296	16	370	17	970	180
14F 8 Dept Hway Oakwood	37 13 37	082 01 08	01	977	393	80-04-11	1180	6.9	380	220	70	49	78	9.2	0	160	420	11	11	850	2500
*14F 11 Vansant Elem. Sch.	37 14 17	082 06 15	01	957	153	74-08	1700	7.2	310		91	24	260	1.9		266	11	437		1030	
14F 22 VA Pocahontas 3	37 13 52	082 05 58	01	930	200	80-09-23	1300	7.4	140	0	39	9.3	230	2.2	610	198	7.7	320	16	765	150
*14F 14 VA Pocahontas 3	37 13 57	082 06 06	01	835	415	75-06	2000	7.8			18	5.2	310	1.6		28	2.2	505		1110	0
GARDEN CREEK BASIN																					
15F 23 Winkous Hale	37 08 05	081 57 42	01	1863	27	81-07-22	140	6.6	32	6	8.4	2.6	12	1.1	6600	26	11	6.0		64	230
15F 21 Cath. Meadows	37 08 43	081 58 23	01	1684	56	81-07-22	360	7.0	76	0	21	5.6	21	1.4	5300	110	1.3	7.1		143	390
15F 22 Wallace King	37 08 44	081 58 27	01	1655	65	81-07-22	280	7.0	72	0	21	4.7	25	1.2	6300	120	.0	7.8		149	290
15F 20 Robert Shell	37 09 03	081 58 36	01	1650	30	81-07-22	274	6.7	97	21	23	9.5	15	3.2	690	76	32	14		185	660
15F 18 Gaston Cook	37 10 32	081 59 45	01	1495	25	81-07-22	108	6.5	37	29	8.7	3.6	7.7	4.2	70	8	28	1.8		83	10
15F 19 Harold Cook	37 10 31	081 59 36	01	1370	150	81-07-22	400	7.1	100	5	29	6.5	49	2.2	2400	95	60	32		254	140
14F 84 Don Shell	37 11 18	082 00 05	01	1352	98	81-07-22	402	7.1	110	0	29	9.2	41	2.0	250	160	35	8.8		256	290
14F 83 Meadows Well	37 11 15	082 00 16	01	1350	60	81-07-22	536	7.3	150	0	40	12	49	2.1	620	170	27	55		308	1400
RIGHT FORK GARDEN CREEK BASIN																					
14F 28 Mt. Baldwin Camp	37 11 21	082 02 18	01	1680	200	80-09-25	120	7.8	42	13	11	3.4	4.4	1.2	3900	29	21	.8	12	85	950
14F 25 Jackie Ray Coal	37 10 23	082 01 30	01	1580	120	80-09-24	355	7.4	120	30	33	10	19	1.3	6800	95	56	5.6	18	217	370
14F 27 Codell Const. Co.	37 09 23	082 01 26	01	1415	185	80-09-24	240	6.8	75	0	23	3.9	16	1.2	3700	92	10	7.8	19	140	230
14F 26 VA Pocahontas 6	37 10 30	082 00 48	01	1245	305	80-09-24	425	7.1	72	0	21	4.5	68	1.5	3200	130	19	49	18	270	210

* Virginia State Water Control Board Analysis

LOCAL IDENTIFIER	LATITUDE	LONGITUDE	SEQ. NO.	ALT. OF WELL BOTTOM DATUM (FT. NGVD)	DEPTH OF WELL, TOTAL (FEET)	DATE OF SAMPLE	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	pH FIELD (UNITS)	HARD-NESS (mg/L AS $CaCO_3$)	HARD-NESS NONCAR-BONATE (mg/L as $CaCO_3$)	CALCIUM, DISSOLVED (mg/L as Ca)	MAGNE-SIUM, DIS-SOLVED (mg/L as Mg)	SODIUM, DIS-SOLVED (mg/L as Na)	POTAS-SIUM DIS-SOLVED (mg/L as K)	IRON, DIS-SOLVED (µg/L as Fe)	ALKA-LINITY (mg/L as $CaCO_3$)	SULFATE DIS-SOLVED (mg/L as SO_4)	CHLO-RIDE DIS-SOLVED (mg/L as Cl)	SILICA, DIS-SOLVED (mg/L as SiO_2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L)	MANGA-NESE, DIS-SOLVED (µg/L as Mn)
