

Prepared in cooperation with the U.S. Environmental Protection Agency, Region 4

Groundwater Quality at Alabama Plating and Vincent Spring, Vincent, Alabama, 2007–2008



Vincent Spring

Open-File Report 2013–1298

U.S. Department of the Interior
U.S. Geological Survey

Cover: Overflow weir at Vincent Spring, Alabama.

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By Michael W. Bradley and Amy C. Gill

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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
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U.S. Geological Survey
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m ²)
acre	0.4047	hectare (ha)
square foot (ft ²)	0.09290	square meter (m ²)
Volume		
ounce, fluid (fl. oz)	0.02957	liter (L)
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m ³)
Flow rate		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m ³ /s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Groundwater Quality at Alabama Plating and Vincent Spring, Vincent, Alabama, 2007–2008

By Michael W. Bradley and Amy C. Gill

Abstract

The former Alabama Plating site in Vincent, Alabama, includes the location where the Alabama Plating Company operated an electroplating facility from 1956 until 1986. The operation of the facility generated waste containing cyanide, arsenic, cadmium, chromium, copper, lead, zinc, and other heavy metals. Contamination resulting from the site operations was identified in groundwater, soil, and sediment. Vincent Spring, used as a public water supply by the city of Vincent, Alabama, is located about ½ mile southwest of the site. The U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, conducted an investigation at Vincent Spring and the Alabama Plating site, Vincent, Alabama, during 2007–2008 to evaluate the groundwater quality and evaluate the potential effect of contaminated groundwater on the water quality of Vincent Spring. The results of the investigation will provide scientific data and information on the occurrence, fate, and transport of contaminants in the water resources of the area and aid in the evaluation of the vulnerability of the public water supply to contamination.

Samples were analyzed to evaluate the water quality at the former plating site, investigate the presence of possible contaminant indicators at Vincent Spring, and determine the usefulness of stable isotopes and geochemical properties in understanding groundwater flow and contaminant transport in the area. Samples collected from 16 monitor wells near the plating site and Vincent Spring were analyzed for major constituents, trace metals, nutrients, and the stable isotopes for hydrogen ($^2\text{H}/\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$).

Groundwater collected from Vincent Spring was characterized as a calcium-magnesium-bicarbonate water type with total dissolved solids concentrations ranging from 110 to 120 milligrams per liter and pH ranging from about 7.5 to 7.9 units. Groundwater chemistry at the monitor wells at the Alabama Plating site was highly variable by location and depth. Dissolved solids concentrations ranged from 28 to 2,880 milligrams per liter, and the water types varied from calcium-magnesium-bicarbonate-chloride, to calcium-sulfate or calcium-magnesium-sulfate, to sodium-chloride water types. The stable isotope ratios for hydrogen ($^2\text{H}/\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$) for water from the monitor wells and from Vincent Spring, based on a single sampling event, can be separated

into three groups: (1) Vincent Spring, (2) monitor wells MW03 and MW28, and (3) the remaining Alabama Plating monitor wells.

The geochemical and stable isotope analyses indicate that water from Vincent Spring is distinct from water from the Alabama Plating monitor wells; however, this evaluation is based on a single sampling event. Although the water from Vincent Spring, for this sampling event, is different and does not seem to be affected by contaminated groundwater from the Alabama Plating site, additional hydrologic and water-quality data are needed to fully identify flow paths, the potential for contaminant transport, and water-quality changes through time.

Introduction

The Alabama Plating Company, located in Vincent, Alabama, is a former metal plating facility. Alabama Plating operated from about 1956 through 1996 and conducted zinc, cadmium, and copper electroplating and hot-dip galvanizing at the facility (Black and Veatch, 2001). During the early operation of the facility, cooling, rinsing, and process wastewater was discharged to an unlined retention pond and then discharged to an unnamed tributary to Spring Creek. The operations at the facility generated waste containing zinc, cadmium, copper, lead, and other heavy metals (U.S. Environmental Protection Agency, 2000). The Alabama Department of Environmental Management (ADEM) referred the site as an abandoned facility to the U.S. Environmental Protection Agency (USEPA). The facility was proposed for listing to the National Priorities List (NPL) in August 2000 and was finalized to the NPL in 2012 on the basis that cyanide and metal contaminants were detected in nearby surface-water and groundwater resources (U.S. Environmental Protection Agency, 2012). The ADEM and USEPA determined that on-site and off-site groundwater is contaminated and that human exposure was plausible because the possible transport of contaminants to drinking water sources was not controlled.

The site is located in northeastern Shelby County in the Coosa Valley Physiographic District of the Alabama Valley and Ridge physiographic section (Kopaska-Merkal and others, 2004). The Vincent, Alabama, area is underlain by Ordovician and

Cambrian units of the Valley and Ridge aquifer system, including the Knox Group, undifferentiated, and the Newala and Longview Limestones (Kopaska-Merkal and others, 2004). In 1968, Vincent Spring was reported to produce 715 gallons per minute from the Newala and Longview Limestones (Kopaska-Merkal and others, 2004). In 2005, the Vincent Water Board produced an average of 240,000 gallons per day for public water supply from Vincent Spring (Hutson and others, 2009). The Newala and Longview Limestones and the Knox Group are carbonate aquifers with karst features, including sinkholes, disappearing streams, and dissolution channel and openings in the rock. The general quality of the water from these aquifers is described as hard, calcium-bicarbonate waters (Kopaska-Merkal and others, 2004).

The U.S. Geological Survey (USGS), in cooperation with the USEPA, conducted an investigation at Vincent Spring and the Alabama Plating site, Vincent, Alabama, during 2007–2008 to evaluate the groundwater quality and evaluate the potential effect of contaminated groundwater on the water quality of Vincent Spring. The results of the investigation will provide further scientific data and information on the occurrence, fate, and transport of contaminants in the water resources of the Nation and aid in the evaluation of the vulnerability of water supplies to contamination (U.S. Geological Survey, 2010; Bright and others, 2013). Water-quality samples were collected from 16 of the 17 monitor wells at the Alabama Plating site and from Vincent Spring near Vincent, Alabama (fig. 1). Samples were collected to evaluate the water quality at the site, the possible contaminant indicators at Vincent Spring, and the use of stable isotopes and geochemical properties to better understand groundwater flow and contaminant transport in the area. One set of water-quality samples was collected from the monitor wells and Vincent Spring in May 2007. Ten samples were collected, approximately monthly, from Vincent Spring during August 2007 through May 2008. The results of the investigation and the water-quality data for the monitor wells and for Vincent Spring are presented in this report.

Groundwater Quality

Groundwater samples were collected at 16 monitor wells (fig. 1; table 1) located near the former Alabama Plating site during May 2007 and at Vincent Spring during 2007 and 2008. During May 2007, water-quality samples were collected by staff from Black and Veatch, and USGS personnel observed and assisted with sample collection. Samples from Vincent Spring were collected by USGS personnel during August 2007 through May 2008. The samples were analyzed for major ions, trace metals, nutrients, and the stable isotope ratios for hydrogen ($^2\text{H}/\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$). The water samples collected by the USGS were analyzed by the USGS National Water Quality Laboratory in Denver, Colorado (Fishman and Friedman, 1989), and the USGS Reston Stable Isotope Laboratory in Reston, Virginia (Révész and Coplen, 2008a and b). Well purging and sample collection were conducted using standard USEPA methods (U.S. Environmental Protection Agency, 1997; Black and Veatch, 2001). Duplicate and matrix spike

quality-assurance and quality-control samples were also collected by Black and Veatch during May 2007.

The water samples collected at Alabama Plating and Vincent Spring were analyzed for major constituents, trace metals, nutrients, and stable isotopes. The analytical results and the use of major constituent, water-type, and stable-isotope data to evaluate differences among the groundwater samples are described in the following sections. Water-quality and geochemical data can be used to identify flow paths, sources of water, and groundwater mixing. The data available from Vincent Spring and from the monitor wells at Alabama Plating, however, represent two points in the groundwater system—Vincent Spring is a natural discharge point, and the Alabama Plating site is an area with shallow recharge occurring along the natural flow path. The small areal extent of the study area and the limited data collection limit the interpretations that can be made about a more regional flow path and about water-quality changes within the regional system, and also limits the comparison to non-contaminated conditions. For example, if gypsum or anhydrite is present in the limestone aquifer, then calcium sulfate (Ca-SO_4) water types may be common; if, however, gypsum or anhydrite is not present, then increasing sulfate could serve as another indicator to monitor for possible impacts from the site.

Water-quality samples were collected from Vincent Spring by the USGS during August 2007 through May 2008 to evaluate water-quality changes through time (table 2). The samples were analyzed for major ions, nutrients, trace metals, and stable isotopes. The analytical results indicate water quality with minimal variation during the study period (table 2). The ranges of concentrations for select constituents were

Dissolved solids (residue-on-evaporation)	109–126	milligrams per liter
Alkalinity, field	100–109	milligrams per liter
Nitrate + Nitrite	0.173–0.205	milligrams per liter
Calcium	26.1–29.1	milligrams per liter
Chloride	1.11–1.28	milligrams per liter
Sulfate	0.98–1.14	milligrams per liter

The trace metal concentrations in the water samples collected from Vincent Spring also showed little variability during August 2007–May 2008. The trace metal concentrations were low and generally below laboratory detection levels (table 2). The concentrations for the contaminants of concern at the Alabama Plating site—zinc, cadmium, copper, and lead—were low in samples from Vincent Spring. The concentration range for these metals in water from Vincent Spring during 2007–2008, compared to the concentrations for these same metals found in water from the monitor wells in May 2007 (Black and Veatch, written commun., 2007), are listed below. Values are in micrograms per liter.

