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

Preliminary Report on Water Quality Associated with the Abandoned Fontana and Hazel Creek Mines, Great Smoky Mountains National Park, North Carolina and Tennessee

by

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ABSTRACT

This report presents water quality data for samples collected in September, 1994, September, 1996, and June, 1997 in Great Smoky Mountains National Park from the areas around the abandoned Fontana and Hazel Creek mines in North Carolina, and the upper reaches of the West Prong of the Little Pigeon River in Tennessee. Data include temperature, pH, specific conductance, dissolved oxygen, alkalinity, flow, total acid soluble and dissolved major and trace element concentrations. Data are interpreted in terms of their impact on the surrounding environment with enumeration of remediation options around the mine sites.

STATEMENT OF PROBLEM

The U. S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), initiated a study of the factors that affect water quality associated with the abandoned Fontana and Hazel Creek mines in Great Smoky Mountains National Park in 1996. The USGS also conducted reconnaissance sampling in 1994. The goals of the research were to (1) assess the quality of water within the abandoned mine workings; (2) assess the environmental impact of waters issuing from the abandoned mines and surrounding country rock; and (3) suggest options for remediation of the sites.

Acid-mine drainage is produced by the weathering and oxidation of pyrite and other heavy-metal sulfide ore minerals in surficial environments. Acid drainage can also occur naturally from weathering of pyrite-bearing rocks such as the Anakeesta Schist found in the park. A key aspect of the evaluation of the environmental impact of acid-mine drainage is the comparison of acid-mine drainage with naturally occurring acid-rock drainage associated with the weathering of the Anakeesta Formation. Any remediation efforts directed at mine drainage should consider the natural background water composition in the watershed as a reference.

In some cases, acid-mine drainage problems are naturally mitigated. Dilution of acidic, heavy metal laden streams by inflowing tributaries can quickly attenuate acid mine drainage problems. Heavy-metal concentrations and acidity can be diluted below toxic levels over short distances. Likewise, reducing environments such as natural wetlands can strip heavy metals from acidic drainage by precipitating heavy-metal sulfide minerals.

PREVIOUS WORK

To date, no published reports are available on water quality associated with the abandoned Fontana and Hazel Creek mines. However, several studies have investigated various aspects of water quality associated with drainage from watersheds underlain by the Anakeesta Schist, and water quality issues related to acid deposition. Abernathy and others (1984) studied the heavy-metal concentrations of surficial sediments in Fontana Lake. Samples from the mouths of the Eagle Creek and Hazel Creek watersheds which host the Fontana and Hazel Creek mines contain elevated zinc and copper concentrations relative to other parts of the lake. Lesure and others (1977) reported geochemical data for stream sediments, soils, and forest litter (ash) from the Fontana and Hazel Creek mine areas. Flohr and others (1995) identified a number of secondary minerals at Alum Cave, which form from the evaporation of ground waters in the sheltered environment of Alum Cave. When wetted by heavy rains, these secondary salt minerals readily dissolve and release acid and heavy metals to the watershed. Similar salts have been identified along the Road To Nowhere. Southworth (1995) mapped the distribution of pyritic rocks in the southern part of the park around the mines. Schultz (1998) mapped the distribution of pyritic rocks and landslides in the Mount Le Conte quadrangle. Flum and Nodvin (1995) and Nodvin and others (1995) investigated the effects of acidic atmospheric deposition on the Great Smoky Mountains ecosystem. Numerous workers have investigated acid drainage generated by road construction in the Anakeesta Formation (Huckbee and others, 1975; Bacon and Maas, 1979; Mathews and Morgan, 1982; Kucken and others, 1994; Byerly, 1996; Schaeffer and Clawson, 1996).

GEOLOGICAL SETTING

The bedrock geology of the Great Smoky Mountains National Park is dominated by metamorphosed sedimentary rocks of the Ocoee Supergroup, which is between 1 billion and 545 million years old (Fig. 1; King and others, 1964). From oldest to youngest, the supergroup consists of the Elkmont Sandstone, the Thunderhead Sandstone, the Anakeesta Formation, the Copper Hill Formation, and the Wehutty Formation (Southworth, 1995). Also, in the Cades Cove area are exposures of the 475 million year old (Ordovician) Jonesboro Formation (Fig. 1). The rocks of the park represent a number of fault blocks which are bound by faults that dip shallowly to the southeast (Southworth, 1995).

From an acid-drainage perspective, some of the most important attributes of the rock units are their acid-buffering (neutralization) and acid-generating capacities. These characteristics are best assessed through the mineralogy and lithogeochemistry (rock chemistry) of the units. Limestone and dolomite units such as the Jonesboro Formation have high acid-buffering potential, but because of their limited geographic extent, they have little effect of the overall water quality of the park. Quartz-rich units such as the Elkmont Sandstone and the Thunderhead Sandstone may be considered generally inert, non-reactive units with respect to acid buffering and generation. However, it is important to realize that on a local scale, these units may contain narrow horizons that may be acid neutralizers or acid generators.

Shale units and the metamorphosed equivalents, such as the Anakeesta Formation and parts of the Copper Hill and Wehutty formations, have extremely low acid-buffering capacity. Other important aspects of the Anakeesta, Copper Hill, and Wehutty formations are that they contain trace amounts of pyrite and pyrrhotite (iron-sulfide minerals) and metamorphosed organic matter, which imparts a black color to the rocks. The weathering of pyrite from these rocks is a significant source of acid. The ancient environment on the ocean floor where these sediments were deposited was anoxic (oxygen-poor) which promoted the accumulation of organic matter and the formation of pyrite in the sediments. This reducing environment is also conducive to enrichment of the sediments in heavy metals such as copper, lead, zinc, and cadmium, among others. In turn, these may be reflected in the modern ground and surface waters that weather these rocks. Copper-rich massive sulfide deposits such as those at the Fontana and Hazel Creek mines and at Ducktown, TN to the southwest also form in this type of environment. The Fontana and Hazel Creek mines are hosted by shaly portions of the

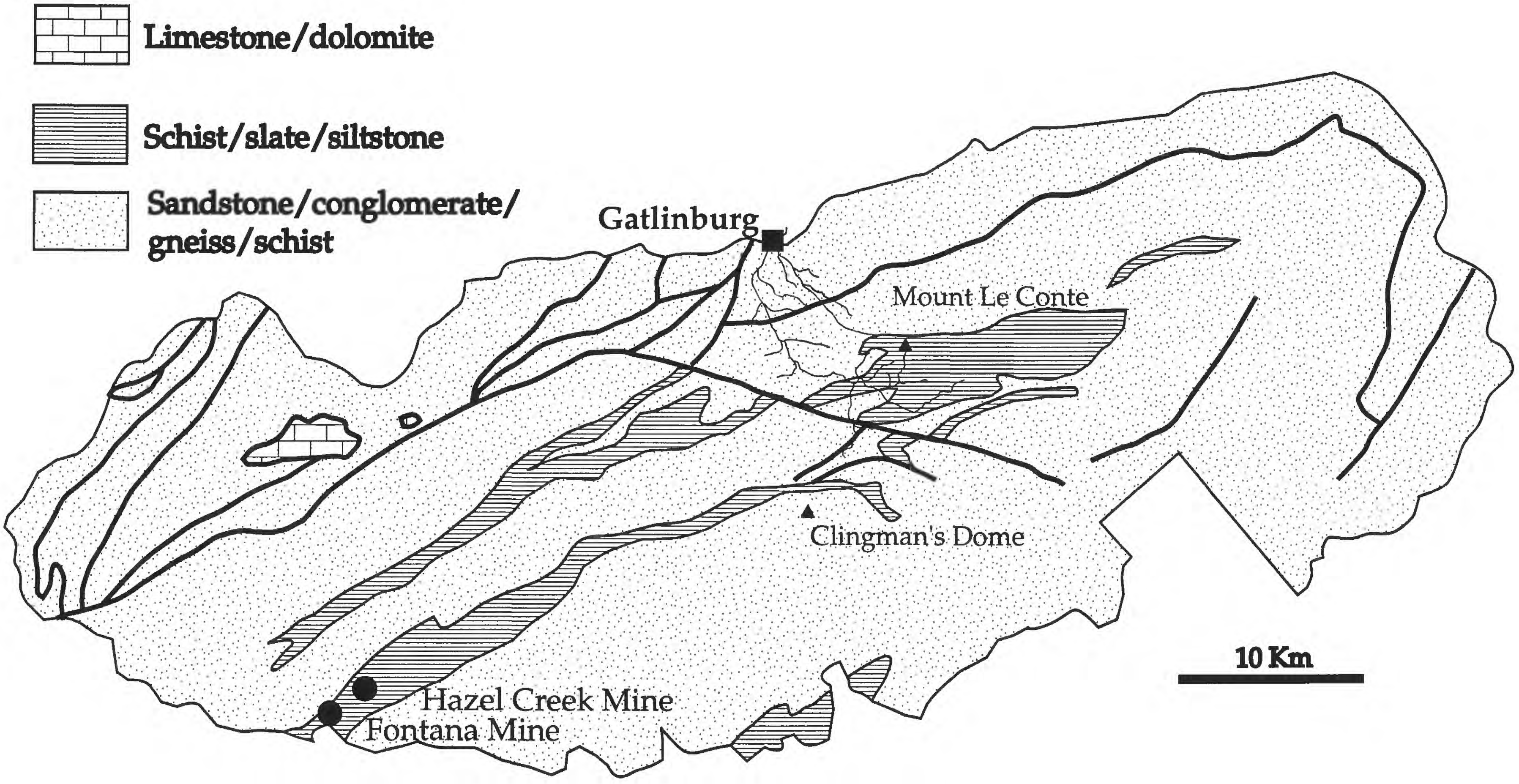

Figure 1. Lithogeochemical map of the Great Smoky Mountains National Park showing the distribution of various rock types. Heavy lines are faults. The location of the West Prong of the Little Pigeon River is shown for reference. Modified from Southworth (1995).

Copper Hill Formation. Thus, ground and surface waters around the mines would be expected to have naturally elevated acidity and heavy-metal contents relative to waters draining sandstone or carbonate rocks in the Park. For the Anakeesta Formation, in particular, a thin regolith develops on the rock and high rainfall events have historically resulted in debris flows on the steep slopes underlain by the unit. The exposure of fresh rock during debris flows serves to enhance naturally the generation of acid from these rocks.

MINERAL DEPOSITS

There are over 100 inactive or abandoned mines and prospects in the southern Appalachians near the Great Smoky Mountains National Park. These sites represent a number of different types of mineral deposits, and produced a variety of different commodities including copper, zinc, lead, silver, and gold. The Fontana and Hazel Creek deposits within the southern boundary of the park (Figs. 1 and 2) are classified as massive sulfide deposits because they are sheet-like bodies dominated by greater than 50 % heavy metal sulfide minerals such as pyrrhotite ($Fe_{1-x}S$), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), sphalerite (ZnS), and galena (PbS). The deposits are enclosed within thick sequences of metamorphosed sedimentary or volcanic rocks. These types of deposits have the potential to adversely affect water quality for two reasons: (1) they contain high concentrations of sulfide minerals that can readily oxidize and decompose on weathering to produce sulfuric acid that is enriched in heavy metals, and (2) the rocks around the deposits typically have limited ability to neutralize the acid. The mineral deposits around Ducktown, TN are geologically similar to the Fontana and Hazel Creek deposits.

Both the Fontana and the Hazel Creek deposits are deeply weathered. So any primary sulfide ore minerals that were once at the earth's surface are oxidized and decomposed. What remains at the surface is a reddish-brown cap of iron-oxide minerals called a gossan. The minerals in the gossan, dominantly goethite and quartz, represent the weathered remnants of the sulfide ores. The unweathered primary sulfide ore lies below the surface, underneath the gossan. An intermediate zone develops between the gossan and the primary ore; this intermediate zone of secondary enrichment is called the supergene zone. It forms as the primary sulfide ore weathers and reacts with ground water. As sulfide minerals dissolve at the surface, copper can leach downward and react to form new copper-bearing minerals. The supergene zone can be as much as 3 meters thick and can contain very high-grade ores. Over time, fluctuations in the water table and in climatic conditions will cause the weathered zones to affect more of the underlying primary ore.

The Fontana mine, also known as the Eagle Creek mine, was discovered by the Montvale Lumber Company between 1900 and 1926. It was in production from 1926 to 1944. During that time, the mine produced 529,350 metric tons of ore that averaged 7% copper, 2% zinc, 14 g/t silver, and 0.28 g/t gold (Feiss and others, 1991). The mine is located along the southern edge of the park, 2.8 miles northeast of Fontana Dam. The mine was developed by underground workings that extend to a depth of about 520 m below the surface. The workings followed an elongated lens of ore that pinches and swells in thickness along a strike length of about 140 m. The ore lens ranges in thickness from 1 to about 6 meters.