										BIG PRATER CREEK BASIN											
14FS 8 L. Cook	37 10 13	082 05 22	01	1700		81-07-23	120	6.6	36	20	9.6	2.9	6.0	3.2	70	16	18	4.9		74	40
14FS 1 Eva Singleton Spg.	37 09 47	082 04 12	01	1630		80-04-09	135	6.6	46	0	10	5.1	5.8	1.0	10	48	14	7.5	10	74	2
14F 7 Fuller, Foster	37 11 56	082 06 02	01	1625	175	80-04-11	290	7.0	80	0	22	5.8	29	1.0	30	150	.0	1.3	13	176	110
14F 2 Boyd, ED	37 09 49	082 04 15	01	1586	34	80-04-09	110	5.5	30	0	7.8	2.6	4.4	1.1	1800	53	13	3.1	9.2	62	200
14F 20 Ratliff, Earl	37 12 32	082 03 40	01	1492	105	80-09-22	488	5.7	130	0	36	8.9	60	1.2	210	180	58	12	17	313	50
14F 61 E. Yates	37 10 47	082 04 55	01	1442	148	81-07-23	220	7.2	39	0	10	3.2	35	2.1		100	9.5	3.6		123	
14F 3 Corr. Unit 29 WL2	37 10 20	082 04 20	02	1410	150	80-04-09	550	6.3	140	39	39	11	40	1.8	2600	106	.0	110	16	311	150
14F 91 E. Yates	37 10 42	082 04 56	01	1401	105	81-07-23	195	7.0	65	0	19	4.2	16	1.3	620	78	10	5.1		117	260
14F 21 Street, Harrison	37 13 03	082 04 28	01	1395	105	80-09-22	200	5.5	63	0	17	4.9	15	.9	1600	69	20	3.8	19	128	150
*14F 15 Paul Yates	37 12 12	082 05 32	01	1304	46	75-06	310	6.4			17	7.9	22	1.2		71	16	52		202	
*14F 18 Edwards Well	37 11 36	082 05 34	01	1180	420	75-06	320	7.2			22	7.2	41	1.0		180	11	1.0		247	
14F 4 Dept. Hway Deskins	37 10 18	082 04 13	01	1175	385	80-04-10	748	6.8	220	110	62	16	58	2.1	2800	115	.0	180	16	519	180
*14F 9 St. Police, Vansant	37 12 43	082 07 18	01	1153	187	74-08	250	6.5	78		24	6.1	33	0.7		98	27	17		148	
14F 6 Goff, John	37 12 21	082 05 52	01	1135	135	80-04-11	590	7.5	140	23	38	11	49	1.7	430	120	3.2	100	14	325	150
14F 23 VA Pocahontas 5	37 11 07	082 05 00	01	1095	305	80-09-23	900	7.0	220	120	16	17	83	2.3	13000	100	4.0	135	17	568	1400
14F 5 Dale, Charles	37 12 22	082 05 53	01	970	305	80-04-11	750	8.0	5	0	1.3	.4	170	.8	0	240	1.5	100	11	446	4
										RUSSELL FORK BASIN ABOVE DAVENPORT, VA											
14E 1 Robinette, W J	37 04 08	082 02 43	01	1945	85	78-06-06	365	6.8	2	0	.5	.2	75	1.4	160	90	5.6	51	14	210	
14E 4 Compton, Harold D	37 05 09	082 04 56	01	1598	36	78-06-06	220	6.7	91	17	26	6.4	8.3	1.4	1600	75	33	1.8	17	143	
14E 3 Compton, Basil	37 04 49	082 04 36	01	1565	55	78-06-06	195	7.0	88	0	26	5.7	6.4	1.3	30	98	2.2	1.5	19	130	
14E 36 Council Elem. Sch.	37 04 48	082 04 18	01	1535	265	81-07-21	320	7.4	64	0	19	3.8	48	2.2	220	150	3.3	9.0		208	30
13E 1 Harris, W C	37 05 58	082 08 11	01	1382	78	78-06-06	1100	7.3	110	0	33	7.4	210	1.7	<10	190	4.0	250	15	624	