Constituent	Vincent Spring	Monitor wells	
	Range	Range	Average
Zinc	<2.0	7.5–370,000	37,300
Cadmium	<0.01–0.02	0.11–544	116
Copper	<1.2	<1–95	12
Lead	0.03–0.38	0.1–76.3	16

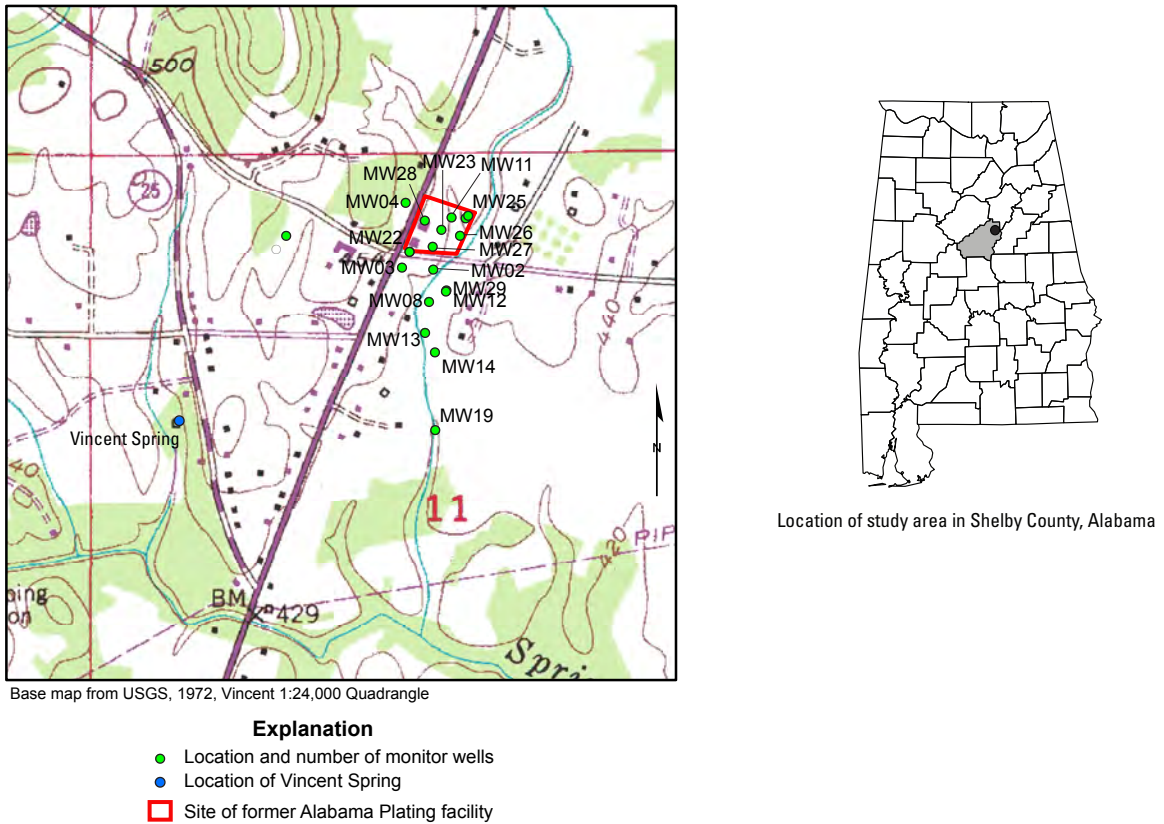


Figure 1. Location of the study site and sample points, former Alabama Plating site and Vincent Spring, Vincent, Alabama.

Table 1. Monitor wells sampled at the former Alabama Plating site, Vincent, Alabama, May 2007.

[USGS, U.S. Geological Survey]

Well number	USGS station number	Screen interval (feet below land surface)
MW02	332533086241601	17.8–18.8
MW03	332353086241901	25.3–35.3
MW08	332350086241701	15.5–25.5
MW11	332357086241501	107–117
MW12	332351086241501	19.1–29.1
MW13	332348086241701	42.0–52.0
MW14	332346086241601	5.2–15.2
MW19	332340086241601	8.4–18.4
MW22	332354086241801	27.8–37.8
MW23	332356086241601	23.2–33.2
MW24	332357086241301	16.4–26.4
MW25	332357086241302	40.4–50.4
MW26	332355086241401	20.5–30.5
MW27	332354086241601	17.4–27.4
MW28	332356086241701	27.8–37.8
MW29	332351086241502	24.7–34.7

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Table 2. Water-quality data for samples collected at Vincent Spring, Vincent, Alabama, August 2007–May 2008.

[°C, degree Celsius; ft³/s, cubic foot per second; na, not analyzed; µS/cm, microsiemens per centimeter; mg/L milligrams per liter; µg/L, micrograms per liter; N, nitrogen; <, less than indicated value; P, phosphorus; E, estimated concentration; FNU, formazin nephelometric unit; per mil, parts per thousand]

Date	Water temperature (°C)	Discharge (ft ³ /s)	Specific conductance (µS/cm at 25 °C)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	pH, field (units)	Carbonate, field (mg/L)	Bicarbonate, field (mg/L)	Nitrite, filtered (mg/L as N)	Nitrate+Nitrite, filtered (mg/L as N)
8/9/2007	17.5	na	210	9.4	100	6.5	0.0	123	< 0.002	0.173
9/12/2007	17.1	na	208	8.3	na	7.7	0.0	133	< 0.002	0.194
10/16/2007	16.9	na	209	8.5	88	7.5	0.0	132	< 0.002	0.200
11/20/2007	16.8	na	205	8.9	92	7.8	0.0	133	< 0.002	0.180
12/11/2007	15.8	na	216	8.6	86	7.9	0.0	134	< 0.002	0.178
1/15/2008	16.6	0.24	195	8.0	82	8.0	0.0	129	na	na
2/21/2008	16.5	0.08	200	8.6	88	7.9	0.0	132	< 0.002	0.204
3/31/2008	17.1	0.65	206	8.3	na	7.9	na	128	< 0.002	0.202
4/29/2008	17.2	0.56	213	8.1	84	7.9	na	131	na	na
5/27/2008	17.2	na	213	8.6	na	7.8	0.0	129	< 0.002	0.205

Table 2. Water-quality data for samples collected at Vincent Spring, Vincent, Alabama, August 2007–May 2008.—Continued

[°C, degree Celsius; ft³/s, cubic foot per second; na, not analyzed; µS/cm, microsiemens per centimeter; mg/L milligrams per liter; µg/L, micrograms per liter; N, nitrogen; <, less than indicated value; P, phosphorus; E, estimated concentration; FNU, formazin nephelometric unit; per mil, parts per thousand]

Date	Ortho-phosphate, filtered (mg/L)	Phosphorus, filtered (mg/L)	Ortho-phosphate, filtered (mg/L as P)	Organic carbon, unfiltered (mg/L)	Organic carbon, filtered (mg/L)	Calcium, unfiltered (mg/L)	Magnesium, unfiltered (mg/L)	Sodium, unfiltered (mg/L)	Potassium, unfiltered (mg/L)	Chloride, filtered (mg/L)
8/9/2007	0.026	<0.04	0.008	0.8	E 0.3	26.1	11.2	0.8	0.25	1.11
9/12/2007	na	<0.04	E 0.006	<0.4	0.4	26.1	10.4	0.7	0.28	1.28
10/16/2007	0.023	<0.04	0.008	0.8	1.2	29.1	11.6	0.9	0.19	1.21
11/20/2007	na	<0.04	E 0.006	1.1	0.5	28.9	11.5	0.8	0.31	1.17
12/11/2007	0.024	<0.04	E 0.006	0.6	0.5	28.3	11.2	0.8	0.36	1.29
1/15/2008	na	na	0.008	<0.4	0.7	27.4	10.6	0.8	0.40	na
2/21/2008	0.021	<0.04	0.007	E 0.2	0.6	26.7	10.8	0.7	0.24	na
3/31/2008	na	<0.04	E 0.006	0.4	0.6	27.9	10.6	0.8	0.19	1.27
4/29/2008	na	na	na	E 0.2	0.5	27.5	10.7	0.8	0.21	1.26
5/27/2008	0.028	<0.04	0.009	E 0.4	0.6	na	na	na	na	na

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Table 2. Water-quality data for samples collected at Vincent Spring, Vincent, Alabama, August 2007–May 2008.—Continued

