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# Quantification of metal loading in French Gulch, Summit County, Colorado, using a tracer-injection study, July 1996

Water-Resources Investigations Report 98–4078

Prepared in cooperation with the
Colorado Department of Natural Resources
Division of Minerals and Geology

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

Cover photo by T.S. Lovering, 1926, showing the Wellington Mine area in French Gulch in the Breckenridge district of Summit County, Colorado. The extensive dredging of French Gulch resulted in the complex hydrology of the current stream channel.

# QUANTIFICATION OF METAL LOADING IN FRENCH GULCH, SUMMIT COUNTY, COLORADO, USING A TRACER-INJECTION STUDY, JULY 1996

By Briant A. Kimball, Robert L. Runkel, and Linda J. Gerner

U.S. GEOLOGICAL SURVEY

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Salt Lake City, Utah
1999

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## CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

| Multiply | By | To obtain |
|---|---|---|
| kilogram (kg) | 2.2046 | pound |
| liter (L) | 0.26417 | gallon |
| meter (m) | 3.2808 | foot |
| micrometer (μm) | 0.0000032808 | foot |

Water temperature is reported in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{o}F = 1.8(^{o}C) + 32.$$

Chemical concentration and water temperature are reported only in metric units. Chemical concentration is reported in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the mass of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (μS/cm).

# Quantification of metal loading in French Gulch, Summit County, Colorado, using a tracer-injection study, July 1996

By Briant A. Kimball, Robert L. Runkel, and Linda J. Gerner

## ABSTRACT

Acid mine drainage degrades the water quality and affects the health of aquatic organisms, including fish, in French Gulch, Colorado, a stream that drains to the Blue and Colorado Rivers. Metals in the water originate from drainage of abandoned and inactive mines in the watershed. Mine drainage enters the stream in a complex pattern. Three tracer injections were used to define hydrologic flowpaths from the mines to the stream and to define hydrologic properties of French Gulch. A lithium chloride tracer added to the Oro Mine Shaft of the Wellington-Oro Mine was diluted by the mine pool but did not move from the shaft. This showed that there was no hydrologic connection of the upper mine-shaft water with the downgradient alluvium or with the stream. A sodium bromide tracer added to water in an alluvial well located next to the stream did not cause any detectable bromide concentration in a downgradient alluvial well or in the stream. A sodium chloride tracer added to the stream during a period of 4 days helped indicate those subreaches of French Gulch where the majority of metal loading occurs. There is substantial inflow of metals where the 11-10 and Bullhide Faults cross the stream, and where surface drainage, originating from the Bullhide Fault, enters the stream. The loading analysis indicates that the metals affecting aquatic life in the stream originate from ground and surface water that drain from the mine pool, except during storm runoff when additional sources may contribute metals.

## INTRODUCTION

Acid mine drainage degrades the water quality and affects the health of fish and other aquatic organisms in French Gulch, Colorado, a stream that drains to the Blue and Colorado Rivers (fig. 1). Metals are present in water that drains abandoned and inactive mines in the watershed. This mine drainage enters French Gulch in a complex pattern. Because French Gulch historically was dredged for placer gold mining, the hyporheic zone, the area of alluvium that exchanges water with the stream, is unnatural. This complex hydrology has obscured a consistent picture or conceptual model of the metal loading to the stream from surface- and ground-water inflows. Effective remediation at this site requires an understanding of the diverse physical and biogeochemical processes that control spatial profiles of metal concentrations and other acid constituents. Much of this understanding can come from a detailed mass-loading profile of metals in the stream. A tracer-injection study was designed in cooperation with the Colorado Division of Minerals and Geology to help with plans for remediation by providing a mass-loading curve and to evaluate the effects of instream geochemical processes.

Spatial variations of pH and toxic metals in streams affected by acid mine drainage are the result of the interplay of hydrologic and geochemical processes (Bencala and McKnight, 1987; Kimball and others, 1994; Broshears and others, 1995). The approach used in this study consisted of a tracer-injection study and synoptic sampling to provide the basis for mass-balance calculations that help to interpret these spatial variations. Tracer-injection methods, combined with computer simulations, have reproduced mass-loading curves with steady-state patterns of observed pH and metal concentrations in other streams around the Western United States (Broshears and others, 1993; Kimball and others, 1994; Broshears and others, 1996).

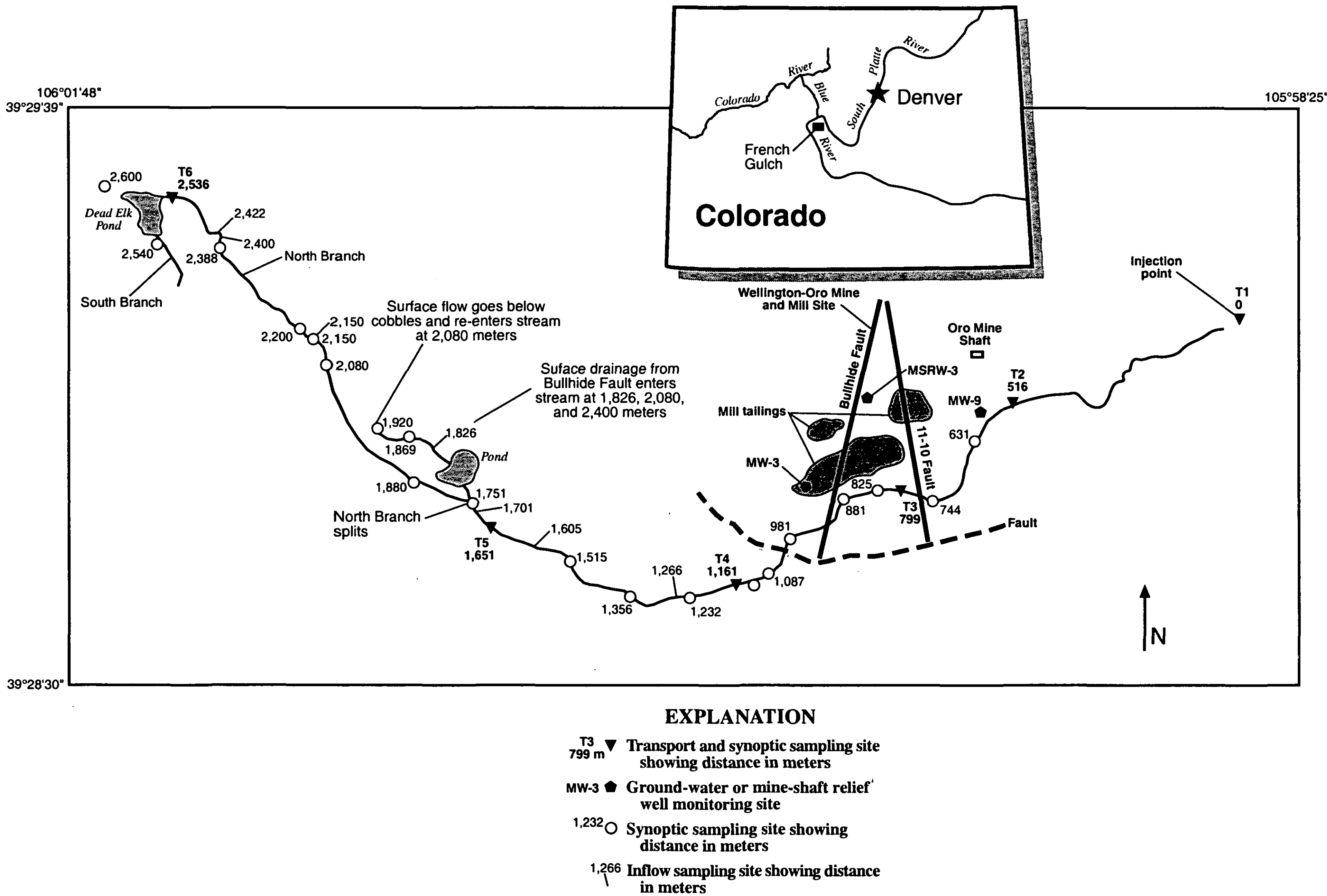


**Figure 1.** Location of selected surface- and ground-water sampling sites and important geologic features along French Gulch, Colorado.

## Purpose and Scope

The objective of this report is to present a description of the complex hydrology of the French Gulch site using the tracer-injection study and the synoptic sampling. In particular, the tracer injection allows for evaluation of the effect of the hydrology on the fate and transport of the metals in French Gulch.

## Description of Study Area and Conditions at the Time of the Study

French Gulch is an alpine stream that originates above 3,000 m at the continental divide. The main source of streamwater is snowmelt runoff, and the highest flows are during May and June when most runoff occurs. During snowmelt runoff, flow occurs in the North and South Branches of French Gulch downstream from the mine (fig. 1). As flow decreases during the summer, much of the flow goes below the surface in some parts of the stream. Because of the large amount of subsurface flow through the dredged cobbles in French Gulch, water continuously exchanges between the stream and the subsurface.

Results of the tracer injection are particular to the hydrologic conditions at the time of the injection. At the time of this study, surface flow decreased between sites T1 and T2, and then almost vanished between sites T2 and T3. In the vicinity of the 11-10 Fault, however, the flow greatly increased because of the discharge of many springs. Flow continued to increase between sites T3 and T4. Downstream from site T4, the flow was complex. There were visible inflows, but also visible outflows where streamwater flowed away from the stream under cobbles. The stream split about 1,730 m downstream from the injection point, sending about half the flow to a pond north of the stream and half down a channel to the west. Water flowed out of the pond and was visible on the surface to about 1,920 m, where it went below the cobbles. Surface drainage that likely originated at a spring along the Bullhide Fault entered from the right side of the channel at 1,826 m, downstream from the pond. The other channel from the split (at about 1,730 m) was the North Branch of French Gulch, and visibly flowed all the way to Dead Elk Pond. The North Branch received inflow at 2,150 m that likely consisted of the return flow from the pond. Two inflows at 2,400 and 2,422 m were from mine drainage on the north side of the stream. This water likely originated from drainage of the Bullhide Fault but may have had additional contributions from tailings piles. Flow in the South Branch of French Gulch originated about 200 m upstream from Dead Elk Pond and was not visibly connected to the flow in the North Branch.

## Methods

Three separate tracer injections were used to study the complex hydrology of French Gulch. First, a slug injection of lithium chloride (LiCl) into the Oro Shaft defined the paths of mine water to the alluvium and the stream. Second, a slug injection of sodium bromide (NaBr) into an alluvial well (MW-9) quantified the interaction of the stream with the alluvium. Third, a continuous injection of sodium chloride (NaCl) into the stream quantified hydrologic parameters, including discharge at each sampling site along the stream, residence time of solutes between sites, and transient storage (Stream Solute Workshop, 1990; Bencala and others, 1990a, 1990b). The sequence of injections is listed in table 1.

### Tracer Sampling

Samples were collected to measure the concentrations of injected tracers and to quantify the residence time or "time of travel" in water from wells and in the stream. Residence-time sampling was done in two parts. The first part included sampling of water from selected wells in the bedrock and alluvium to quantify the arrival of LiCl or NaBr from slug injections. This sampling continued for 4 days, mostly at hourly intervals, in six wells. Residence-time samples for the wells were unfiltered because of the difficulty of filtering iron-rich waters in the field. The samples were filtered in the laboratory prior to analysis by atomic adsorption spectrophotometry (AA) and ion chromatography (IC).

The second part included sampling at selected "transport" sites along the stream to quantify the arrival and departure of NaCl. These samples established the hydrologic framework by providing residence time between sites, discharge at each site, stream cross-sectional area, and other parameters needed for transport modeling. This sampling continued for 2 days prior to the synoptic sampling and 1 day after the synoptic sampling to allow time for the alluvial tracer to reach the stream and to help define the hyporheic zone. These samples were filtered on site through 0.45-µm membrane filters.

**Table 1.** Sequence of tracer-injection activities and sampling in French Gulch, Colorado

| Date | Time | Activity |
|---|---|---|
| 7/23/96 | 09:00 | Began tracer sampling for wells |
| | 09:15 | Slug injection of lithium chloride into Oro Shaft |
| | 09:38 | Slug injection of sodium bromide into well MW-9 |
| | 10:00 | Flow-meter discharge measurements at selected stream sites |
| 7/24/96 | 09:00 | Started sodium chloride injection in the stream (runs into day 5) |
| | 09:00 | Began tracer sampling at six sites |
| | 14:42 | Added sodium chloride to injection pool |
| | 17:24 | Added sodium chloride to injection pool |
| 7/25/96 | 11:12 | Started spot-tracer injections at six sites |
| | 17:20 | Added sodium chloride to injection pool |
| 7/26/96 | 08:00 | Synoptic sampling of stream sites and inflows |
| | 11:21 | Added sodium chloride to injection pool |
| 7/27/96 | 09:00 | Shut off tracer |
| | 08:30 | Time-of-travel sampling |
| 7/28/96 | 12:00 | End of sampling |

### Synoptic Sampling

During the NaCl injection, water samples from stream and selected inflows were collected to develop mass-loading profiles for metals and anions. Both filtered and unfiltered samples were collected. Filtered samples were passed through a 0.45-µm filter to determine "operationally defined" dissolved metals; including cadmium (Cd), iron (Fe), manganese (Mn), and zinc (Zn). The use of 0.45-µm filtration was to satisfy regulatory objectives. Filtration of water using 10-kilo-Dalton, 0.1-µm, and 0.45-µm membrane filters indicated a significant difference in Fe concentrations among filtrates (B.A. Kimball, unpub. data, 1996). The concentrations of total-recoverable metals were determined from unfiltered samples.

### Analytical Methods

Anions were analyzed in the 0.45-µm filtered, unacidified samples by ion chromatography. These filtered, unacidified samples also were analyzed for sodium (Na) and lithium (Li) by atomic adsorption. Dissolved and total-recoverable metal concentrations were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES). Filtered samples were analyzed for ferrous iron (FeII) colorimetrically. Alkalinity, total suspended solids, and total organic carbon were determined from unfiltered samples.

To present the time series of data from the stream and wells, a smoothed line is plotted on the figures. The smoothed line uses medians to summarize consecutive, overlapping segments of the sequence, for example, the first five data values, then the second through sixth values, and so on (Velleman and Hoaglin, 1981).

## QUANTIFICATION OF METAL LOADING

Results of chemical determinations for tracer concentrations in water from wells and stream sites are listed in appendices 1 and 2. Site descriptions and physical properties of water from the synoptic sampling sites are listed in appendix 3. Results of chemical concentrations in water from the synoptic sampling sites are presented in appendix 4 for major ions and in appendix 5 for filtered and total metals. Data are sorted in downstream order within groups of mainstem and inflow sites to emphasize the downstream changes.

## Tracer Injections in the Wells

### Slug Injection of LiCl in the Oro Mine Shaft

Three kg of LiCl were mixed into 5 L of deionized water and added to the Oro Mine Shaft through 20 m of plastic tubing. After an initial peak and subsequent decline, the concentration of Li remained above the preinjection level for several weeks (fig. 2a). Water from a mine-shaft relief well, MSRW-3, was sampled to detect Li and Cl from the slug injection. No Li was detected in water from well MSRW-3, nor was there a variation in Cl concentration in water from the mine well, MSRW-3 (fig. 2b); or in the alluvial well, MW-3 (fig. 2c).

The initial decrease of Li in the Oro Mine Shaft can best be interpreted as the dilution of Li as it mixed into the mine pool. After mixing, however, there was not a continual decrease of Li, as might be expected if water from the mine pool was moving to the bedrock and the downgradient alluvium. Lithium was not detected in water from MSRW-3 or in any of the stream samples. Thus, the most likely explanation of the trend in Cl concentration is that the mine pool, at least the top of the mine pool in this shaft, was isolated from the ground-water system that supplies metal-rich water to the bedrock and the alluvium. This information is important to help refine the conceptual model of the hydrologic system of the mine, even without an indication of a pathway from the mine pool to the stream. The information indicates that the mine drainage affecting the stream is from lower levels of the mine.

### Slug Injection of NaBr in Well MW-9

One kg of NaBr was mixed into 3 L of deionized water and poured inside the casing of well MW-9 at 09:38 on July 23. The concentration of Br in the well water increased with the slug injection, and then decreased to preinjection levels within 24 hours (fig. 3). Despite the high concentration of Br in water from well MW-9, Br could not be detected in water from the downgradient alluvial well, MW-3, or in water from the stream at any of the sampling sites.

There are three possible reasons why Br was not detected in water from the downgradient alluvial well or in the stream: (1) the downgradient alluvial well may not have been located along a potential flowpath for the Br traveling in the alluvial aquifer, (2) the Br could have been diluted below detection limits by dispersion before it arrived at either the well or the stream, or (3), for both the well and the stream, the travel time of Br to the downgradient wells could have been greater than the time allotted for sampling. Additional samples collected during the following months did not indicate Br in water from either the well or the stream. The most likely explanation is that water from well MW-9 did not flow to well MW-3.

## Tracer Injection in the Stream

The tracer injection for the stream was prepared by adding 400 kg of NaCl to 440 L of streamwater in a 3-m diameter wading pool. This tracer was to be pumped into the stream at a rate that would maintain a constant Cl concentration of a few mg/L. After mixing the solution, however, the pool leaked. Because of this leak, some of the NaCl solution reached the stream before the intended injection began and resulted in Cl concentrations slightly greater than normal background values (fig. 4). Additional NaCl had to be added to the pool periodically during the 4-day injection to compensate for the loss and to avoid a premature end of the injection. These unplanned additions resulted in greater variability in the Cl profile of the stream than otherwise would have been observed (fig. 4). Chloride concentrations at stream sites are listed in appendix 2.

The tracer injection was divided into three periods (fig. 4). The first period was the arrival of the tracer. The second period was a plateau where the Cl concentration should have been at a constant plateau value, which depended on the discharge, at any point downstream. This allows accurate calculation of discharge at any given site along the stream for the synoptic samples. Because of the periodic additions of salt to the pool, there was substantial variation in tracer concentration during the plateau period in French Gulch. By sampling the salt solution being pumped to the stream and monitoring the pump rate, the mass balance of salt and the discharge in the stream could still be determined. The third period includes the departure of the tracer at the downstream sites after the injection was stopped.

### Time of Travel

Information from the arrival and departure periods can be used to calculate the travel time between sites (fig. 4). Despite the complications caused by the leaky pool, the arrival times of the tracer at the downstream sites were not affected. The injection began at 09:00 on July 24 and continued until 09:00 on July 27. The time of arrival at a site is defined as the time at

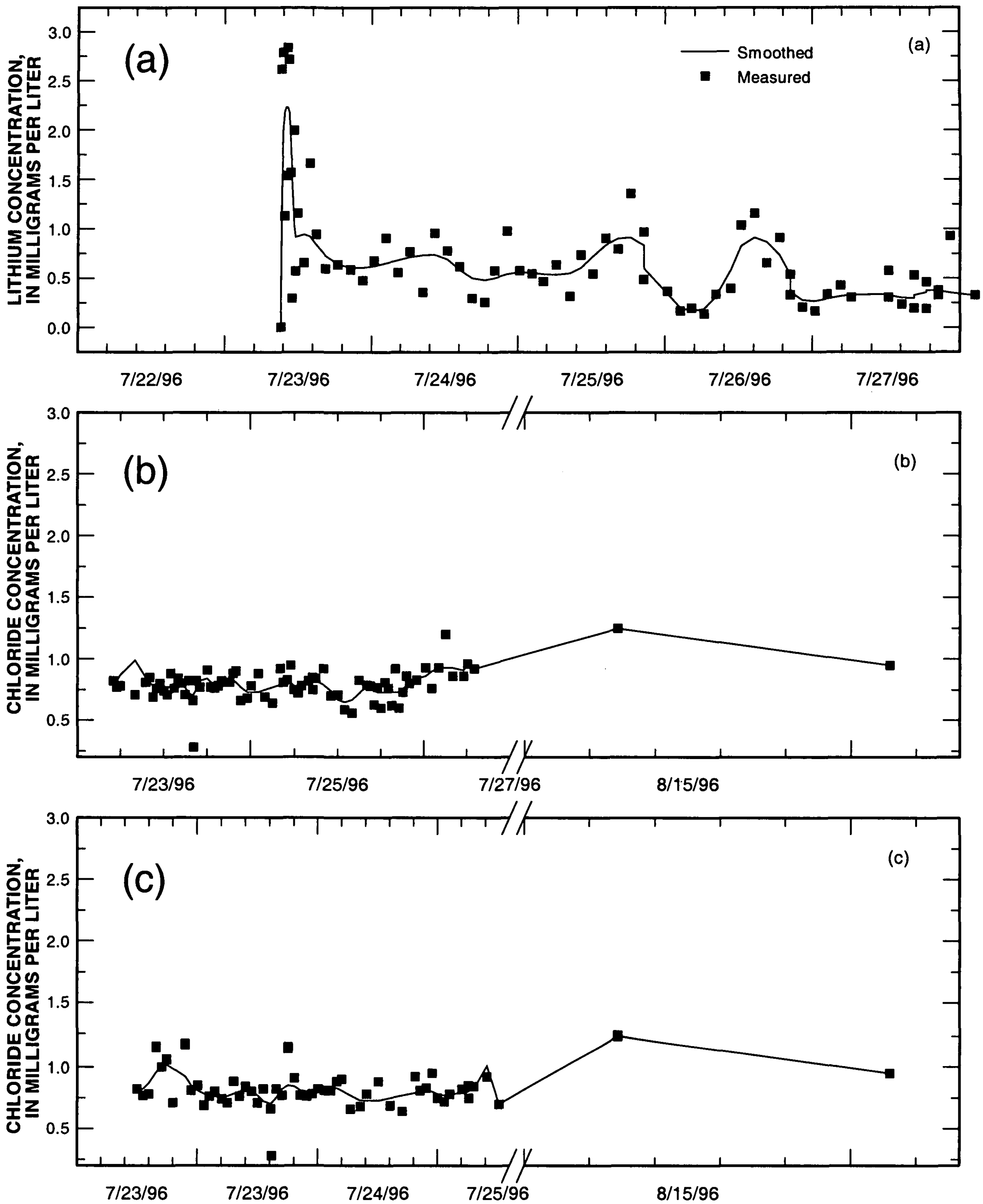


**Figure 2.** Concentration of (a) lithium in water from the Oro Mine Shaft, (b) chloride in water from the mine-shaft relief well, MSRW-3, and (c) chloride in water from the alluvial well, MW-3, near French Gulch, Colorado.