The primary ore is dominated by pyrrhotite with lesser amounts of chalcopyrite, sphalerite, galena, pyrite, and the iron-oxide mineral magnetite (Fe_3O_4). The non-ore minerals associated with the deposits are dominated by chlorite, quartz, feldspar, talc, and ankerite and lesser amounts of calcite, biotite, muscovite, among others (Ross, 1935). Ankerite is an iron-rich variety of the carbonate mineral dolomite. Above the unweathered portion of the deposit in the supergene zone of secondary enrichment, the mineral chalcocite (Cu_2S) dominates with minor amounts of other copper minerals such as native copper, cuprite, aurichalcite, and chrysocolla. Pyrrhotite is completely leached out of the supergene zone; small patches of chalcopyrite and pyrite survived the alteration process, and some sphalerite remains. The gossan at the Fontana mine is less-developed than the gossan at the Hazel Creek mine because the Fontana mine is along the bottom of a ravine and therefore less exposed to weathering. Modern weathering of the Fontana deposit that contributes to the water quality of the mine waters and surrounding surface waters includes interactions with unmined primary ore, unmined supergene ore, and pyritic country rocks. Ore was processed off-site and there is no evidence of solid-mine waste on the site. The area is completely revegetated.

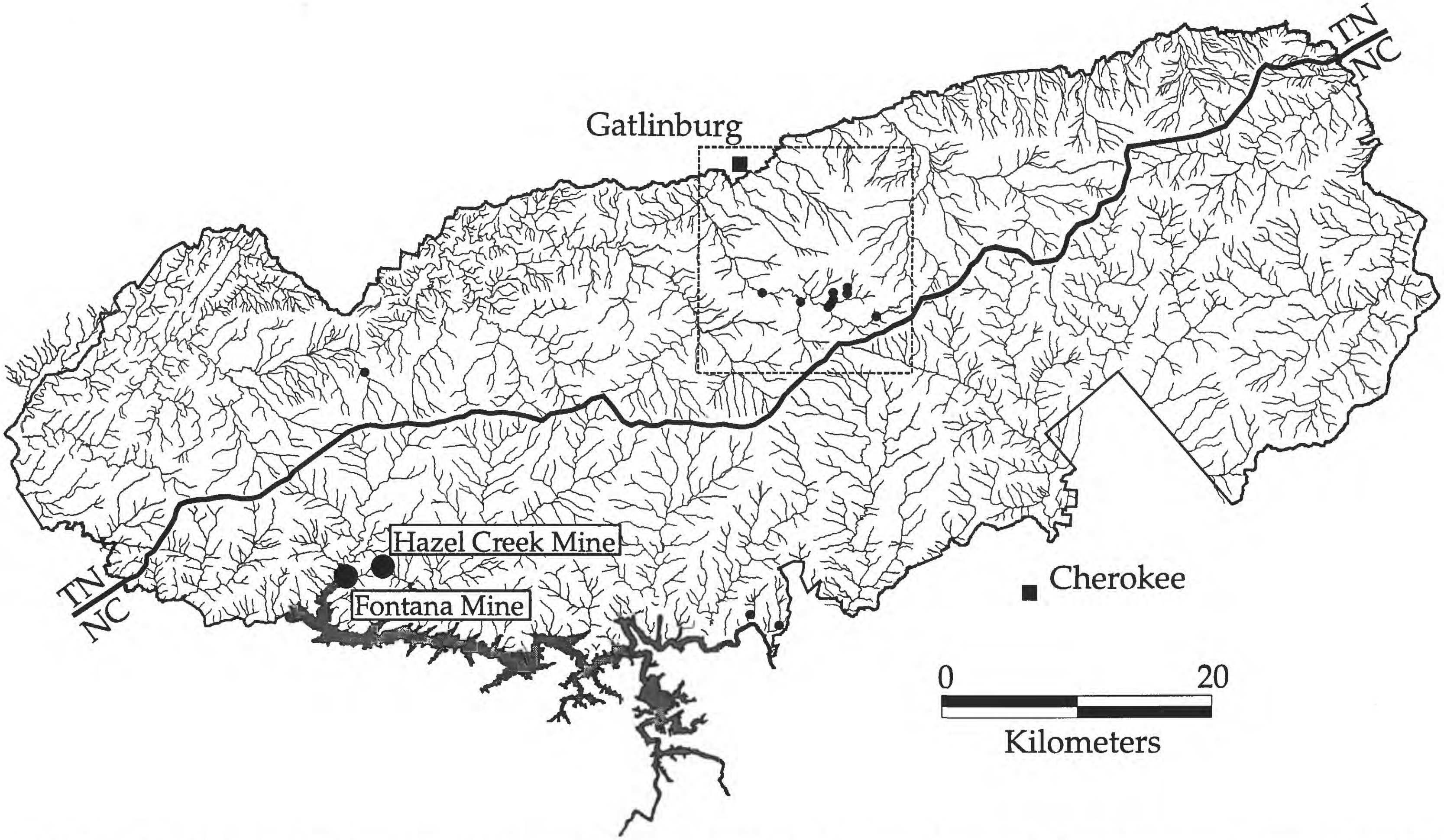

Figure 2. Map showing streams within Great Smoky Mountains National Park. Fontana Lake is the gray area at the southern boundary of the park. The locations of the Fontana and Hazel Creek mines and sample sites (small filled circles) are shown for reference. Dashed rectangle marks area of Figure 3.

The Hazel Creek mine, also known as the Everett, Adams, or Sugar Fork mine, was opened in 1900. The mine operated intermittently between 1900 and 1944, but no ore shipments were reported until 1943-1944 when records indicate that 14 metric tons of ore averaging 3.23 % copper and 3.25% zinc were produced (Espenshade, 1963, and unpublished data). Ore reserves from exploration prior to the 1943 mining indicated that the deposit contained 15,400 metric tons of high-grade ore averaging 3.0 to 3.5% each of copper and zinc and an additional 29,000 metric tons of low grade-ore averaging to 1.7 % combined concentrations of copper and zinc (Espenshade, 1963). The Hazel Creek mine is on a tributary of the Sugar Fork of Hazel Creek.

The Hazel Creek mine explored a pipe-shaped orebody that followed a fold in the host rocks. The orebody plunges towards the southwest. The 1 to 2 m thick high-grade lenses can be followed down-plunge for distances of 20 to 60 m. The low-grade ore zones are narrow sulfide-rich veinlets between the massive sulfide lenses that probably formed when sulfide minerals were remobilized during deformation. The major sulfide minerals in the Hazel Creek ore are chalcopyrite, sphalerite, and galena. Pyrrhotite, the major sulfide mineral at the Fontana mine, is present throughout the Hazel Creek orebody in minor amounts. The supergene enrichment zone is dominated by chalcocite. The mineralogy of the gossan zone is dominated by quartz and hydrous iron-oxide minerals, such as goethite. The lead-sulfate mineral, anglesite ($PbSO_4$), has also been identified in the gossan zone. Ore from the Hazel Creek mine included 600 tons of high-grade ore mined from the supergene zone in 1943 that averaged 12.5 % copper and 3.5 % zinc. Modern weathering of the Hazel Creek deposits that contributes to the water quality of the mine waters and surrounding surface waters includes interactions with unmined primary ore, unmined supergene ore, and pyritic country rocks. Significant tailings piles are also present at the site, the weathering of which also affects to the local water quality.

WATER QUALITY

Sample Sites

To date, 49 water samples have been analyzed from the Great Smoky Mountains National Park (Figs. 2 to 5). Sample collection and analysis methodologies are described in Appendix 1. Brief descriptions of the sample sites are found in Appendix 2. These data include samples of mine waters (15) and streams around the mines (11), Fontana Lake (3), drainages along the Road To Nowhere in the southern part of the park (2), the head waters of the West Prong of the Little Pigeon River and its tributaries (16), and several miscellaneous streams elsewhere in the park (2). The samples in and around the mine were collected to characterize the mine waters and their immediate impact on the local ecosystem (Figs. 4 and 5). The samples from drainages away from any known mines were collected to characterize the natural background in unmineralized rock. At each site, two splits were collected for cation analysis; one split was unfiltered and the other split was filtered through either a 0.22 or 0.45 µm filter. The collection of two splits was done to assess qualitatively the transport of heavy metals adsorbed on fine-grained suspended particulate matter.

In the vicinity of the Fontana mine, water samples were collected from 12 sites which included 5 sites from the underground mine workings, 6 samples of stream and lake waters, and one sample of the only identifiable effluent (seep) from the mine workings (Fig. 4). Mine waters included the water filling the main shaft, large and small ponded bodies of water, and drip waters from hydrous iron-oxide stalactites growing within the mine workings. Surface waters included samples from the small stream that flows past the mine, both upstream and downstream of the workings, an adjacent stream, and Fontana Lake near the mouth of the stream that flows past the mine. Only one site of surface water discharge was identified and was volumetrically insignificant. The discharge came from the lowest portal at the mine.

In the vicinity of the Hazel Creek mine, water samples were collected at 7 sites which included 6 sites from the mine workings, and one site downstream from the workings (Fig. 5). Mine waters included the water filling the main shaft, large and small ponded bodies of waters, and drip waters from hydrous iron-oxide stalactites growing within the mine workings. Samples of waters

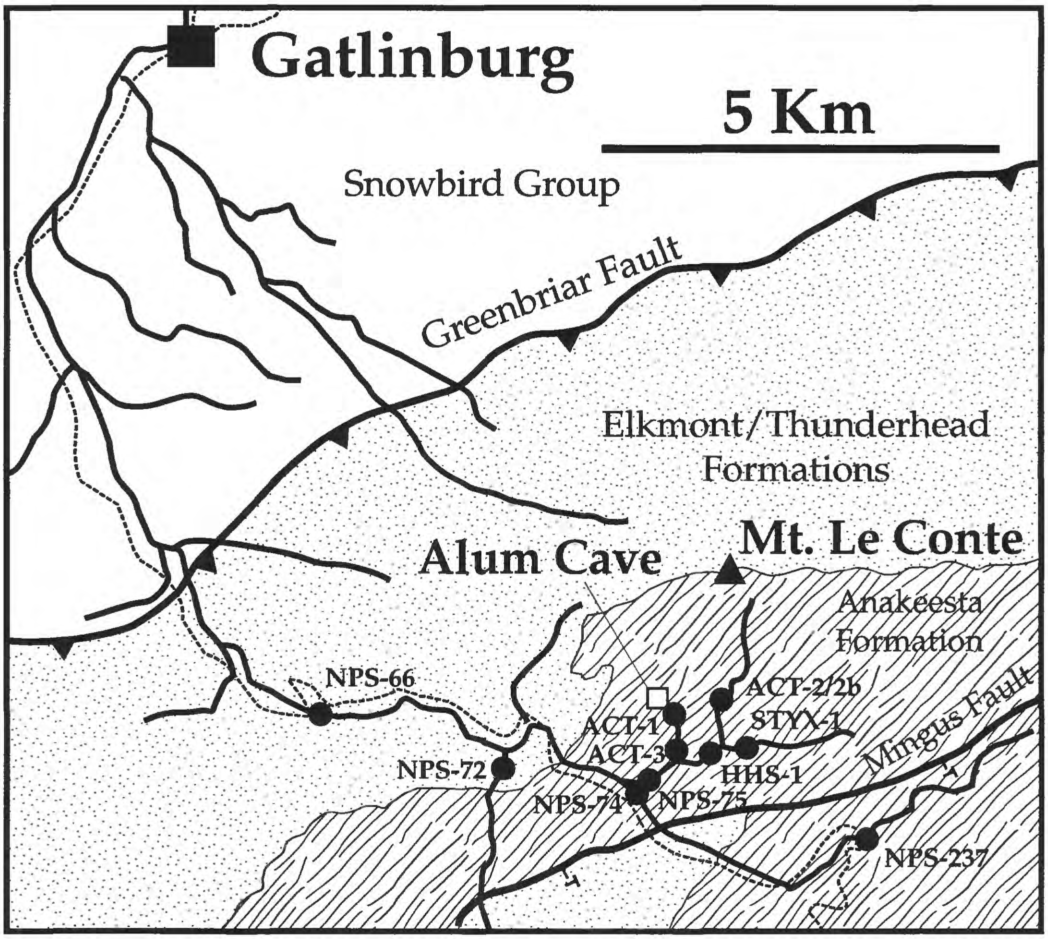

Figure 3. Location of water samples along the upper reaches of the West Prong of the Little Pigeon River. Naturally acid-producing pyritic rocks are found dominantly in the Anakeesta Formation. Newfound Gap Road is dashed. Modified from Schultz (1998).