[°C, degree Celsius; ft³/s, cubic foot per second; na, not analyzed; μS/cm, microsiemens per centimeter; mg/L, milligrams per liter; μg/L, micrograms per liter; N, nitrogen; <, less than indicated value; P, phosphorus; E, estimated concentration; FNU, formazin nephelometric unit; per mil, parts per thousand]

Date	Antimony, unfiltered (μg/L)	Aluminum, unfiltered (μg/L)	Selenium, unfiltered (μg/L)	Alkalinity, lab (mg/L as CaCO ₃)	Alkalinity, field (mg/L as CaCO ₃)	Turbidity (FNU)	Residue on evapora- tion at 180 °C (mg/L)	Hydrogen-2/ Hydrogen ratio (mg/L)	Oxygen-18 / Oxygen-16 ratio (per mil)	Specific conduc- tance, lab (μS/cm at 25 °C)
8/9/2007	<0.2	11	0.10	111	101	0.0	117	na	na	213
9/12/2007	<0.2	5	0.11	111	109	0.0	na	na	na	214
10/16/2007	<0.1	7	0.11	112	108	na	126	-26.20	-4.95	209
11/20/2007	<0.1	14	0.10	112	109	0.0	118	-26.60	-4.91	212
12/11/2007	<0.1	8	0.11	112	100	na	109	-26.50	-4.92	211
1/15/2008	<0.1	<4	0.10	112	106	na	119	-26.20	-4.98	210
2/21/2008	<0.1	E 3	0.12	110	108	na	116	-26.20	-5.00	207
3/31/2008	<0.1	6	0.09	112	105	na	118	-26.60	-4.97	210
4/29/2008	<0.1	<4	0.12	111	107	na	118	na	na	212
5/27/2008	na	na	na	na	106	na	na	-27.50	-4.96	na

Major Constituents and Water Type

Major cations and anions were used to define the water type and to evaluate changes in water quality due to geochemical changes. The analytical results for the major ions, field measurements, and total dissolved solids for water samples from Vincent Spring and the monitor wells during May 2007 are listed in table 3.

Groundwater samples collected at Vincent Spring indicated a calcium-magnesium-bicarbonate water type with total dissolved solids concentrations of about 110 to 120 milligrams per liter (mg/L) and pH values ranging from 7.5 to 7.9. The water chemistry from Vincent Spring is typical of water chemistry for other springs discharging from a limestone and dolomite aquifer in the Valley and Ridge physiographic province (Johnson, 2002; Kopaska-Merkal and others, 2004). The major-ion water quality from the monitor wells at Alabama Plating indicated variable conditions, both laterally and with depth. Water-quality characteristics are summarized by depth in table 4. Water-quality results for the monitor wells between 30 and 39 feet deep are separated into two groups in table 4 due to the difference in total dissolved solids concentrations between water from wells MW03 and MW28 (28 and 52 mg/L) when compared to the dissolved solids concentrations (134 to 1,740 mg/L) for water from the other monitor wells in the same depth range.

Water types for the groundwater samples were determined by converting the concentrations, in milligrams per liter, for major cations (calcium, magnesium, sodium, and potassium) and major anions (bicarbonate plus carbonate, sulfate, chloride, and fluoride) to milliequivalents per liter. The resulting values, in milliequivalents per liter, were plotted as Stiff diagrams to show water type by distinct shapes. On a common scale, the relative sizes of the diagrams are indicative of the relative concentrations of the cations and anions among sites; higher concentrations plot wider on the Stiff diagrams. The cation-anion calculations and individual Stiff diagrams for each water-quality sample are provided in appendix 1.

Samples collected from Vincent Spring indicated a calcium-magnesium-bicarbonate water type (plate 1), typical of a carbonate aquifer (Hem, 1985). The water types for samples from the Alabama Plating monitor wells were not as easily characterized. Contamination from the site, low pH, and interaction with the soil, regolith, and aquifer matrix all affect the water type. The Stiff diagrams do not show a consistent water type for the samples collected from the monitor wells. In general, Stiff diagrams for water from the monitor wells indicated the following patterns:

1. Water from wells to the northeast of the study site were categorized as a calcium-magnesium-bicarbonate-chloride water type (wells MW11, MW24, MW25, MW26, and MW23);
2. Water from wells near and just downgradient from the site had higher concentrations of major ions and a transition to a calcium-sulfate or calcium-magnesium-sulfate water type (wells MW27, MW02, MW29, and MW12); however, low pH was measured at MW02 (3.27 units) and MW27 (4.22 units);

3. Water from wells further to the southwest of the site had lower concentrations of major ions with a mixed water type at well MW13 and calcium-sulfate water types at MW08, MW14, and MW19; and
4. Water from wells MW03, MW22, and MW28, aligned along U.S. Highway 231 and west of the site had low concentrations of major ions and a primarily sodium-chloride water type.

Wells MW03, MW22, and MW28 are located in a line parallel to U.S. Highway 231 (fig. 1). The only samples with a sodium-chloride water type were collected at these wells. It is not clear what factors or combination of factors resulted in the unique water chemistry at these three wells.

The Stiff diagrams shown for water types from Vincent Spring are not similar to any of the Stiff diagrams shown for water types from the monitor wells at the Alabama Plating site. The water samples from Vincent Spring were a calcium-magnesium-bicarbonate water type. The anion bicarbonate composed about 97 percent of the major anion chemistry at Vincent Spring (appendix 1). Water samples from the monitor wells all included substantial percentages of other major anions (sulfate and (or) chloride) that were unlike the results observed for Vincent Spring.

Analytical results for the major constituents were also plotted on a Piper diagram to identify similarities and differences between water from different sites and to evaluate possible changes along flow paths (fig. 2). A Piper diagram uses two tri-linear plots for the relative composition of the cations and anions, expressed as a percentage, and a central diagram that combines the cations and anions into a single diagram. Similar to Stiff diagrams, Piper diagrams indicate water type and can identify different groupings for similar water types.

Data for water samples from Vincent Spring plot at a location on the Piper diagram that is distinct from the water samples collected from the monitor wells (fig. 2). Data for water samples from Vincent Spring plot at a corner of the central diagram characterized by a high percentage of calcium-magnesium (greater than 97 percent) and bicarbonate-carbonate (greater than 97 percent). The water type, percentages, and location of the Vincent Spring data on the Piper diagram are typical for groundwater from a carbonate aquifer (Hem, 1985). Water samples from the three monitor wells, MW03, MW22, and MW28, plot in a separate group on the Piper diagram, primarily because of the higher relative percentage of sodium. The samples from the other monitor wells at Alabama Plating plot along a line in the upper left of the Piper diagram, reflecting the high percentage of calcium and magnesium and the varying percentages of bicarbonate, sulfate, and chloride. Piper diagrams also can indicate geochemical changes occurring along a groundwater flow path. In general, samples from the wells located near the former plating site plot in the upper part of the Piper diagram (fig. 2), indicating high percentages of calcium-magnesium and chloride-sulfate. For the Alabama Plating site, the water-quality transition from upgradient, beneath the site, and then downgradient from the site is better illustrated by the Stiff diagrams than by the Piper diagram.

Table 3. Major constituents, field measurements, and total dissolved solids concentrations for water samples collected from Vincent Spring and monitor wells at the former Alabama Plating site, Vincent, Alabama, May 2007.

[yyyyymmdd, year/month/day; mg/L, milligram per liter, µg/L, microgram per liter, µS/cm, microsiemens per centimeter at 25 degrees Celsius; E, estimated concentration below the reporting limit, < less than indicated value]

Sample number or well number	Date (yyyyymmdd)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sulfate (mg/L)	Iron (µg/L)	Silica (mg/L)	Specific conductivity, field (µS/cm)	pH, field (units)	Total dissolved solids (mg/L)
SP01	20070522	26.5	10.9	0.8	0.25	112	1.13	E0.06	1.13	8	8	202	7.9	109
SP02	20070523	26.4	11.5	0.82	0.29	112	1.29	E0.09	1.19	14	8.34	215	7.93	118
SP03	20070525	26.4	11.4	0.79	<0.16	112	1.26	E0.06	1.05	7	8.34	326	7.47	119
MW02	20070525	246	86.7	25.7	2.97	0	240	0.72	1,750	126,000	54.2	5,474	3.27	2,880
MW03	20070523	1	0.762	2.22	E0.15	5	2.73	<0.1	0.51	112	8.28	32	4.97	28
MW08	20070525	30.5	15.4	6.94	1.11	6	36.2	E0.09	114	96	10.9	725	4.83	252
MW11	20070520	134	59.9	31.3	2.27	163	234	<0.1	157	32	10.8	2,256	7.17	1,110
MW12	20070525	192	76.3	24.4	3.41	48	164	0.3	716	213	16.6	1,834	5.59	1,460
MW13	20070524	90	36.8	19.1	1.19	202	63.9	0.16	124	64	9.81	825	7.03	506
MW14	20070524	64.6	14.2	11.4	0.72	82	25.9	E0.09	121	2,540	10.6	503	6.25	311
MW19	20070524	29	4.52	4.29	0.51	33	7.55	E0.08	53	152	8.09	209	5.88	139
MW22	20070522	7.04	1.71	26.2	0.51	14	29.3	<0.1	5.82	462	9.41	218	5.14	134
MW23	20070520	47.7	10.2	11.2	2.27	0	148	0.23	1.22	507	10.2	1,035	4.02	493
MW24	20070521	42.5	21.3	9.4	2.04	67	57.6	<0.1	14.4	497	10.3	588	6.05	273
MW25	20070522	60.6	32	11.2	1.6	166	76.1	<0.1	25.9	1,270	10.5	597	7.56	310
MW26	20070522	75.9	9.16	12.1	1.39	0	115	0.4	118	10	10.3	1,239	4.13	448
MW27	20070522	334	39.3	30.8	2.5	5	108	0.58	973	11,900	17	3,586	4.22	1,580
MW28	20070520	0.83	0.789	12.6	0.29	5	15.4	<0.1	0.89	569	9.65	148	4.58	52
MW29	20070525	267	95.3	26.7	3.98	110	184	0.28	873	5,830	13	2,010	5.95	1,740