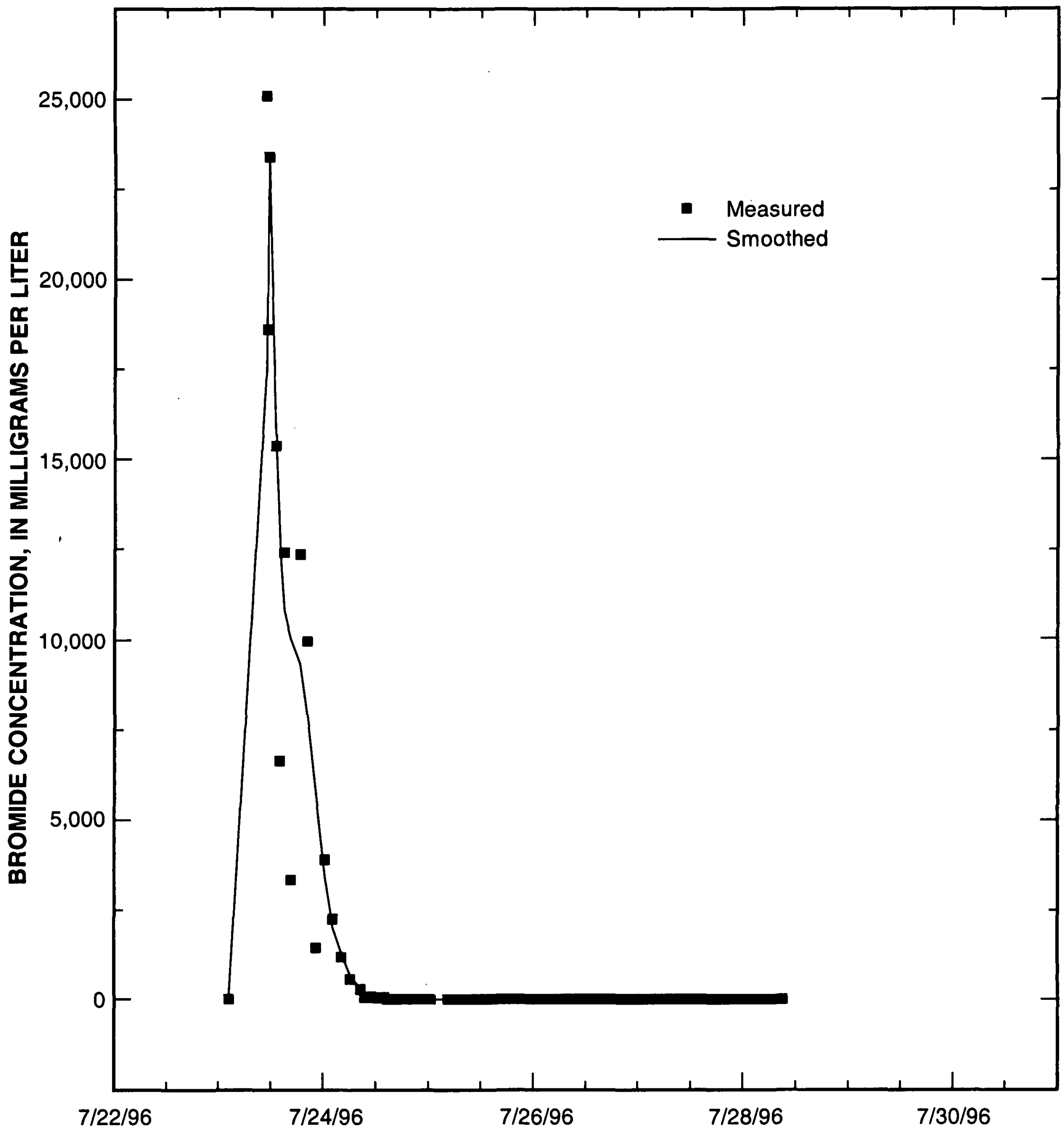


**Figure 3.** Bromide concentration in water from well MW-9, site of the NaBr slug injection, French Gulch, Colorado.

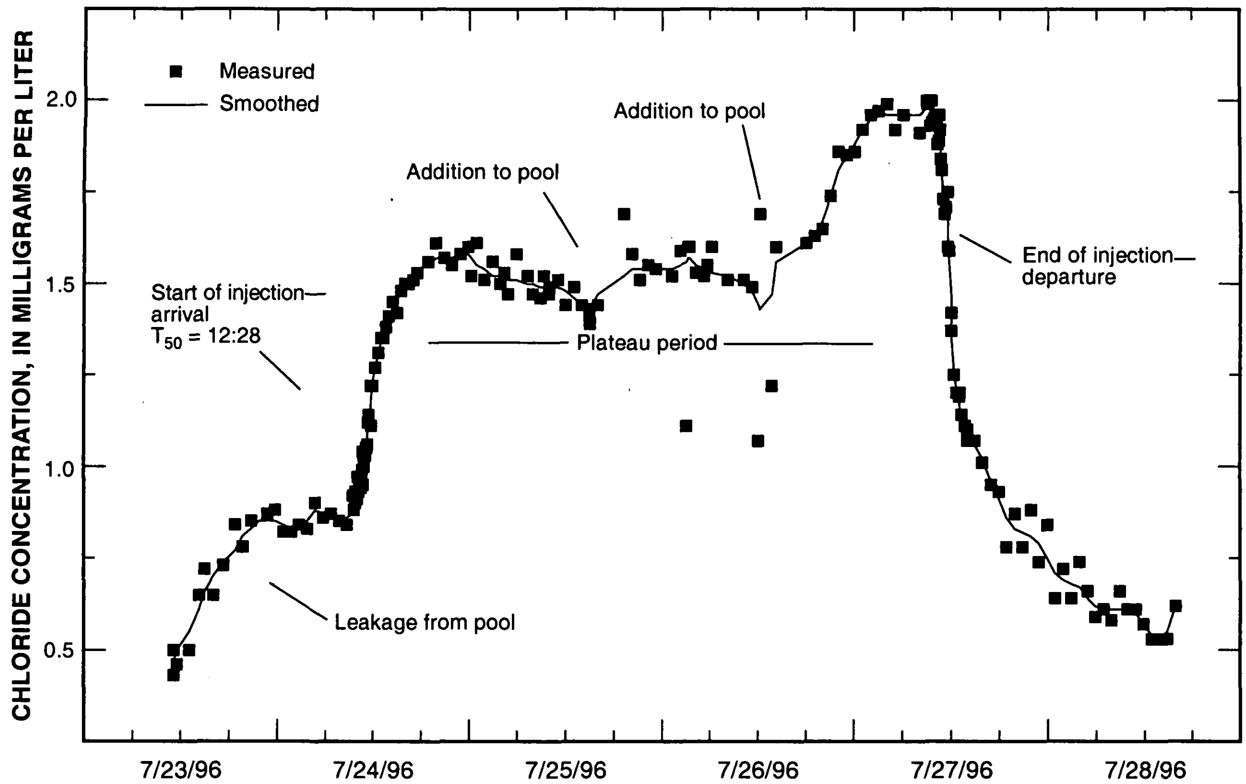


**Figure 4.** Chloride concentration for site T4 during the period of injection, French Gulch, Colorado.

which the instream-tracer concentration reaches half of the plateau concentration (Zellweger and others, 1988). Plateau concentrations, ½ plateau concentrations ($C_{50}$), arrival times ($T_{50}$), travel time between sites, and cumulative travel time downstream are listed in table 2.

The chronology of the tracer concentration at each site can be normalized to allow comparisons of the hydrologic properties between sites (fig. 5). Normalization of transport time was relative to the arrival times in table 2. Normalization of concentration was relative to maximum and background tracer concentrations at each site (see Bencala and others, 1990b). Comparison of the sites indicates a significant difference in arrival of tracer at sites T2 and T4. This difference was caused by the leaky pool and indicates that the Cl entering the stream from the leaking pool entered the hyporheic zone and generally bypassed site T2. Streamflow almost disappeared between sites T2 and T3 and then rejoined the stream just upstream from site T3. Several inflows had Cl concentrations substantially higher than instream concentrations, all on the right bank between sites T2 and T4. The higher concentrations likely were caused by the return of streamwater that had entered the hyporheic zone upstream from site T2.

Effects of solute storage in the hyporheic zone were much more pronounced at the end of the injection period than at the beginning. After 3 days of tracer injection, the bleeding of solutes from transient storage was more pronounced at each downstream site. The effect of the hyporheic zone varied from almost no effect at site T2, which had a rapid return to baseline concentrations, to a pronounced effect at site T6, which had about 40 percent of the maximum tracer concentration still present 24 hours after stopping the injection. In a stream where mining operations have dredged almost the entire reach, the streamflow is complex, and these tracer patterns indicate a clear effect on solute storage.

### Discharge Profile of the Stream

An evaluation of mass loading along French Gulch requires an accurate discharge measurement at each sampling site. Two characteristics of the streamflow in French Gulch made the calculation of discharge difficult. First, tracer-dilution methods can quantify gains, but not losses of discharge. Once a tracer has mixed into the stream water, the loss of water does not change the concentration of tracer in the remaining

**Table 2.** Instream chloride concentration and travel time at sites downstream from the tracer injection, French Gulch, Colorado, July 24-27, 1996

[m, meters; mg/L, milligrams per liter; $C_{50}$, half plateau concentration; $T_{50}$, arrival time for the $C_{50}$ concentration; <, less than]

| Site—Distance downstream | Preinjection concentration (mg/L) | Plateau concentration (mg/L) | $C_{50}$ (mg/L) | $T_{50}$ (hours) | Time between sites (minutes) | Cumulative time (minutes) |
|---|---|---|---|---|---|---|
| T1— 0 m | 0.09 | 1.30 | 0.7 | 09:01 | < 2 | < 2 |
| T2— 516 m | .08 | 1.67 | .87 | 09:23 | 23 | 23 |
| T3— 799 m | .76 | 1.21 | .99 | 10:59 | 96 | 119 |
| T4—1,161 m | .84 | 1.48 | 1.16 | 11:38 | 39 | 158 |
| T5—1,651 m | .86 | 1.58 | 1.22 | 12:10 | 32 | 190 |
| T6—2,536 m | .63 | 1.08 | .86 | 14:00 | 110 | 300 |

water. For example, between 84 m and 631 m, almost all of the surface flow in French Gulch disappeared into the alluvium, but there was no significant change in the Cl concentration (fig. 6). By contrast, downstream from 631 m, a large inflow of water caused the instream Cl concentration to decrease from 3.3 to 0.4 mg/L between 631 m and 744 m. The second characteristic was that the Cl concentrations of inflows between 744 m and 799 m exceeded the instream concentrations. This caused a sharp increase of Cl concentration from 744 to 799 m, and a gradual increase to 1,161 m. These flow characteristics in French Gulch required the use of an independent measure of discharge to prepare a discharge profile of the stream.

## Spot Injection for Discharge at Selected Sites

To account for these two characteristics of streamflow in French Gulch, spot injections of NaCl tracer were used to obtain instantaneous discharge measurements at sites T2 through T6. Spot injections required the addition of enough tracer to raise the Cl concentration above any Cl from upstream injections (fig. 7). The stream was then sampled for about an hour at a well-mixed point downstream from the spot injection. These injections proved to be the solution to calculating discharge in certain subreaches of the stream. By knowing the concentration of the injectate and the rate of injection, the discharge at the site can be calculated from the change in concentration measured downstream from the injection.

At site T1, mixing of the tracer into the stream was poor and caused a large overcalculation of discharge (fig. 8). The spot injections were comparable to discharge measurements made with a flow meter at sites T2 and T3. At sites T4 and T6, the calculated discharge from the tracer injection is about 30 percent greater than the discharge measured with a flow meter (Kimball, 1997). This result is expected in mountain streams with cobble bottoms where a large percentage of the streamflow can be among the cobbles of the streambed where it cannot be measured by a flow meter. At site T5, the spot-injection calculation indicated less discharge than the flow-meter measurement. Visible losses and gains of flow occurred all along the stream between sites T4 and T6, so the discharge could have been smaller, but the reason why the flow-meter measurement exceeded the spot-injection calculation is unknown.

Despite the difference in discharge measurements at site T5, most of the lost streamflow appeared to have returned to the stream channel upstream from site T6. Some of the flow could move to the South Branch of French Gulch and appear at site FG-46, but

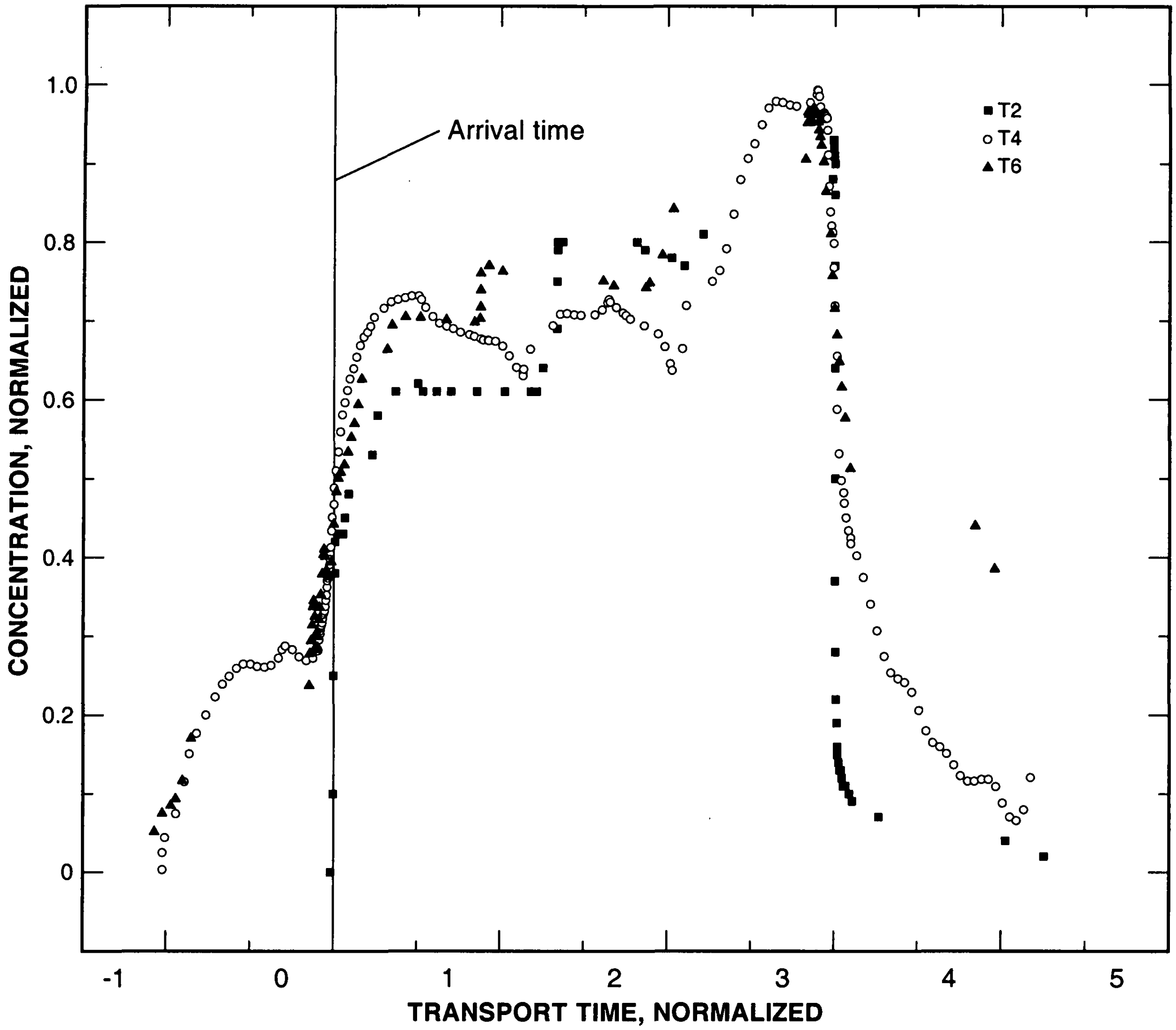


**Figure 5.** Normalized tracer concentration versus normalized transport time at sites T2, T4, and T6 for the injection period, French Gulch, Colorado.

most of the flow was in the North Branch so that loads could be compared between sites T4 and T6.

By knowing discharge at each of the spot-injection sites, discharge could be calculated for intermediate sites in gaining reaches of French Gulch. Although the reach from sites T2 to T3 had a net gain in flow, the flow nearly disappeared below the surface before much of it was regained from large springs upstream from site T3. This pattern made it impossible to calculate discharge at intermediate sites between T2 and T3. Intermediate discharge was calculated for sampling sites between T3 and T4 by using the spot-injection discharge at site T3 as the first upstream discharge and calculating the next downstream discharge with the equation:

$$Q_d = \frac{Q_u(C_u - C_i)}{(C_d - C_i)} \qquad (1)$$

where $Q_d$ is the downstream discharge,

$Q_u$ is the upstream discharge,

$C_u$ and $C_d$ are the upstream and downstream tracer concentrations, and

$C_i$ is the inflow concentration.

Thus, the discharge profile was well defined at intermediate points between sites T3 and T4, which includes a critical reach of fault seepage (fig. 9). There also were reliable discharge measurements for sites T2 and T6. Between sites T4 and T6, there was a small, net increase in discharge. Flow along that reach was complex; for calculating mass-balance, this small increase in discharge was prorated by distance along the reach.

## Synoptic Sampling of Stream Sites

Synoptic sampling sites were chosen to bracket all of the visible and likely inflow areas to French Gulch. A description of each sampling site including measurements of temperature, pH, and specific conductance is listed in appendix 3.

### Major-Ion Chemistry

Upstream from the mines, the water in French Gulch was mostly a calcium bicarbonate type (see appendix 4). The calculated dissolved-solids concentration was 63 mg/L at 516 m (T2), indicating that upstream from mining, French Gulch was a dilute headwater stream. Inflows from mine drainage mostly added calcium sulfate type water, which reflects the oxidation of sulfide minerals and the release of calcium from rocks weathered by the increased acidity of the water. Downstream from all the mine inflows, the stream changed to a calcium sulfate-magnesium carbonate type water at 2,536 m (T6), with a dissolved-solids concentration of 124 mg/L. Thus, mine-drainage inflows caused a slight change in major ion chemistry and a doubling of the dissolved-solids concentration.

### Metal Chemistry

Oxidation of sulfide minerals, accelerated by mining along French Gulch, has produced substantial concentrations of Fe, Cd, Mn, and sulfate ($SO_4$) in the ground and surface water. Metals such as aluminum (Al), copper (Cu), and lead (Pb) occur in the water of French Gulch, but generally in very low concentrations (appendix 5). Upstream from the effects of mine drainage, at 516 m (T2), the metal concentrations were low, often below detection limits. The highest metal concentrations occurred at 2,536 m (T6), downstream from all the metal-rich inflows. Further downstream at 2,600

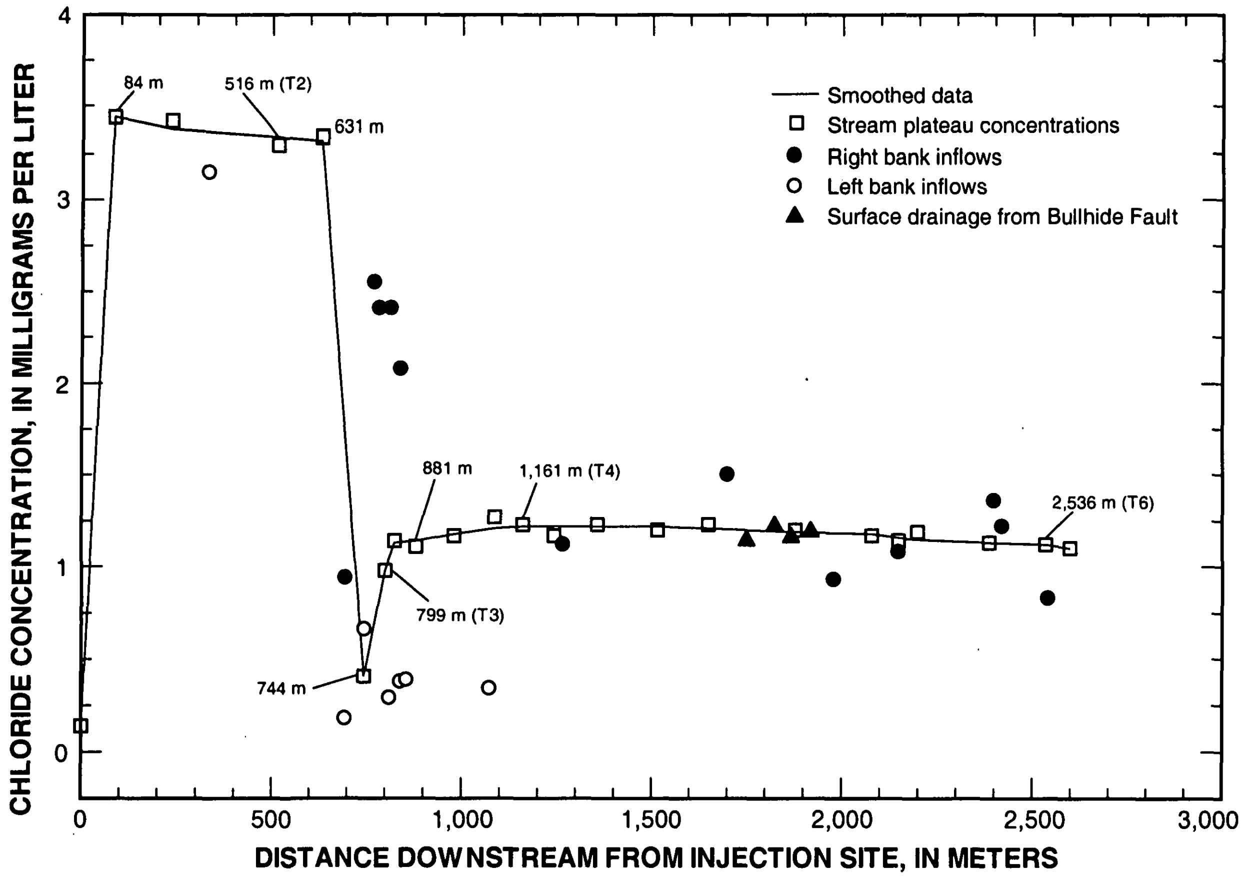


**Figure 6.** Chloride concentration downstream from the injection site, French Gulch, Colorado.

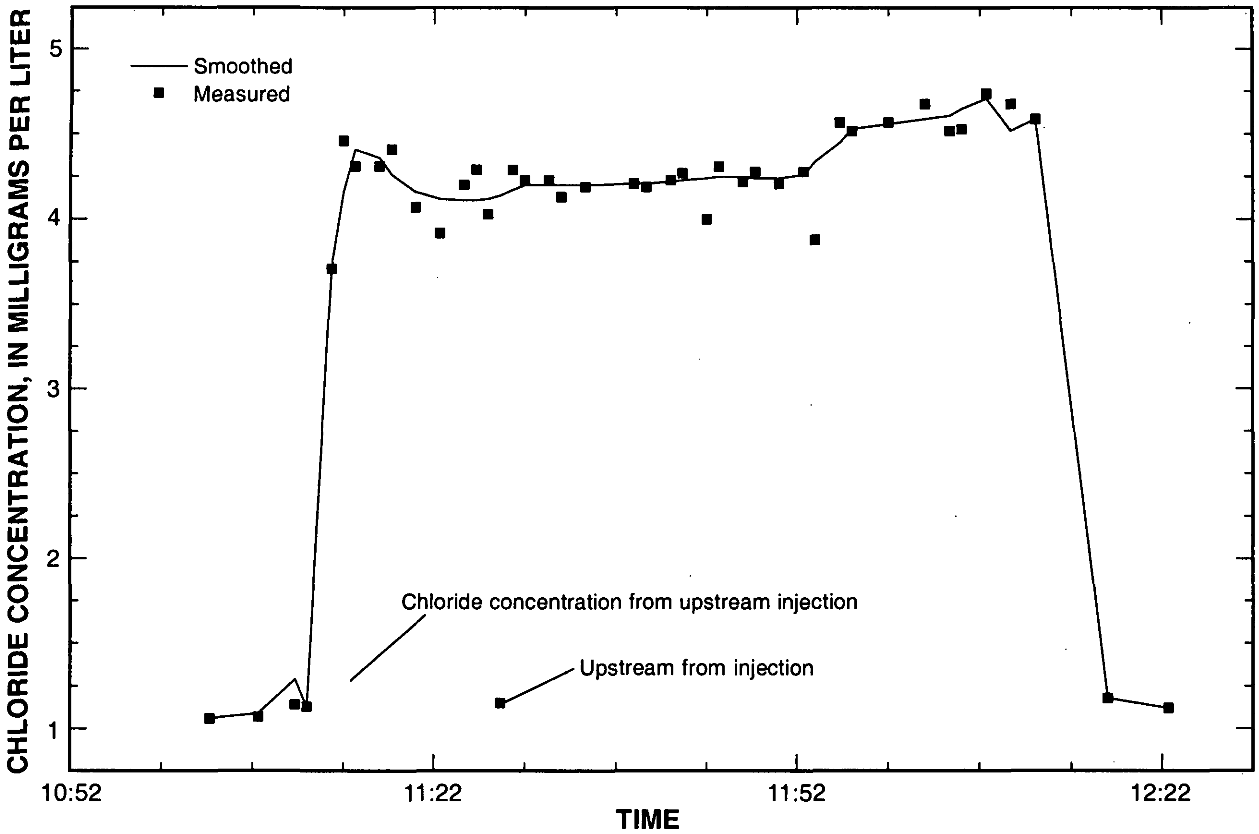


**Figure 7.** Chloride concentration at site T3 during the spot injection, French Gulch, Colorado.

m, these concentrations were diluted by the inflow of the South Branch of French Gulch.