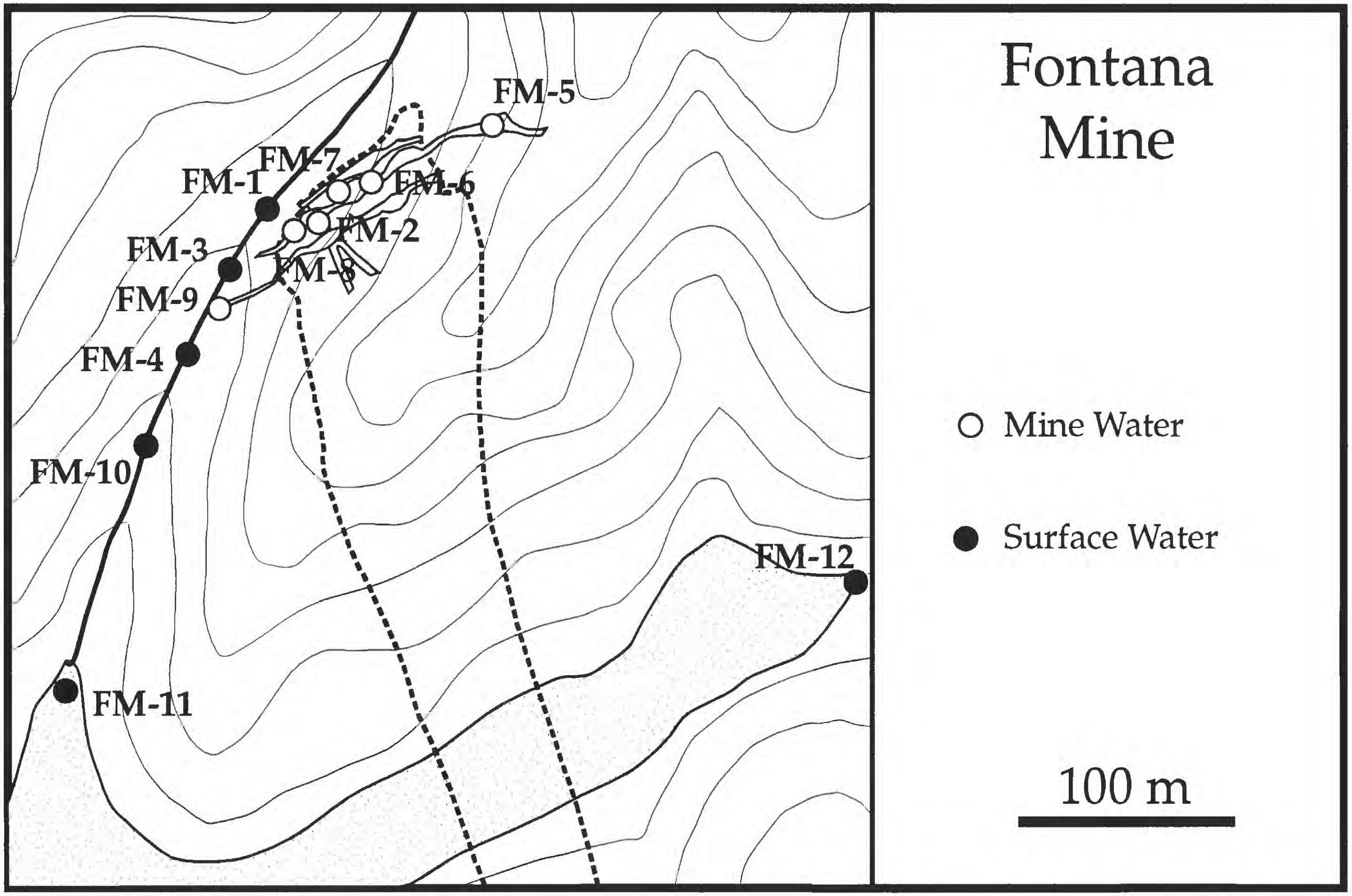

Figure 4. Map showing distribution of water samples from around the Fontana Mine site. Patterned area is Fontana Lake. Dashed area represents the surface projection of the mine workings. The upper levels of the mine workings are shown by solid lines. Contour interval is 40 feet.

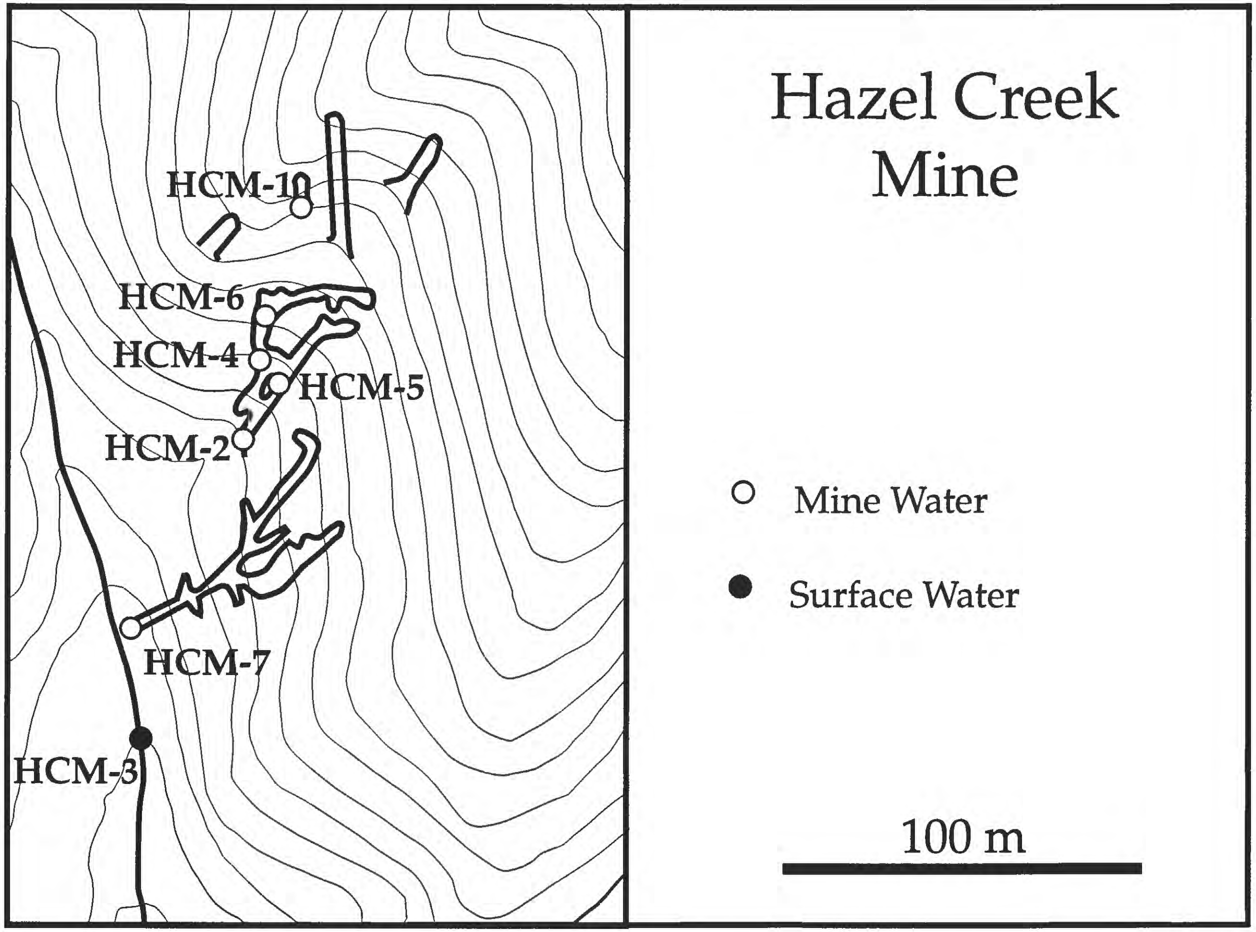

Figure 5. Map showing distribution of water samples from around the Hazel Creek Mine site. Mine workings are shown as heavy lines. Contour interval is 40 feet.

were taken from included the small stream that flows by the mine downstream of the workings. Only one site of surface water discharge was identified and was volumetrically insignificant. The discharge came from the lowest portal at the mine.

Results

A general comparison of water quality among samples from the Fontana mine, the Hazel Creek mine, streams nearby the mines, streams away from any known mineralization, and Fontana Lake can be made by examining data presented in Table 1. Complete analyses of all water samples are presented in Appendix 3. The waters within the mine workings generally show considerable range in values. The most extreme values of pH and dissolved constituents are found in the workings of the Fontana mine. The pH reached a minimum of 2.4. Dissolved sulfate ranged up to 11 g/L. Maximum values for iron (2.6 g/L), aluminum (0.14 g/L), copper (0.29 g/L), zinc (0.43 g/L), and total base metals (copper + zinc + nickel + cobalt + cadmium + lead = 0.72 g/L) are all high (Figs. 6 to 8). The water quality within the workings of the Hazel Creek mine are less extreme than that of the Fontana mine, but still well above regulatory standards. The lowest observed pH value was 3.7 from the Hazel Creek mine. The maximum dissolved concentrations from the Hazel Creek mine for sulfate (150 mg/L), iron (7.8 mg/L), aluminum (3.3 mg/L), copper (16 mg/L), zinc (11 mg/L), and total base metals (27.6 mg/L) range from 333 to 18 times more dilute than the maximum concentrations from the Fontana mine (Figs. 6 to 8). Only the maximum concentration of lead is higher from the Hazel Creek mine (0.62 mg/L) than that from the Fontana mine (0.38 mg/L). The total solubility of lead may be controlled by the solubility of the lead-sulfate mineral, anglesite ($PbSO_4$), which has been identified in the gossan zone at the Hazel Creek mine. Thus, higher lead concentrations would be expected in waters with lower sulfate concentrations. In this regard, the sulfate concentration of the most dilute mine water in the Fontana mine (270 mg/L) is higher than the sulfate concentration of the most concentrated mine water from the Hazel Creek mine (150 mg/L). This is consistent with anglesite controlling lead concentrations. For both mines, alkalinities are low (<0.1 mg/L $CaCO_3$) and hardness values are variable (Table 1).

Surface-water effluent has only been identified at one place from each mine. In general, the pH of the effluent (4.5 to 6.2) is higher than that of the mine waters. The concentrations of dissolved sulfate (17 to 37 mg/L), aluminum (<6 to 1,400 µg/L), iron (14 to 270 µg/L) and total base metals (0.4 to 7.1 mg/L) are lower than the associated mine waters.

The water quality of streams which drain watersheds dominantly underlain by the Anakeesta and Copper Hill formations away from any known mineral deposits is highly variable. The pH values range from 4.0 to 7.0. The maximum concentrations of sulfate (10 mg/L), copper (2.2 µg/L), zinc (21.0 µg/L), and lead (0.32 µg/L) are considerably less than those for the mine waters. The maximum concentrations of iron (6.2 mg/L) and aluminum (1.2 mg/L) are also lower, but the disparity with mine waters is much less (Table 1). In general, the alkalinities of these streams are low (<5.4 mg/L $CaCO_3$) which limits their acid-neutralizing capacity. In addition, the waters also are very soft (hardness <10 mg/L $CaCO_3$) which enhances the toxic effects of heavy metals on aquatic life.

The water quality of streams near the mines, both upstream and downstream of the mine workings, is variable. The pH ranges from 5.5 to 7.8. In general, the concentrations of dissolved constituents are intermediate between those of the mine waters and those of the streams away from known mining activity. The most notable exceptions to this generalization are that the maximum concentration of iron and aluminum in the streams away from the mines (6,200 and 1,200 µg/L, respectively) are higher than those for the streams near the mines (47 and 18 µg/L, respectively). Presumably, this exception reflects areas of anomalous, natural "acid-rock drainage" within the Anakeesta Formation away from the mine sites.

Fontana Lake, the ultimate destination of waters draining the mine areas, is near neutral in pH (6.7 to 8.1). Like the streams in the park, it is characterized by low alkalinity (4.0 to 6.4 mg/L

Table 1. Comparison of the Range of Selected Water Quality Parameters for Filtered Samples.