Table 4. Summary of water-quality characteristics, by depth, for monitor wells at the former Alabama Plating site and Vincent Spring, Vincent, Alabama, May 2007.[mg/L, milligrams per liter; Ca, calcium; Mg, magnesium; SO₄, sulfate; HCO₃, bicarbonate; Cl, chloride; Na, sodium]

Depth range, feet below land surface	Well number	pH (units)	Total dissolved solids (mg/L)	Water type
15 to 19	MW02	3.27	2,880	Ca-Mg-SO ₄
	MW14	6.25	311	Ca-Mg-SO ₄
	MW19	5.88	139	Ca-Mg-SO ₄
25 to 29	MW08	4.83	252	Ca-Mg-SO ₄
	MW12	5.59	1,460	Ca-Mg-SO ₄
	MW24	6.05	273	Ca-HCO ₃ -Cl
	MW27	4.22	1,580	Ca-SO ₄
30 to 39	MW22	5.14	134	Na-Cl
	MW23	4.02	493	Ca-Cl
	MW26	4.13	448	Ca-Cl-SO ₄
	MW29	5.95	1,740	Ca-Mg-SO ₄
30 to 39	MW03	4.97	28	Na-HCO ₃ -Cl
	MW28	4.58	52	Na-Cl
50 to 55	MW13	7.03	506	Mix
	MW25	7.56	310	Mix
117	MW11	7.17	1,110	Mix
spring	3	7.9	109	Ca-Mg-HCO ₃

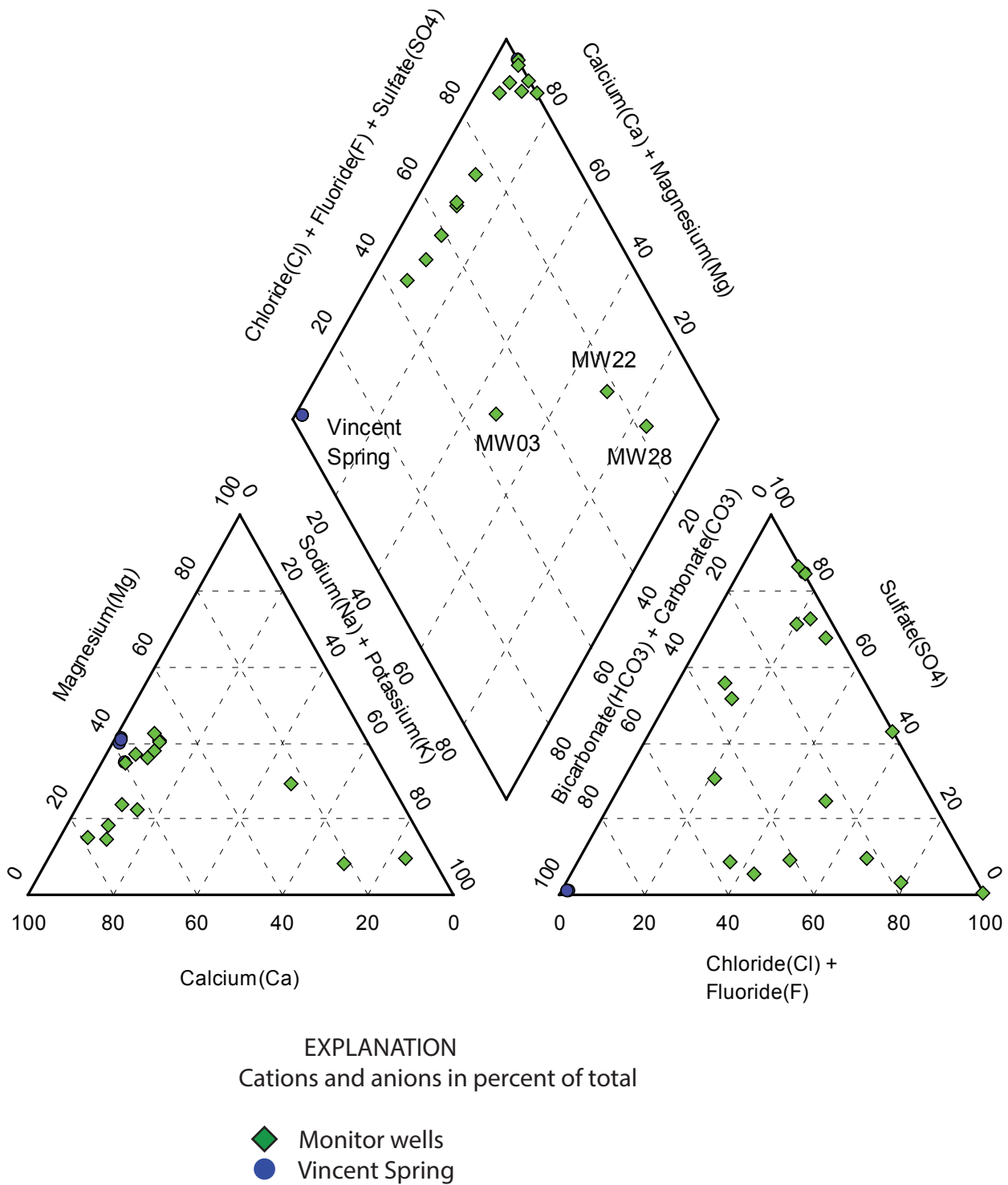


Figure 2. Piper diagram for water samples collected from Vincent Spring and the monitor wells at the former Alabama Plating site, Vincent, Alabama, May, 2007

Stable Isotopes

The ratios for stable isotopes of hydrogen ($^2\text{H}/\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$) in groundwater are affected by rainfall, evaporation, transpiration, groundwater/surface-water interactions, and other geochemical reactions (Clark and Fritz 1997). The values for the stable isotopes of hydrogen and oxygen, abbreviated as $\delta^2\text{H}$ and $\delta^{18}\text{O}$ respectively, are plotted and related to the global meteoric water line (GMWL), which represents isotopic values of global recharge. The relation of the plotted $\delta^2\text{H}$ and $\delta^{18}\text{O}$ can be used to evaluate patterns of groundwater recharge, groundwater movement, and groundwater mixing. Results for stable isotopes in groundwater at other sites have been used to identify different groundwater zones (shallow, intermediate, and deep) and the interaction of those zones along flow paths and at springs. Samples were collected for isotope analysis from the monitor wells and from Vincent Spring in May 2007. Additional samples were collected from Vincent Spring during October 2007–May 2008.

The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for the monitor wells and Vincent Spring (table 5) were isotopically light compared to the GMWL (fig. 3). The isotopic results for water from Vincent Spring also are isotopically lighter than most of the samples from the monitor wells. The stable isotope results for groundwater from the Alabama

Plating monitor wells and from Vincent Spring separate into two clusters that, when considering water type and total dissolved solids, further separate into three groups: (1) Vincent Spring, (2) wells MW03 and MW28, and (3) the Alabama Plating monitor wells. The isotope ratios for the first group, Vincent Spring, for May 2007–May 2008 ranged from -25.5 to -27.5 per mil for $\delta^2\text{H}$ and from -4.91 to -5.00 per mil for $\delta^{18}\text{O}$ (table 5). The second group, consisting of wells MW03 and MW28, had isotope ratios similar to Vincent Spring, but were grouped separately from Vincent Spring because water from these two wells had low pH values and very low total dissolved solids concentrations (less than 55 mg/L). The third group, consisting of water samples from the other 14 monitor wells had $\delta^2\text{H}$ and $\delta^{18}\text{O}$ data that were isotopically heavier and appear distinct from water from Vincent Spring. The isotope ratios for water from the monitor wells were -19.8 to -25.2 per mil for $\delta^2\text{H}$ and -3.96 to -4.66 per mil for $\delta^{18}\text{O}$ (table 5).

The stable isotope data for the monitor wells and for Vincent Spring indicate a distinct difference between water from the spring and water from most of the monitor wells. Analysis of additional water-quality and stable isotope samples from Vincent Spring, the monitor wells, and additional springs or wells in the deeper aquifer system would better define groundwater differences and mixing.