There was a large range of metal concentration among the sampled inflows. The inflow at 1,701 m had the highest concentration of Cd, Mn, and Zn, followed by the inflow at 2,400 m. Both these inflows were a long distance downstream from the 11-10 and Bullhide Faults. Inflows with high concentrations of metals also occurred in the area between the 11-10 and Bullhide Faults at 840 m, 812 m, 814 m, and 857 m. These metal-rich inflows occurred on both sides of the stream.

### Downstream Profiles of Sulfate and Metals

Mine-related $SO_4$ and metals have similar downstream concentration profiles (figs. 10 and 11). These profiles are controlled by the geology and hydrology of French Gulch.

The concentration of $SO_4$ in French Gulch ranged from 10.6 mg/L upstream from the mine-affected area to 62 mg/L downstream from the mine-affected area. The range of $SO_4$ concentration among inflows was even greater, from 10.8 to 453 mg/L.

Instream $SO_4$ concentrations substantially increased in three reaches along the stream (fig. 10). The first increase occurred between 631 and 881 m, where the concentration increased to almost 21 mg/L. This was in the vicinity of the 11-10 Fault (fig. 1) and was likely related to mine drainage from the Wellington-Oro Mine along the fault. The second increase occurred between 2,080 m and 2,200 m, where the concentration increased to about 45 mg/L. This is where the North Branch gained a substantial inflow of metal- and sulfate-rich water that entered the side channel at 1,826 m. Finally, the third increase occurred between 2,388 m and 2,536 m (T6), where the concentration increased to 62 mg/L.

Each of the mine-related metals had concentration profiles similar to that of $SO_4$ (fig. 11). The filtered Fe concentration ranged from less than 1 µg/L upstream from the mine-affected area, to 53 µg/L at T6 (2,536 m) downstream from the mine-drainage inflows (fig. 11a). Iron was the most variable of the metals because it precipitates more readily than most metals. The concentration of filtered Cd was low, ranging from

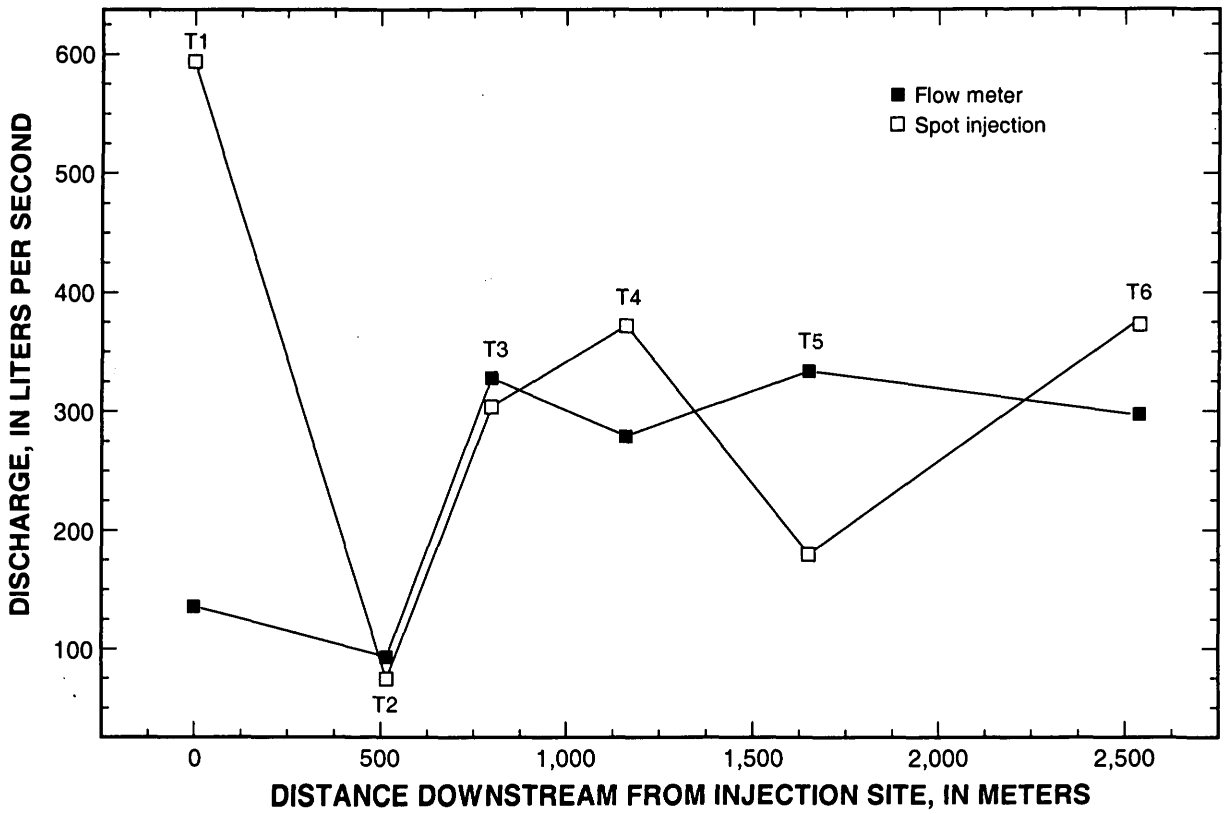


**Figure 8.** Discharge calculation by spot injection of tracer with discharge measurement by flow meter, French Gulch, Colorado.

less than detection to 13 μg/L, but indicated a very clear increase with distance downstream (fig. 11b). Unlike the other solutes, the increase of filtered Cd was not as great between 2,150 and 2,220 m. The concentration of Cd in the inflows between 819 and 840 m was greater than in the inflows at 1,701 and 2,200 m. The filtered concentration of Mn and Zn (figs. 11c and d) increased at the same inflow locations. The concentration of Mn and Zn was substantially greater than that of Fe and Cd. The concentration of Mn ranged from near 1 μg/L upstream of the mining inflows to about 1,000 μg/L at site T6 (2,536 m). The concentration of filtered Zn ranged from about 10 μg/L upstream of mine-drainage inflows to about 5,000 μg/L at site T6. The Zn that enters the stream could be a cause of fish toxicity in French Gulch.

### Mass-Loading Profiles

The concentration profiles compiled from spatially intensive sampling of stream sites and inflows can be converted into mass-loading profiles. Because mass-loading profiles take discharge into account, they are more useful than concentration profiles to indicate those reaches of the stream most affected by mine drainage and to evaluate the relative importance of the inflows (fig. 12). Each of the increases in solutes can be quantified as a percentage of the load at the site farthest downstream, site T6. Inflows between 516 m (T2) and 799 m (T3) accounted for 19 percent of the $SO_4$ load (fig. 12a). The concentration of $SO_4$ in these inflows was low, indicating that the inflows were not affected by mine drainage. The $SO_4$-rich inflows between 799 (T3) and 1,161 m (T4) likely are related to the 11-10 and Bullhide Faults, and accounted for 16 percent of the load. The remaining 65 percent of the load entered the last, broad subreach from 1,161 (T4) to 2,536 m (T6). The largest increases in load likely occurred at 2,150 m and 2,220 m, where the stream gained $SO_4$ from surface drainage of the Bullhide Fault. These final inflows to the North Branch are the most significant for adding $SO_4$.

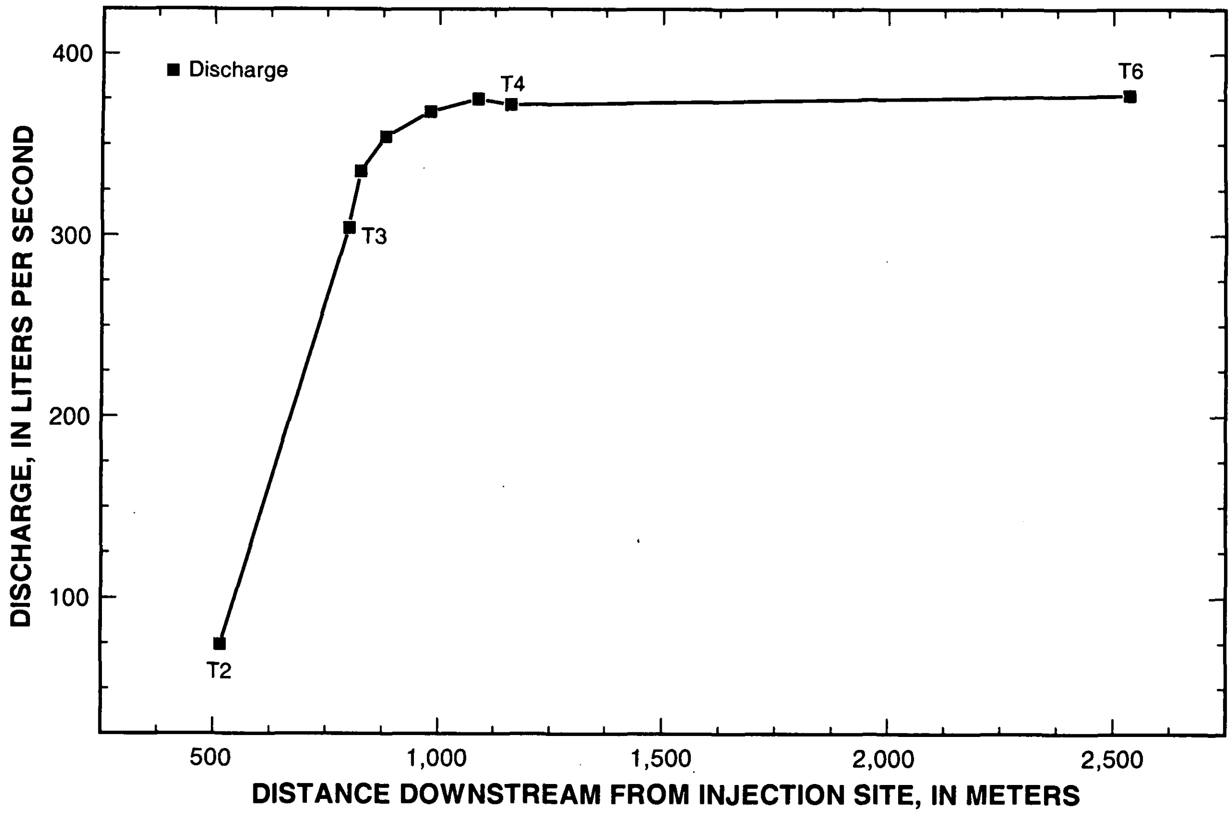


**Figure 9.** Discharge profile calculated from chloride-tracer concentration downstream from the injection site, French Gulch, Colorado.

A different pattern of mass loading occurred for Cd (fig. 12b). Essentially none of the Cd load was added upstream from 799 m (T3). Between 799 m and 1,161 m (T4), however, 66 percent of the downstream load was added, indicating the importance of the 11-10 and Bullhide Faults. Thirty-four percent of the load entered between 1,161 m and 2,536 m (T6). This loading could be proportionally smaller than the loading for Mn and Zn because Cd could have been sorbed onto the abundant Fe oxides that line the bottoms of stream channels where water flows from the Bullhide Fault to inflows at 1,826, 2,400, and 2,422 m.

The mass loadings of Mn and Zn were similar to $SO_4$ (figs. 12c and 12d). The first significant inflow between 799 m (T3) and 1,161 m (T4) accounted for 26 percent of the Mn load and about 32 percent of the Zn load. The remainder of the Mn and Zn loads entered the North Branch with the inflows at 2,150 and 2,400 m, which drain flow from the Bullhide Fault.

Between 799 m (T3) and 1,161 m (T4), the individual inflows have different effects on the mass loading in each subreach of the stream (fig. 13). For example, the inflows in the first two subreaches, from 799 to 825 m and from 825 to 881 m, caused the instream Zn concentration to increase from 48 μg/L to 368 μg/L and then to 700 μg/L. However, from 881 to 981 m no visible surface inflows occurred and yet the concentration of Zn more than doubled to 1,570 μg/L. The likely cause of this large increase was discharge from the Bullhide Fault, which crosses the stream in that subreach. In the next two subreaches, from 981 to 1,087 m and then from 1,087 m to 1,161 m, again no visible surface inflows occurred and the Zn concentration did not increase. Sulfate, Cd, and Mn concentrations all increased in this same detailed pattern, indicating that discharge from the Bullhide Fault contributes substantially to the instream loads.

## Instream Processes Affecting Metal Transport

The difference between the total recoverable and dissolved concentrations of Fe (fig. 14) indicated that most of the Fe transport was by Fe-rich colloidal particles. The concentration of these colloids in the stream

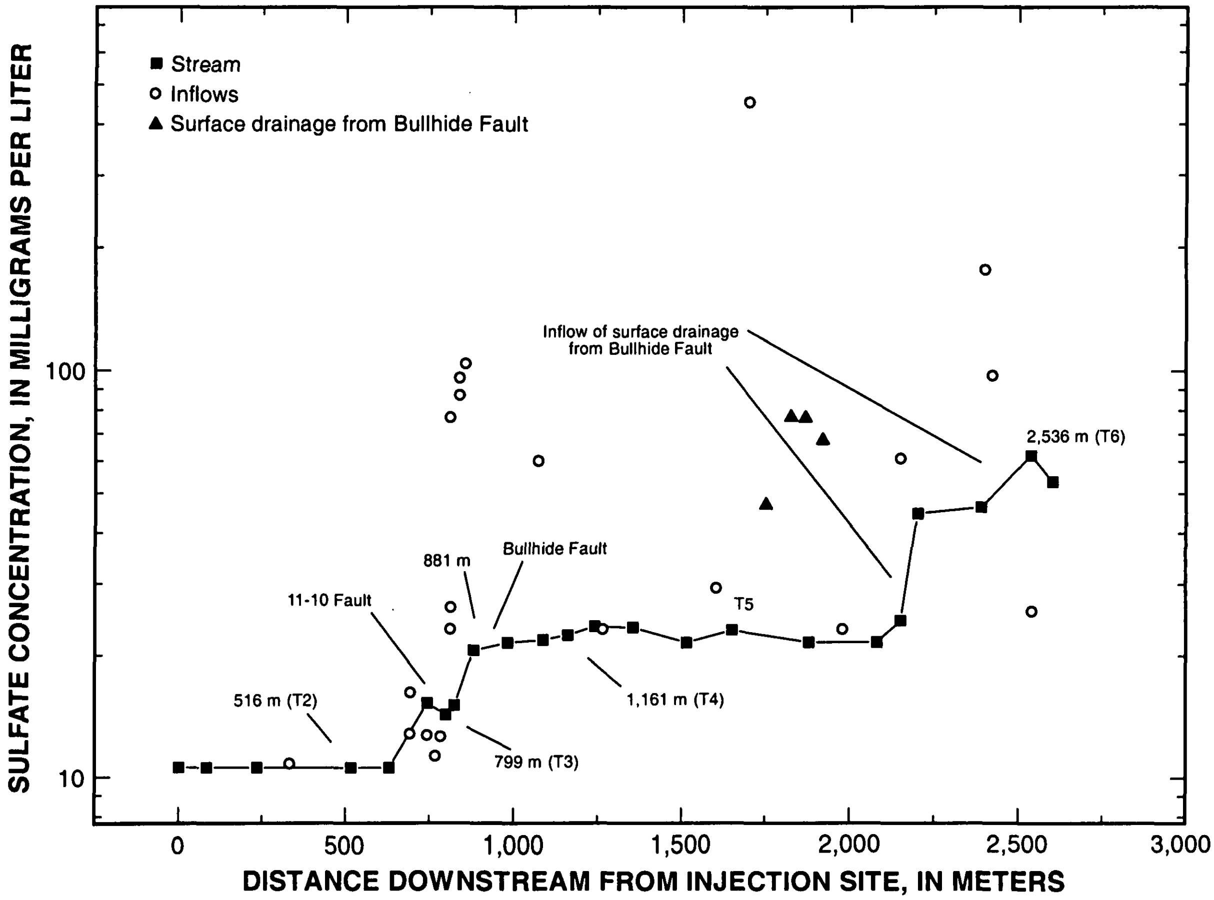


**Figure 10.** Range of instream and inflow sulfate concentration downstream from the injection site, French Gulch, Colorado.

is the difference between the two concentrations. Colloids have been shown to have a role in the metal transport of other Rocky Mountain streams affected by mine drainage (Kimball and others, 1992; Kimball and others, 1995; Broshears and others, 1996). Iron colloids are not toxic unless other metals are sorbed to them. Very little of the Zn was transported by the Fe colloids (fig. 14b), but other metals like Cd and Cu generally are associated with Fe colloids (Kimball and others, 1992, table 3). These data indicate that colloidal transport can influence the occurrence and distribution of metals downstream from the mine drainage.

## SUMMARY

Acid mine drainage degrades the water quality and affects the health of fish and other aquatic organisms in French Gulch, Colorado, a stream that drains to the Blue and Colorado Rivers. Metals are present in water that drains abandoned and inactive mines in the watershed. Metals in the water of French Gulch, Colorado, originate from mine drainage in the watershed and enter the stream in a complex pattern. Among the metals that were found in the water, Zn was likely the most significant as a cause of toxicity. A LiCl tracer injection into the Oro Mine Shaft of the Wellington-Oro Mine did not indicate flowpaths from the upper levels of the mine to the alluvium and the stream. The persistence of the LiCl tracer in the upper part of the Oro Mine Shaft indicated that there was little hydrologic connection with the ground water discharging into the alluvium and affecting the stream. A NaBr injection into an alluvial well was attenuated by ground-water flow in the alluvium, but Br was not detected in water from the downgradient alluvial well or in the stream. When a NaCl tracer injection and synoptic sampling were used, the downstream profile of metal concentrations and mass loading indicates those subreaches of French Gulch where most of the metal loading occurred. There was substantial inflow of metals where the Bullhide Fault crosses the stream. Most of metal load entered French Gulch downstream from the fault

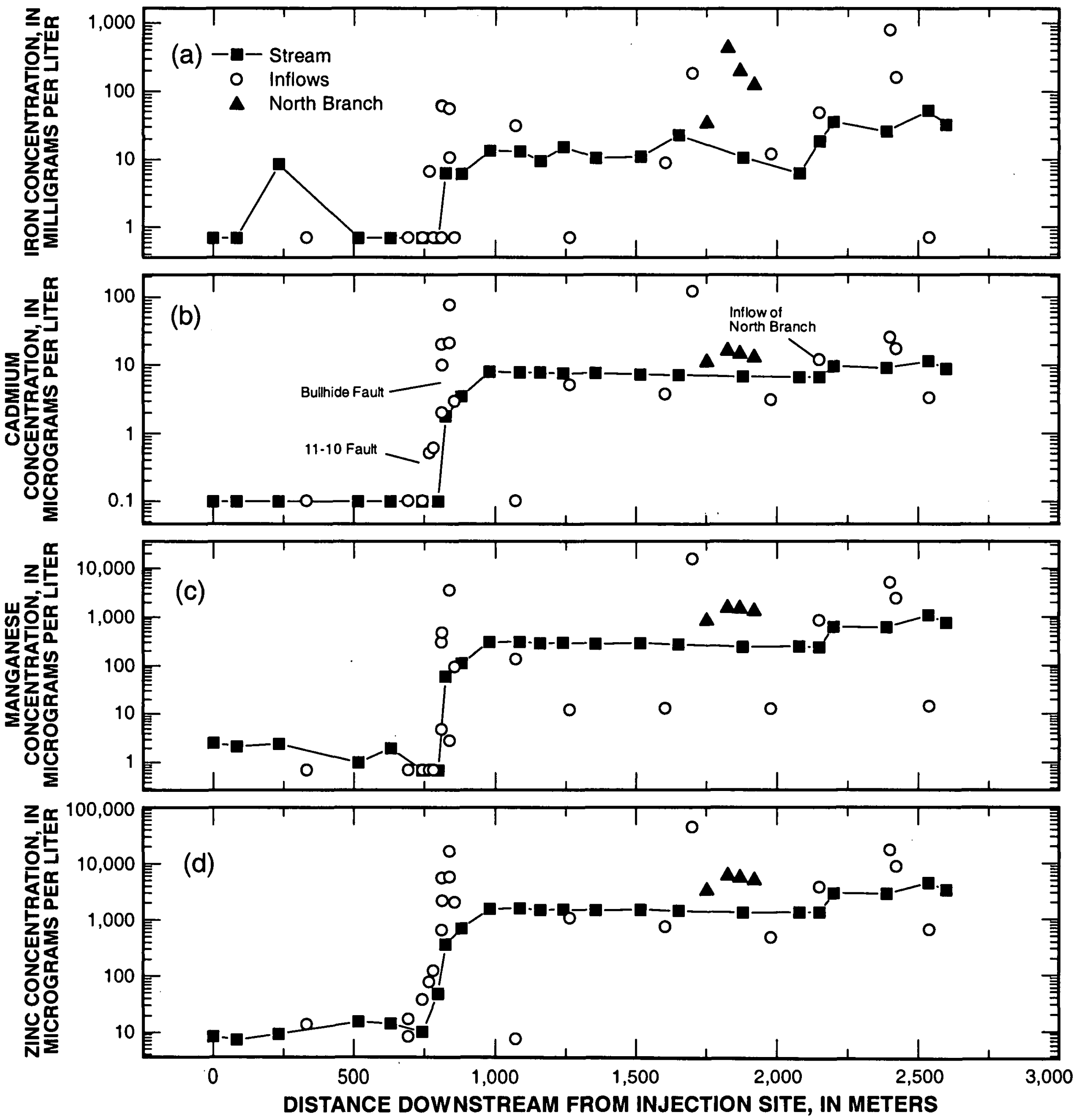


**Figure 11.** Range of concentration of (a) iron, (b) cadmium, (c) manganese, and (d) zinc downstream from the injection site, French Gulch, Colorado.