	Fontana Mine		Hazel Creek Mine		Streams Near Mines		Stream Away From Mines		Fontana Lake		Acute Toxicity
	High	Low	High	Low	High	Low	High	Low	High	Low	
pH	3.2	2.4	6.4	3.7	7.8	5.5	7.0	4.0	8.1	6.7	
Sp. Conductance µS/cm	8,230.0	682.0	333.0	38.0	151.5	16.2	46.9	12.3	21.6	19.5	
Dissolved Oxygen mg/L	12.0	8.0	8.0	6.0	11.0	7.0	11.0	0.3	9.0	8.0	
Alkalinity mg/L $CaCO_3$	0.0	0.0	3.0	0.0	9.8	5.3	5.4	0.0	6.4	4.0	
SO_4 mg/L	11,000.0	270.0	150.0	19.0	35.0	1.2	10.0	1.3	1.8	1.3	
Hardness mg/L $CaCO_3$	988.0	94.2	76.0	8.3	56.4	4.1	7.1	0.7	5.9	4.4	
Fe µg/L	2,600,000.0	9.7	7,800.0	0.05	47.0	<0.05	6200.0	<0.05	<0.05		
Al µg/L	140,000.0	8,300.0	3,300.0	<0.01	18.0	1	1200.0	4.6	12.0	2.8	
Cu µg/L	290,000.0	11,000.0	16,000.0	<0.5	150.0	<0.4	2.2	<0.5	0.6	<0.5	0.97*
Zn µg/L	430,000.0	7,500.0	11,000.0	960.0	360.0	<10	21.0	1.0	1.2	0.5	8.73*
Cd µg/L	840.0	9.2	30.0	<0.02	0.7	<0.02	0.1	<0.02	<0.1		0.137*
Pb µg/L	380.0	33.0	620.0	<0.05	5.6	<0.05	0.32	<0.05	0.21	<0.05	2.11*
Total Base Metals mg/L	722.4	18.7	27.6	1.7	0.45	<0.01	0.029	0.001	0.0020	0.0005	

* Criterion Maximum Concentrations were calculated based on the average hardness (4.8 mg/L $CaCO_3$) of the streams away from areas of past mining.

$CaCO_3$) and low hardness (4.4 to 5.9 mg/L $CaCO_3$). Sulfate (1.3 to 1.8 mg/L), aluminum (2.8 to 12.0 µg/L), iron (<0.05 µg/L), and total base metal (0.5 to 2.0 µg/L) concentrations are low. With regards to surface water impacts on the lake from the mines, the composition of lake less than 3 m from the mouth of the small stream that flows past the Fontana mine (sample FM-11-2) is indistinguishable from samples from the center of the lake (FL-1) and the bottom of Fontana Dam (FL-2). This observation suggests that surface-water impacts on the lake are minimal to non-existent because no compositional gradient was observed.

Controls on Water Chemistry

The primary control on the concentration of dissolved constituents is provided by the solids (rocks and minerals) that are sources of these elements. For example, aluminum occurs mineralogically in silicate minerals that comprise the host rocks of the ore deposits. No significant aluminum is found in the ore sulfide minerals. Therefore, for both the mine waters and the streams away from the mines, aluminum is derived from the reaction of acid generated from the weathering of pyrite, or from atmospheric deposition, with the aluminous silicate minerals in the host rocks, such as feldspars, micas, and clays. Because of the single source of aluminum, the aluminous host rocks, the concentration of aluminum in all water samples, regardless of whether they are mine waters or streams, lie on a linear trend that is negatively correlated with pH (Fig. 6a). Likewise, iron is dominantly derived from the weathering of iron-sulfide minerals such as pyrite and pyrrhotite, although minor contributions may come from iron-silicate minerals such as biotite, amphibole, and chlorite, or iron-oxide minerals such as magnetite or hematite. The concentration of iron in all samples is negatively correlated with pH (Fig. 6b). The greater scatter observed at higher pH compared to the data for aluminum probably reflects either minor contributions from iron-silicate minerals and(or) the influence of oxidation and reduction reactions on the solubility of iron.

The base metals, zinc, copper, cobalt, nickel, cadmium, and lead, show a different behavior (Fig. 7). The concentration of total base metals from both mine waters and streams away from the mines show an inverse correlation with pH. However, for a given pH, the mine waters contain more heavy metals than the streams draining pyritic country rocks away from the mines. The same observations hold true for individual heavy metals, such as zinc and lead (Fig. 8). At the mines, the mineralogical sources of heavy metals are dominated by ore-sulfide minerals. Copper, zinc, and lead are the major metals in minerals such as chalcopyrite ($CuFeS_2$), sphalerite (ZnS), and galena (PbS), whereas cobalt, nickel, and cadmium occur as minor elements in the ore-sulfide minerals. In pyritic country rocks such as the Anakeesta Schist, the heavy metals do not occur as discrete heavy-metal minerals. Instead they occur as trace elements in pyrite, which itself is a trace mineral in these rocks, and in rock-forming silicate minerals. Because of the mineralogical differences of the heavy-metal hosts between the mines and the watersheds away from the mines, the reactivity of these minerals and "geoavailability" of these elements is different as well. Ore minerals at the mines such as pyrrhotite, chalcopyrite, sphalerite, and galena are very reactive. In contrast, pyrite is somewhat less reactive, and rock-forming silicate minerals are fairly non-reactive in low-temperature acidic solutions. Thus, this difference in mineralogical reactivity is probably a major control on the differences in dissolved heavy-metal concentrations between these two geochemical settings. Another important factor that may explain these differences is that the ores are significantly enriched in heavy metals compared to the pyritic country rocks. However, it should be noted that the average heavy-metal concentration of "black" shales such as the Anakeesta schist is over 400 mg/kg (Vine and Tourtelot, 1970), which is approximately 10,000 times more concentrated than the most concentrated water samples from watersheds away from the mines.

As noted above, the saturation of mine waters with respect to the lead-sulfate mineral anglesite ($PbSO_4$) and its precipitation appears to be an important control that limits the concentration of lead in the mine waters. Sorption is another important process that can both limit the dissolved concentrations of metal, and aid in the transport of heavy metals away from point sources. The importance of sorption processes to the transport of heavy metals can be assessed qualitatively by

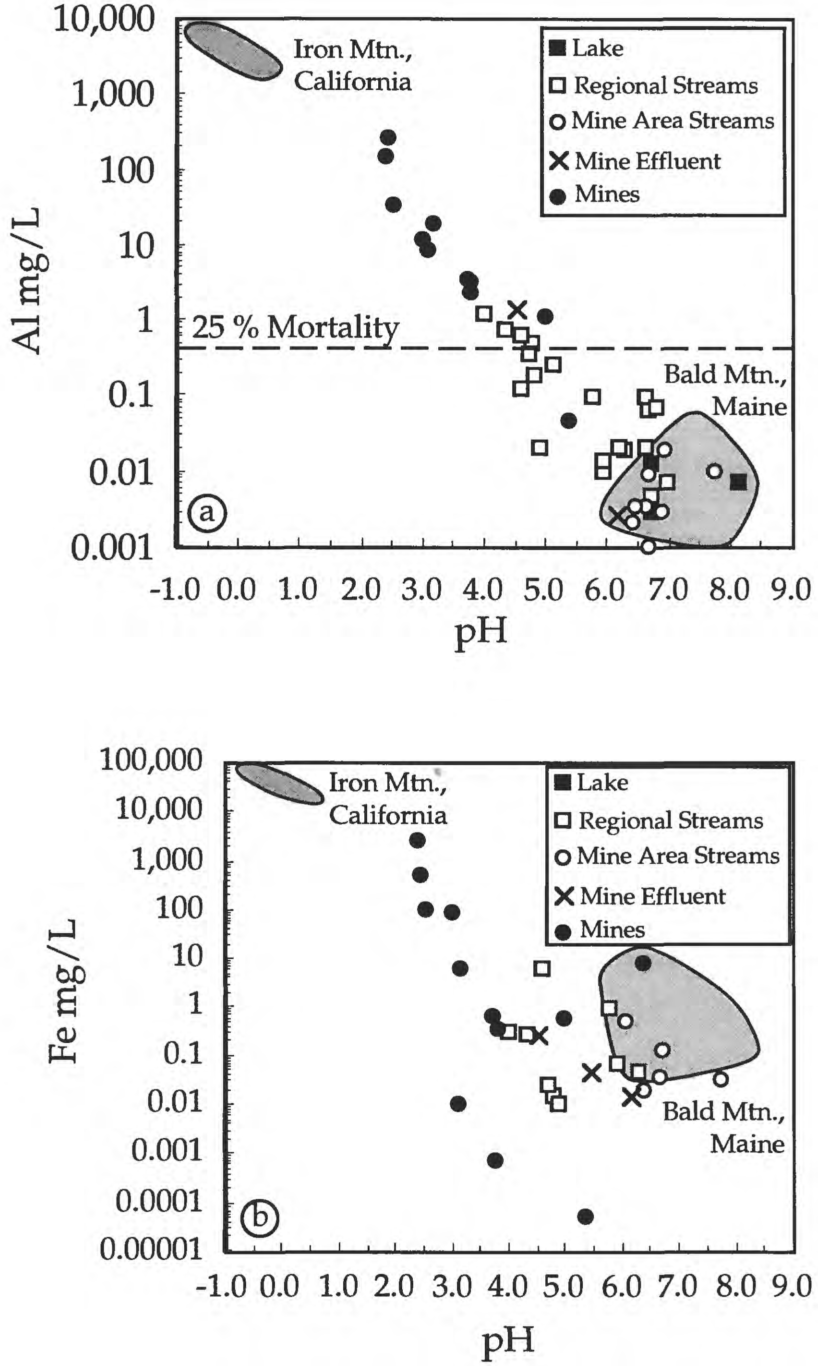

Figure 6. Variation of dissolved metals with pH. Fields for Iron Mountain, California and Bald Mountain, Maine are shown for comparison. a. Aluminum. 25 % Mortality limit for brook trout is from Mount and others (1988); b. Iron.

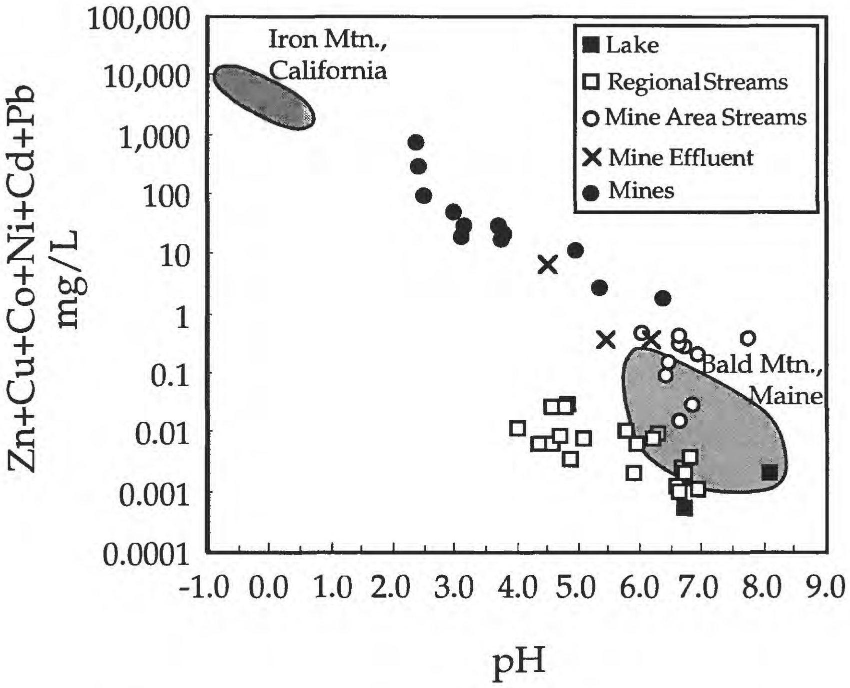

Figure 7. Variation of total dissolved base metals with pH. Fields for Iron Mountain, California and Bald Mountain, Maine are shown for comparison.