Table 5. Stable isotope ratios for oxygen and hydrogen in water from Vincent Springs and monitor wells at the former Alabama Plating site, Vincent, Alabama, 2007–2008.

[yyyymmdd, year/month/day; na, not analyzed; per mil, parts per thousand]

Sample number or well number	USGS station number	Date, (yyyymmdd)	Well depth (feet below land surface)	Oxygen-18 / Oxygen-16 ratio (per mil)	Hydrogen-2/ Hydrogen ratio (per mil)
Vincent Spring					
SP01	332341086244001	20070522	spring	-4.96	-26.7
SP02	332341086244001	20070523	spring	-4.92	-25.9
SP03	332341086244001	20070525	spring	-4.96	-25.5
SP-08-07	332341086244001	20070809	spring	na	na
SP-09-07	332341086244001	20070912	spring	na	na
SP-10-07	332341086244001	20071016	spring	-4.95	-26.2
SP-11-07	332341086244001	20071120	spring	-4.91	-26.6
SP-12-07	332341086244001	20071211	spring	-4.92	-26.5
SP-01-08	332341086244001	20080115	spring	-4.98	-26.2
SP-02-08	332341086244001	20080221	spring	-5	-26.2
SP-03-08	332341086244001	20080331	spring	-4.97	-26.6
SP-04-08	332341086244001	20080429	spring	na	na
SP-05-08	332341086244001	20080527	spring	-4.96	-27.5
Monitor wells					
MW02	332533086241601	20070525	19	-4.07	-20.1
MW03	332353086241901	20070523	35.3	-4.90	-25.2
MW08	332350086241701	20070525	25.5	-4.66	-22.6
MW11	332357086241501	20070520	117	-4.35	-23.8
MW12	332351086241501	20070525	29	-4.54	-22.2
MW13	332348086241701	20070524	52	-4.44	-23.2
MW14	332346086241601	20070524	15	-4.42	-21.8
MW19	332340086241601	20070524	18.4	-4.48	-22.3
MW22	332354086241801	20070522	38	-4.30	-22.1
MW23	332356086241601	20070520	33	-3.96	-22.3
MW24	332357086241301	20070521	26.4	-4.60	-24.6
MW25	332357086241302	20070522	50.4	-4.65	-25.2
MW26	332355086241401	20070522	30.5	-4.14	-21.8
MW27	332354086241601	20070522	27.4	-4.00	-19.8
MW28	332356086241701	20070520	37.8	-4.90	-26.9
MW29	332351086241502	20070525	34.7	-4.40	-22.1

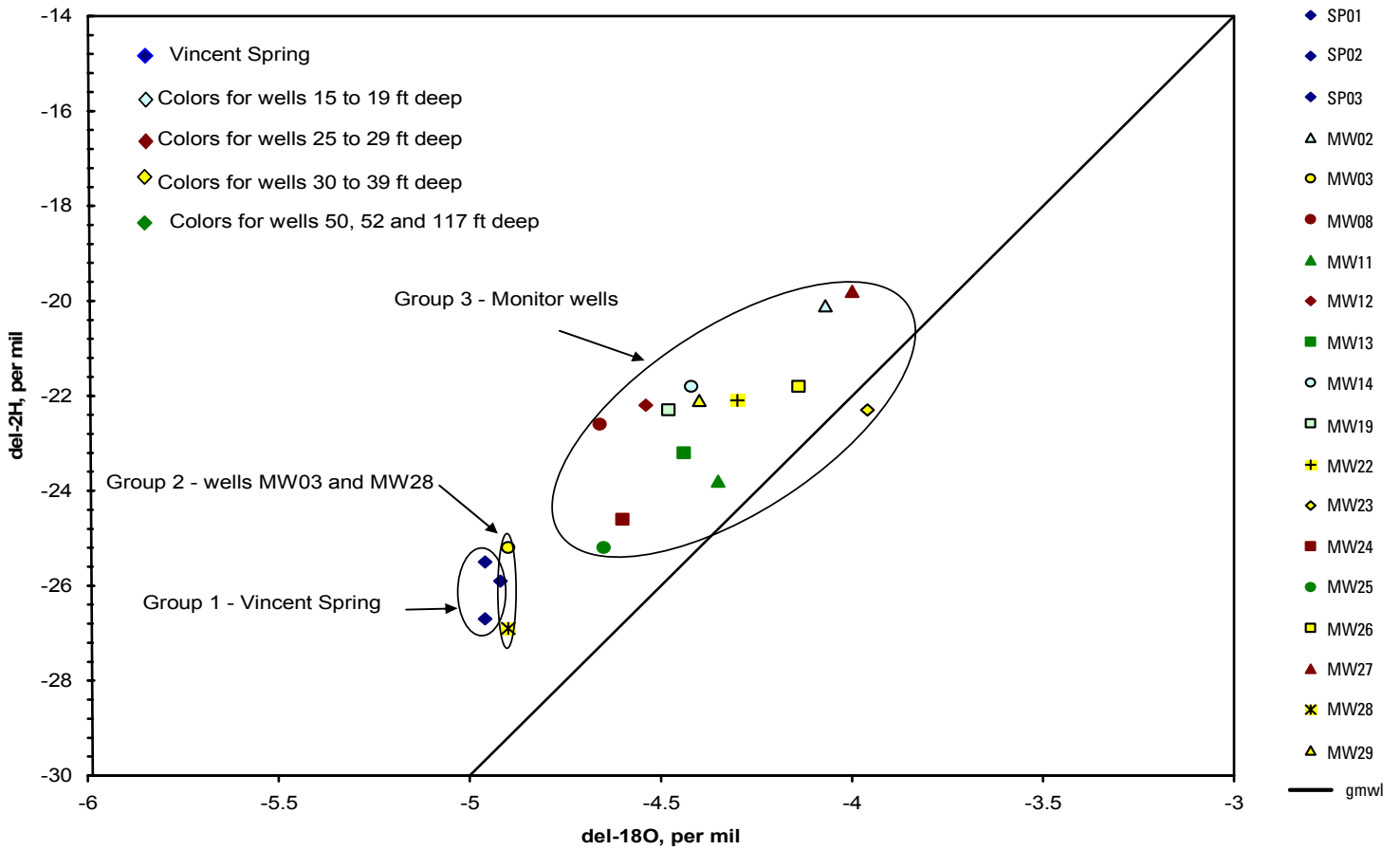


Figure 3. Graph showing relation between stable isotope ratios for hydrogen ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$) for water from monitor wells at the former Alabama Plating site and Vincent Spring, Vincent, Alabama, 2007–2008.

Summary and Conclusions

The former Alabama Plating site in Vincent, Alabama, includes the location where the Alabama Plating Company operated an electroplating facility from 1956 until 1986. The operation of the facility generated waste that contained heavy metals, including cyanide, arsenic, cadmium, chromium, copper, lead, and zinc. The Alabama Department of Environmental Management and the U.S. Environmental Protection Agency determined that on-site and off-site groundwater is contaminated and that human exposure was plausible because the possible transport of contaminants to Vincent Spring and other sources of drinking water was not controlled. The U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, conducted an investigation at Vincent Spring and the Alabama Plating site, Vincent, Alabama, during 2007–2008 to evaluate the groundwater quality and evaluate the potential effect of contaminated groundwater on the water quality of Vincent Spring. The results of the investigation will also provide further scientific data and information on the occurrence, fate, and transport of contaminants in the water resources of the Nation and aid in the evaluation of the vulnerability of water supplies to contamination.

Water-quality samples were collected from Vincent Spring and 16 monitor wells located at the former Alabama Plating site near Vincent, Alabama, in May 2007 and from Vincent Spring during August 2007 through May 2008. The preliminary analysis of the data from the sample collection has some limitations that include the following.

- The evaluation described the geochemical conditions present for only one sampling event at the monitor wells, and seasonal variations were not considered.
- The evaluation was limited to the Alabama Plating site with only one additional point, Vincent Spring. Samples from a reference site with no potential effects from the Alabama Plating site were not collected.
- Geochemical and isotopic results were not compared to trace metal chemistry.
- The evaluation did not confirm or rule out a hydrologic connection between Vincent Spring and the monitor wells located at or near the Alabama Plating site.

Analytical results for the major cations (calcium, magnesium, sodium, and potassium) and anions (bicarbonate, sulfate, chloride, and fluoride) were used to develop Stiff diagrams for each sample and also were plotted on a Piper diagram. The Stiff and Piper diagrams indicated the following patterns.

- Water from Vincent Spring was typical of water discharging from the limestone and dolomite aquifer in the Valley

and Ridge physiographic province. The calcium-magnesium-bicarbonate water type for Vincent Spring was distinct from all of the samples collected from the Alabama Plating monitor wells. The pH and total dissolved solids concentrations for the water from Vincent Spring ranged from about 7.5 to 7.9 pH units and 110 to 120 mg/L, respectively.