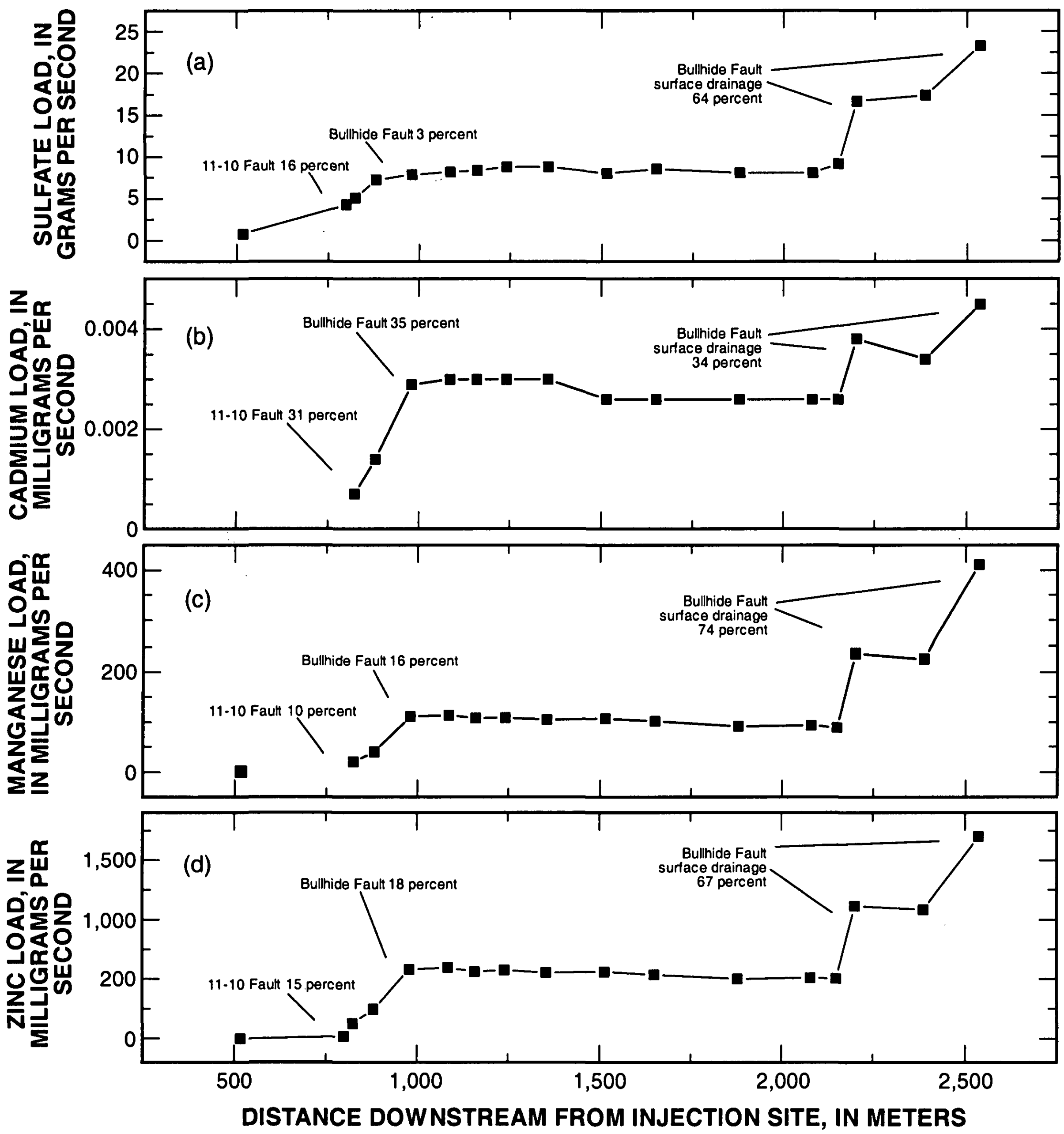


**Figure 12.** Mass-loading profile for (a) sulfate, (b) cadmium, (c) manganese, and (d) zinc downstream from injection site, French Gulch, Colorado.

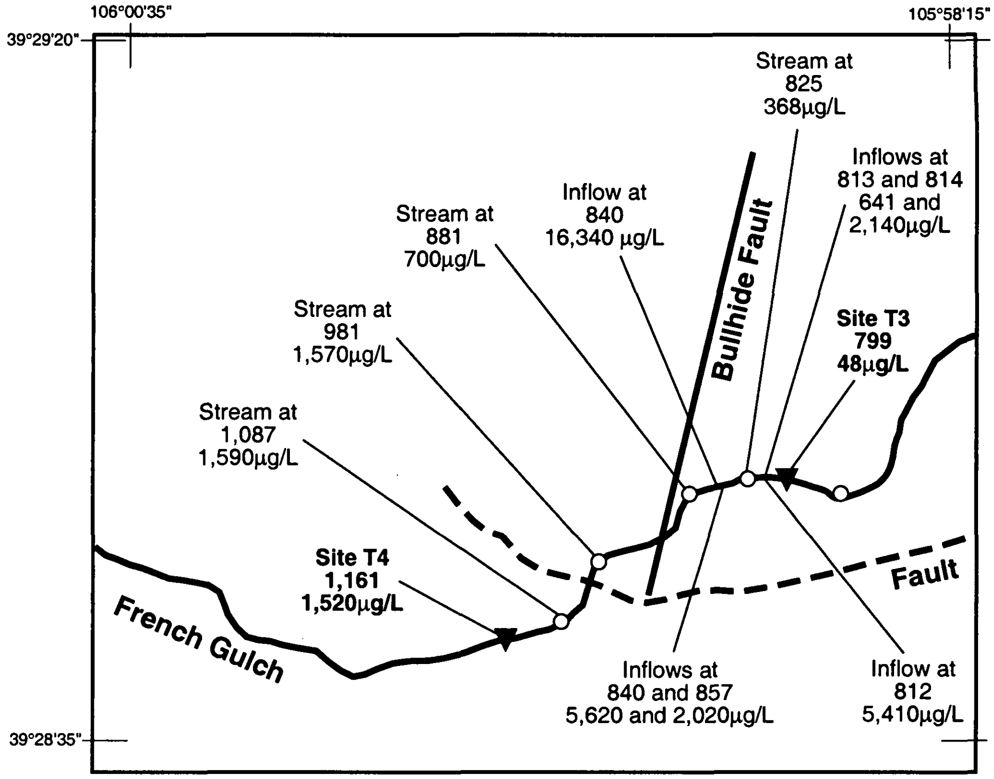


**Figure 13.** Effects of inflows on zinc concentration between sites T3 and T4, French Gulch, Colorado.

at points where, by inference, surface drainage, originating from the Bullhide Fault, entered the North Branch. The largest loading came from springs that are affected by drainage from the Wellington-Oro Mine on the north side of French Gulch. Some of the metal transport was by colloidal Fe oxides, but the extent of that transport needs to be defined in further studies. The loading profiles indicated the importance of the geologic structure on instream metal concentrations and that the stream was mostly affected by mine-pool drainage and inflows of metals where faults cross the stream.

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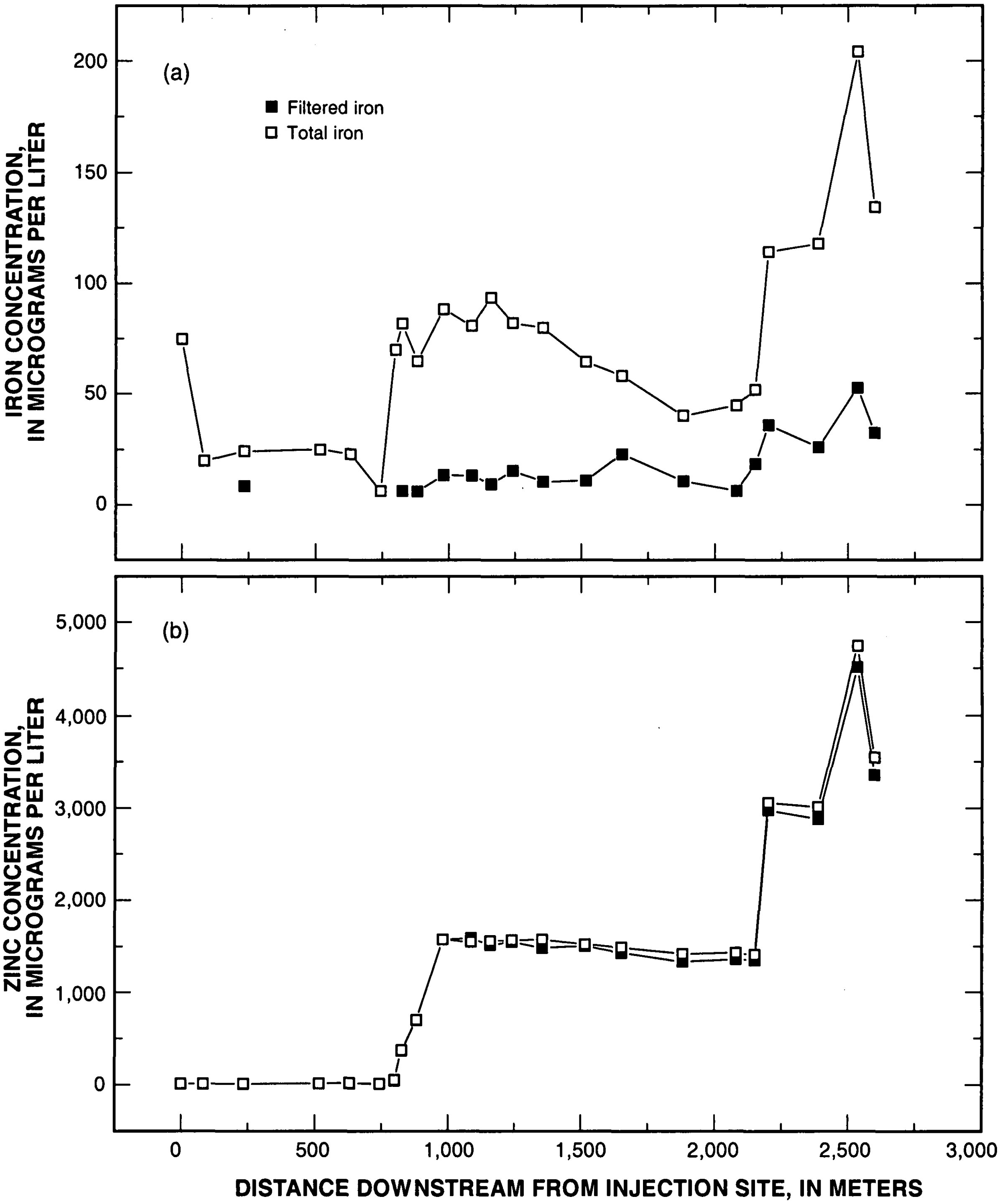


**Figure 14.** Filtered and total concentration of (a) iron and (b) zinc downstream from injection site, French Gulch, Colorado.

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# APPENDICES

**Appendix 1.** Concentration of chloride in water from selected wells along French Gulch, Colorado, July 24-28, 1996

[Concentration in milligrams per liter; <, less than]

| Site | Date | Time | Chloride |
|---|---|---|---|
| MSRW-3 | 7/23/96 | 10:06 | 2.05 |
| MSRW-3 | 7/23/96 | 10:06 | < .01 |
| MSRW-3 | 7/23/96 | 22:12 | 2.04 |
| MSRW-3 | 7/23/96 | 22:12 | 2.51 |
| MSRW-3 | 7/26/96 | 11:36 | 2.40 |
| MSRW-3 | 8/9/96 | 11:16 | 2.72 |
| MSRW-3 | 8/23/96 | 13:03 | 2.42 |
| MSRW-3 | 9/17/96 | 13:42 | 1.89 |
| MW-1 | 7/26/96 | 11:23 | 2.14 |
| MW-1 | 8/9/96 | 10:53 | 2.25 |
| MW-1 | 8/23/96 | 13:20 | 1.97 |
| MW-1 | 9/17/96 | 13:20 | 1.24 |
| MW-3 | 7/26/96 | 10:17 | 3.99 |
| MW-3 | 7/27/96 | 16:15 | 3.59 |
| MW-3 | 7/27/96 | 16:15 | 3.63 |
| MW-3 | 7/27/96 | 16:15 | < .01 |
| MW-3 | 7/27/96 | 20:14 | 3.56 |
| MW-3 | 7/27/96 | 20:14 | 3.65 |
| MW-3 | 7/27/96 | 20:14 | < .01 |
| MW-3 | 8/9/96 | 12:24 | 3.88 |
| MW-3 | 8/23/96 | 13:55 | 1.25 |
| MW-3 | 9/17/96 | 14:20 | .95 |
| MW-9 | 7/23/96 | 2:25 | .36 |
| MW-9 | 7/23/96 | 9:32 | .39 |
| MW-9 | 7/23/96 | 9:42 | < .01 |
| MW-9 | 7/23/96 | 9:57 | < .01 |
| MW-9 | 7/23/96 | 10:12 | < .01 |
| MW-9 | 7/23/96 | 10:27 | < .01 |
| MW-9 | 7/23/96 | 10:42 | < .01 |
| MW-9 | 7/23/96 | 10:57 | < .01 |
| MW-9 | 7/23/96 | 11:13 | < .01 |
| MW-9 | 7/23/96 | 11:26 | < .01 |
| MW-9 | 7/23/96 | 11:41 | < .01 |
| MW-9 | 7/23/96 | 12:00 | .44 |
| MW-9 | 7/23/96 | 13:00 | < .01 |
| MW-9 | 7/23/96 | 14:02 | 2.55 |
| MW-9 | 7/23/96 | 14:02 | 3.69 |
| MW-9 | 7/23/96 | 15:04 | 2.99 |
| MW-9 | 7/23/96 | 16:37 | 1.86 |
| MW-9 | 7/23/96 | 18:39 | 6.17 |
| MW-9 | 7/23/96 | 20:27 | 5.37 |
| MW-9 | 7/23/96 | 22:25 | 3.19 |
| MW-9 | 7/24/96 | 0:20 | 2.18 |
| MW-9 | 7/24/96 | 2:15 | 1.44 |
| MW-9 | 7/24/96 | 4:15 | .93 |
| MW-9 | 7/24/96 | 6:13 | .65 |
| MW-9 | 7/24/96 | 8:37 | .54 |
| MW-9 | 7/24/96 | 9:11 | .43 |
| MW-9 | 7/24/96 | 9:30 | .42 |
| MW-9 | 7/24/96 | 10:01 | .37 |
| MW-9 | 7/24/96 | 10:31 | .38 |
| MW-9 | 7/24/96 | 11:01 | .44 |
| MW-9 | 7/24/96 | 11:30 | .45 |
| MW-9 | 7/24/96 | 12:01 | .45 |
| MW-9 | 7/24/96 | 12:29 | .40 |
| MW-9 | 7/24/96 | 13:00 | .45 |
| MW-9 | 7/24/96 | 13:30 | .47 |
| MW-9 | 7/24/96 | 14:01 | .44 |
| MW-9 | 7/24/96 | 14:30 | .36 |
| MW-9 | 7/24/96 | 15:01 | .34 |
| MW-9 | 7/24/96 | 15:29 | .40 |
| MW-9 | 7/24/96 | 16:03 | .48 |
| MW-9 | 7/24/96 | 16:31 | .34 |
| MW-9 | 7/24/96 | 17:03 | .46 |
| MW-9 | 7/24/96 | 17:35 | .44 |
| MW-9 | 7/24/96 | 18:02 | .34 |
| MW-9 | 7/24/96 | 18:30 | .36 |
| MW-9 | 7/24/96 | 19:06 | .39 |
| MW-9 | 7/24/96 | 19:31 | .50 |
| MW-9 | 7/24/96 | 20:22 | .46 |
| MW-9 | 7/24/96 | 21:31 | .36 |
| MW-9 | 7/24/96 | 22:24 | .38 |
| MW-9 | 7/24/96 | 23:10 | .48 |
| MW-9 | 7/25/96 | 0:26 | .34 |
| MW-9 | 7/25/96 | 4:23 | .54 |
| MW-9 | 7/25/96 | 6:26 | .42 |
| MW-9 | 7/25/96 | 8:42 | .45 |
| MW-9 | 7/25/96 | 9:11 | .42 |
| MW-9 | 7/25/96 | 10:31 | .45 |
| MW-9 | 7/25/96 | 11:12 | .42 |
| MW-9 | 7/25/96 | 12:18 | .46 |
| NW-9 | 7/25/96 | 13:14 | .43 |
| MW-9 | 7/25/96 | 16:15 | .45 |
| MW-9 | 7/25/96 | 17:14 | .53 |
| MW-9 | 7/25/96 | 17:20 | .47 |
| MW-9 | 7/25/96 | 18:12 | .44 |
| MW-9 | 7/25/96 | 19:18 | .45 |
| MW-9 | 7/25/96 | 20:40 | .43 |
| MW-9 | 7/25/96 | 22:40 | .44 |
| MW-9 | 7/26/96 | 0:30 | .49 |
| MW-9 | 7/26/96 | 2:36 | .40 |
| MW-9 | 7/26/96 | 4:28 | .44 |
| MW-9 | 7/26/96 | 6:30 | .43 |
| MW-9 | 7/26/96 | 8:20 | .44 |
| MW-9 | 7/26/96 | 9:09 | .44 |
| MW-9 | 7/26/96 | 10:50 | .43 |
| MW-9 | 7/26/96 | 11:23 | .42 |
| MW-9 | 7/26/96 | 12:28 | .38 |
| MW-9 | 7/26/96 | 13:26 | .42 |
| MW-9 | 7/26/96 | 14:40 | .50 |
| MW-9 | 7/26/96 | 15:16 | .41 |
| MW-9 | 7/26/96 | 16:41 | .51 |
| MW-9 | 7/26/96 | 17:23 | .47 |
| MW-9 | 7/26/96 | 18:43 | .43 |

**Appendix 1.** Concentration of chloride in water from selected wells along French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride |
|---|---|---|---|
| MW-9 | 7/26/96 | 19:21 | .40 |
| MW-9 | 7/26/96 | 20:29 | .40 |
| MW-9 | 7/26/96 | 22:30 | .48 |
| MW-9 | 7/27/96 | 0:32 | .43 |
| MW-9 | 7/27/96 | 2:29 | .42 |
| MW-9 | 7/27/96 | 4:40 | .35 |
| MW-9 | 7/27/96 | 4:40 | .51 |
| MW-9 | 7/27/96 | 6:30 | .49 |
| MW-9 | 7/27/96 | 8:29 | .42 |
| MW-9 | 7/27/96 | 9:12 | .38 |
| MW-9 | 7/27/96 | 10:32 | .32 |
| MW-9 | 7/27/96 | 10:32 | .46 |
| MW-9 | 7/27/96 | 11:23 | .40 |
| MW-9 | 7/27/96 | 12:27 | .43 |
| MW-9 | 7/27/96 | 13:26 | .44 |
| MW-9 | 7/27/96 | 14:36 | .41 |
| MW-9 | 7/27/96 | 15:18 | .42 |
| MW-9 | 7/27/96 | 17:19 | .41 |
| MW-9 | 7/27/96 | 18:34 | .45 |
| MW-9 | 7/27/96 | 19:22 | .41 |
| MW-9 | 7/27/96 | 20:38 | .43 |
| MW-9 | 7/27/96 | 22:32 | .40 |
| MW-9 | 7/27/96 | 22:32 | .93 |
| MW-9 | 7/28/96 | 0:30 | .43 |
| MW-9 | 7/28/96 | 2:34 | .36 |
| MW-9 | 7/28/96 | 2:34 | .58 |
| MW-9 | 7/28/96 | 4:34 | .45 |
| MW-9 | 7/28/96 | 6:33 | .46 |
| MW-9 | 7/28/96 | 9:01 | .44 |
| MW-9 | 8/9/96 | 12:42 | .45 |
| MW-9 | 8/23/96 | 14:10 | .42 |
| MW-9 | 9/17/96 | 11:25 | .30 |
| MW-16 | 7/26/96 | 11:13 | 1.73 |
| MW-16 | 8/9/96 | 10:40 | 2.11 |
| MW-16 | 8/23/96 | 13:08 | 1.76 |
| MW-16 | 9/17/96 | 13:10 | 1.51 |
| MW-20 | 7/24/96 | 10:28 | .84 |
| MW-20 | 7/24/96 | 11:26 | .84 |
| MW-20 | 7/24/96 | 12:27 | .95 |
| MW-20 | 7/24/96 | 14:30 | .85 |
| MW-20 | 7/24/96 | 17:33 | .86 |
| MW-20 | 7/24/96 | 18:28 | 1.09 |
| MW-20 | 7/24/96 | 19:23 | .93 |
| MW-20 | 7/24/96 | 20:26 | .85 |
| MW-20 | 7/24/96 | 23:17 | .86 |
| MW-20 | 7/25/96 | 2:01 | .82 |
| MW-20 | 7/25/96 | 4:29 | .87 |
| MW-20 | 7/25/96 | 9:22 | .87 |

| Site | Date | Time | Chloride |
|---|---|---|---|
| MW-20 | 7/25/96 | 10:11 | .85 |
| MW-20 | 7/25/96 | 12:07 | .84 |
| MW-20 | 7/25/96 | 16:05 | .86 |
| MW-20 | 7/25/96 | 17:29 | .92 |
| MW-20 | 7/26/96 | 2:02 | .89 |
| MW-20 | 7/26/96 | 4:00 | .91 |
| MW-20 | 7/26/96 | 5:54 | .94 |
| MW-20 | 7/26/96 | 8:05 | .87 |
| MW-20 | 7/26/96 | 9:22 | .64 |
| MW-20 | 7/26/96 | 9:28 | .80 |
| MW-20 | 7/26/96 | 13:10 | .89 |
| MW-20 | 7/26/96 | 15:17 | .95 |
| MW-20 | 7/26/96 | 16:18 | .79 |
| MW-20 | 7/26/96 | 17:12 | .83 |
| MW-20 | 7/26/96 | 20:01 | .79 |
| MW-20 | 7/27/96 | 0:02 | .76 |
| MW-20 | 7/27/96 | 2:00 | .76 |
| MW-20 | 7/27/96 | 4:05 | .77 |
| MW-20 | 7/27/96 | 6:01 | .85 |
| MW-20 | 7/27/96 | 9:01 | .93 |
| MW-20 | 7/27/96 | 10:03 | .70 |
| MW-20 | 7/27/96 | 11:06 | .70 |
| MW-20 | 7/27/96 | 16:07 | .73 |
| MW-20 | 7/27/96 | 17:06 | .92 |
| MW-20 | 7/27/96 | 20:07 | .80 |
| MW-20 | 7/27/96 | 22:03 | .75 |
| MW-20 | 7/28/96 | 0:01 | .76 |
| MW-20 | 7/28/96 | 2:04 | .83 |
| MW-20 | 7/28/96 | 4:05 | .80 |
| MW-20 | 7/28/96 | 6:05 | .88 |
| MW-20 | 7/28/96 | 8:13 | .86 |
| MW-20 | 8/9/96 | 11:32 | .66 |
| MW-20 | 8/23/96 | 13:35 | .64 |
| MW-20 | 9/17/96 | 15:00 | .62 |
| ORO1 | 7/26/96 | 9:42 | 28.18 |
| ORO1 | 7/27/96 | 8:23 | 38.48 |
| ORO1 | 7/27/96 | 8:23 | 48.66 |
| ORO1 | 7/27/96 | 10:26 | 48.48 |
| ORO1 | 7/27/96 | 10:26 | 60.21 |
| ORO1 | 7/28/96 | 0:22 | 23.39 |
| ORO1 | 7/28/96 | 0:22 | 25.11 |
| ORO1 | 7/28/96 | 0:22 | 27.27 |
| ORO1 | 7/28/96 | 9:13 | 23.58 |
| ORO1 | 7/28/96 | 9:13 | 25.74 |
| ORO1 | 7/28/96 | 9:13 | 29.57 |
| ORO1 | 8/9/96 | 13:00 | 8.28 |
| ORO1 | 8/23/96 | 14:25 | 28.66 |
| ORO1 | 9/17/96 | 10:30 | 23.55 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996