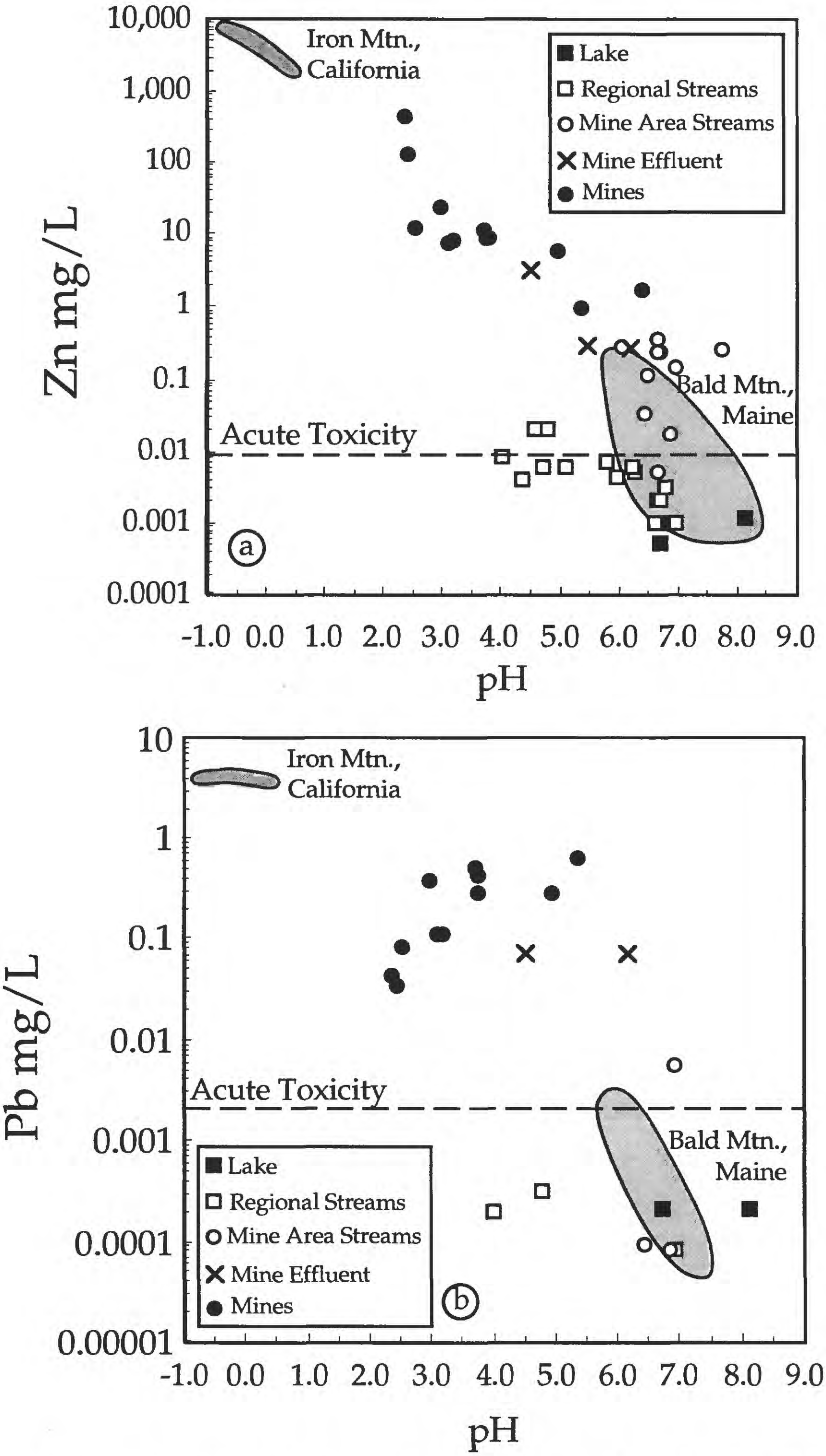

Figure 8. Variation of dissolved base metals with pH. Fields for Iron Mountain, California and Bald Mountain, Maine are shown for comparison. Acute toxicity limits are Criterion Maximum Concentrations (CMC) calculated according to E.P.A. (1996) a. Zinc; b. Lead.

comparing filtered and unfiltered splits of water samples. The filtered split (FA) represents the "true" dissolved composition of the water. (Note that some fine colloids can pass through 0.22 and 0.45 μm filters.) The unfiltered split (RA) represents a combination of both the dissolved composition and the composition sorbed onto particulates suspended in the water. The most common inorganic particulates include aluminous clay minerals weathered from the rock, and hydrous iron oxides and amorphous silica precipitated from the waters. The importance of sorption processes can be assessed by plotting the difference in concentration of a given element in the unfiltered and filtered splits against the filtered concentration of the sample (Fig. 9). In Figure 9, positive "unfiltered - filtered" values indicate samples where particulates are playing an important role. For aluminum and iron, particulates, probably clay minerals and hydrous iron oxides, respectively, appear to be especially important at low concentrations (Fig. 9a, c). Similarly for copper and zinc, sorption onto particulates may be important at low concentrations (Fig. 9b, d). In contrast, sorption onto particulates appears to be important for lead at high concentrations (Fig. 9f).

Comparison with Other Massive Sulfide Deposits

The mine waters of the abandoned Fontana and Hazel Creek mines are best described as "intermediate" in composition when compared to the spectrum of waters associated with other massive sulfide deposits. The two extremes of this spectrum are represented by the Iron Mountain deposit in northern California and the Bald Mountain deposit in northern Maine (Figs. 6 to 8). Iron Mountain is an U.S.E.P.A. Superfund site, from which world-record ultra-low pH values (less than -1) and high total dissolved solids have been documented (Alpers et al., 1994). The extreme conditions at Iron Mountain can be attributed the unique combination of its hydrologic and climatic setting. The bulk of the deposit is located in the unsaturated zone. The area has a distinct wet and dry season and a high mean annual temperature which promotes evaporative concentration of the mine waters. None of these conditions are representative of the southern Appalachian mountains.

Bald Mountain in northern Maine, is the other end of the spectrum. It is a large massive sulfide deposit that was discovered in the late 1970's in an area that has had no historic mining activity. Therefore, ground- and surface-water data from this area represent natural background values. These data are extremely important for assessing the environmental impact of mining by providing a pre-mining perspective on water chemistry. Although Bald Mountain is at a more northerly latitude than the Great Smoky Mountains National Park, the seasonal variations of precipitation should be somewhat analogous to those of the park.

The mine waters of the Fontana and Hazel Creek mines clearly fail to reach the extreme conditions observed at Iron Mountain (Figs. 6 to 8) which would be expected from the differences in the hydrologic and climatic settings. Compared to Bald Mountain (unpublished USGS data), the Fontana and Hazel creek mine waters have lower pH values and higher concentrations in general (Figs. 6 to 8). The most notable exception is the considerable overlap in iron values (Fig. 6b). Interestingly, waters from the streams around the mines are virtually indistinguishable from the Bald Mountain waters as are two of the three samples of mine effluent for most elements. Waters from streams in the park away from the mines have pH values that are much lower than those at Bald Mountain. However, dissolved metals from these streams are indistinguishable from Bald Mountain.

Environmental Impact

The environmental impact of the mine waters from the Fontana and Hazel Creek mines on the surrounding ecosystem should be assessed relative to both modern and pre-mining conditions. Modern conditions are evaluated in a straightforward fashion from available data. However, pre-mining conditions are more problematic. Two approaches to determine this are used in the present study. First, streams were sampled in the park away from areas of known mining activity. In the park, this approach is especially important because the Anakeesta and Copper Hill formations are known natural acid producers. Any attempt to remediate water conditions to arbitrary standards of

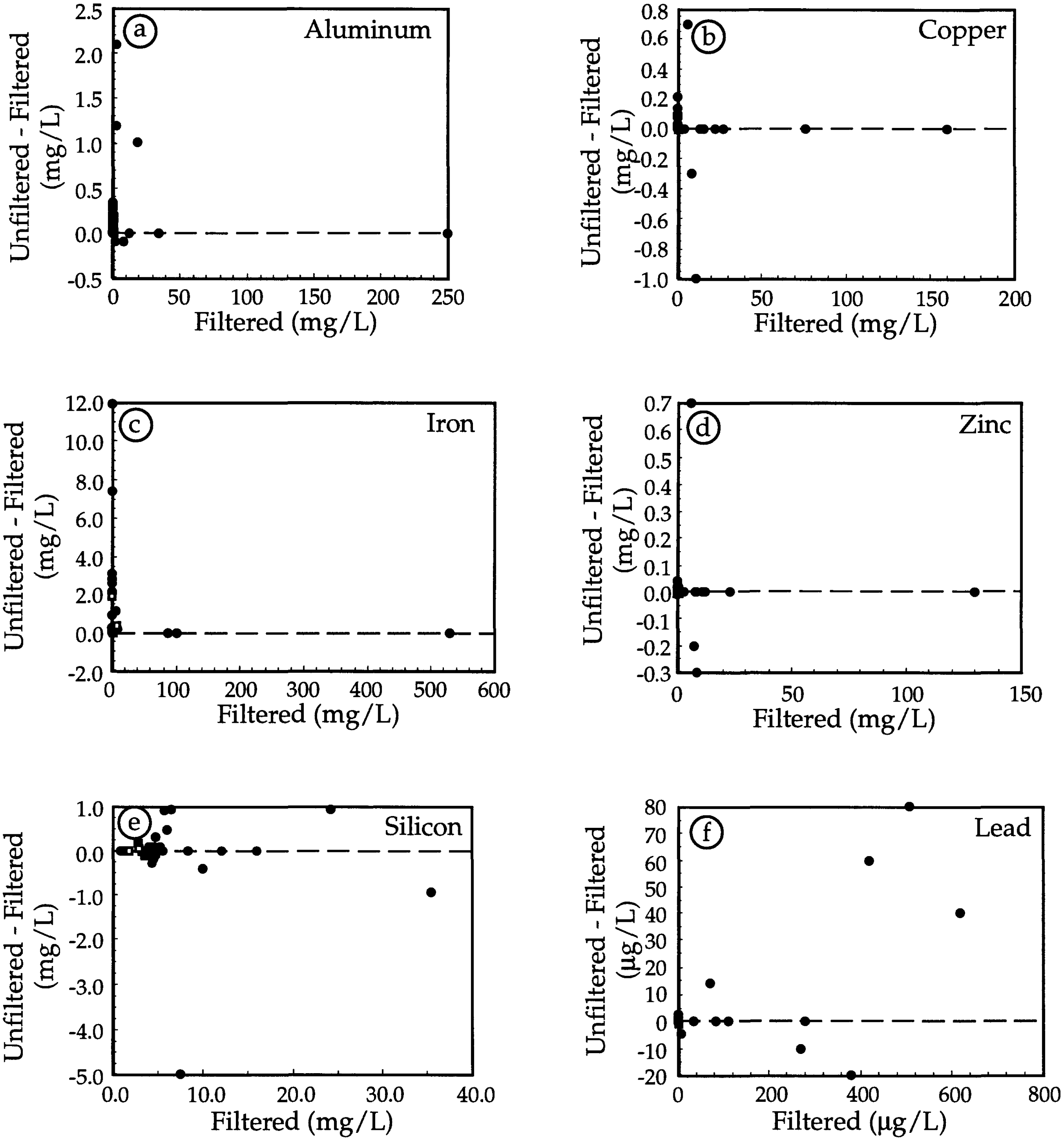

Figure 9. Comparison of data from unfiltered and filtered sample splits. Solid circles are mine waters; open squares are from regional streams. Samples that fall along the dashed horizontal line theoretically carry all of their metals as dissolved constituents. Samples that lie above the line carry a portion of their metals either as particulate matter or sorbed onto particulate matter. The scatter of data below the line presumably reflects the analytical uncertainty in the determinations. Note that all units are mg/L except for f (µg/L).

lower acidity or lower metal concentrations than these waters would disturb the Great Smoky Mountains ecosystem because the ecosystem has been adapting to these conditions for thousands or millions of years.

Second, ground- and surface-water samples around the unmined Bald Mountain massive sulfide deposit in northern Maine provide a reference for natural background conditions around an example of this type of deposit under eastern climatic conditions. Data from Bald Mountain may provide the most accurate perspective on the compositions of pre-mining ground and surface water. The ground surrounding the Fontana and Hazel Creek deposits should have had elevated concentrations of heavy metals which should have been reflected in the composition of pre-mining surface waters draining these areas. Therefore, waters draining watersheds underlain by the Anakeesta Formation away from the mines will probably provide an unrealistically low background for mineralized areas. As with the watersheds underlain by the Anakeesta and Copper Hill formations away from areas of known mining activity, the local ecosystem would have been adapting to these water compositions. Thus, any attempt to alter the local water chemistry away from these baseline conditions would also disturb the natural, pre-mining ecosystem.

With regards to the modern, local ecosystem, the mine waters are clearly elevated in terms of acidity and dissolved constituents relative to the surrounding streams and Fontana Lake. There is also considerable overlap in terms of pH with streams away from known areas of mining (Figs. 6 to 8). However, effluent has only been observed from one point at the Fontana mine and one point at the Hazel Creek mine. The flow rates from both are small (<12 L/minute) compared to flow from the small streams that flow past the Fontana (up to 300 L/minute) and Hazel Creek (as much as 200 L/minute) mines. For pH, the mine effluent overlaps the range defined by watersheds away from the mines; the effluent is slightly more acidic than waters from Bald Mountain, Maine. For most metals, the concentration of the effluent is slightly elevated relative to the concentration in watersheds away from the mines. Two of the three samples of effluent are similar to the natural waters around Bald Mountain.

Dilution of the effluent waters also appears to be an effective, naturally mitigating process. In June 1997, effluent from the Fontana mine was near neutral (6.2) and was rapidly diluted downstream to a pH of 6.7, which was indistinguishable from the lake (Fig. 4). Effluent from the Hazel Creek mine was acidic (4.5), but was rapidly diluted to a near neutral value of 6.5 (Fig. 5). Furthermore, as discussed above, the composition of Fontana Lake at the mouth of the small stream that flows past the workings of the Fontana mine (FM-11-2) was indistinguishable from the composition of the lake at the bottom of Fontana Dam (FL-2) in June 1997, which suggests that the impact of the stream on the lake is minimal to non-existent.

The water quality of ground-water effluent from the mines is difficult to assess. The underground workings of the Fontana mine reach well below the lake, but their greater density due to their high concentration of dissolved solids would tend to make them sink relative to dilute ground waters beneath the lake. Therefore, ground-water input to the lake from the mine workings would qualitatively seem unlikely. In addition, the mine waters of the Fontana mine are near saturation with respect to dissolved oxygen. Flow out of the mine workings through the surrounding aquifer should rapidly reduce the oxidation state of the waters which would tend to strip metals from the solution and naturally mitigate poor water quality.