- Water samples from the monitor wells on the northeast side of the Alabama Plating site (wells MW11, MW24, MW25, MW26, and MW23) showed a calcium-magnesium-bicarbonate-chloride water type. Total dissolved solids concentrations for these wells ranged from about 270 to 490 mg/L with 1,110 mg/L found at well MW11.
- Water samples from wells near and just downgradient from the site (wells MW27, MW02, MW29, and MW12) show transition to a calcium-sulfate or calcium-magnesium-sulfate water type. The total dissolved solids concentrations for these wells ranged from 1,460 to 2,880 mg/L.
- Samples collected from wells further to the southwest of the site (wells MW08, MW13, MW14, and MW19) had a mixed water type at MW13 and calcium-sulfate water types at MW08, MW14, and MW19. The total dissolved solids concentrations ranged from 139 to 506 mg/L.
- Water from wells MW03, MW22, and MW28 had a distinct sodium-chloride water type. The total dissolved solids concentrations for water from wells MW03 and MW28 were low, 28 and 52 mg/L, respectively, and 134 mg/L from well MW22. The three wells are located along U.S. Highway 231.

The analytical results for the stable isotopes of oxygen ($^{18}\text{O}/^{16}\text{O}$) and hydrogen ($^2\text{H}/\text{H}$) were plotted relative to the global meteoric water line (GMWL) and evaluated for any grouping or trends. The stable isotope results plotted in two clusters that, when considering water type and total dissolved solids, could be separated into three groups:

- Samples collected from Vincent Spring are distinct from most of the samples collected from the Alabama Plating site monitor wells. Isotope ratios for Vincent Spring ranged from -25.5 to -27.5 per mil for $\delta^2\text{H}$ and from -4.91 to -5.00 per mil for $\delta^{18}\text{O}$.
- Water samples from wells MW03 and MW28 had similar isotopic ratios to Vincent Spring but are considered a distinct group from Vincent Spring because of the low pH and low total dissolved solids concentrations found at these wells.
- Samples collected from the other 14 Alabama Plating monitor wells represent the third stable isotope ratio group. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ data from these wells were distinct and isotopically heavier than water from Vincent Spring.

The geochemical and stable isotope analyses indicate that water from Vincent Spring is distinct from water from the Alabama Plating site monitor wells. This evaluation, however, is based on a single sampling event. Although the water from Vincent Spring for this sampling event is different and does not seem to be substantially affected by contaminated groundwater from the Alabama Plating site, additional hydrologic and water-quality data are needed to fully identify flow paths and potential contaminant transport. Groundwater flow, water-quality, or contaminant transport models could be developed to identify and test concepts of contaminant occurrence and transport.

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16 Groundwater Quality at Alabama Plating and Vincent Spring, Vincent, Alabama, 2007–2008

Appendix 1. Cation-anion calculations and Stiff diagrams for water-quality samples collected at Alabama Plating and Vincent Spring, 2007.

Samples from Vincent Spring are SP01, SP02, and SP03.
All other samples are identified by the monitor well number.

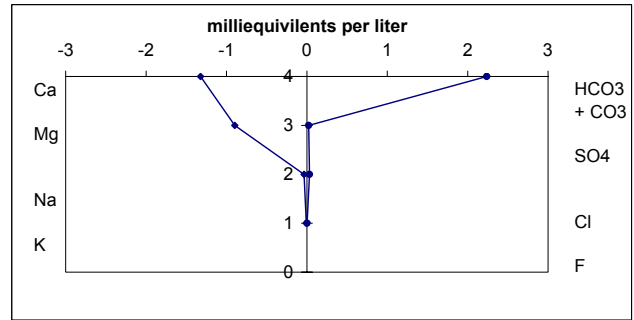
NOTE - Different scales are used on the Stiff diagrams to better show the shape of the diagram to compare water type from site to site

mg/L -- milligrams per liter
meq/l -- milliequivalents per liter

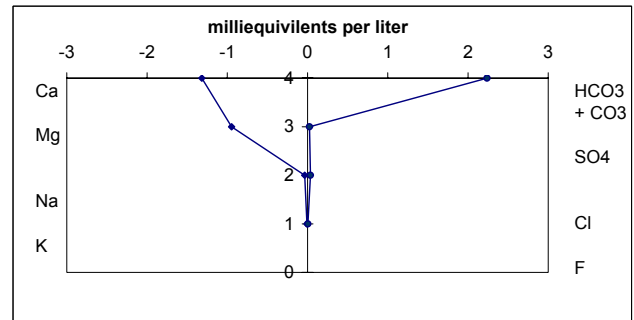
Negative values for meq/l on the Stiff diagram are for plotting convenience only

Bicarbonate calculated from field alkalinity

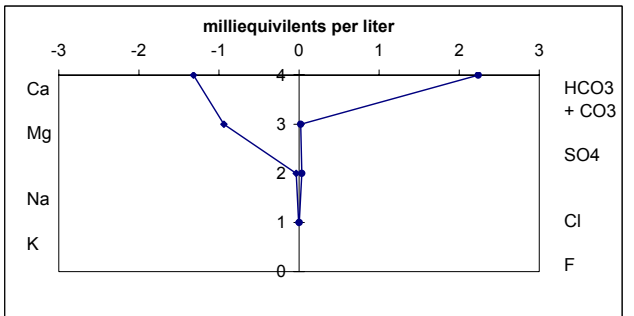
name	SP01			Date	20070522		
site_id	332341086244001						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	26.5	1.32	58.5%	bicarbonate	136.55	2.24	97.5%
Magnesium	10.9	0.90	39.7%	Sulfate	1.13	0.02	1.0%
Sodium	0.8	0.03	1.5%	Chloride	1.13	0.03	1.4%
Potassium	0.25	0.01	0.3%	Fluoride	0.06	0.00	0.1%
sum		2.26	100.0%	sum		2.30	100.0%
	percent difference			-0.8%			
Specific conductance	202			dissolved solids ratio	109 0.54		



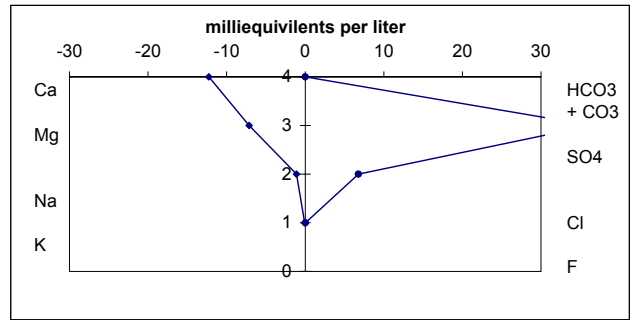
name	SP02			Date	20070523		
site_id	332341086244001						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	26.4	1.32	57.1%	bicarbonate	136.55	2.24	97.1%
Magnesium	11.5	0.95	41.0%	Sulfate	1.19	0.02	1.1%
Sodium	0.82	0.04	1.5%	Chloride	1.29	0.04	1.6%
Potassium	0.29	0.01	0.3%	Fluoride	0.09	0.00	0.2%
sum		2.31	100.0%	sum		2.30	100.0%
	percent difference			0.1%			
Specific conductance	215			dissolved solids ratio	118 0.55		



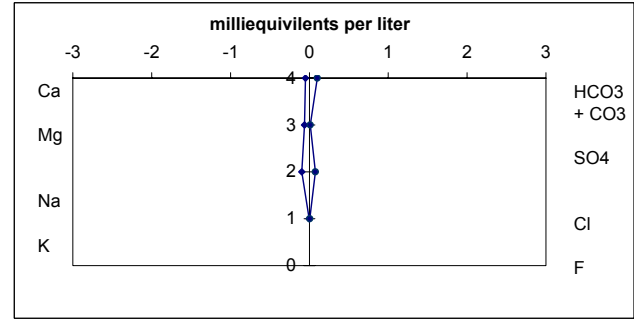
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site_id	332341086244001						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	26.4	1.32	57.4%	bicarbonate	136.55	2.24	97.4%
Magnesium	11.4	0.94	40.9%	Sulfate	1.05	0.02	1.0%
Sodium	0.79	0.03	1.5%	Chloride	1.26	0.04	1.5%
Potassium	0.16	0.00	0.2%	Fluoride	0.06	0.00	0.1%
sum		2.29	100.0%	sum		2.30	100.0%
	percent difference			-0.1%			
Specific conductance	326			dissolved solids ratio	119 0.37		



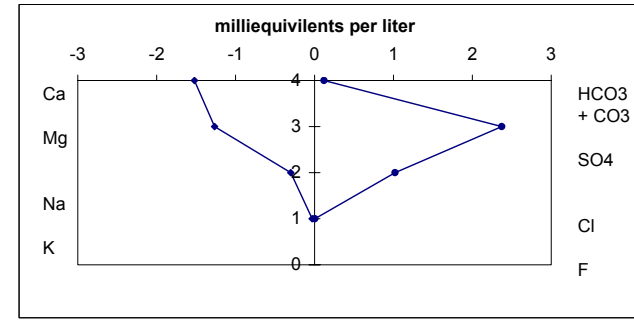
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site_id	<u>332533086241601</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	246	12.28	59.6%	bicarbonate	0.00	0.00	0.0%
Magnesium	86.7	7.13	34.6%	Sulfate	1750	36.44	84.3%
Sodium	25.7	1.12	5.4%	Chloride	240	6.77	15.7%
Potassium	2.97	0.08	0.4%	Fluoride	0.72	0.04	0.1%
sum	20.60	100.0%		sum	43.24	100.0%	
percent difference				-35.5%			
Specific conductance	5474			dissolved solids ratio	2880 0.53		