[Concentrations are in milligrams per liter; n.v., no value obtained for sample]

| Site | Date | Time | Chloride | Sulfate | Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|---|---|---|---|---|
| T0 | 7/24/96 | 8:55 | 1.26 | 9.6 | T1 | 7/24/96 | 9:35 | 1.46 | 9.0 |
| T0 | 7/24/96 | 9:15 | .08 | 9.5 | T1 | 7/24/96 | 9:40 | 1.03 | 9.1 |
| T0 | 7/24/96 | 9:35 | .08 | 9.6 | T1 | 7/24/96 | 9:50 | .91 | 9.1 |
| T0 | 7/24/96 | 9:55 | .09 | 9.7 | T1 | 7/24/96 | 9:55 | 1.14 | 9.0 |
| T0 | 7/24/96 | 11:15 | .09 | 9.5 | T1 | 7/24/96 | 10:00 | 1.02 | 9.6 |
| T0 | 7/24/96 | 13:15 | .09 | 9.5 | T1 | 7/24/96 | 10:15 | .78 | 8.5 |
| T0 | 7/24/96 | 15:30 | .09 | 9.6 | T1 | 7/24/96 | 10:45 | 1.30 | 9.0 |
| T0 | 7/24/96 | 17:21 | .11 | 9.7 | T1 | 7/24/96 | 11:00 | 1.61 | 8.4 |
| T0 | 7/24/96 | 21:02 | .09 | 9.7 | T1 | 7/24/96 | 11:15 | 1.03 | 8.5 |
| T0 | 7/24/96 | 22:00 | .10 | 9.6 | T1 | 7/24/96 | 11:45 | 1.12 | 8.4 |
| T0 | 7/25/96 | 0:00 | .17 | 9.8 | T1 | 7/24/96 | 12:00 | 1.29 | 9.1 |
| T0 | 7/25/96 | 2:05 | .09 | 9.7 | T1 | 7/24/96 | 13:25 | .68 | 9.1 |
| T0 | 7/25/96 | 5:52 | .09 | 10.1 | T1 | 7/24/96 | 15:34 | 1.41 | 8.5 |
| T0 | 7/25/96 | 9:43 | .09 | 9.7 | T1 | 7/24/96 | 18:10 | 1.16 | 9.1 |
| T0 | 7/25/96 | 12:31 | .12 | 9.8 | T1 | 7/25/96 | 0:04 | .69 | 8.6 |
| T0 | 7/25/96 | 13:26 | .10 | 9.6 | T1 | 7/25/96 | 1:31 | .81 | 9.1 |
| T0 | 7/25/96 | 14:26 | .08 | 9.7 | T1 | 7/25/96 | 2:12 | .84 | 9.7 |
| T0 | 7/25/96 | 15:20 | .12 | 9.8 | T1 | 7/25/96 | 9:44 | .96 | 11.1 |
| T0 | 7/25/96 | 16:26 | .09 | 9.7 | T1 | 7/25/96 | 15:21 | .91 | 11.0 |
| T0 | 7/25/96 | 17:30 | .10 | 9.7 | T1 | 7/25/96 | 16:29 | 1.11 | 11.0 |
| T0 | 7/26/96 | 5:03 | .09 | 9.8 | T1 | 7/26/96 | 4:55 | 2.79 | 11.1 |
| T0 | 7/26/96 | 5:47 | .08 | 9.7 | T1 | 7/26/96 | 5:48 | 1.98 | 11.1 |
| T0 | 7/26/96 | 9:39 | .13 | 10.3 | T1 | 7/26/96 | 9:42 | 2.22 | 11.2 |
| T0 | 7/26/96 | 11:30 | .10 | 9.9 | T1 | 7/26/96 | 11:32 | 1.70 | 11.0 |
| T0 | 7/26/96 | 14:14 | .15 | 10.1 | T1 | 7/26/96 | 14:29 | .92 | 9.6 |
| T0 | 7/27/96 | 8:11 | .10 | 9.7 | T1 | 7/27/96 | 8:12 | 2.44 | 11.2 |
| T0 | 7/27/96 | 15:45 | .14 | 11.2 | T1 | 7/27/96 | 8:57 | 3.04 | 11.3 |
| T0 | 7/28/96 | 9:47 | .13 | 11.2 | T1 | 7/27/96 | 8:58 | 2.69 | 11.1 |
| T0 | 7/28/96 | 15:33 | .13 | 11.3 | T1 | 7/27/96 | 9:00 | 2.47 | 11.2 |
| T1 | 7/24/96 | 8:55 | .12 | 9.1 | T1 | 7/27/96 | 9:02 | .13 | 11.1 |
| T1 | 7/24/96 | 9:00 | .02 | 9.1 | T1 | 7/27/96 | 9:03 | .12 | 11.1 |
| T1 | 7/24/96 | 9:01 | 1.41 | 9.1 | T1 | 7/27/96 | 9:04 | .10 | 11.1 |
| T1 | 7/24/96 | 9:02 | 1.21 | 9.1 | T1 | 7/27/96 | 9:05 | .10 | 11.1 |
| T1 | 7/24/96 | 9:03 | 1.39 | 9.0 | T1 | 7/27/96 | 9:06 | .10 | 11.1 |
| T1 | 7/24/96 | 9:04 | .99 | 8.5 | T1 | 7/27/96 | 9:07 | .10 | 11.1 |
| T1 | 7/24/96 | 9:05 | 1.30 | 9.1 | T1 | 7/27/96 | 9:09 | .10 | 11.0 |
| T1 | 7/24/96 | 9:06 | 1.52 | 9.1 | T1 | 7/27/96 | 9:10 | .10 | 11.2 |
| T1 | 7/24/96 | 9:07 | 1.09 | 8.5 | T1 | 7/27/96 | 9:11 | .10 | 11.1 |
| T1 | 7/24/96 | 9:08 | 1.30 | 9.1 | T1 | 7/27/96 | 9:12 | .10 | 11.1 |
| T1 | 7/24/96 | 9:08 | .10 | 11.1 | T1 | 7/27/96 | 9:13 | .14 | 11.2 |
| T1 | 7/24/96 | 9:09 | 1.38 | 9.1 | T1 | 7/27/96 | 9:14 | .12 | 11.2 |
| T1 | 7/24/96 | 9:10 | 1.21 | 9.1 | T1 | 7/27/96 | 9:15 | .12 | 11.2 |
| T1 | 7/24/96 | 9:11 | 1.25 | 8.4 | T1 | 7/27/96 | 9:16 | .11 | 11.1 |
| T1 | 7/24/96 | 9:12 | 1.29 | 9.1 | T1 | 7/27/96 | 9:18 | .11 | 11.1 |
| T1 | 7/24/96 | 9:13 | 1.08 | 8.5 | T1 | 7/27/96 | 9:20 | .16 | 11.2 |
| T1 | 7/24/96 | 9:14 | 1.03 | 8.5 | T1 | 7/27/96 | 9:22 | .11 | 11.1 |
| T1 | 7/24/96 | 9:17 | 1.34 | 9.7 | T1 | 7/27/96 | 9:25 | .10 | 11.1 |
| T1 | 7/24/96 | 9:21 | 1.39 | 9.1 | T1 | 7/27/96 | 9:30 | .10 | 11.1 |
| T1 | 7/24/96 | 9:23 | 1.28 | 9.0 | T1 | 7/27/96 | 9:35 | .20 | 11.2 |
| T1 | 7/24/96 | 9:27 | 1.10 | 8.5 | T1 | 7/27/96 | 9:40 | .10 | 11.1 |
| T1 | 7/24/96 | 9:30 | .99 | 8.5 | T1 | 7/27/96 | 9:50 | .10 | 11.1 |
| T1 | 7/24/96 | 9:30 | 1.00 | 8.5 | T1 | 7/27/96 | 10:00 | .13 | 11.2 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T1 | 7/27/96 | 10:20 | .11 | 11.2 |
| T1 | 7/27/96 | 10:40 | .14 | 11.2 |
| T1 | 7/27/96 | 11:00 | .10 | 11.1 |
| T1 | 7/27/96 | 11:30 | .09 | 11.2 |
| T1 | 7/27/96 | 12:00 | .11 | 11.1 |
| T1 | 7/27/96 | 15:47 | n.v. | 11.2 |
| T1 | 7/28/96 | 9:49 | .13 | 11.2 |
| T1 | 7/28/96 | 15:33 | .14 | 11.3 |
| T1 | 7/28/96 | 15:53 | .14 | 11.3 |
| T1 | 8/9/96 | 14:10 | .13 | 12.1 |
| T2 | 7/24/96 | 9:00 | .07 | 8.5 |
| T2 | 7/24/96 | 9:17 | .05 | 8.1 |
| T2 | 7/24/96 | 9:25 | 1.12 | 8.5 |
| T2 | 7/24/96 | 9:35 | 1.58 | 8.5 |
| T2 | 7/24/96 | 9:36 | 1.57 | 8.4 |
| T2 | 7/24/96 | 10:00 | 1.69 | 8.5 |
| T2 | 7/24/96 | 10:40 | 1.60 | 9.0 |
| T2 | 7/24/96 | 11:00 | 1.77 | 8.4 |
| T2 | 7/24/96 | 11:30 | 1.50 | 7.9 |
| T2 | 7/24/96 | 14:51 | 2.03 | 8.7 |
| T2 | 7/24/96 | 15:40 | 2.25 | 10.4 |
| T2 | 7/24/96 | 18:15 | 2.35 | 9.8 |
| T2 | 7/24/96 | 21:32 | 2.34 | 8.6 |
| T2 | 7/24/96 | 22:12 | 2.40 | 8.6 |
| T2 | 7/25/96 | 0:11 | 2.32 | 9.8 |
| T2 | 7/25/96 | 2:17 | 2.31 | 8.6 |
| T2 | 7/25/96 | 6:04 | 2.06 | 10.9 |
| T2 | 7/25/96 | 10:00 | 2.38 | 10.5 |
| T2 | 7/25/96 | 13:44 | 2.41 | 11.8 |
| T2 | 7/25/96 | 14:40 | 2.24 | 10.9 |
| T2 | 7/25/96 | 15:32 | 2.37 | 8.6 |
| T2 | 7/25/96 | 15:37 | 10.18 | 11.2 |
| T2 | 7/25/96 | 16:06 | 11.15 | 11.1 |
| T2 | 7/25/96 | 16:39 | 2.41 | 9.7 |
| T2 | 7/25/96 | 17:26 | 10.46 | 9.6 |
| T2 | 7/25/96 | 17:32 | 2.66 | 11.1 |
| T2 | 7/25/96 | 17:33 | 2.87 | 9.6 |
| T2 | 7/25/96 | 17:34 | 2.98 | 11.0 |
| T2 | 7/25/96 | 17:35 | 3.07 | 11.1 |
| T2 | 7/25/96 | 17:36 | 3.45 | 11.2 |
| T2 | 7/25/96 | 17:38 | 10.57 | 11.1 |
| T2 | 7/25/96 | 17:39 | 10.10 | 11.2 |
| T2 | 7/25/96 | 17:40 | 10.42 | 11.1 |
| T2 | 7/25/96 | 17:42 | 10.16 | 11.1 |
| T2 | 7/25/96 | 17:44 | 10.26 | 11.1 |
| T2 | 7/25/96 | 17:48 | 11.28 | 11.0 |
| T2 | 7/25/96 | 17:50 | 11.26 | 11.0 |
| T2 | 7/25/96 | 17:52 | 10.80 | 9.6 |
| T2 | 7/25/96 | 17:54 | 9.95 | 11.1 |
| T2 | 7/25/96 | 17:56 | 10.07 | 11.1 |
| T2 | 7/25/96 | 17:58 | 10.11 | 11.1 |
| T2 | 7/25/96 | 18:00 | 10.09 | 11.1 |
| T2 | 7/25/96 | 18:00 | 2.85 | 9.6 |
| T2 | 7/25/96 | 18:02 | 10.07 | 11.1 |
| T2 | 7/25/96 | 18:04 | 10.62 | 11.0 |
| T2 | 7/25/96 | 18:08 | 3.00 | 9.6 |
| T2 | 7/25/96 | 18:10 | 2.82 | 11.1 |
| T2 | 7/25/96 | 18:15 | 2.90 | 11.1 |
| T2 | 7/26/96 | 4:52 | 3.36 | 9.8 |
| T2 | 7/26/96 | 6:01 | 3.39 | 9.8 |
| T2 | 7/26/96 | 9:51 | 2.74 | 11.1 |
| T2 | 7/26/96 | 9:55 | 0.65 | 10.7 |
| T2 | 7/26/96 | 11:42 | 2.64 | 10.5 |
| T2 | 7/26/96 | 14:22 | 2.97 | 9.8 |
| T2 | 7/27/96 | 9:00 | 3.65 | 9.8 |
| T2 | 7/27/96 | 9:05 | 3.56 | 11.0 |
| T2 | 7/27/96 | 9:07 | 3.64 | 11.0 |
| T2 | 7/27/96 | 9:09 | 3.46 | 11.0 |
| T2 | 7/27/96 | 9:11 | 3.35 | 11.2 |
| T2 | 7/27/96 | 9:13 | 3.79 | 10.7 |
| T2 | 7/27/96 | 9:15 | 3.44 | 11.0 |
| T2 | 7/27/96 | 9:17 | 3.44 | 11.1 |
| T2 | 7/27/96 | 9:19 | 3.35 | 11.9 |
| T2 | 7/27/96 | 9:21 | 3.47 | 9.9 |
| T2 | 7/27/96 | 9:23 | 2.97 | 11.0 |
| T2 | 7/27/96 | 9:25 | 2.41 | 12.1 |
| T2 | 7/27/96 | 9:27 | 1.96 | 11.9 |
| T2 | 7/27/96 | 9:29 | 1.29 | 12.0 |
| T2 | 7/27/96 | 9:31 | 1.09 | 9.8 |
| T2 | 7/27/96 | 9:35 | .85 | 10.6 |
| T2 | 7/27/96 | 9:40 | .74 | 10.6 |
| T2 | 7/27/96 | 9:45 | .68 | 9.8 |
| T2 | 7/27/96 | 9:50 | .60 | 11.5 |
| T2 | 7/27/96 | 10:00 | .57 | 12.0 |
| T2 | 7/27/96 | 10:10 | .56 | 9.8 |
| T2 | 7/27/96 | 10:20 | .54 | 10.7 |
| T2 | 7/27/96 | 10:30 | .48 | 11.4 |
| T2 | 7/27/96 | 10:40 | .50 | 9.9 |
| T2 | 7/27/96 | 10:50 | .43 | 11.4 |
| T2 | 7/27/96 | 11:00 | .45 | 12.0 |
| T2 | 7/27/96 | 11:30 | .45 | 9.9 |
| T2 | 7/27/96 | 12:00 | .40 | 11.4 |
| T2 | 7/27/96 | 15:50 | .30 | 11.3 |
| T2 | 7/28/96 | 9:57 | .16 | 9.8 |
| T2 | 7/28/96 | 15:27 | .12 | 9.8 |
| T2 | 8/9/96 | 14:00 | .14 | 12.0 |
| T3 | 7/22/96 | 9:00 | .76 | 11.1 |
| T3 | 7/22/96 | 9:05 | .84 | 11.0 |
| T3 | 7/23/96 | 10:35 | .52 | 15.2 |
| T3 | 7/23/96 | 10:35 | .46 | 12.8 |
| T3 | 7/23/96 | 11:22 | .40 | 13.7 |
| T3 | 7/23/96 | 12:54 | .44 | 14.1 |
| T3 | 7/23/96 | 13:50 | .58 | 13.7 |
| T3 | 7/23/96 | 14:52 | .58 | 14.2 |
| T3 | 7/23/96 | 15:54 | .64 | 12.9 |
| T3 | 7/23/96 | 17:03 | .61 | 13.9 |
| T3 | 7/23/96 | 18:36 | .66 | 14.0 |
| T3 | 7/23/96 | 19:36 | .73 | 11.1 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T3 | 7/23/96 | 20:36 | .69 | 14.0 |
| T3 | 7/23/96 | 21:36 | .70 | 13.9 |
| T3 | 7/23/96 | 22:36 | .73 | 14.0 |
| T3 | 7/23/96 | 23:36 | .75 | 13.1 |
| T3 | 7/24/96 | 0:36 | .77 | 13.6 |
| T3 | 7/24/96 | 1:36 | .76 | 13.9 |
| T3 | 7/24/96 | 2:36 | .80 | 13.8 |
| T3 | 7/24/96 | 3:36 | .76 | 14.0 |
| T3 | 7/24/96 | 4:36 | .82 | 14.0 |
| T3 | 7/24/96 | 5:36 | .78 | 14.1 |
| T3 | 7/24/96 | 6:36 | .77 | 13.8 |
| T3 | 7/24/96 | 7:36 | .79 | 13.8 |
| T3 | 7/24/96 | 8:36 | .80 | 13.9 |
| T3 | 7/24/96 | 9:10 | .83 | 11.2 |
| T3 | 7/24/96 | 9:15 | .74 | 13.8 |
| T3 | 7/24/96 | 9:20 | .76 | 13.8 |
| T3 | 7/24/96 | 9:25 | .76 | 14.1 |
| T3 | 7/24/96 | 9:30 | .76 | 10.9 |
| T3 | 7/24/96 | 9:35 | .80 | 11.1 |
| T3 | 7/24/96 | 9:36 | .75 | 14.0 |
| T3 | 7/24/96 | 9:40 | .79 | 11.1 |
| T3 | 7/24/96 | 9:45 | .82 | 13.8 |
| T3 | 7/24/96 | 9:50 | .81 | 13.9 |
| T3 | 7/24/96 | 9:55 | .84 | 14.0 |
| T3 | 7/24/96 | 10:00 | .84 | 13.9 |
| T3 | 7/24/96 | 10:05 | .85 | 13.8 |
| T3 | 7/24/96 | 10:10 | .80 | 13.9 |
| T3 | 7/24/96 | 10:15 | .86 | 14.0 |
| T3 | 7/24/96 | 10:20 | .90 | 14.0 |
| T3 | 7/24/96 | 10:30 | .90 | 11.1 |
| T3 | 7/24/96 | 10:35 | .96 | 13.9 |
| T3 | 7/24/96 | 10:36 | .95 | 13.0 |
| T3 | 7/24/96 | 10:40 | .92 | 14.0 |
| T3 | 7/24/96 | 10:45 | .96 | 11.0 |
| T3 | 7/24/96 | 10:50 | .96 | 14.0 |
| T3 | 7/24/96 | 10:55 | 1.00 | 14.2 |
| T3 | 7/24/96 | 11:00 | .93 | 11.0 |
| T3 | 7/24/96 | 11:15 | 1.04 | 14.0 |
| T3 | 7/24/96 | 11:30 | 1.13 | 11.0 |
| T3 | 7/24/96 | 11:45 | 1.08 | 11.4 |
| T3 | 7/24/96 | 12:00 | 1.09 | 14.2 |
| T3 | 7/24/96 | 12:20 | 1.13 | 14.1 |
| T3 | 7/24/96 | 12:40 | 1.15 | 11.0 |
| T3 | 7/24/96 | 13:00 | 1.16 | 14.0 |
| T3 | 7/24/96 | 13:20 | 1.18 | 11.3 |
| T3 | 7/24/96 | 13:40 | 1.20 | 11.1 |
| T3 | 7/24/96 | 14:00 | 1.22 | 14.0 |
| T3 | 7/24/96 | 14:30 | 1.24 | 11.3 |
| T3 | 7/24/96 | 15:00 | 1.18 | 11.1 |
| T3 | 7/24/96 | 15:30 | 1.21 | 11.0 |
| T3 | 7/24/96 | 16:00 | 1.21 | 11.1 |
| T3 | 7/24/96 | 18:39 | 1.34 | 13.6 |
| T3 | 7/24/96 | 19:39 | 1.28 | 13.6 |
| T3 | 7/24/96 | 20:37 | 1.25 | 13.6 |
| T3 | 7/24/96 | 21:39 | 1.27 | 13.6 |
| T3 | 7/24/96 | 22:39 | 1.27 | 13.6 |
| T3 | 7/24/96 | 23:39 | 1.23 | 13.6 |
| T3 | 7/25/96 | 1:39 | 1.21 | 13.6 |
| T3 | 7/25/96 | 2:39 | 1.16 | 13.6 |
| T3 | 7/25/96 | 3:39 | 1.18 | 13.6 |
| T3 | 7/25/96 | 4:39 | 1.16 | 13.6 |
| T3 | 7/25/96 | 5:39 | 1.11 | 13.6 |
| T3 | 7/25/96 | 6:39 | 1.18 | 13.6 |
| T3 | 7/25/96 | 7:39 | 1.15 | 13.6 |
| T3 | 7/25/96 | 8:39 | 1.09 | 13.5 |
| T3 | 7/25/96 | 8:39 | 1.29 | 13.6 |
| T3 | 7/25/96 | 10:00 | 1.09 | 14.1 |
| T3 | 7/25/96 | 11:00 | 1.09 | 13.9 |
| T3 | 7/25/96 | 12:00 | 1.05 | 13.9 |
| T3 | 7/25/96 | 13:00 | 1.03 | 14.0 |
| T3 | 7/25/96 | 14:00 | 1.04 | 13.1 |
| T3 | 7/25/96 | 14:51 | 1.37 | 15.6 |
| T3 | 7/25/96 | 14:56 | 1.00 | 14.0 |
| T3 | 7/25/96 | 15:00 | 1.03 | 14.2 |
| T3 | 7/25/96 | 16:00 | 1.08 | 13.1 |
| T3 | 7/25/96 | 16:09 | 1.01 | 14.0 |
| T3 | 7/25/96 | 16:10 | 1.04 | 14.0 |
| T3 | 7/25/96 | 16:11 | 1.01 | 14.1 |
| T3 | 7/25/96 | 16:12 | 4.67 | 14.2 |
| T3 | 7/25/96 | 16:13 | 4.66 | 14.1 |
| T3 | 7/25/96 | 16:14 | 3.92 | 14.2 |
| T3 | 7/25/96 | 16:16 | 4.80 | 14.1 |
| T3 | 7/25/96 | 16:18 | 4.20 | 14.1 |
| T3 | 7/25/96 | 16:20 | 4.32 | 14.0 |
| T3 | 7/25/96 | 16:22 | 5.15 | 15.6 |
| T3 | 7/25/96 | 16:22 | 3.84 | 13.2 |
| T3 | 7/25/96 | 16:24 | 5.13 | 15.6 |
| T3 | 7/25/96 | 16:24 | 4.22 | 14.1 |
| T3 | 7/25/96 | 16:30 | 2.43 | 14.3 |
| T3 | 7/25/96 | 16:30 | 5.20 | 14.0 |
| T3 | 7/25/96 | 16:30 | 5.17 | 14.1 |
| T3 | 7/25/96 | 16:30 | 3.63 | 14.1 |
| T3 | 7/25/96 | 16:30 | 2.13 | 13.6 |
| T3 | 7/25/96 | 16:34 | 4.58 | 14.1 |
| T3 | 7/25/96 | 16:36 | 3.88 | 14.2 |
| T3 | 7/25/96 | 16:37 | 4.51 | 14.1 |
| T3 | 7/25/96 | 16:38 | 3.57 | 13.2 |
| T3 | 7/25/96 | 16:40 | 4.04 | 14.1 |
| T3 | 7/25/96 | 16:43 | 1.34 | 15.6 |
| T3 | 7/25/96 | 16:45 | 1.03 | 13.1 |
| T3 | 7/25/96 | 19:04 | 1.25 | 13.8 |
| T3 | 7/25/96 | 20:04 | 1.14 | 13.7 |
| T3 | 7/25/96 | 21:04 | 1.12 | 13.7 |
| T3 | 7/25/96 | 21:15 | 1.62 | 25.6 |
| T3 | 7/25/96 | 22:04 | 1.11 | 13.8 |
| T3 | 7/25/96 | 23:04 | 1.10 | 13.6 |
| T3 | 7/26/96 | 0:04 | 1.09 | 13.7 |
| T3 | 7/26/96 | 1:04 | 1.10 | 13.7 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T3 | 7/26/96 | 2:04 | 1.12 | 13.7 |
| T3 | 7/26/96 | 3:33 | 1.00 | 14.2 |
| T3 | 7/26/96 | 4:27 | .97 | 14.2 |
| T3 | 7/26/96 | 5:04 | 1.18 | 14.1 |
| T3 | 7/26/96 | 5:49 | 1.06 | 13.4 |
| T3 | 7/26/96 | 6:04 | 1.08 | 13.7 |
| T3 | 7/26/96 | 7:04 | 1.08 | 13.7 |
| T3 | 7/26/96 | 8:04 | 1.07 | 13.7 |
| T3 | 7/26/96 | 9:04 | 1.04 | 13.7 |
| T3 | 7/26/96 | 10:04 | 1.07 | 14.0 |
| T3 | 7/26/96 | 11:04 | 1.12 | 14.0 |
| T3 | 7/26/96 | 13:04 | 1.04 | 13.8 |
| T3 | 7/26/96 | 14:04 | 1.09 | 13.9 |
| T3 | 7/26/96 | 17:42 | 1.07 | 14.2 |
| T3 | 7/26/96 | 18:42 | 1.13 | 14.3 |
| T3 | 7/26/96 | 19:42 | 1.15 | 14.1 |
| T3 | 7/26/96 | 20:42 | 1.24 | 14.3 |
| T3 | 7/26/96 | 21:42 | 1.25 | 14.3 |
| T3 | 7/26/96 | 22:42 | 1.23 | 13.8 |
| T3 | 7/26/96 | 23:42 | 1.25 | 14.1 |
| T3 | 7/27/96 | 0:42 | 1.34 | 13.9 |
| T3 | 7/27/96 | 1:42 | 1.28 | 14.2 |
| T3 | 7/27/96 | 2:42 | 1.29 | 14.1 |
| T3 | 7/27/96 | 3:42 | 1.28 | 14.0 |
| T3 | 7/27/96 | 4:04 | 1.11 | 14.0 |
| T3 | 7/27/96 | 4:42 | 1.36 | 14.3 |
| T3 | 7/27/96 | 5:42 | 1.25 | 14.0 |
| T3 | 7/27/96 | 5:42 | 1.29 | 14.1 |
| T3 | 7/27/96 | 6:42 | 1.24 | 14.1 |
| T3 | 7/27/96 | 9:00 | 1.18 | 13.5 |
| T3 | 7/27/96 | 9:05 | 1.23 | 13.0 |
| T3 | 7/27/96 | 9:10 | 1.20 | 13.5 |
| T3 | 7/27/96 | 9:15 | 1.41 | 13.4 |
| T3 | 7/27/96 | 9:20 | 1.23 | 13.4 |
| T3 | 7/27/96 | 9:25 | 1.32 | 13.4 |
| T3 | 7/27/96 | 9:30 | 1.37 | 13.4 |
| T3 | 7/27/96 | 9:35 | 1.21 | 13.4 |
| T3 | 7/27/96 | 9:40 | 1.31 | 13.5 |
| T3 | 7/27/96 | 9:45 | 1.35 | 13.4 |
| T3 | 7/27/96 | 9:50 | 1.28 | 13.5 |
| T3 | 7/27/96 | 9:55 | 1.25 | 13.4 |
| T3 | 7/27/96 | 10:00 | 1.20 | 13.5 |
| T3 | 7/27/96 | 10:05 | 1.17 | 13.5 |
| T3 | 7/27/96 | 10:10 | 1.16 | 13.4 |
| T3 | 7/27/96 | 10:15 | 1.15 | 13.0 |
| T3 | 7/27/96 | 10:20 | 1.13 | 13.5 |
| T3 | 7/27/96 | 10:25 | 1.21 | 13.4 |
| T3 | 7/27/96 | 10:30 | 1.10 | 13.5 |
| T3 | 7/27/96 | 10:35 | 1.08 | 13.4 |
| T3 | 7/27/96 | 10:40 | 1.10 | 13.4 |
| T3 | 7/27/96 | 10:50 | 1.08 | 13.4 |
| T3 | 7/27/96 | 11:00 | 1.06 | 13.4 |
| T3 | 7/27/96 | 11:20 | .96 | 13.6 |
| T3 | 7/27/96 | 11:40 | .92 | 13.5 |
| T3 | 7/27/96 | 12:00 | .80 | 13.5 |
| T3 | 7/27/96 | 12:20 | .70 | 13.0 |
| T3 | 7/27/96 | 12:40 | .75 | 13.3 |
| T3 | 7/27/96 | 13:00 | .67 | 13.1 |
| T3 | 7/27/96 | 15:56 | .55 | 13.6 |
| T3 | 7/28/96 | 10:01 | .37 | 13.6 |
| T3 | 7/28/96 | 15:19 | .36 | 13.9 |
| T3 | 8/9/96 | 13:52 | .37 | 15.4 |
| T3 | 8/9/96 | 13:52 | .28 | 14.3 |
| T3 | 8/23/96 | 12:35 | .27 | 16.4 |
| T4 | 7/23/96 | 11:10 | .52 | 24.4 |
| T4 | 7/23/96 | 11:10 | .43 | 21.0 |
| T4 | 7/23/96 | 11:32 | .47 | 24.1 |
| T4 | 7/23/96 | 13:06 | .51 | 24.1 |
| T4 | 7/23/96 | 14:20 | .67 | 24.1 |
| T4 | 7/23/96 | 15:00 | .73 | 26.3 |
| T4 | 7/23/96 | 16:05 | .67 | 25.2 |
| T4 | 7/23/96 | 17:21 | .75 | 24.7 |
| T4 | 7/23/96 | 18:47 | .87 | 25.4 |
| T4 | 7/23/96 | 19:47 | .78 | 24.9 |
| T4 | 7/23/96 | 20:47 | .88 | 25.3 |
| T4 | 7/23/96 | 21:47 | n.v. | 27.0 |
| T4 | 7/23/96 | 22:47 | .90 | 25.2 |
| T4 | 7/23/96 | 23:47 | .91 | 24.7 |
| T4 | 7/24/96 | 0:47 | .85 | 25.3 |
| T4 | 7/24/96 | 1:47 | .83 | 24.4 |
| T4 | 7/24/96 | 2:47 | .85 | 24.3 |
| T4 | 7/24/96 | 3:47 | .84 | 24.5 |
| T4 | 7/24/96 | 4:21 | 1.61 | 25.1 |
| T4 | 7/24/96 | 4:47 | .93 | 23.9 |
| T4 | 7/24/96 | 5:47 | .87 | 25.1 |
| T4 | 7/24/96 | 6:47 | .89 | 24.6 |
| T4 | 7/24/96 | 7:47 | .86 | 25.0 |
| T4 | 7/24/96 | 8:47 | .85 | 25.0 |
| T4 | 7/24/96 | 9:30 | .94 | 24.2 |
| T4 | 7/24/96 | 9:40 | .92 | 24.9 |
| T4 | 7/24/96 | 9:47 | .95 | 26.0 |
| T4 | 7/24/96 | 9:50 | .96 | 24.4 |
| T4 | 7/24/96 | 9:50 | .91 | 24.5 |
| T4 | 7/24/96 | 9:56 | .93 | 23.4 |
| T4 | 7/24/96 | 10:00 | .98 | 25.3 |
| T4 | 7/24/96 | 10:05 | .96 | 25.1 |
| T4 | 7/24/96 | 10:10 | .98 | 22.9 |
| T4 | 7/24/96 | 10:15 | .98 | 24.2 |
| T4 | 7/24/96 | 10:20 | .99 | 24.9 |
| T4 | 7/24/96 | 10:25 | .98 | 24.0 |
| T4 | 7/24/96 | 10:30 | .98 | 24.8 |
| T4 | 7/24/96 | 10:35 | 1.01 | 24.9 |
| T4 | 7/24/96 | 10:40 | 1.04 | 25.1 |
| T4 | 7/24/96 | 10:45 | 1.05 | 23.5 |
| T4 | 7/24/96 | 10:47 | .97 | 24.9 |
| T4 | 7/24/96 | 10:50 | 1.09 | 24.0 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T4 | 7/24/96 | 10:55 | 1.05 | 24.9 |
| T4 | 7/24/96 | 11:00 | 1.06 | 24.2 |
| T4 | 7/24/96 | 11:05 | 1.08 | 24.6 |
| T4 | 7/24/96 | 11:10 | 1.10 | 24.5 |
| T4 | 7/24/96 | 11:15 | 1.10 | 24.4 |