13E 1 Harris, Billy K	37 06 01	082 08 09	01	1280	200	78-06-06	520	7.2	240	54	66	19	26	1.5	<10	190	96	6.1	12	350	

Appendix 2.--Chemical analyses of ground water sampled within the study area. (continued)

LOCAL IDENTIFIER	LATITUDE	LONGITUDE	SEQ. NO.	ALT. OF WELL BOTTOM DATUM (FT. NGVD)	DEPTH OF WELL, TOTAL (FEET)	DATE OF SAMPLE	SPE- CIFIC CON- DUCT- ANCE- (MICRO- MHOS)	pH FIELD (UNITS)	HARD- NESS (mg/L AS $CaCO_3$)	HARD- NESS NONCAR- BONATE (mg/L as $CaCO_3$)	CALCIUM, DISSOLVED (mg/L as Ca)	MAGNE- SIUM, DIS- SOLVED (mg/L as Mg)	SODIUM, DIS- SOLVED (mg/L as Na)	POTAS- SIUM DIS- SOLVED (mg/L as K)	IRON, DIS- SOLVED (µg/L as Fe)	ALKA- LINITY (mg/L as $CaCO_3$)	SULFATE DIS- SOLVED (mg/L as SO_4)	CHLO- RIDE DIS- SOLVED (mg/L as Cl)	SILICA, DIS- SOLVED (mg/L as SiO_2)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (mg/L)	MANGA- NESE, DIS- SOLVED (µg/L as Mn)
BALL CREEK BASIN																					
14ES12 P. McGloth	37 07 04	082 03 34	01	2580		81-06-11	39	5.4	6	0	1.0	.9	2.8	1.3	100	17	2.7	1.8	13	44	70
14ES 3 Martin Bath Spg	37 06 26	082 02 21	01	2510		81-01-16	24	6.3	6	0	1.0	.8	1.9	.7	60	10	4.0	.7	16	27	40
14ES11 R. Rutherford	37 06 10	082 03 29	01	2485		81-06-11	28	5.8	5	2	1.1	.6	1.6	1.0	<10	3	1.0	2.0	11	30	1
14ES 6 A.L. Hess	37 06 37	082 03 24	01	2440		81-02-18	30	5.1	5	0	.7	.7	2.0	.8	10	12	1.8	.6	14	25	0
14E 23 Perry Glothlin	37 07 01	082 03 32	01	2210	285	81-06-11	320	6.6	140	0	39	9.7	8.9	1.5	<10	140	14	1.5	16	186	0
14ES 9 Ida Saunders	37 06 41	082 02 38	01	2180		81-02-20	35	5.5	9	6	2.1	1.0	1.3	.7	30	3	7.3	.6	7.5	24	10
14E 14 Arthur Lee Hess	37 06 22	082 03 24	01	2115	9.5	81-01-21	283	6.1	95	45	27	6.7	7.3	13	<10	50	33	15	8.9	191	9
14ES 8 Pete Harris	37 06 39	082 02 56	01	2105		81-02-20	48	5.4	13	8	2.7	1.4	1.6	.9	20	5	5.9	.7	7.8	30	3
14ES 2 Hess Cow Spg	37 05 26	082 02 55	01	2065		81-01-16	234	6.4	110	0	27	9.5	7.9	1.7	760	112	13	.9	18	149	40
14ES 5 Stewart Harris Spg	37 05 54	082 02 20	01	2025		81-02-17	54	5.3	13	11	2.3	1.7	2.0	1.0	30	4	8.8	2.6	8.1	37	0
14E 12 Martha B Thomas	37 05 52	082 02 54	01	2025	50	81-01-21	277	6.6	74	0	20	5.4	26	1.4	50	138	2.5	.8	16	151	50
14E 13 Chester McGlothlin	37 06 09	082 03 00	01	2025	20	81-01-21	127	6.6	41	8	10	3.8	5.7	4.5	30	33	9.6	4.3	8.1	83	10
14E 19 Ruben Harris	37 06 01	082 02 15	01	2017	57	81-02-18	177	5.8	46	0	12	3.8	6.7	.9	58	58	2.3	1.1	16	80	200
14E 24 Jerry Bostick	37 06 04	082 02 54	01	2017	83	81-06-11	270	7.2	98	0	27	7.3	18	1.3	310	120	11	3.0	15	177	60