It is also important to consider the environmental impact in terms of toxicity limits for fresh water aquatic ecosystems. The toxicity of many heavy metals, such as copper, zinc, cadmium, and lead, is increased in waters having low hardness values, such as the waters in the Great Smoky Mountains National Park. For the present discussion, acute toxicity limits (Criterion Maximum Concentrations, as defined by U.S.E.P.A., 1996) were calculated for copper, zinc, cadmium, and lead, assuming a hardness of 4.8 mg/L equivalent $CaCO_3$, which is the average hardness for watersheds away from areas of mining activity in the park. The toxicity of aluminum for brook trout is complex and is related to both pH and dissolved calcium concentrations (Mount and others, 1988). Mount and others (1988) found 25 % percent mortality of adult brook trout in low pH (4.42 to 5.60) waters with greater than 0.407 mg/L aluminum. All mine waters exceed these toxicity limits (Table 1; Figs. 6a, 8a, and 8b). For the mine effluent, the limits are exceeded for zinc and lead for all samples; for aluminum, samples are both above and below the limit (Fig. 6a). The data from the streams away from mining areas are significant because they show that many of the samples naturally exceed the toxicity limits for aluminum (Fig. 6a) and zinc (Fig. 8a). In other words, parts of some of these watersheds may stress higher-order aquatic life. It is important to note that the zinc toxicity limits are generic for freshwater aquatic ecosystems and that individual species within the park may be more tolerant to higher concentrations. All samples of Fontana Lake fall below the toxicity limits.

REMEDIATION OPTIONS

The selection of a remediation option must consider the potential impact on the environment, not only of the existing problem, but also of the potential resulting effects of the remediation option. Key considerations for the Fontana and Hazel Creek mines are that (1) surface-water effluent from the mines has only been identified from one point at each mine; (2) the volume of the effluent from each mine is roughly 5 % of the flow of the stream into which it drains; (3) natural dilution of the effluent by these streams is relatively rapid such that elevated concentrations of heavy metals, sulfate, and acidity were not identified in Fontana Lake near the mouth of the stream that flows past the Fontana mine workings; (4) the composition of the mine effluent is similar to water in streams away from areas of known mining activity; and (5) the composition of mine effluent is similar to natural ground and surface waters around the unmined Bald Mountain massive sulfide deposit in northern Maine.

Numerous remediation options are commonly considered for abandoned massive sulfide mines. The most relevant ones to the Fontana and Hazel Creek mines include the addition of base additives, utilization of covers and caps, and collection and treatment of contaminants. While no specific recommendations are made for the abandoned mines in the park, a brief critique of each option is provided as an aid for National Park Service decision makers. It should also be noted that significant ground instability was noted around the mine sites, especially at the Hazel Creek mine, during the sampling visits, which bears on the physical safety of park visitors. Although no recommendations regarding this aspect of the mine sites are discussed, this issue should also be addressed by decision makers. Remediation options for the mines include, but are not limited to:

1. Limestone neutralization of mine waters;
2. Resource recovery;
3. Ground water interception;
4. Air sealing;
5. Mine plugging;
6. Artificial wetland construction;
7. Combined alternatives; and
8. No Action.

Limestone neutralization of mine waters and resource recovery provide a means of neutralizing acid and removing heavy metals. These options require the treatment of the waters within the workings which do not appear to pose a current threat to the surrounding ecosystem. In higher iron waters, such as those in the Fontana and Hazel Creek mines, limestone amendment eventually can become coated by hydrous iron-oxides which will isolate it from reaction with the mine waters and reduce its effectiveness. Resource recovery may not be cost effective and requires maintenance in perpetuity.

Ground-water inception, air sealing, and mine plugging provide a means of limiting the essential acid-mine drainage ingredients of water and oxygen. Ground-water interception is impractical at the Fontana and Hazel Creek mines because of the significant depths of the mine workings. Air sealing would also prove impractical because of the size of the mine workings. This option would also destroy bat habitats and the landscape. At present, surface water effluent flows from a single point from each mine. Mine plugging could alter greatly the ground-water hydrology of the area and produce multiple point sources at each mine rather than the single point source present today at each mine which appears to have minimal effect on the ecosystem.

The construction of artificial wetlands provides a means of stripping heavy metals and acidity from the contaminated waters. The establishment of wetlands would alter the natural ecology of the mine areas. Furthermore, comparison of the mine effluent and adjacent streams with natural ground and surface waters around the unmined Bald Mountain deposit in Maine suggests that the modern waters around the mines may be quite similar in composition to their pre-mining natural conditions. Combined alternatives are subject to the same inherent problems that affect the individual methodologies.

The "no action" option clearly offers the greatest cost advantage, but may also represent the scientifically soundest alternative because natural processes currently operating at the mines appear to attenuate drainage problems to near "normal" background levels as defined by the data from watersheds away from mining activity within the park, and from the area surrounding the geologically similar, unmined Bald Mountain deposit in Maine. Thus, any attempt to "treat" the effluent from the mines could result in adversely changing the water chemistry of the adjacent streams away from their natural, pre-mining conditions and negatively impact the natural ecology. Note that the physical safety of park visitors around the abandoned mine sites should be evaluated as a separate issue independent of the environmental remediation options.

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APPENDIX 1: FIELD AND ANALYTICAL METHODS

Water samples were collected in one-liter high-density polyethylene bottles that were doubly-rinsed with sample water prior to collection. Samples were divided into four splits for chemical analysis: two for cation analysis, one for anion analysis, and one for alkalinity determination. The cations splits included filtered and unfiltered aliquots. Samples were filtered through 0.45 µm nitrocellulose filters (or 0.22 µm filters as noted in Appendix 3). Cation splits were made and stored at ambient temperature in acid-washed (10 % HCl) high-density polyethylene bottles and preserved with 1 drop of ultra-pure nitric acid per each 10 ml of sample. Anion and alkalinity splits were stored in high-density polyethylene bottles that were not acid-washed and were kept on ice until time of analysis.

On-site measurements at the time of collection included air temperature, water temperature, pH, specific conductance, dissolved oxygen, dissolved ferrous iron, dissolved total iron, dissolved sulfate, dissolved nitrate, and water-flow rate. The pH was measured using an Orion 230A pH meter with a 91-07probe, calibrated with pH = 4.00 and 7.00 buffer solutions. Specific conductance was measured with an Orion 135 specific conductance meter. Dissolved oxygen concentrations were determined with Chemetrix high-range ampoules. Dissolved total iron, ferrous iron, sulfate, and nitrate concentrations were determined in the field using a Hach DR2000 spectrophotometer. Alkalinity samples were analyzed by Gran titration with 0.18 N H_2SO_4.

Cations were analyzed at U.S. Geological Survey (Central Mineral Resources Team) laboratories in Denver, CO, by inductively-coupled plasma mass spectrometry (ICP-MS) and (or) inductively-coupled plasma atomic emission spectrometry (ICP-AES). ICP-MS was extremely useful in this study because of its ability to determine as many as 70 elements directly in the sample with detection limits in the sub-part-per-billion range and linear range of nine orders of magnitude or more without the need for dilution. Calibration for this extensive elemental coverage is accomplished by using a standard containing known concentration of some of the elements across the elemental mass range to construct a response curve for the instrument. By using the response derived curve, the degree of ionization, and the natural isotopic abundance, quantitative estimates of concentration for all elements can be made in samples without the need of a calibration standard for every element. The main limitations of the technique come from drift due to clogging of sampling orifices, changes in ion transfer efficiencies due to sample matrix effects, plasma conditions, nebulizer, or electronics, and isobaric interference from polyatomic or doubly charged ions. Internal standards are used to correct for drift; interference is minimized by selection of isotope used for determination or by mathematical correction. Anions were analyzed at U.S. Geological Survey (Water Resources Division) laboratories in Ocala, FL by ion chromatography (chloride, and sulfate) and by ion-selective electrode (fluoride).

APPENDIX 2: DESCRIPTIONS OF SAMPLE SITES

ACT-1: 35° 38′ 44.5″N; 83° 26′ 35.1′ W ; TN; drip water from rock face along Alum Cave Trail approximately 100 m down hill from Alum Cave. Flow rate = 0.6 L/min.

ACT-2: 35° 38′ 35.7″; 83° 26′ 27.8″; TN; small flow crossing Alum Cave Trail at an elevation of approximately 4600 feet. Flow rate = 6 L/min. Small channel with orange floc joins main channel below the trail. Sample taken below confluence of two channels.

ACT-2b: 35° 38′ 35.7″; 83° 26′ 27.8″; TN; source pool, above trail on east side of debris flow, for small channel with orange floc. Flow rate = 2.5 L/min.

ACT-3: TN; small flow along side of Alum Creek Trail, below Arch Rock and Huggins Hell Slide. Flow rate = 18 L/min.

CCAC-1: 35° 35.654' N, 83° 45.753' W; TN; Anthony Creek, at footbridge above confluence with Maynard Creek; Cades Cove area.

FC-1: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek at high-water line of Fontana Lake .

FC-2: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek just below inflow from adit (FM-9-2).

FC-3: 35° 28.648' N, 83° 45.960' W; NC; Seep on East side of Eagle Creek near small waterfall; above Fontana Lake and below Fontana Mine (same site as FM-9-2).

FC-4: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek 70 m upstream from last fenced adit of Fontana Mine.

FL-1: 35° 26.979' N, 83° 47.3' W; NC; middle of Fontana Lake.

FL-2: 35° 26.788' N, 83° 48.360' W; TN, NC; Tennessee River below Fontana dam at campground; 421 m elevation.

FM-1-1: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek near uppermost fenced entrance to Fontana Mine; flow rate = 20 L/min (same site as FM-1-2).

FM-1-2: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek near uppermost fenced entrance to Fontana Mine; flow rate = 300 L/min (same site as FM-1).

FM-2-1: 35° 28.648' N, 83° 45.960' W; NC; Water in main adit at base of wooden ladder inside lowermost fenced entrance to Fontana Mine (same site as FM-2-2).

FM-2-2: 35° 28.648' N, 83° 45.960' W; NC; Water in main adit at base of wooden ladder inside lowermost fenced entrance to Fontana Mine (same site as FM-2).

FM-3-1: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek at 120 m upstream from seep sample FM-4; near lowermost opening to Fontana Mine.

FM-4-1: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek below seep 40 m upstream from high water mark; floc in stream; Fontana Mine area; flow rate = 25 L/min.

FM-5-2: 35° 28.648' N, 83° 45.960' W; NC; Large pond at far end of Fontana Mine adit.

FM-6-2; 35° 28.648' N, 83° 45.960' W; NC; Water flowing down terrace on west wall of adit; near FM-5-2.

FM-7-2: 35° 28.648' N, 83° 45.960' W; NC; Dark red pool under wooden bench along west wall of Fontana Mine main adit.

FM-8-2: 35° 28.648' N, 83° 45.960' W; NC; Water dripping from stalactite in Fontana Mine adit.

FM-9-2: 35° 28.648' N, 83° 45.960' W; NC; Seep on East side of Eagle Creek near small waterfall; above Fontana Lake and below Fontana Mine (same site as FC-3).

FM-10-2: 35° 28.648' N, 83° 45.960' W; NC; Eagle Creek, below site of sample FM-9-2.

FM-11-2: 35° 28.648' N, 83° 45.960' W; NC; Fontana Lake; near shore with fallen leaves below surface; a few feet East of outlet of Eagle Creek.

FM-12-2: 35° 28.688' N, 83° 46.134' W; NC; Ecoah Branch stream; East of Eagle Creek; green moss on rocks; flow rate = 3500 L/min.

HCM-1-1: 35° 30.001' N, 83° 41.776' W; NC; Stagnant water in main adit of Hazel Creek Mine; 896 m elevation (same site as HCM-1-2).

HCM-1-2: 35° 30.001' N, 83° 41.776' W; NC; Stagnant water in main adit of Hazel Creek Mine; 896 m elevation (same site as HCM-1).

HCM-2-1: 35° 30.001' N, 83° 41.776' W; NC; Pool at adit having bat gate at Hazel Creek Mine; decaying leaves and algae in pool (same site as SUG-1).

HCM-3-1: 35° 30.001' N, 83° 41.776' W; NC; Little Sugar Fork below mine waste at Hazel Creek Mine; 838 m elevation; flow rate = 200 L/min (same site as HCM-3-2; SCLF-1).

HCM-3-2: 35° 30.001' N, 83° 41.776' W; NC; Little Sugar Fork below mine waste at Hazel Creek Mine; 838 m elevation (same site as HCM-3-1; SCLF-1).