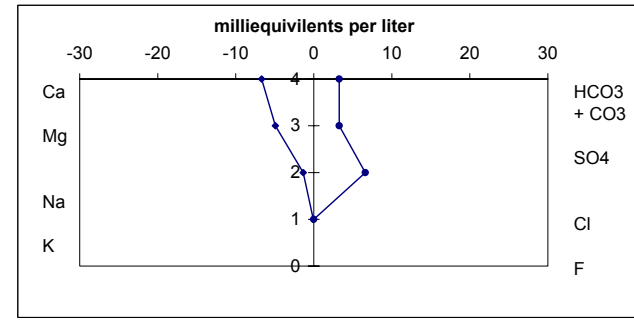
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site_id	<u>332353086241901</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	1	0.05	23.4%	bicarbonate	6.10	0.10	51.8%
Magnesium	0.762	0.06	29.4%	Sulfate	0.51	0.01	5.5%
Sodium	2.22	0.10	45.3%	Chloride	2.73	0.08	39.9%
Potassium	0.15	0.00	1.8%	Fluoride	0.1	0.01	2.7%
sum	0.21	100.0%		sum	0.19	100.0%	
percent difference				5.0%			
Specific conductance	32			dissolved solids ratio	28 0.88		



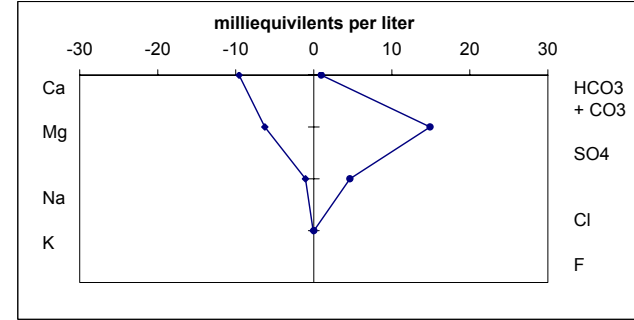
name	<u>MW08</u>			Date	<u>20070525</u>		
site_id	<u>332350086241701</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	30.5	1.52	48.8%	bicarbonate	7.32	0.12	3.4%
Magnesium	15.4	1.27	40.6%	Sulfate	114	2.37	67.4%
Sodium	6.94	0.30	9.7%	Chloride	36.2	1.02	29.0%
Potassium	1.11	0.03	0.9%	Fluoride	0.09	0.00	0.1%
sum	3.12	100.0%		sum	3.52	100.0%	
percent difference				-6.0%			
Specific conductance	725			dissolved solids ratio	252 0.35		



name	<u>MW11</u>			Date	<u>20070520</u>		
site_id	<u>332357086241501</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	134	6.69	51.3%	bicarbonate	198.73	3.26	24.8%
Magnesium	59.9	4.93	37.8%	Sulfate	157	3.27	24.9%
Sodium	31.3	1.36	10.4%	Chloride	234	6.60	50.3%
Potassium	2.27	0.06	0.4%	Fluoride	0.1	0.01	0.0%
sum	13.04	100.0%		sum	13.13	100.0%	
percent difference				-0.4%			
Specific conductance	2256			dissolved solids ratio	1110 0.49		

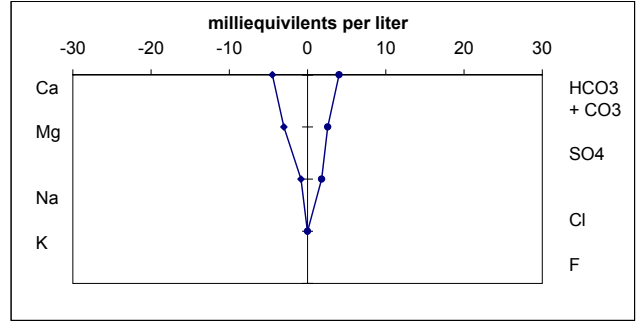


name	<u>MW12</u>			Date	<u>20070525</u>		
site_id	<u>332351086241501</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	192	9.58	56.3%	bicarbonate	58.52	0.96	4.7%
Magnesium	76.3	6.28	36.9%	Sulfate	716	14.91	72.7%
Sodium	24.4	1.06	6.2%	Chloride	164	4.63	22.6%
Potassium	3.41	0.09	0.5%	Fluoride	0.3	0.02	0.1%
sum	17.01	100.0%		sum	20.51	100.0%	
percent difference				-9.3%			
Specific conductance	1834			dissolved solids ratio	1460 0.80		

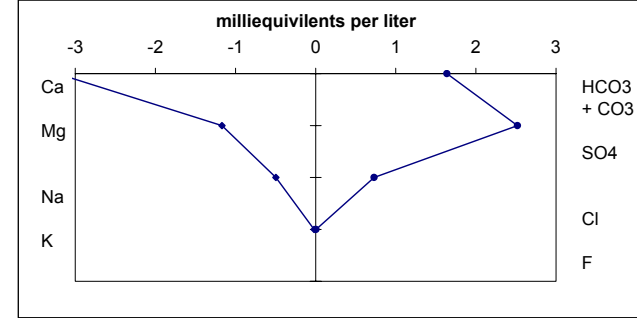


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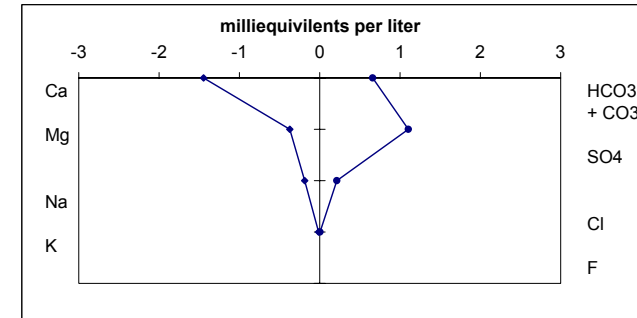
name	MW13		Date	20070524	
site_id	332348086241701				
	mg/L	meq/l	%	mg/L	meq/l
Calcium	90	4.49	53.6%	bicarbonate	246.28
Magnesium	36.8	3.03	36.1%	Sulfate	124
Sodium	19.1	0.83	9.9%	Chloride	63.9
Potassium	1.19	0.03	0.4%	Fluoride	0.16
sum	8.38	100.0%		sum	8.43
	percent difference		-0.3%		
Specific conductance	825		dissolved solids ratio	506	
				0.61	



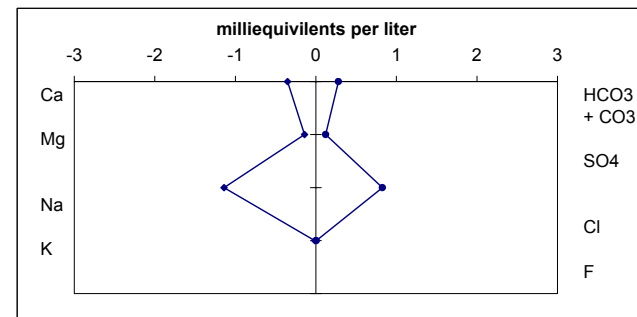
name	MW14		Date	20070524	
site_id	332346086241601				
	mg/L	meq/l	%	mg/L	meq/l
Calcium	64.6	3.22	65.7%	bicarbonate	99.98
Magnesium	14.2	1.17	23.8%	Sulfate	121
Sodium	11.4	0.50	10.1%	Chloride	25.9
Potassium	0.72	0.02	0.4%	Fluoride	0.09
sum	4.91	100.0%		sum	4.89
	percent difference		0.1%		
Specific conductance	503		dissolved solids ratio	311	
				0.62	



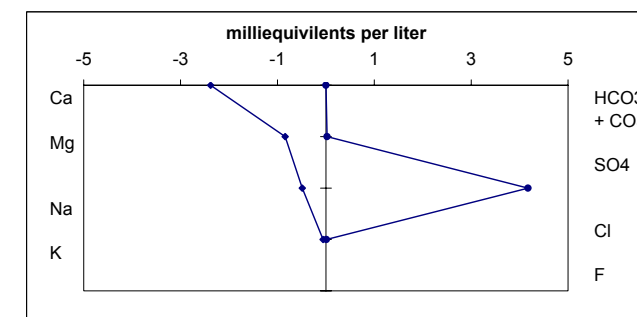
name	MW19		Date	20070524	
site_id	332340086241601				
	mg/L	meq/l	%	mg/L	meq/l
Calcium	29	1.45	71.7%	bicarbonate	40.23
Magnesium	4.52	0.37	18.4%	Sulfate	53
Sodium	4.29	0.19	9.2%	Chloride	7.55
Potassium	0.51	0.01	0.6%	Fluoride	0.08
sum	2.02	100.0%		sum	1.98
	percent difference		1.0%		
Specific conductance	209		dissolved solids ratio	139	
				0.67	