14E 20 Donald Austin	37 07 45	082 03 11	01	2010	65	81-02-18	152	5.8	46	0	13	3.3	9.1	.8	320	58	4.2	.9	14	85	190
14ES 1 Hess Driveway Spg	37 05 28	082 02 57	01	2010		81-01-16	102	6.7	37	8	7.5	4.4	4.0	1.2	60	29	14	1.0	9.8	63	4
14E 22 J.M. Boyd	37 06 17	082 03 16	01	1970	90	81-06-11	146	6.4	53	0	15	3.6	8.2	.9	5900	55	8.0	3.8	16	102	320
14E 17 Bill Sheppard	37 05 42	082 02 22	01	1933	67	81-02-18	121	5.3	46	0	12	3.8	5.4	.8	70	52	5.3	1.1	19	78	120
14E 11 Arthur B Hess	37 05 23	082 02 57	01	1925	30	81-01-20	161	6.6	63	15	15	6.2	5.5	2.5	40	48	14	11	9.9	100	2
14E 16 Paul Harris	37 05 28	082 02 18	01	1910	80	81-02-17	136	5.8	51	0	13	4.5	10	1.1	60	70	1.4	1.2	18	89	80
14E 5 Irvine Combs	37 05 14	082 02 45	01	1906	19	81-01-19	226	6.1	89	38	21	8.9	4.6	2.3	20	51	34	14	5.3	122	20
14E 10 Howard Hess	37 05 28	082 02 58	01	1887	123	81-01-20	197	6.5	60	0	17	4.0	15	1.4	410	101	.9	2.8	16	114	100
14E 15 Michael Harris	37 05 08	082 02 08	01	1880	60	81-02-17	197	6.8	51	0	14	3.7	18	1.2	1700	86	2.8	2.5	16	107	120
14ES 7 Mike Harris	37 05 07	082 02 06	01	1880		81-02-18	207	5.9	100	86	21	12	3.1	1.8	10	16	84	1.3	5.9	154	3
14E 18 Stewart Harris	37 05 57	082 02 19	01	1845	180	81-02-18	162	5.7	50	22	12	4.7	7.1	.8	11000	28	35	2.2	16	109	660
14E 9 Curtis Austin	37 50 00	082 02 40	01	1823	52	81-01-20	178	6.5	69	0	18	5.6	7.2	1.4	1600	87	4.3	1.8	19	112	290
14ES 4 Lethridge Spg	37 04 38	082 02 19	01	1800		81-01-20	312	6.4	67	0	17	5.9	39	1.8	880	128	22	7.8	14	190	160
14E 8 Eugene Austin	37 04 45	082 02 27	01	1740	90	81-01-20	256	7.6	7	0	2.0	.5	53	1.5	150	140	7.6	1.8	10	170	4
14E 6 Robert E Austin	37 04 42	082 02 22	01	1707	98	81-01-19	221	6.9	68	0	19	4.7	16	2.1	1000	91	17	2.3	16	133	70
14E 7 Vilinie Hess	37 04 36	082 02 22	01	1705	90	81-01-19	268	6.7	62	0	18	4.1	31	1.7	1600	133	4.2	7.8	15	164	130
14E 2 Curvin Harris	37 04 39	082 03 16	01	1690	11	78-06-06	80	5.6	23	15	5.2	2.4	4.0	1.8	<10	8	20	2.4	9.9	56	

Appendix 2.--Chemical analyses of ground water sampled within the study area. (continued)

82-4022 (11)

LOCAL IDENTIFIER	LATITUDE	LONGITUDE	SEQ. NO.	ALT. OF WELL BOTTOM DATUM (FT. NGVD)	DEPTH OF WELL, TOTAL (FEET)	DATE OF SAMPLE	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	pH FIELD (UNITS)	HARD-NESS (mg/L AS $CaCO_3$)	HARD-NESS NONCAR-BONATE (mg/L as $CaCO_3$)	CALCIUM, DISSOLVED (mg/L as Ca)	MAGNE-SIUM, DIS-SOLVED (mg/L as Mg)	SODIUM, DIS-SOLVED (mg/L as Na)	POTAS-SIUM DIS-SOLVED (mg/L as K)	IRON, DIS-SOLVED (µg/L as Fe)	ALKA-LINITY (mg/L as $CaCO_3$)	SULFATE DIS-SOLVED (mg/L as SO_4)	CHLO-RIDE DIS-SOLVED (mg/L as Cl)	SILICA, DIS-SOLVED (mg/L as SiO_2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L)	MANGA-NESE, DIS-SOLVED (µg/L as Mn)