HCM-4-2: 35° 30.001' N, 83° 41.776' W; NC; Shallow pool off main adit in Hazel Creek Mine tunnel; red hardpan and floc on bed.

HCM-5-2: 35° 30.001' N, 83° 41.776' W; NC; Water above boards covering main mine shaft; Hazel Creek Mine.

HCM-6-2: 35° 30.001' N, 83° 41.776' W; NC; Drip water from stalactite above main mine shaft; Hazel Creek Mine.

HCM-7-2: 35° 30.001' N, 83° 41.776' W; NC; Adit water on east side of stream at stream level; Hazel Creek Mine; flow rate = 12 L/min.

HHS-1-R1: 35° 38.335' N, 83° 26.285' W; TN; pool among boulders from flow seeping from Huggins Hell Slide, approximately 30 m west of footbridge leading to the bottom of Arch Rock; flow rate = 25 L/min (same site as HHS-R1-2).

HHS-R1-2: 35° 38.335' N, 83° 26.285' W; TN; pool among boulders from flow seeping from Huggins Hell Slide; approximately 30 m west of footbridge leading to the bottom of Arch Rock.

NPS 66: 35° 38.3' N, 83° 29.2' W TN; West Prong Little Pigeon River at footbridge near Chimneys picnic area; 817 m elevation; Mount Le Conte Area.

NPS 72: 35° 37.997' N, 83° 28.190' W; TN; Road Prong just above confluence of Road Prong and Walker Camp Prong; below small falls; Mt. Le Conte area.

NPS 74: 35° 37.753' N, 83° 27.028' W; TN; Walker Camp Prong at bridge on Alum Cave Trail.

NPS 75: 35° 37.792' N, 83° 26.958' W; TN; Alum Creek at bridge on Alum Cave Trail; 50 m from NPS-74; 1164 m elevation.

NPS-237: 35° 37.488' N, 83° 25.017' W; TN; Walker Camp Prong bridge on U.S. 441; 1375 m elevation.

RTN-1: 35° 27.347' N, 83° 29.425' W; NC; drip water from roadcut in Wehutty Formation on the Road to Nowhere; east of Noland Creek and west of Peach Tree Creek. Flow rate = 1 L/min.

RTN-3: 35° 27.299' N, 83° 28.962' W; NC; Peachtree Creek north of the Road to Nowhere 0.4 miles within the GSMNP boundary; 646 m elevation; rapid flow.

SCLF-1: 35° 30.001' N, 83° 41.776' W; NC; Little Fork of Sugar Fork of Hazel Creek, near bottom of tailings pile.

SUG-1: 35° 30.001' N, 83° 41.776' W; NC; Pool at adit having bat gate at Hazel Creek Mine (same site as HCM-2-1).

STYX-1: 35° 38.437' N, 83° 26.027' W; TN; Styx Creek at footbridge on Alum Cave Trail (same site as STYX-1-R1; STYX-R1-2).

STYX-1-R1: 35° 38.437' N, 83° 26.027' W; TN; Styx Creek at footbridge on Alum Cave Trail; flow rate = 10,900 L/min (same site as STYX-1; STYX-R1-2).

STYX-R1-2: 35° 38.437' N, 83° 26.027' W; TN; Styx Creek at footbridge on Alum Cave Trail (same site as STYX-1; STYX-1-R1).

STYX-2: Styx Creek 30 m downstream from confluence with Huggins Hell Slide chute, below Arch Rock.

APPENDIX 3: WATER QUALITY DATA (Values in bold were determined by ICP-AES; see Appendix 1)

Sample	**ACT-1**	**ACT-2**	**ACT-2b**	**ACT-3**	**CCAC-1**	**FC-1**	**FC-2**	**FC-3**	**FC-4**	**FL-1**
Collection Date	6/22/97	6/22/97	6/22/97	6/22/97	6/24/97	9/20/94	9/20/94	9/20/94	9/20/94	9/11/96
Field Parameters										
pH	4.0	6.3	5.8	4.4	6.6	6.7	6.0	5.5	6.4	8.1
Spec. Cond. µS/cm	46.9	20.6	23.9	23.8	12.3	151.5	87	73.2	21	21
Water T °C	14.0	15.0	11.0	16.0	16.0	14.0	17.0	14.0	17.0	25.0
Air T °C		21.0	21.0			24.0		22.0	20.0	25.0
Dissolved O_2 mg/L	9.0	11.0	6.0	8.0				6.5	7.0	8.0
Filter Size (µm)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.22
Dissolved Concentrations										
Hardness $CaCO_3$ mg/L	2.0	6.5	6.5	0.7	2.9	56.4	29.3	26.3	7.4	5.8
Alkalinity $CaCO_3$ mg/L		2.0	3.5		3.8	8.2	7.6	11.8	9.8	6.4
NO_3 mg/L	2.3	4.6	2.4	2.6	2.0					
F mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.05	<0.05	0.06	<0.05	< 0.1
Cl mg/L	0.5	0.5	0.5	0.3	0.5	0.48	0.44	0.48	0.42	1.2
SO_4 mg/L	5.9	4.8	4.8	2.5	1.3	5.9	32	23	1.2	1.3
Li µg/L	2.8	1.7	1.6	1.0	< 0.1	1	0.7	0.9	0.6	< 0.3
Be µg/L	0.07	< 0.05	< 0.05	< 0.05	< 0.05	<0.2	<0.2	<0.2	<0.2	< 0.2
B µg/L						**<50**	**<50**	**<50**	**<50**	**< 10**
Na mg/L	0.27	0.24	0.27	0.20	0.75	1.3	0.97	1.4	1.1	**1.6**
Mg mg/L	0.45	0.66	0.68	0.13	0.22	4.60	2.50	2.20	0.83	0.45
Al µg/L	1200.00	18.00	94.00	720.00	21.00	<6	<6	<6	<6	7.00
Si mg/L	1.40	0.93	0.93	1.40	2.94	**4.7**	**4.8**	**5.8**	**4.5**	2.80
P µg/L	< 1	< 1	11	6	51	**<500**	**<500**	**<500**	**<500**	< 100
K µg/L	25	79	110	36	450	**<1000**	**<1000**	**<1000**	**<1000**	800
Ca mg/L	0.05	1.5	1.5	0.05	0.79	**15**	**7.6**	**6.9**	**1.6**	**1.6**
Sc µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	3.6	3.8	3.8	3.5	< 10
Ti µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	2	3	<2	<2	< 2
V µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.2	3.5	<0.2	<0.2	< 10
Cr µg/L	1	0.6	0.8	0.7	< 0.5	<0.4	5.3	<0.4	<0.4	< 10
Fe^{2+} mg/L	0.14	0.57	1.08	0.12	0.03	0.09	0.41	0.01	0	

Sample	ACT-1	ACT-2	ACT-2b	ACT-3	CCAC-1	FC-1	FC-2	FC-3	FC-4	FL-1
Dissolved Concentrations (cont.)										
Fe µg/L	320	48	1000	280	< 10	130	520	47	20	< 0.05
Mn µg/L	33	300	150	23	0.40	410	200	120	0.4	< 20
Co µg/L	0.84	3.1	1.9	0.83	< 0.02	2.90	1.20	1.20	<0.1	< 0.5
Ni µg/L	0.9	1.1	1.3	0.6	< 0.1	1.3	1	1	<0.4	< 1
Cu µg/L	1	< 0.5	0.5	1	< 0.5	25	180	84	<0.4	0.6
Zn µg/L	8	5	7	4	1	240	270	300	<10	1.2
Ga µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.5
Ge µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	<0.2	< 0.2
As µg/L	< 0.2	0.2	0.9	0.2	< 0.2	<1	<1	<1	<1	< 0.5
Se µg/L	0.3	0.3	0.3	0.5	0.3					< 5
Rb µg/L	0.2	0.5	0.5	0.3	1.1	2.5	1.6	2.4	0.6	1.2
Sr µg/L	1.6	3.9	4.0	1.1	7.5	56	30	29	7.6	11
Y µg/L	0.4	0.2	0.2	0.2	0.1	<0.1	0.5	0.6	<0.1	< 0.1
Zr µg/L	0.1	< 0.05	< 0.05	0.09	< 0.05	<0.1	<0.1	<0.1	<0.1	< 0.1
Nb µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.1
Mo µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.3	<0.3	<0.3	<0.3	0.1
Ag µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Cd µg/L	0.02	0.1	0.03	< 0.02	< 0.02	0.9	0.9	0.7	<0.4	< 0.1
In µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01					< 0.05
Sn µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.5	<0.4	<0.4	<0.4	< 1
Sb µg/L	0.02	0.09	0.05	0.08	0.02	<0.2	3	<0.2	<0.2	0.42
Te µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.9	<0.9	<0.9	<0.9	< 0.5
Cs µg/L	0.03	0.01	< 0.01	0.01	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Ba µg/L	4	4	4	4	8.1	8.1	7.5	4.8	2	1.1
La µg/L	0.73	0.3	0.4	0.4	0.06	<0.1	0.5	0.4	<0.1	< 0.05
Ce µg/L	1.6	0.78	1.1	0.91	0.05	<0.2	0.63	0.2	<0.1	< 0.05
Pr µg/L	0.2	0.08	0.1	0.1	0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Nd µg/L	0.74	0.39	0.51	0.44	0.05	<0.1	0.3	0.3	<0.1	< 0.05

Sample	**ACT-1**	**ACT-2**	**ACT-2b**	**ACT-3**	**CCAC-1**	**FC-1**	**FC-2**	**FC-3**	**FC-4**	**FL-1**
Dissolved Concentrations (cont.)										
Sm µg/L	0.2	0.08	0.1	0.08	0.02	<0.1	<0.1	<0.1	<0.1	< 0.05
Eu µg/L	0.02	0.01	0.01	0.01	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.05
Tb µg/L	0.01	0.007	0.009	0.007	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.05
Gd µg/L	0.11	0.062	0.062	0.064	0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Dy µg/L	0.086	0.04	0.04	0.050	0.02	<0.1	<0.1	<0.1	<0.1	< 0.05
Ho µg/L	0.01	0.006	0.008	0.009	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.05
Er µg/L	0.03	0.01	0.02	0.03	0.006	<0.1	<0.1	<0.1	<0.1	< 0.05
Tm µg/L	0.005	< 0.005	< 0.005	< 0.005	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.05
Yb µg/L	0.04	< 0.01	0.02	0.04	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Lu µg/L										< 0.05
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	<0.1	< 0.05
Ta µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.05
W µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	<0.2	< 0.05
Re µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	
Au µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.01
Tl µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.6	<0.6	<0.6	<0.6	< 0.1
Pb µg/L	0.2	< 0.05	< 0.05	< 0.05	< 0.05	<0.6	<0.6	<0.6	<0.6	0.21
Bi µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.6	<0.6	<0.6	<0.6	< 0.05
Th µg/L	0.05	< 0.005	< 0.005	0.008	< 0.005	<0.5	<0.5	<0.5	<0.5	< 0.05
U µg/L	0.07	0.006	0.01	0.06	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.02
Total Acid Soluble Concentrations										
Li µg/L	3.2	1.9	1.7	1.1	< 0.1	1.1	0.8	1.2	0.4	< 0.3
Be µg/L	0.08	< 0.05	< 0.05	< 0.05	< 0.05	<0.2	<0.2	<0.2	<0.2	< 0.2
B µg/L						**<50**	**<50**	**62**	**<50**	**< 10**
Na mg/L	0.27	0.24	0.27	0.21	0.75	1.2	1.1	1.3	1.2	**1.7**
Mg mg/L	0.45	0.66	0.69	0.13	0.23	4.40	2.50	2.10	0.89	0.48
Al µg/L	1200.00	360.00	410.00	860.00	220.00	27.00	20.00	320.00	80.00	18.00
Si mg/L	1.40	0.93	0.93	1.40	2.99	**4.8**	**4.7**	**6.7**	**4.6**	3.00