| T4 | 7/24/96 | 11:20 | 1.11 | 25.2 |
| T4 | 7/24/96 | 11:25 | 1.16 | 24.5 |
| T4 | 7/24/96 | 11:30 | 1.20 | 24.6 |
| T4 | 7/24/96 | 11:45 | 1.27 | 25.0 |
| T4 | 7/24/96 | 11:47 | 1.13 | 25.0 |
| T4 | 7/24/96 | 12:00 | 1.28 | 24.6 |
| T4 | 7/24/96 | 12:20 | 1.33 | 25.0 |
| T4 | 7/24/96 | 12:40 | 1.33 | 22.9 |
| T4 | 7/24/96 | 13:00 | 1.39 | 24.3 |
| T4 | 7/24/96 | 13:20 | 1.38 | 24.1 |
| T4 | 7/24/96 | 13:40 | 1.41 | 24.7 |
| T4 | 7/24/96 | 14:00 | 1.49 | 24.3 |
| T4 | 7/24/96 | 14:30 | 1.48 | 24.4 |
| T4 | 7/24/96 | 15:00 | 1.50 | 25.1 |
| T4 | 7/24/96 | 15:30 | 1.56 | 24.9 |
| T4 | 7/24/96 | 16:00 | 1.57 | 25.3 |
| T4 | 7/24/96 | 16:30 | 1.53 | 24.9 |
| T4 | 7/24/96 | 17:00 | 1.55 | 25.0 |
| T4 | 7/24/96 | 17:30 | 1.61 | 24.7 |
| T4 | 7/24/96 | 18:53 | 1.61 | 25.6 |
| T4 | 7/24/96 | 19:53 | 1.66 | 25.6 |
| T4 | 7/24/96 | 20:53 | 1.63 | 25.6 |
| T4 | 7/24/96 | 21:53 | 1.61 | 25.4 |
| T4 | 7/24/96 | 22:53 | 1.61 | 25.8 |
| T4 | 7/24/96 | 23:53 | 1.62 | 24.7 |
| T4 | 7/25/96 | 0:15 | 1.56 | 24.4 |
| T4 | 7/25/96 | 0:53 | 1.63 | 24.5 |
| T4 | 7/25/96 | 1:53 | 1.56 | 24.4 |
| T4 | 7/25/96 | 2:53 | 1.62 | 25.2 |
| T4 | 7/25/96 | 3:53 | 1.51 | 24.8 |
| T4 | 7/25/96 | 4:53 | 1.51 | 24.9 |
| T4 | 7/25/96 | 5:53 | 1.61 | 25.7 |
| T4 | 7/25/96 | 7:15 | 1.55 | 24.7 |
| T4 | 7/25/96 | 7:53 | 1.52 | 23.9 |
| T4 | 7/25/96 | 8:53 | 1.52 | 26.0 |
| T4 | 7/25/96 | 9:15 | 1.55 | 24.7 |
| T4 | 7/25/96 | 9:53 | 1.50 | 25.9 |
| T4 | 7/25/96 | 10:00 | 1.55 | 25.3 |
| T4 | 7/25/96 | 11:00 | 1.53 | 22.6 |
| T4 | 7/25/96 | 12:00 | 1.49 | 24.6 |
| T4 | 7/25/96 | 13:00 | 1.52 | 24.6 |
| T4 | 7/25/96 | 14:00 | 1.46 | 23.5 |
| T4 | 7/25/96 | 14:59 | 1.48 | 25.3 |
| T4 | 7/25/96 | 15:00 | 1.46 | 25.3 |
| T4 | 7/25/96 | 15:00 | 1.50 | 25.4 |
| T4 | 7/25/96 | 15:02 | 1.47 | 25.4 |
| T4 | 7/25/96 | 15:03 | 4.29 | 25.2 |
| T4 | 7/25/96 | 15:04 | 4.48 | 25.2 |
| T4 | 7/25/96 | 15:05 | 4.16 | 25.4 |
| T4 | 7/25/96 | 15:06 | 4.44 | 25.5 |
| T4 | 7/25/96 | 15:07 | 4.25 | 25.4 |
| T4 | 7/25/96 | 15:08 | 4.32 | 25.3 |
| T4 | 7/25/96 | 15:09 | 4.24 | 25.4 |
| T4 | 7/25/96 | 15:10 | 4.00 | 25.2 |
| T4 | 7/25/96 | 15:11 | 4.30 | 25.2 |
| T4 | 7/25/96 | 15:12 | 4.15 | 25.3 |
| T4 | 7/25/96 | 15:13 | n.v. | 26.0 |
| T4 | 7/25/96 | 15:15 | 4.41 | 25.3 |
| T4 | 7/25/96 | 15:17 | 4.20 | 25.3 |
| T4 | 7/25/96 | 15:19 | 4.17 | 25.4 |
| T4 | 7/25/96 | 15:21 | 4.28 | 25.5 |
| T4 | 7/25/96 | 15:23 | 4.13 | 25.3 |
| T4 | 7/25/96 | 15:25 | 4.19 | 25.3 |
| T4 | 7/25/96 | 15:27 | 4.36 | 25.3 |
| T4 | 7/25/96 | 15:29 | 4.17 | 25.5 |
| T4 | 7/25/96 | 15:31 | 4.55 | 25.4 |
| T4 | 7/25/96 | 15:32 | 1.50 | 25.2 |
| T4 | 7/25/96 | 16:00 | 1.46 | 23.1 |
| T4 | 7/25/96 | 19:15 | 1.72 | 24.9 |
| T4 | 7/25/96 | 20:15 | 1.62 | 25.6 |
| T4 | 7/25/96 | 21:15 | 1.58 | 25.7 |
| T4 | 7/25/96 | 22:15 | 1.60 | 25.6 |
| T4 | 7/25/96 | 23:15 | 1.59 | 24.0 |
| T4 | 7/26/96 | 1:15 | 1.57 | 25.2 |
| T4 | 7/26/96 | 2:15 | 1.63 | 24.9 |
| T4 | 7/26/96 | 3:04 | 1.11 | 14.0 |
| T4 | 7/26/96 | 3:15 | 1.65 | 24.2 |
| T4 | 7/26/96 | 3:25 | 1.67 | 25.7 |
| T4 | 7/26/96 | 4:15 | 1.57 | 24.4 |
| T4 | 7/26/96 | 5:15 | 1.56 | 24.5 |
| T4 | 7/26/96 | 5:39 | 1.57 | 22.9 |
| T4 | 7/26/96 | 6:15 | 1.63 | 24.4 |
| T4 | 7/26/96 | 8:15 | 1.56 | 24.5 |
| T4 | 7/26/96 | 10:15 | 1.54 | 24.6 |
| T4 | 7/26/96 | 11:15 | 1.51 | 25.0 |
| T4 | 7/26/96 | 12:04 | 1.07 | 14.1 |
| T4 | 7/26/96 | 12:15 | 1.73 | 26.1 |
| T4 | 7/26/96 | 13:47 | 1.22 | 21.7 |
| T4 | 7/26/96 | 14:16 | 1.62 | 24.7 |
| T4 | 7/26/96 | 18:03 | 1.57 | 25.5 |
| T4 | 7/26/96 | 19:03 | 1.63 | 25.6 |
| T4 | 7/26/96 | 20:03 | 1.65 | 25.4 |
| T4 | 7/26/96 | 21:03 | 1.75 | 25.8 |
| T4 | 7/26/96 | 22:03 | 1.88 | 26.1 |
| T4 | 7/26/96 | 23:03 | 1.83 | 25.5 |
| T4 | 7/27/96 | 0:03 | 1.87 | 25.5 |
| T4 | 7/27/96 | 1:03 | 1.96 | 25.8 |
| T4 | 7/27/96 | 2:03 | 1.91 | 25.5 |
| T4 | 7/27/96 | 3:03 | 1.92 | 25.6 |
| T4 | 7/27/96 | 4:03 | 1.97 | 25.2 |
| T4 | 7/27/96 | 5:03 | 1.89 | 25.4 |
| T4 | 7/27/96 | 6:03 | 1.92 | 25.6 |
| T4 | 7/27/96 | 8:03 | 1.87 | 25.1 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T4 | 7/27/96 | 9:00 | 1.96 | 25.8 |
| T4 | 7/27/96 | 9:03 | 2.02 | 25.8 |
| T4 | 7/27/96 | 9:10 | 2.01 | 25.7 |
| T4 | 7/27/96 | 9:20 | 1.96 | 25.9 |
| T4 | 7/27/96 | 9:30 | 2.02 | 25.9 |
| T4 | 7/27/96 | 9:35 | 1.98 | 26.0 |
| T4 | 7/27/96 | 9:40 | 1.98 | 26.0 |
| T4 | 7/27/96 | 9:45 | 1.90 | 25.8 |
| T4 | 7/27/96 | 9:50 | 1.96 | 26.0 |
| T4 | 7/27/96 | 9:55 | 1.95 | 25.9 |
| T4 | 7/27/96 | 10:00 | 1.99 | 26.1 |
| T4 | 7/27/96 | 10:03 | 1.97 | 26.0 |
| T4 | 7/27/96 | 10:05 | 1.99 | 26.2 |
| T4 | 7/27/96 | 10:10 | 1.97 | 25.9 |
| T4 | 7/27/96 | 10:15 | 1.85 | 25.7 |
| T4 | 7/27/96 | 10:20 | 1.97 | 26.2 |
| T4 | 7/27/96 | 10:25 | 1.93 | 26.5 |
| T4 | 7/27/96 | 10:30 | 1.97 | 26.9 |
| T4 | 7/27/96 | 10:35 | 1.97 | 27.0 |
| T4 | 7/27/96 | 10:40 | 1.89 | 26.8 |
| T4 | 7/27/96 | 10:50 | 1.77 | 27.0 |
| T4 | 7/27/96 | 11:00 | 1.73 | 26.8 |
| T4 | 7/27/96 | 11:10 | 1.71 | 27.4 |
| T4 | 7/27/96 | 11:20 | 1.76 | 27.6 |
| T4 | 7/27/96 | 11:30 | 1.76 | 27.2 |
| T4 | 7/27/96 | 11:30 | 1.63 | 27.7 |
| T4 | 7/27/96 | 11:40 | 1.64 | 27.8 |
| T4 | 7/27/96 | 12:00 | 1.36 | 27.0 |
| T4 | 7/27/96 | 12:03 | 1.45 | 27.9 |
| T4 | 7/27/96 | 12:20 | 1.23 | 27.0 |
| T4 | 7/27/96 | 12:40 | 1.21 | 27.2 |
| T4 | 7/27/96 | 13:00 | 1.20 | 27.8 |
| T4 | 7/27/96 | 13:03 | 1.23 | 27.7 |
| T4 | 7/27/96 | 13:20 | 1.16 | 27.5 |
| T4 | 7/27/96 | 13:40 | 1.14 | 27.5 |
| T4 | 7/27/96 | 14:00 | 1.10 | 27.7 |
| T4 | 7/27/96 | 14:03 | 1.12 | 27.4 |
| T4 | 7/27/96 | 14:53 | 1.08 | 26.3 |
| T4 | 7/27/96 | 15:53 | 1.04 | 26.4 |
| T4 | 7/27/96 | 16:53 | .98 | 26.0 |
| T4 | 7/27/96 | 17:53 | .95 | 26.1 |
| T4 | 7/27/96 | 18:53 | .79 | 25.7 |
| T4 | 7/27/96 | 19:53 | .88 | 26.1 |
| T4 | 7/27/96 | 20:53 | .80 | 26.1 |
| T4 | 7/27/96 | 21:53 | .90 | 26.8 |
| T4 | 7/27/96 | 22:53 | .76 | 26.2 |
| T4 | 7/27/96 | 23:53 | .87 | 25.9 |
| T4 | 7/28/96 | 0:53 | .66 | 25.6 |
| T4 | 7/28/96 | 1:53 | .74 | 25.7 |
| T4 | 7/28/96 | 2:53 | .66 | 25.6 |
| T4 | 7/28/96 | 3:53 | .76 | 25.6 |
| T4 | 7/28/96 | 4:53 | .68 | 25.6 |
| T4 | 7/28/96 | 5:53 | .60 | 25.5 |
| T4 | 7/28/96 | 6:53 | .63 | 25.7 |
| T4 | 7/28/96 | 7:53 | .60 | 25.7 |
| T4 | 7/28/96 | 8:53 | .67 | 25.3 |
| T4 | 7/28/96 | 9:53 | .63 | 25.5 |
| T4 | 7/28/96 | 10:53 | .62 | 25.1 |
| T4 | 7/28/96 | 11:53 | .58 | 25.6 |
| T4 | 7/28/96 | 12:53 | .54 | 25.2 |
| T4 | 7/28/96 | 13:53 | .55 | 25.9 |
| T4 | 7/28/96 | 14:53 | .54 | 25.7 |
| T4 | 7/28/96 | 15:53 | .63 | 25.9 |
| T4 | 8/9/96 | 13:45 | .36 | 23.9 |
| T4 | 8/23/96 | 12:25 | .33 | 24.3 |
| T4 | 9/17/96 | 14:50 | .14 | 23.3 |
| T4A | 7/25/96 | 15:35 | 4.50 | 25.4 |
| T4C | 7/25/96 | 15:35 | 4.51 | 25.4 |
| T4D | 7/25/96 | 15:35 | 4.00 | 25.5 |
| T5 | 7/21/96 | 11:50 | 1.12 | 24.9 |
| T5 | 7/22/96 | 10:00 | .86 | 25.0 |
| T5 | 7/23/96 | 11:53 | .49 | 24.6 |
| T5 | 7/23/96 | 13:18 | .54 | 25.2 |
| T5 | 7/23/96 | 14:33 | .60 | 24.1 |
| T5 | 7/23/96 | 15:13 | .69 | 24.4 |
| T5 | 7/23/96 | 16:15 | .71 | 25.1 |
| T5 | 7/23/96 | 17:29 | .71 | 24.7 |
| T5 | 7/23/96 | 18:58 | .74 | 25.0 |
| T5 | 7/23/96 | 19:58 | .87 | 24.8 |
| T5 | 7/23/96 | 20:58 | .80 | 25.1 |
| T5 | 7/23/96 | 21:58 | .81 | 24.9 |
| T5 | 7/23/96 | 22:58 | .90 | 24.8 |
| T5 | 7/23/96 | 23:58 | .89 | 25.0 |
| T5 | 7/24/96 | 0:58 | .82 | 24.4 |
| T5 | 7/24/96 | 1:43 | 1.15 | 20.2 |
| T5 | 7/24/96 | 1:58 | .87 | 25.4 |
| T5 | 7/24/96 | 2:58 | .87 | 25.1 |
| T5 | 7/24/96 | 3:58 | .89 | 25.1 |
| T5 | 7/24/96 | 4:58 | .87 | 25.0 |
| T5 | 7/24/96 | 5:58 | .91 | 24.9 |
| T5 | 7/24/96 | 6:58 | .89 | 25.1 |
| T5 | 7/24/96 | 7:58 | .86 | 25.2 |
| T5 | 7/24/96 | 8:58 | .89 | 25.0 |
| T5 | 7/24/96 | 9:58 | .86 | 25.0 |
| T5 | 7/24/96 | 10:20 | .92 | 25.1 |
| T5 | 7/24/96 | 10:40 | .95 | 25.2 |
| T5 | 7/24/96 | 11:00 | .98 | 24.8 |
| T5 | 7/24/96 | 11:05 | 1.02 | 24.9 |
| T5 | 7/24/96 | 11:10 | 1.11 | 25.1 |
| T5 | 7/24/96 | 11:15 | 1.02 | 24.7 |
| T5 | 7/24/96 | 11:20 | 1.04 | 24.8 |
| T5 | 7/24/96 | 11:25 | 1.02 | 25.0 |
| T5 | 7/24/96 | 11:30 | 1.11 | 24.8 |
| T5 | 7/24/96 | 11:35 | 1.12 | 25.0 |
| T5 | 7/24/96 | 11:40 | 1.14 | 25.1 |
| T5 | 7/24/96 | 11:45 | 1.10 | 25.1 |
| T5 | 7/24/96 | 11:55 | 1.16 | 24.6 |
| T5 | 7/24/96 | 12:00 | 1.22 | 25.2 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T5 | 7/24/96 | 12:10 | 1.25 | 25.4 |
| T5 | 7/24/96 | 12:20 | 1.39 | 24.8 |
| T5 | 7/24/96 | 12:30 | 1.27 | 25.0 |
| T5 | 7/24/96 | 12:45 | 1.36 | 25.3 |
| T5 | 7/24/96 | 13:00 | 1.37 | 25.3 |
| T5 | 7/24/96 | 13:15 | 1.40 | 25.0 |
| T5 | 7/24/96 | 13:30 | 1.39 | 25.1 |
| T5 | 7/24/96 | 13:45 | 1.44 | 25.0 |
| T5 | 7/24/96 | 14:00 | 1.47 | 25.0 |
| T5 | 7/24/96 | 14:30 | 1.47 | 25.8 |
| T5 | 7/24/96 | 15:00 | 1.48 | 25.5 |
| T5 | 7/24/96 | 15:30 | 1.47 | 25.3 |
| T5 | 7/24/96 | 16:00 | 1.50 | 25.6 |
| T5 | 7/24/96 | 16:30 | 1.70 | 25.0 |
| T5 | 7/24/96 | 17:00 | 1.61 | 25.5 |
| T5 | 7/24/96 | 17:30 | 1.62 | 25.7 |
| T5 | 7/24/96 | 18:00 | 1.71 | 25.0 |
| T5 | 7/24/96 | 20:05 | 1.59 | 25.7 |
| T5 | 7/25/96 | 10:00 | 1.48 | 25.2 |
| T5 | 7/25/96 | 11:00 | 1.50 | 25.4 |
| T5 | 7/25/96 | 12:00 | 1.47 | 25.1 |
| T5 | 7/25/96 | 13:00 | 1.52 | 25.2 |
| T5 | 7/25/96 | 13:32 | 1.45 | 24.4 |
| T5 | 7/25/96 | 13:33 | 1.47 | 24.4 |
| T5 | 7/25/96 | 13:34 | 1.45 | 25.2 |
| T5 | 7/25/96 | 13:35 | 6.77 | 25.0 |
| T5 | 7/25/96 | 13:36 | 6.49 | 24.7 |
| T5 | 7/25/96 | 13:37 | 6.10 | 24.4 |
| T5 | 7/25/96 | 13:38 | 6.23 | 24.3 |
| T5 | 7/25/96 | 13:40 | 6.43 | 24.3 |
| T5 | 7/25/96 | 13:42 | 6.76 | 25.0 |
| T5 | 7/25/96 | 13:46 | 6.58 | 25.5 |
| T5 | 7/25/96 | 13:48 | 6.13 | 24.6 |
| T5 | 7/25/96 | 13:50 | 6.53 | 25.3 |
| T5 | 7/25/96 | 13:52 | 6.16 | 24.5 |
| T5 | 7/25/96 | 13:56 | 6.50 | 25.3 |
| T5 | 7/25/96 | 13:58 | 6.60 | 25.3 |
| T5 | 7/25/96 | 14:00 | 1.53 | 26.3 |
| T5 | 7/25/96 | 14:00 | 6.19 | 24.7 |
| T5 | 7/25/96 | 14:02 | 6.75 | 25.4 |
| T5 | 7/25/96 | 14:06 | 1.49 | 25.2 |
| T5 | 7/25/96 | 14:10 | 1.45 | 25.1 |
| T5 | 7/25/96 | 14:15 | 1.45 | 25.3 |
| T5 | 7/25/96 | 15:00 | 1.42 | 25.6 |
| T5 | 7/25/96 | 16:00 | 1.56 | 26.1 |
| T5 | 7/25/96 | 18:28 | 1.51 | 25.3 |
| T5 | 7/25/96 | 19:28 | 1.78 | 25.4 |
| T5 | 7/25/96 | 20:28 | 1.76 | 26.1 |
| T5 | 7/25/96 | 21:28 | 1.78 | 25.5 |
| T5 | 7/25/96 | 22:28 | 1.65 | 25.1 |
| T5 | 7/25/96 | 23:28 | 1.63 | 25.2 |
| T5 | 7/26/96 | 0:28 | 1.67 | 25.1 |
| T5 | 7/26/96 | 1:28 | 1.57 | 25.0 |
| T5 | 7/26/96 | 2:26 | 1.63 | 26.3 |
| T5 | 7/26/96 | 2:28 | 1.66 | 25.1 |
| T5 | 7/26/96 | 3:15 | 1.64 | 26.2 |
| T5 | 7/26/96 | 3:28 | 1.63 | 25.7 |
| T5 | 7/26/96 | 4:12 | 1.56 | 25.6 |
| T5 | 7/26/96 | 4:28 | 1.60 | 26.2 |
| T5 | 7/26/96 | 5:24 | 1.58 | 26.0 |
| T5 | 7/26/96 | 5:28 | 1.59 | 26.4 |
| T5 | 7/26/96 | 6:28 | 1.63 | 25.3 |
| T5 | 7/26/96 | 7:28 | 1.61 | 24.8 |
| T5 | 7/26/96 | 8:28 | 1.62 | 25.1 |
| T5 | 7/26/96 | 9:28 | 1.61 | 25.2 |
| T5 | 7/26/96 | 10:28 | 1.64 | 26.1 |
| T5 | 7/26/96 | 11:28 | 1.59 | 26.0 |
| T5 | 7/26/96 | 12:28 | 1.56 | 25.7 |
| T5 | 7/26/96 | 13:08 | 1.58 | 25.2 |
| T5 | 7/26/96 | 17:23 | 1.72 | 25.8 |
| T5 | 7/26/96 | 17:43 | 1.19 | 22.3 |
| T5 | 7/26/96 | 18:43 | 1.69 | 25.8 |
| T5 | 7/26/96 | 18:43 | 1.28 | 22.4 |
| T5 | 7/26/96 | 19:43 | 1.74 | 25.8 |
| T5 | 7/26/96 | 19:43 | 1.32 | 22.3 |
| T5 | 7/26/96 | 20:43 | 1.81 | 25.9 |
| T5 | 7/26/96 | 20:43 | 1.32 | 22.2 |
| T5 | 7/26/96 | 21:43 | 1.09 | 20.5 |
| T5 | 7/26/96 | 22:43 | 1.14 | 20.7 |
| T5 | 7/26/96 | 23:43 | 1.14 | 20.6 |
| T5 | 7/27/96 | 0:43 | 1.22 | 20.4 |
| T5 | 7/27/96 | 2:43 | 1.41 | 21.8 |
| T5 | 7/27/96 | 3:43 | 1.26 | 20.5 |
| T5 | 7/27/96 | 3:43 | 1.40 | 21.8 |
| T5 | 7/27/96 | 4:43 | 1.21 | 20.6 |
| T5 | 7/27/96 | 6:43 | 1.20 | 20.4 |
| T5 | 7/27/96 | 7:03 | 2.00 | 25.6 |
| T5 | 7/27/96 | 7:43 | 1.33 | 20.5 |
| T5 | 7/27/96 | 8:43 | 1.40 | 21.8 |
| T5 | 7/27/96 | 9:30 | 2.28 | 26.2 |
| T5 | 7/27/96 | 9:40 | 2.10 | 26.2 |
| T5 | 7/27/96 | 9:43 | 1.53 | 22.1 |
| T5 | 7/27/96 | 9:45 | 2.09 | 26.1 |
| T5 | 7/27/96 | 9:50 | 2.03 | 25.9 |
| T5 | 7/27/96 | 9:55 | 1.99 | 25.7 |
| T5 | 7/27/96 | 10:00 | 2.04 | 26.2 |
| T5 | 7/27/96 | 10:05 | 2.03 | 26.1 |
| T5 | 7/27/96 | 10:10 | 2.05 | 25.8 |
| T5 | 7/27/96 | 10:15 | 2.04 | 25.6 |
| T5 | 7/27/96 | 10:20 | 2.04 | 26.1 |
| T5 | 7/27/96 | 10:25 | 2.00 | 26.4 |
| T5 | 7/27/96 | 10:30 | 2.09 | 26.3 |
| T5 | 7/27/96 | 10:35 | 2.03 | 25.9 |
| T5 | 7/27/96 | 10:40 | 2.04 | 26.3 |
| T5 | 7/27/96 | 10:43 | 1.37 | 22.6 |
| T5 | 7/27/96 | 10:45 | 1.97 | 26.5 |
| T5 | 7/27/96 | 10:50 | 1.98 | 26.8 |
| T5 | 7/27/96 | 10:55 | 1.89 | 26.2 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T5 | 7/27/96 | 11:00 | 1.93 | 26.7 |
| T5 | 7/27/96 | 11:20 | 1.78 | 26.9 |
| T5 | 7/27/96 | 11:40 | 1.80 | 27.6 |
| T5 | 7/27/96 | 11:43 | 1.06 | 21.9 |
| T5 | 7/27/96 | 12:00 | 1.46 | 27.6 |
| T5 | 7/27/96 | 12:20 | 1.47 | 28.0 |
| T5 | 7/27/96 | 12:40 | 1.37 | 27.8 |
| T5 | 7/27/96 | 13:00 | 1.35 | 27.8 |
| T5 | 7/27/96 | 13:20 | 1.23 | 27.7 |
| T5 | 7/27/96 | 13:40 | 1.20 | 28.9 |
| T5 | 7/27/96 | 14:00 | 1.17 | 27.5 |
| T5 | 7/27/96 | 14:30 | 1.08 | 27.1 |
| T5 | 7/27/96 | 15:00 | 1.10 | 27.0 |
| T5 | 7/27/96 | 16:05 | .94 | 26.3 |
| T5 | 7/28/96 | 10:13 | .55 | 24.9 |
| T5 | 7/28/96 | 15:11 | .55 | 25.8 |
| T5 | 8/23/96 | 12:15 | .32 | 24.1 |
| T6 | 7/23/96 | 12:23 | .45 | 58.0 |
| T6 | 7/23/96 | 13:31 | .63 | 68.7 |
| T6 | 7/23/96 | 14:42 | .40 | 62.1 |
| T6 | 7/23/96 | 15:24 | .50 | 61.5 |
| T6 | 7/23/96 | 16:23 | .47 | 65.3 |
| T6 | 7/23/96 | 17:37 | .56 | 64.0 |
| T6 | 7/24/96 | 10:30 | .94 | 63.5 |
| T6 | 7/24/96 | 10:40 | .66 | 56.7 |
| T6 | 7/24/96 | 10:50 | .69 | 59.0 |
| T6 | 7/24/96 | 11:00 | .65 | 55.5 |
| T6 | 7/24/96 | 11:05 | .74 | 55.9 |
| T6 | 7/24/96 | 11:10 | .74 | 56.0 |
| T6 | 7/24/96 | 11:15 | .73 | 56.4 |
| T6 | 7/24/96 | 11:20 | .72 | 56.0 |
| T6 | 7/24/96 | 11:25 | .63 | 57.1 |
| T6 | 7/24/96 | 11:30 | .68 | 56.8 |
| T6 | 7/24/96 | 11:35 | .67 | 56.7 |
| T6 | 7/24/96 | 11:40 | .68 | 58.5 |
| T6 | 7/24/96 | 11:45 | .67 | 58.1 |
| T6 | 7/24/96 | 11:50 | .73 | 57.7 |
| T6 | 7/24/96 | 11:55 | .63 | 58.5 |
| T6 | 7/24/96 | 12:00 | .74 | 58.7 |
| T6 | 7/24/96 | 12:10 | .75 | 57.8 |
| T6 | 7/24/96 | 12:20 | .71 | 58.3 |
| T6 | 7/24/96 | 12:30 | 1.06 | 70.7 |
| T6 | 7/24/96 | 12:40 | .80 | 59.8 |
| T6 | 7/24/96 | 12:50 | .81 | 59.7 |
| T6 | 7/24/96 | 13:00 | .76 | 64.4 |
| T6 | 7/24/96 | 13:20 | .75 | 62.7 |
| T6 | 7/24/96 | 13:40 | .74 | 59.7 |
| T6 | 7/24/96 | 14:00 | .85 | 64.9 |
| T6 | 7/24/96 | 14:20 | .92 | 62.9 |
| T6 | 7/24/96 | 14:40 | .89 | 65.6 |
| T6 | 7/24/96 | 15:00 | .84 | 61.9 |
| T6 | 7/24/96 | 15:30 | .89 | 63.8 |
| T6 | 7/24/96 | 16:00 | .97 | 64.4 |
| T6 | 7/24/96 | 16:30 | .90 | 65.3 |
| T6 | 7/24/96 | 17:00 | 1.03 | 65.6 |
| T6 | 7/24/96 | 17:30 | .95 | 64.6 |
| T6 | 7/24/96 | 18:00 | .98 | 64.0 |
| T6 | 7/24/96 | 21:40 | 1.09 | 55.8 |
| T6 | 7/24/96 | 22:20 | 1.07 | 55.3 |
| T6 | 7/25/96 | 0:18 | 1.08 | 55.0 |
| T6 | 7/25/96 | 2:29 | 1.09 | 55.6 |
| T6 | 7/25/96 | 6:11 | 1.06 | 55.0 |
| T6 | 7/25/96 | 10:19 | 1.18 | 58.6 |
| T6 | 7/25/96 | 11:04 | 1.06 | 71.2 |
| T6 | 7/25/96 | 11:08 | 1.07 | 59.0 |
| T6 | 7/25/96 | 11:11 | 1.14 | 58.4 |
| T6 | 7/25/96 | 11:12 | 1.13 | 57.7 |
| T6 | 7/25/96 | 11:14 | 3.71 | 58.0 |
| T6 | 7/25/96 | 11:15 | 4.46 | 60.0 |
| T6 | 7/25/96 | 11:16 | 4.31 | 58.4 |
| T6 | 7/25/96 | 11:18 | 4.31 | 58.6 |
| T6 | 7/25/96 | 11:19 | 4.41 | 59.4 |
| T6 | 7/25/96 | 11:21 | 4.07 | 60.7 |
| T6 | 7/25/96 | 11:23 | 3.92 | 59.4 |
| T6 | 7/25/96 | 11:25 | 4.20 | 60.1 |
| T6 | 7/25/96 | 11:26 | 4.29 | 60.0 |
| T6 | 7/25/96 | 11:27 | 4.03 | 58.3 |
| T6 | 7/25/96 | 11:28 | 1.15 | 70.4 |
| T6 | 7/25/96 | 11:29 | 4.29 | 58.0 |
| T6 | 7/25/96 | 11:30 | 4.23 | 58.6 |
| T6 | 7/25/96 | 11:32 | 4.23 | 58.4 |
| T6 | 7/25/96 | 11:33 | 4.13 | 60.0 |
| T6 | 7/25/96 | 11:35 | 4.19 | 58.1 |
| T6 | 7/25/96 | 11:39 | 4.21 | 58.3 |
| T6 | 7/25/96 | 11:40 | 4.19 | 58.3 |
| T6 | 7/25/96 | 11:42 | 4.23 | 58.6 |
| T6 | 7/25/96 | 11:43 | 4.27 | 58.8 |
| T6 | 7/25/96 | 11:45 | 4.00 | 60.0 |
| T6 | 7/25/96 | 11:46 | 1.10 | 69.5 |
| T6 | 7/25/96 | 11:46 | 4.31 | 58.5 |
| T6 | 7/25/96 | 11:48 | 4.22 | 58.9 |
| T6 | 7/25/96 | 11:49 | 4.28 | 60.4 |
| T6 | 7/25/96 | 11:51 | 4.21 | 60.2 |
| T6 | 7/25/96 | 11:53 | 4.28 | 58.3 |
| T6 | 7/25/96 | 11:54 | 3.88 | 56.5 |
| T6 | 7/25/96 | 11:56 | 4.57 | 58.8 |
| T6 | 7/25/96 | 11:57 | 4.52 | 58.3 |
| T6 | 7/25/96 | 11:58 | 1.14 | 71.4 |
| T6 | 7/25/96 | 12:00 | 4.57 | 58.4 |
| T6 | 7/25/96 | 12:03 | 4.68 | 59.3 |
| T6 | 7/25/96 | 12:05 | 4.52 | 58.5 |
| T6 | 7/25/96 | 12:06 | 4.53 | 58.8 |
| T6 | 7/25/96 | 12:08 | 4.74 | 58.5 |
| T6 | 7/25/96 | 12:10 | 4.68 | 58.5 |
| T6 | 7/25/96 | 12:12 | 1.22 | 65.9 |
| T6 | 7/25/96 | 12:12 | 4.59 | 61.1 |
| T6 | 7/25/96 | 12:18 | 1.18 | 59.4 |
| T6 | 7/25/96 | 12:23 | 1.12 | 61.8 |