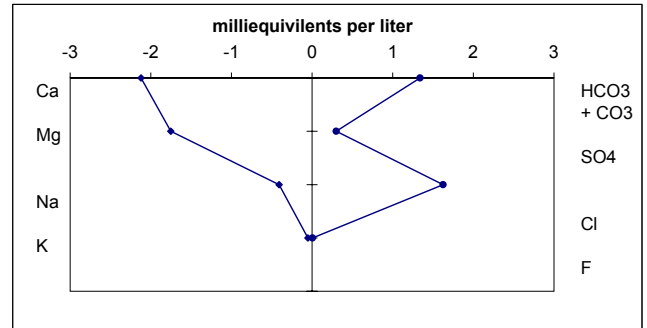
name	MW22		Date	20070522	
site_id	332354086241801				
	mg/L	meq/l	%	mg/L	meq/l
Calcium	7.04	0.35	21.4%	bicarbonate	17.07
Magnesium	1.71	0.14	8.6%	Sulfate	5.82
Sodium	26.2	1.14	69.3%	Chloride	29.3
Potassium	0.51	0.01	0.8%	Fluoride	0.1
sum	1.64	100.0%		sum	1.23
	percent difference		14.3%		
Specific conductance	218		dissolved solids ratio	134	
				0.61	



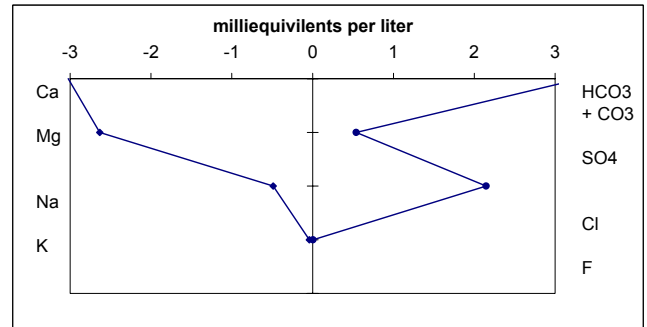
name	MW23		Date	20070520	
site_id	332356086241601				
	mg/L	meq/l	%	mg/L	meq/l
Calcium	47.7	2.38	63.2%	bicarbonate	0.00
Magnesium	10.2	0.84	22.3%	Sulfate	1.22
Sodium	11.2	0.49	12.9%	Chloride	148
Potassium	2.27	0.06	1.5%	Fluoride	0.23
sum	3.76	100.0%		sum	4.21
	percent difference		-5.6%		
Specific conductance	1035		dissolved solids ratio	493	
				0.48	



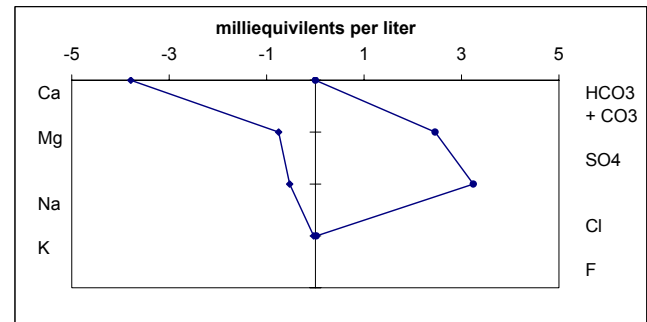
name	<u>MW24</u>			Date	<u>20070521</u>		
site_id	<u>332357086241301</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	42.5	2.12	48.9%	bicarbonate	81.69	1.34	41.0%
Magnesium	21.3	1.75	40.4%	Sulfate	14.4	0.30	9.2%
Sodium	9.4	0.41	9.4%	Chloride	57.6	1.62	49.7%
Potassium	2.04	0.05	1.2%	Fluoride	0.1	0.01	0.2%
sum		4.33	100.0%	sum		3.27	100.0%
	percent difference			14.0%			
Specific conductance	588			dissolved solids ratio	273 0.46		



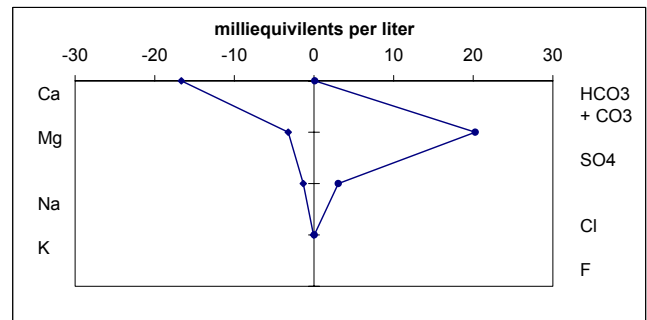
name	<u>MW25</u>			Date	<u>20070522</u>		
site_id	<u>332357086241302</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	60.6	3.02	48.9%	bicarbonate	202.39	3.32	55.2%
Magnesium	32	2.63	42.6%	Sulfate	25.9	0.54	9.0%
Sodium	11.2	0.49	7.9%	Chloride	76.1	2.15	35.7%
Potassium	1.6	0.04	0.7%	Fluoride	0.1	0.01	0.1%
sum		6.19	100.0%	sum		6.01	100.0%
	percent difference			1.5%			
Specific conductance	597			dissolved solids ratio	310 0.52		



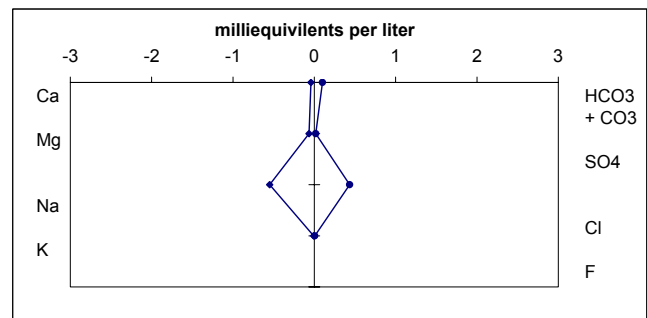
name	<u>MW26</u>			Date	<u>20070522</u>		
site_id	<u>332355086241401</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	75.9	3.79	74.2%	bicarbonate	0.00	0.00	0.0%
Magnesium	9.16	0.75	14.8%	Sulfate	118	2.46	42.9%
Sodium	12.1	0.53	10.3%	Chloride	115	3.24	56.7%
Potassium	1.39	0.04	0.7%	Fluoride	0.4	0.02	0.4%
sum		5.10	100.0%	sum		5.72	100.0%
	percent difference			-5.7%			
Specific conductance	1239			dissolved solids ratio	448 0.36		



name	<u>MW27</u>			Date	<u>20070522</u>		
site_id	<u>332354086241601</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	334	16.67	78.2%	bicarbonate	6.10	0.10	0.4%
Magnesium	39.3	3.23	15.2%	Sulfate	973	20.26	86.4%
Sodium	30.8	1.34	6.3%	Chloride	108	3.05	13.0%
Potassium	2.5	0.06	0.3%	Fluoride	0.58	0.03	0.1%
sum		21.30	100.0%	sum		23.43	100.0%
	percent difference			-4.8%			
Specific conductance	3586			dissolved solids ratio	1580 0.44		

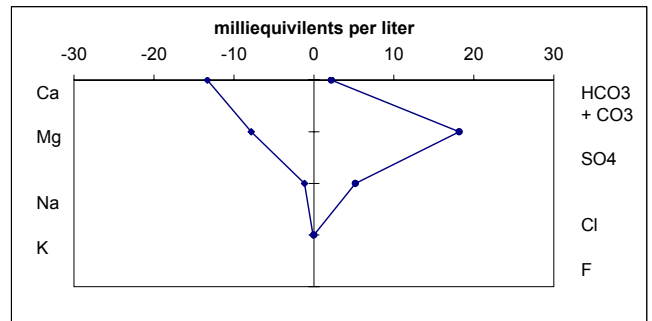


name	<u>MW28</u>			Date	<u>20070520</u>		
site_id	<u>332356086241701</u>						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	0.83	0.04	6.3%	bicarbonate	6.10	0.10	17.9%
Magnesium	0.789	0.06	9.8%	Sulfate	0.89	0.02	3.3%
Sodium	12.6	0.55	82.8%	Chloride	15.4	0.43	77.8%
Potassium	0.29	0.01	1.1%	Fluoride	0.1	0.01	0.9%
sum		0.66	100.0%	sum		0.56	100.0%
	percent difference			8.5%			
Specific conductance	148			dissolved solids ratio	52 0.35		



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name	MW29			Date	20070525		
site_id	332351086241502						
	mg/L	meq/l	%		mg/L	meq/l	%
Calcium	267	13.32	59.4%	bicarbonate	134.11	2.20	8.6%
Magnesium	95.3	7.84	35.0%	Sulfate	873	18.18	71.1%
Sodium	26.7	1.16	5.2%	Chloride	184	5.19	20.3%
Potassium	3.98	0.10	0.5%	Fluoride	0.28	0.01	0.1%
sum		22.43	100.0%	sum		25.58	100.0%
percent difference				-6.6%			
Specific conductance	2010			dissolved solids ratio	1740 0.87		



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