										HURRICANE CREEK BASIN											
14F 89 J.Blankenship	37 07 55	082 03 09	01	1895	15	81-07-21	120	6.6	39	0	9.2	3.8	2.8	2.2	170	40	7.3	1.5		67	1500
14FS 7 E. Wampler	37 07 55	082 03 55	01			81-07-21	120	7.5	44	0	11	3.9	3.3	1.2	40	44	9.6	.7		65	0
14F 88 Willard Johnson	37 07 50	082 04 37	01	1687	23	81-07-21	50	5.3	15	2	2.9	1.8	1.5	1.0	70	13	10	.9		36	0
14E 33 Edna Hess	37 07 20	082 04 58	02	1670	85	81-07-21	98	6.7	35	18	10	2.4	11	2.7	810	21	10	3.0		70	140
14ES13 Harry Presley	37 07 13	082 51 00	01	1665		81-07-21	120	6.7	44	7	11	3.9	9.8	1.9	20	37	12	2.4		83	0
14E 35 Edna Hess	37 07 20	082 04 58	01	1655	20	81-07-21	380	7.4	60	0	15	5.3	56	1.3	70	190	1.6	1.6		222	10
14E 30 Dan Compton	37 06 28	082 07 01	01	1518	37	81-07-21	226	7.3	70	0	19	5.3	24	1.1	2300	110	2.5	4.2		140	130
14E 29 Lawrnce Compton	37 06 28	082 07 16	01	1493	62	81-07-21	320	7.3	94	0	26	6.8	31	1.2	840	160	2.2	5.4		183	30
13E 7 Ron O'Quinn	37 06 42	082 07 57	01	1470	45	81-07-21	285	7.2	79	0	20	7.0	33	1.0	3000	120	3.6	9.6		165	140
14E 31 Carl Ray	37 06 34	082 05 55	01	1455	165	81-07-21	310	7.4	37	0	10	2.7	59	1.1	170	150	1.9	6.0		189	10
13E 6 Hettie Board	37 06 38	082 07 54	01	1418	62	81-07-21	195	6.9	63	0	17	4.9	12	2.8	110	69	8.6	5.4		110	50
13E 4 Burl Presley	37 06 08	082 05 19	01	1412	78	81-07-21	240	6.7	95	41	23	9.0	13	1.7	2900	54	37	12		169	660
14E 34 J.Rice Trl Crt	37 06 37	082 05 19	01	1400	200	81-07-21	380	8.4	23	0	6.4	1.6	75	.9	90	180	1.4	8.4		229	10
13E 5 Jerry Graslick	37 06 07	082 08 09	01	1385	175	81-07-20	350	7.3	120	23	32	10	20	1.7	160	100	20	42		231	110
										LEFT FORK HURRICANE CREEK BASIN											
14FS 5 Barton Spring	37 09 06	082 05 32	01	1740		81-07-20	120	7.1	55	19	13	5.5	4.2	1.3	<10	36	13	0.6		62	0
14FS 6 Barton Sisters	37 09 18	082 05 59	01	1780		81-07-20	328	7.1	140	120	30	15	5.0	2.2	<10	22	110	1.4		218	4
14F 86 Boyd Well	37 08 30	082 06 26	01	1622	38	81-07-20	176	6.8	42	0	11	3.6	19	1.6		87	1.6	1.6		92	
14F 85 Robey Breeding	37 08 28	082 06 33	01	1615	20	81-07-20	58	6.5	25	10	5.9	2.4	4.0	1.3	60	15	11	1.2		43	30
14E 28 Lindsey Barton	37 06 58	082 07 26	01	1537	63	81-07-20	310	7.0	110	20	28	8.8	16	1.4	5200	87	32	6.5		177	590
14E 27 Arthur Nuckles	37 06 59	082 07 31	01	1504	56	81-07-20	250	6.9	86	20	23	6.8	14	1.6	10000	66	32	10		139	290
13E 8 Jerry Owens	37 06 55	082 07 31	01	1500	50	81-07-20	210	7.0	70	1	18	6.0	10	1.0	650	69	18	9.5		125	110