**Appendix 2.** Concentration of chloride and sulfate at selected sites in French Gulch, Colorado, July 24-28, 1996—Continued

| Site | Date | Time | Chloride | Sulfate |
|---|---|---|---|---|
| T6 | 7/25/96 | 14:20 | 1.29 | 59.9 |
| T6 | 7/25/96 | 15:50 | 1.83 | 59.6 |
| T6 | 7/26/96 | 4:43 | 1.12 | 66.7 |
| T6 | 7/26/96 | 6:13 | 1.13 | 66.3 |
| T6 | 7/26/96 | 10:49 | 1.11 | 58.4 |
| T6 | 7/26/96 | 11:20 | 1.31 | 60.9 |
| T6 | 7/26/96 | 13:09 | 1.10 | 62.7 |
| T6 | 7/26/96 | 14:44 | 1.12 | 62.8 |
| T6 | 7/27/96 | 9:40 | 1.36 | 60.9 |
| T6 | 7/27/96 | 10:00 | 1.35 | 60.4 |
| T6 | 7/27/96 | 10:05 | 1.32 | 60.9 |
| T6 | 7/27/96 | 10:10 | 1.36 | 60.7 |
| T6 | 7/27/96 | 10:15 | 1.31 | 60.8 |
| T6 | 7/27/96 | 10:20 | 1.33 | 60.6 |
| T6 | 7/27/96 | 10:25 | 1.31 | 60.7 |
| T6 | 7/27/96 | 10:30 | 1.36 | 61.3 |
| T6 | 7/27/96 | 10:35 | 1.33 | 60.7 |
| T6 | 7/27/96 | 10:40 | 1.32 | 60.9 |
| T6 | 7/27/96 | 10:45 | 1.37 | 60.3 |
| T6 | 7/27/96 | 10:50 | 1.33 | 60.7 |
| T6 | 7/27/96 | 10:55 | 1.36 | 60.7 |
| T6 | 7/27/96 | 11:00 | 1.35 | 60.4 |
| T6 | 7/27/96 | 11:10 | 1.29 | 60.6 |
| T6 | 7/27/96 | 11:30 | 1.32 | 61.2 |
| T6 | 7/27/96 | 11:40 | 1.35 | 60.9 |
| T6 | 7/27/96 | 11:50 | 1.30 | 61.4 |
| T6 | 7/27/96 | 12:00 | 1.30 | 62.3 |
| T6 | 7/27/96 | 12:20 | 1.27 | 64.1 |
| T6 | 7/27/96 | 12:40 | 1.27 | 63.5 |
| T6 | 7/27/96 | 13:20 | 1.18 | 64.4 |
| T6 | 7/27/96 | 13:40 | 1.13 | 65.0 |
| T6 | 7/27/96 | 14:00 | 1.09 | 67.0 |
| T6 | 7/27/96 | 14:20 | 1.07 | 66.1 |
| T6 | 7/27/96 | 14:40 | 1.04 | 65.7 |
| T6 | 7/27/96 | 15:00 | .97 | 65.8 |
| T6 | 7/27/96 | 15:30 | .95 | 66.9 |
| T6 | 7/27/96 | 16:12 | 1.34 | 81.5 |
| T6 | 7/28/96 | 10:14 | .82 | 73.1 |
| T6 | 7/28/96 | 13:00 | .79 | 74.0 |
| T6 | 8/9/96 | 13:24 | .50 | 81.1 |
| T6 | 8/23/96 | 12:00 | .44 | 86.3 |
| T6 | 9/17/96 | 15:40 | .35 | 87.7 |

**Appendix 3.** Site description and physical properties of water from synoptic sampling sites, French Gulch, Colorado, July 26, 1996

[Site, field identification label; Distance, downstream from injection, in meters; Temp, temperature, in degrees Celsius; pH, in log units; Cond, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; Q, discharge from tracer calculations, in liters per second; Qmeter, discharge from flow-meter measurement, in liters per second; RB, right bank; LB, left bank]

| Site | Distance | Description of site | Temp | pH | Cond | Q | Qmeter |
|---|---|---|---|---|---|---|---|
| | | **Stream sites** | | | | | |
| FG00 | 0 | Injection point; Site T0 just upstream from injection | 10.5 | 8.23 | 84 | | 136.0 |
| FG03 | 84 | Along straight portion of stream | 11.0 | 8.16 | 101 | | |
| FG05 | 234 | Along straight portion of stream | 11.0 | 8.19 | 98 | | |
| TS02 | 516 | Site T2 (State site FG5) | 11.0 | 7.82 | 98 | 74.2 | 93.4 |
| FG09 | 631 | Flag on RB at downstream end of willows, channel is about 35 feet wide | 11.5 | 8.08 | 100 | | |
| FG09d | 744 | End of culvert at Country Boy Road | 5.5 | 8.17 | 109 | | |
| TS03 | 799 | Site T3; stream at top of cascade; ISCO site | 7.0 | 7.96 | 108 | 304.0 | 328.0 |
| FG17b | 825 | Stream site added to see effect of FG16-b&c; distance estimated | 7.0 | 7.81 | 112 | 334.6 | |
| FG18 | 881 | Stream; at bottom of steep rock hill | 8.0 | 8.06 | 131 | 354.0 | |
| FG25 | 981 | Old FG25 was inflow that is now dry; this is stream site to replace FG24 | 9.0 | 7.74 | 136 | 368.0 | |
| FG28 | 1,087 | Stream near white semi trailer | 7.0 | 7.71 | 135 | 375.0 | |
| TS04 | 1,161 | Site T4; stream below culvert; ISCO site | 7.0 | 7.74 | 135 | 372.0 | 279.0 |
| FG31 | 1,242 | By big cut in alluvium with foot bridge (pole across stream) | 7.0 | 7.53 | 138 | | |
| FG33 | 1,356 | Downstream from triple power pole | 8.0 | 7.70 | 137 | | |
| FG35 | 1,515 | Before double power poles | 7.5 | 7.61 | 135 | | |
| TS05 | 1,651 | Site T5; below inflow area; ISCO Site | 10.0 | 7.35 | 138 | 179.7 | 334.0 |
| FG39 | 1,751 | Above split of north branch to ponded area | 9.0 | 7.17 | 192 | | |
| FG50 | 1,880 | Wide gravel bar; north branch, first site downstream from FG39 | 8.5 | 7.27 | 137 | | |
| FG52 | 2,080 | Open area after bend | 11.0 | 7.26 | 128 | | |
| FG53 | 2,150 | Narrow channel above confluence with re-emergent flow from FG41 | 9.0 | 7.19 | 132 | | |
| FG55 | 2,200 | Below FG53/54 confluence | 8.0 | 7.32 | 184 | | |
| FG45 | 2,388 | Open area 100 meters upstream from triple power pole; upstream from dirty inflow | 7.5 | 7.28 | 170 | | |
| TS06 | 2,536 | Site T6 (State FG7 site) downstream from inflow of acid drainage | 7.5 | 7.38 | 214 | 376.6 | 297.0 |
| FG46 | 2,540 | South branch inflow to Dead Elk Pond (State site FG8) | 7.0 | 7.28 | 122 | | |
| FG42 | 2,600 | Culvert at the end of Dead Elk Pond; farthest downstream point | 8.0 | 7.31 | 139 | | |

**Appendix 3.** Site description and physical properties of water from synoptic sampling sites, French Gulch, Colorado, July 26, 1996—Continued

| Site | Distance | Description of site | Temp | pH | Cond | Q | Qmeter |
|---|---|---|---|---|---|---|---|
| | | **Inflow sites** | | | | | |
| FG06 | 333 | LB water exits from rocks all the way over to the dredge pile | 8.5 | 8.05 | 97 | | |
| FG09b | 694 | LB water exits from rocks | 6.0 | 8.15 | 95 | | |
| FG09c | 695 | RB water exits from rocks | 7.0 | 7.90 | 117 | | |
| FG10 | 745 | LB water exits from rocks; downstream end of culvert at Country Boy mine | 6.5 | 8.50 | 102 | | |
| FG12 | 769 | RB another inflow; large flow from rocks | 6.5 | 8.05 | 100 | | |
| FG13 | 784 | RB third inflow RB 20 feet downstream again | 8.0 | 8.04 | 101 | | |
| FG16 | 812 | Inflow LB along cascade section | | 7.62 | 266 | | |
| FG16b | 813 | RB inflow – mine water | 8.0 | 7.77 | 135 | | |
| FG16c | 814 | RB inflow – mine water | 8.0 | 7.78 | 144 | | |
| FG19 | 840 | LB inflow | 6.0 | 7.53 | 306 | | |
| FG15 | 840 | RB pool with "yellow boy" precipitate; downstream from FG-16 | 8.0 | 7.27 | 292 | | |
| FG22 | 857 | LB | 10.0 | 8.09 | 444 | | |
| FG27 | 1,073 | LB inflow near double tower; about 10 meters left of stream | 17.5 | 7.87 | 366 | | |
| FG32 | 1,266 | RB just around bend, about 3 meters | 6.5 | 7.72 | 135 | | |
| FG36b | 1,605 | Inflow added 7/24/96, never makes it to the stream - parallels stream | 6.5 | 7.60 | 144 | | |
| FG38 | 1,701 | Inflow RB spring at base of dredge pile; water coming in all along base of | 5.0 | 6.63 | 860 | | |
| FG51 | 1,980 | Drainage from spring FG-6; re-enters split off branch after pond | 7.5 | 7.34 | 137 | | |
| FG54 | 2,150 | Re-emergent water from FG41 area | 7.5 | 7.19 | 206 | | |
| FG44 | 2,400 | Mine drainage, dirty inflow RB; - sample near road instead of by stream | 7.0 | 7.01 | 412 | | |
| FG56 | 2,422 | FG44 and water from the base of rubble pile where it joins stream | 8.0 | 6.97 | 280 | | |
| | | **Bullhide Fault surface drainage** | | | | | |
| FG39b | 1,826 | RB inflow below pond; orange suggests it differs from water out of pond | 9.0 | 7.33 | 262 | | |
| FG40 | 1,869 | North branch beyond pond; water leaving channel at this point | 9.0 | 7.38 | 251 | | |
| FG41 | 1,920 | Point where all the water goes under the rocks (drain from pond only) | 9.0 | 7.30 | 244 | | |

**Appendix 4.** Concentration of major ions in water from synoptic sampling sites along French Gulch, Colorado, July 26, 1996

[Dist, distance downstream from injection site, in meters; Site, field sample and flag identifier; concentration in milligrams per liter ]

| Dist | Site | Calcium | Magnesium | Sodium | Potassium | Chloride | Sultafe | Bicarbonate |
|---|---|---|---|---|---|---|---|---|
| | | | | **Stream samples** | | | | |
| 0 | FG00 | 17.8 | 1.43 | 1.3 | | .1 | 10.6 | 39.4 |
| 84 | FG03 | 17.9 | 1.42 | 4.0 | | 3.4 | 10.6 | 39.9 |
| 234 | FG05 | 18.6 | 1.47 | 4.2 | | 3.4 | 10.6 | 40.4 |
| 516 | TS02 | 17.5 | 1.40 | 3.6 | | 3.3 | 10.6 | 40.2 |
| 631 | FG09 | 17.7 | 1.42 | 3.6 | | 3.3 | 10.6 | 39.4 |
| 744 | FG09d | 22.1 | 1.93 | 1.5 | | .4 | 15.3 | 47.9 |
| 799 | TS03 | 22.0 | 1.92 | 2.0 | | 1.0 | 14.3 | 45.4 |
| 825 | FG17b | 21.1 | 1.95 | 2.0 | | 1.1 | 15.1 | 44.8 |
| 881 | FG18 | 23.2 | 2.49 | 2.0 | 2.0 | 1.1 | 20.6 | 47.2 |
| 981 | FG25 | 23.0 | 2.62 | 2.0 | | 1.2 | 21.5 | 45.1 |
| 1,087 | FG28 | 23.2 | 2.62 | 2.0 | | 1.3 | 21.9 | 45.7 |
| 1,161 | TS04 | 22.6 | 2.54 | 2.0 | | 1.2 | 22.5 | 45.3 |
| 1,242 | FG31 | 23.2 | 2.60 | 2.0 | | 1.2 | 23.6 | 45.6 |
| 1,356 | FG33 | 22.8 | 2.55 | 2.0 | | 1.2 | 23.5 | 45.1 |
| 1,515 | FG35 | 23.2 | 2.59 | 2.0 | | 1.2 | 21.5 | 44.8 |
| 1,651 | TS05 | 22.7 | 2.54 | 2.0 | | 1.2 | 23.1 | 46.2 |
| 1,751 | FG39 | 28.0 | 4.01 | 2.0 | | 1.1 | 46.7 | 43.5 |
| 1,880 | FG50 | 21.8 | 2.47 | 1.9 | | 1.2 | 21.6 | 45.1 |
| 2,080 | FG52 | 23.0 | 2.60 | 2.0 | | 1.2 | 21.6 | 45.8 |
| 2,150 | FG53 | 22.7 | 2.60 | 2.0 | | 1.1 | 24.4 | 45.0 |
| 2,200 | FG55 | 28.2 | 4.08 | 2.1 | | 1.2 | 44.6 | 42.0 |
| 2,388 | FG45 | 26.5 | 3.90 | 2.0 | | 1.1 | 46.3 | 42.5 |
| 2,536 | TS06 | 30.1 | 5.00 | 2.1 | | 1.1 | 62.0 | 40.4 |
| 2,540 | FG46 | 21.3 | 2.63 | 1.6 | 1.0 | .8 | 25.7 | 39.1 |
| 2,600 | FG42 | 26.8 | 4.19 | 1.9 | | 1.1 | 53.4 | 39.9 |
| | | | | **Inflow samples** | | | | |
| 333 | FG06 | 18.3 | 1.44 | 3.4 | | 3.1 | 10.8 | 39.1 |
| 694 | FG09b | 19.4 | 1.71 | 1.3 | | .2 | 12.8 | 42.9 |
| 695 | FG09c | 22.8 | 1.98 | 1.8 | | .9 | 16.2 | 48.5 |
| 745 | FG10 | 20.0 | 1.74 | 1.6 | | .7 | 12.7 | 44.8 |
| 769 | FG12 | 18.4 | 1.50 | 2.9 | | 2.6 | 11.3 | 39.8 |
| 784 | FG13 | 20.0 | 1.65 | 2.7 | | 2.4 | 12.6 | 40.9 |
| 812 | FG16 | 39.4 | 7.75 | 1.6 | | .3 | 76.6 | 52.3 |
| 813 | FG16b | 23.1 | 2.39 | 2.5 | | 2.2 | 23.2 | 41.6 |
| 814 | FG16c | 23.2 | 2.72 | 2.7 | | 2.4 | 26.2 | 40.3 |
| 840 | FG19 | 43.2 | 8.95 | 1.6 | | .4 | 86.7 | 56.9 |
| 840 | FG15 | 33.1 | 8.07 | 2.5 | | 2.1 | 95.6 | 36.0 |

**Appendix 4.** Concentration of major ions in water from synoptic sampling sites along French Gulch, Colorado, July 26, 1996—Continued

| Dist | Site | Calcium | Magnesium | Sodium | Potassium | Chloride | Sultafe | Bicarbonate |
|---|---|---|---|---|---|---|---|---|
| | | | | **Inflow samples—Continued** | | | | |
| 857 | FG22 | 72.6 | 14.2 | 2.0 | 2.0 | .4 | 104 | 124 |
| 1,073 | FG27 | 63.8 | 6.07 | 3.4 | | .3 | 59.9 | 119 |
| 1,266 | FG32 | 23.3 | 2.57 | 2.0 | | 1.1 | 23.2 | 43.4 |
| 1,605 | FG36b | 24.7 | 2.94 | 1.7 | | .9 | 29.3 | 43.1 |
| 1,701 | FG38 | 107 | 29.6 | 3.7 | 2.0 | 1.5 | 453 | 26.3 |
| 1,980 | FG51 | 22.7 | 2.53 | 1.4 | | .9 | 23.2 | 41.1 |
| 2,150 | FG54 | 30.0 | 4.68 | 2.0 | | 1.1 | 60.7 | 39.9 |
| 2,400 | FG44 | 52.8 | 12.2 | 2.7 | | 1.4 | 176 | 29.6 |
| 2,422 | FG56 | 39.3 | 7.72 | 2.5 | 1.0 | 1.2 | 97.2 | 37.5 |
| | | | | **Bullhide Fault surface flow** | | | | |
| 1,826 | FG39b | 36.1 | 6.26 | 2.2 | | 1.2 | 76.7 | 39.6 |
| 1,869 | FG40 | 35.5 | 5.97 | 2.2 | | 1.2 | 76.4 | 40.4 |
| 1,920 | FG41 | 34.8 | 5.72 | 2.2 | 1.0 | 1.2 | 67.3 | 41.3 |

**Appendix 5.** Concentration of metals in water from synoptic sampling sites along French Gulch, Colorado, July 26, 1996

[Dist, distance downstream from injection site, in meters; Site, field sample identifier; concentration in micrograms per liter; -d, dissolved concentration; -t, total recoverable concentration; Al, aluminum; Cd, cadmium; Cu, copper; Fe, iron; Mn, manganese; Pb, lead; Zn, zinc. Blank entries indicate concentrations below detection limits]

| Dist | Site | Al-d | Al-t | Cd-d | Cd-t | Cu-d | Cu-t | Fe-d | Fe-t | Mn-d | Mn-t | Pd-d | Pd-t | Zn-d | Zn-t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stream samples** | | | | | | | | | | | | | | | |
| 0 | FG00 | | 55.0 | | | | | | 74.9 | 3.0 | 6.0 | | 1.0 | 8.5 | 10.2 |
| 84 | FG03 | | | | | | | | 19.9 | 2.0 | 4.0 | | 1.0 | 7.3 | 8.1 |
| 234 | FG05 | | | | | | | 8.0 | 24.3 | 2.0 | 4.0 | | | 9.3 | 10.6 |
| 516 | TS02 | | | | | | | | 24.9 | 1.0 | 2.0 | | 1.0 | 15.5 | 14.8 |
| 631 | FG09 | | | | | | | | 23.0 | 2.0 | 4.0 | | 1.0 | 14.1 | 17.4 |
| 744 | FG09d | | | | | | | | 6.4 | | | | | 10.2 | 11.2 |
| 799 | TS03 | | 62.0 | | 1.0 | | | | 69.9 | | 4.0 | | 2.0 | 47.8 | 50.5 |
| 825 | FG17b | | 63.0 | 2.0 | 2.0 | | 1.0 | 6.0 | 82.0 | 60.0 | 67.0 | | 2.0 | 368 | 372 |
| 881 | FG18 | | 72.0 | 4.0 | 4.0 | | | 6.0 | 64.9 | 111 | 119 | | 2.0 | 699 | 704 |
| 981 | FG25 | | 69.0 | 8.0 | 8.0 | | | 13.0 | 88.2 | 302 | 320 | | | 1,570 | 1,570 |
| 1,087 | FG28 | | 81.0 | 8.0 | 8.0 | | 2.0 | 13.0 | 80.7 | 305 | 314 | | | 1,590 | 1,550 |
| 1,161 | TS04 | | 57.0 | 8.0 | 8.0 | | | 9.0 | 93.6 | 289 | 313 | | | 1,520 | 1,560 |
| 1,242 | FG31 | | 68.0 | 8.0 | 8.0 | | | 16.0 | 82.2 | 292 | 307 | | 1.0 | 1,540 | 1,570 |
| 1,356 | FG33 | | 55.0 | 8.0 | 8.0 | | 1.0 | 11.0 | 79.9 | 281 | 308 | | | 1,480 | 1,570 |
| 1,515 | FG35 | | 48.0 | 7.0 | 8.0 | | | 11.0 | 64.5 | 285 | 299 | | | 1,500 | 1,520 |
| 1,651 | TS05 | | | 7.0 | 8.0 | | | 23.0 | 58.2 | 271 | 291 | | | 1,430 | 1,490 |
| 1,751 | FG39 | 76.0 | 55.0 | 11.0 | 12.0 | 2.0 | 1.0 | 34.0 | 77.9 | 809 | 851 | | 1.0 | 3,180 | 3,240 |
| 1,880 | FG50 | | 66.0 | 7.0 | 8.0 | 1.0 | 2.0 | 11.0 | 40.1 | 243 | 266 | | 1.0 | 1,340 | 1,420 |
| 2,080 | FG52 | | 43.0 | 7.0 | 8.0 | | 1.0 | 6.0 | 44.7 | 249 | 270 | | 1.0 | 1,360 | 1,430 |
| 2,150 | FG53 | | 77.0 | 7.0 | 8.0 | | | 19.0 | 51.8 | 237 | 254 | | 1.0 | 1,350 | 1,410 |
| 2,200 | FG55 | | 40.0 | 10.0 | 12.0 | | | 36.0 | 114 | 631 | 667 | 1.0 | 3.0 | 2,980 | 3,060 |
| 2,388 | FG45 | 40.0 | | 9.0 | 11.0 | | | 26.0 | 118 | 603 | 617 | 1.0 | 3.0 | 2,880 | 3,020 |
| 2,536 | TS06 | 43.0 | | 12.0 | 12.0 | 2.0 | 2.0 | 53.0 | 204 | 1,090 | 1,120 | | 5.0 | 4,510 | 4,740 |
| 2,540 | FG46 | 44.0 | | 3.0 | 4.0 | | | | 61.2 | 14.0 | 18.0 | | 2.0 | 647 | 702 |
| **Inflow samples** | | | | | | | | | | | | | | | |
| 333 | FG06 | | | | | | | | 26.8 | | 2.0 | | 1.0 | 13.6 | 14.8 |
| 530 | MW9 | | | 1.0 | 9.0 | | | | | | | | | | |
| 694 | FG09b | | | | | | | | 8.2 | | | | | 8.1 | 11.2 |
| 695 | FG09c | | | | | | | | 39.8 | | 2.0 | | 1.0 | 16.9 | 17.0 |

**Appendix 5.** Concentration of metals in water from synoptic sampling sites along French Gulch, Colorado, July 26, 1996—Continued

| Dist | Site | Al-d | Al-t | Cd-d | Cd-t | Cu-d | Cu-t | Fe-d | Fe-t | Mn-d | Mn-t | Pd-d | Pd-t | Zn-d | Zn-t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Inflow samples—Continued** | | | | | | | |
| 745 | FG10 | | 119 | | 1.0 | | | | 136 | | 7.0 | | 3.0 | 37.2 | 58.5 |
| 769 | FG12 | | | 0.0 | 1.0 | 1.0 | | 7.0 | 48.4 | | 4.0 | | 1.0 | 76.2 | 79.8 |
| 784 | FG13 | | 127 | 1.0 | 1.0 | | | | 183 | | 15.0 | | 5.0 | 122 | 135 |
| 812 | FG16 | | | 20.0 | 18.0 | | | | 38.8 | 5.0 | 8.0 | | | 5,410 | 5,080 |
| 813 | FG16b | | | 2.0 | 2.0 | | | 61.0 | 115 | 297 | 311 | | | 641 | 637 |
| 814 | FG16c | | | 10.0 | 11.0 | 1.0 | 3.0 | 60.0 | 122 | 466 | 458 | | | 2,140 | 2,000 |
| 840 | FG19 | | | 21.0 | 20.0 | | | 10.0 | 15.8 | 3.0 | 4.0 | | 1.0 | 5,620 | 5,550 |
| 840 | FG15 | | 278 | 76.0 | 76.0 | 4.0 | 8.0 | 55.0 | 637 | 3,480 | 3,450 | | 3.0 | 16,300 | 15,800 |
| 857 | FG22 | | | 3.0 | 3.0 | | | | | 92.0 | 97.0 | | | 2,020 | 2,000 |
| 1,073 | FG27 | | | | | | | 31.0 | 277 | 134 | 183 | | | 7.3 | 10.8 |
| 1,266 | FG32 | | 210 | 5.0 | 6.0 | | | | 183 | 12.0 | 37.0 | | 2.0 | 1,040 | 1,100 |
| 1,605 | FG36b | | | 4.0 | 5.0 | | | 9.0 | 13.9 | 13.0 | 14.0 | | | 737 | 750 |
| 1,701 | FG38 | 58.0 | 58.0 | 121.0 | 130.0 | 13.0 | 14.0 | 182 | 201 | 15,300 | 17,100 | 24.0 | 21.0 | 43,900 | 47,200 |
| 1,980 | FG51 | | | 3.0 | 4.0 | | | 12.0 | 20.7 | 12.0 | 14.0 | | | 470 | 487 |
| 2,150 | FG54 | | 131 | 12.0 | 13.0 | 1.0 | 1.0 | 48.0 | 154 | 832 | 922 | 2.0 | 5.0 | 3,740 | 3,990 |
| 2,400 | FG44 | | | 25.0 | 31.0 | | | 178 | 1,030 | 5,010 | 5,400 | 4.0 | 17.0 | 17,100 | 18,000 |
| 2,422 | FG56 | | | 17.0 | 20.0 | | | 159 | 420 | 2,360 | 2,320 | 1.0 | 8.0 | 8,640 | 8,640 |
| | | | | | | | | **Bullhide Fault surface flow** | | | | | | | |
| 1,826 | FG39b | | | 16.0 | 17.0 | | 2.0 | 428 | 929 | 1,510 | 1,600 | | 14.0 | 5,930 | 6,150 |
| 1,869 | FG40 | | | 14.0 | 13.0 | | 1.0 | 196 | 427 | 1,470 | 1,520 | | 6.0 | 5,400 | 5,400 |
| 1,920 | FG41 | | 54.0 | 13.0 | 14.0 | | | 122 | 374 | 1,310 | 1,360 | 1.0 | 6.0 | 4,910 | 4,960 |

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