Sample	**ACT-1**	**ACT-2**	**ACT-2b**	**ACT-3**	**CCAC-1**	**FC-1**	**FC-2**	**FC-3**	**FC-4**	**FL-1**
Total Acid Soluble Concentrations (cont.)										
P µg/L	6	50	61	18	55	**<500**	**<500**	**<500**	**<500**	< 100
K µg/L	25	78	110	44	470	**<1000**		**<1000**	**<1000**	800
Ca mg/L	< 0.05	1.5	1.6	0.05	0.83	**15**	**7.6**	**6.6**	**1.2**	**1.7**
Sc µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	3	3.6	3.9	3.2	< 10
Ti µg/L	< 0.1	0.4	0.2	0.1	4.3	<2	<2	5	<2	< 2
V µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.2	<0.2	<0.2	<0.2	< 10
Cr µg/L	1	< 0.5	1	0.7	< 0.5	<0.4	<0.4	<0.4	<0.4	< 10
Fe µg/L	360	2000	3100	510	84	2700	730	12000	140	< 0.05
Mn µg/L	32	310	170	23	7.7	390	190	140	8.3	< 20
Co µg/L	0.86	3.5	2.1	0.87	0.08	2.70	1.30	1.50	0.40	< 0.5
Ni µg/L	0.8	1.4	1.5	0.6	0.2	1.4	1.3	1.7	<0.4	< 1
Cu µg/L	1	1	1	1	< 0.5	160	180	300	<0.4	< 0.5
Zn µg/L	7	5	8	3	1	280	270	310	<10	< 0.5
Ga µg/L	< 0.02	0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.5
Ge µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	<0.2	< 0.2
As µg/L	< 0.2	1	2.0	0.4	< 0.2	<1	<1	<1	<1	< 0.5
Se µg/L	0.4	0.4	0.6	0.3	0.2					< 5
Rb µg/L	0.2	0.51	0.50	0.3	1.3	2.3	1.8	2.7	0.8	1.3
Sr µg/L	1.5	3.8	4.1	1.1	7.8	56	29	28	8.3	11
Y µg/L	0.4	0.50	0.5	0.3	0.4	1.2	0.6	4.5	0.3	< 0.1
Zr µg/L	0.1	< 0.05	< 0.05	0.1	< 0.05	<0.1	<0.1	<0.1	<0.1	< 0.1
Nb µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.1
Mo µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.3	<0.3	<0.3	<0.3	< 0.1
Ag µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.1	<0.1	<0.1	<0.1	< 0.05
Cd µg/L	0.02	< 0.02	0.04	0.02	< 0.02	1	0.8	0.8	<0.4	< 0.1
In µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01					< 0.05
Sn µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.4	<0.4	<0.4	<0.4	< 1
Sb µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	<0.2	0.06

Sample	ACT-1	ACT-2	ACT-2b	ACT-3	CCAC-1	FC-1	FC-2	FC-3	FC-4	FL-1
Total Acid Soluble Concentrations (cont.)										
Te µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.9	<0.9	<0.9	<0.9	< 0.5
Cs µg/L	0.03	0.02	0.01	0.02	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.05
Ba µg/L	4	4	4	4	9.7	8.4	6.1	6	2.3	1.0
La µg/L	0.74	1.0	0.97	0.4	0.3	0.8	0.5	2.7	0.5	0.08
Ce µg/L	1.6	3.7	3.1	1.1	0.5	0.94	0.7	4.3	1.2	0.16
Pr µg/L	0.20	0.31	0.30	0.1	0.08	0.3	0.2	1.2	0.2	< 0.05
Nd µg/L	0.72	1.4	1.3	0.48	0.30	0.8	0.8	4.8	0.4	0.11
Sm µg/L	0.1	0.25	0.22	0.1	0.08	0.2	<0.1	1.4	<0.1	< 0.05
Eu µg/L	0.02	0.04	0.04	0.02	0.01	<0.1	<0.1	0.2	<0.1	< 0.05
Tb µg/L	0.02	0.02	0.02	0.01	0.01	<0.1	<0.1	1.2	<0.1	< 0.05
Gd µg/L	0.11	0.18	0.18	0.083	0.066	<0.1	0.1	0.1	<0.1	< 0.05
Dy µg/L	0.092	0.10	0.095	0.070	0.063	<0.1	0.1	0.9	<0.1	< 0.05
Ho µg/L	0.02	0.02	0.02	0.01	0.01	<0.1	<0.1	0.2	<0.1	< 0.05
Er µg/L	0.04	0.03	0.04	0.02	0.03	<0.1	<0.1	0.3	<0.1	< 0.05
Tm µg/L	0.005	0.005	0.005	0.005	< 0.005	<0.1	<0.1	<0.1	<0.1	< 0.05
Yb µg/L	0.04	0.03	0.04	0.03	0.03	<0.1	<0.1	0.3	<0.1	< 0.05
Lu µg/L										< 0.05
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	<0.1	< 0.05
Ta µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	< 0.05
W µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	<0.2	< 0.05
Re µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	<0.1	
Au µg/L	< 0.01	0.02	0.01	0.01	< 0.01	<0.1	<0.1	<0.1	<0.1	< 0.01
Tl µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.6	<0.6	<0.6	<0.6	< 0.1
Pb µg/L	0.2	< 0.05	0.07	0.2	< 0.05	<0.6	<0.6	2	<0.6	< 0.05
Bi µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.6	<0.6	<0.6	<0.6	< 0.05
Th µg/L	0.02	0.02	0.03	< 0.005	< 0.005	<0.5	<0.5	<0.5	<0.5	< 0.05
U µg/L	0.08	0.05	0.05	0.07	0.007	<0.1	<0.1	<0.1	<0.1	< 0.02

Sample	**FL-2**	**FM-1-1**	**FM-1-2**	**FM-2-1**	**FM-2-2**	**FM-3-1**	**FM-4-1**	**FM-5-2**	**FM-6-2**	**FM-7-2**
Collection Date	6/21/97	9/11/96	6/17/97	9/11/96	6/17/97	9/11/96	9/11/96	6/17/97	6/17/97	6/17/97
Field Parameters										
pH	6.7	6.4	6.7	3.1	3.2	6.9	6.7	2.4	3.0	2.4
Spec. Cond. µS/cm	21.6	24	18.3	709	682	24	101	5020	1112	8230
Water T °C	12.0	18.5	15.0	13.0	12.0	20.0	18.5	12.5	14.5	13.0
Air T °C	19.0	20.0		16.0		25.0	25.0	14.0	14.0	14.0
Dissolved O_2 mg/L	9.0	9.0	9.0	11.0	8.0	9.0	11.0	12.0	9.0	12.0
Filter Size (µm)	0.45	0.22	0.45	0.22	0.45	0.22	0.22	0.45	0.45	0.45
Dissolved Concentrations										
Hardness $CaCO_3$ mg/L	5.3	4503.9	5.8	62565.6	94.2	4754.0	27516.0	981.0	74.2	988.0
Alkalinity $CaCO_3$ mg/L	5.8	7.1	6.3			8.2	9.1			
NO_3 mg/L	1.8									
F mg/L	< 0.1	< 0.1	< 0.1	0.4	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cl mg/L	1.3	0.4	0.5	0.4	0.7	0.4	0.4	4.5	1	1.9
SO_4 mg/L	1.7	2.2	1.3	400	270	2.8	35	3900	430	11000
Li µg/L	< 0.1	< 0.3	0.2	6.5	7.9	< 0.3	< 0.3	110	5.5	82
Be µg/L	< 0.05	< 0.2	< 0.05	0.6	1.0	< 0.2	< 0.2	3.1	0.2	4.5
B µg/L		**< 10**		**< 10**		**< 10**	**< 10**			
Na mg/L	1.5	**1.3**	0.96	**1.3**	0.94	**1.3**	**1.9**	0.66	0.82	0.74
Mg mg/L	0.49	0.94	0.81	**16.00**	12.00	0.98	**3.90**	160.00	12.00	180.00
Al µg/L	12.00	2.00	3.30	**8300.00**	19000.00	3.00	1.00	250000.00	12000.00	140000.00
Si mg/L	3.60	4.80	4.39	16.00	12.15	4.90	5.30	35.53	8.41	28.51
P µg/L	29	< 100	60	< 100	46	< 100	< 100	400	66	1300
K µg/L	590	500	340	**2400**	1500	500	1000	130	750	1200
Ca mg/L	1.3	**1800**	1.0	**25000**	18	**1900**	**11000**	130	10	100
Sc µg/L	< 0.1	< 10	< 0.1	< 10	2	< 10	< 10	20	2	11
Ti µg/L	< 0.1	< 2	< 0.1	< 2	1.3	< 2	< 2	30	2.4	61
V µg/L	< 0.1	< 10	< 0.1	< 10	< 0.1	< 10	< 10	3	0.5	2
Cr µg/L	0.7	< 10	< 0.5	< 10	3	< 10	< 10	1	3	< 0.5
Fe^{2+} mg/L	0	0	0		0.38	0.03	0.07	27.9	17.6	144.5

Sample	**FL-2**	**FM-1-1**	**FM-1-2**	**FM-2-1**	**FM-2-2**	**FM-3-1**	**FM-4-1**	**FM-5-2**	**FM-6-2**	**FM-7-2**
Dissolved Concentrations (cont.)										
Fe µg/L	< 10	< 0.05	< 10	9.7	6200	< 0.05	< 0.05	530000	88000	2600000
Mn µg/L	6.8	< 20	0.53	1500	1200	< 20	290	15000	1600	24000
Co µg/L	< 0.02	< 0.5	< 0.02	**24**	34	< 0.5	1.1	580	64	1300
Ni µg/L	0.1	< 1	< 0.1	7	9.0	< 1	1	130	9.5	190
Cu µg/L	0.5	**59**	11	**11000**	22000	11	**82**	160000	27000	290000
Zn µg/L	1	**32**	5	**7500**	8200	18	**360**	130000	23000	430000
Ga µg/L	< 0.02	< 0.5	< 0.02	< 0.5	0.4	< 0.5	< 0.5	< 0.02	0.77	8.5
Ge µg/L	< 0.02	< 0.2	< 0.02	< 0.2	0.06	< 0.2	< 0.2	< 0.02	0.03	< 0.02
As µg/L	< 0.2	< 0.5	< 0.2	< 0.5	< 0.2	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
Se µg/L	0.4	< 5	0.4	< 5	2	< 5	< 5	10	1	9.4
Rb µg/L	1.3	1.0	0.83	18	18	1.0	2.2	14	6.9	38
Sr µg/L	11	7.7	6.1	**85**	62	7.9	**38**	300	34	280
Y µg/L	0.2	< 0.1	0.04	27	27	< 0.1	< 0.1	200	4.3	67
Zr µg/L	< 0.05	< 0.1	< 0.05	< 0.1	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.1	< 0.02	< 0.1	< 0.02	< 0.1	< 0.1	< 0.02	< 0.02	0.2
Mo µg/L	< 0.02	< 0.1	< 0.02	< 0.1	< 0.02	< 0.1	< 0.1	0.1	< 0.02	0.3
Ag µg/L	< 0.01	< 0.05	< 0.01	< 0.05	0.06	< 0.05	< 0.05	0.4	0.1	0.77
Cd µg/L	< 0.02	< 0.1	< 0.02	9.2	17	< 0.1	0.7	310	56	840
In µg/L	< 0.01	< 0.05	< 0.01	0.52	1.0	< 0.05	< 0.05	34	2.8	58
Sn µg/L	< 0.05	< 1	< 0.05	< 1	< 0.05	< 1	< 1	9.0	< 0.05	11
Sb µg/L	0.03	0.23	0.04	0.09	0.03	< 0.05	0.09	0.51	0.05	0.04
Te µg/L	< 0.1	< 0.5	< 0.1	< 0.5	0.4	< 0.5	< 0.5	< 0.1	< 0.1	< 0.1
Cs µg/L	< 0.01	< 0.05	< 0.01	0.62	1.4	< 0.05	< 0.05	13	1.4	17
Ba µg/L	7.7	0.86	3	13	18	1.9	4.3	2	9.7	2
La µg/L	0.1	< 0.05	0.04	39	40	< 0.05	0.06	230	5.8	140
Ce µg/L	0.2	< 0.05	0.06	83	170	< 0.05	< 0.05	540	12	280
Pr µg/L	0.04	< 0.05	< 0.01	9.7	12	< 0.05	< 0.05	62	1.5	35
Nd µg/L	0.2	< 0.05	0.02	38	49	< 0.05	< 0.05	250	6.2	140

Sample	FL-2	FM-1-1	FM-1-2	FM-2-1	FM-2-2	FM-3-1	FM-4-1	FM-5-2	FM-6-2	FM-7-2
Dissolved Concentrations (cont.)										
Sm µg/L	0.02	< 0.05	< 0.01	7.6	9.2	< 0.05	< 0.05	47	1.2	28
Eu µg/L	0.005	< 0.05	< 0.005	1.2	1.4	< 0.05	< 0.05	6.8	0.36	7.1
Tb µg/L	< 0.005	< 0.05	< 0.005	1.1	1.2	< 0.05	< 0.05	6.9	0.18	3.7
Gd µg/L	0.02	< 0.05	0.01	7.0	8.3	< 0.05	< 0.05	47	1.2	27
Dy µg/L	0.03	< 0.05	0.006	5.4	6.7	< 0.05	< 0.05	37	0.95	17
Ho µg/L	0.006	< 0.05	< 0.005	0.90	1.2	< 0.05	< 0.05	6.8	0.18	2.7
Er µg/L	0.02	< 0.05	< 0.005	2.2	2.7	< 0.05	< 0.05	17	0.44	6.0
Tm µg/L	< 0.005	< 0.05	< 0.005	0.27	0.36	< 0.05	< 0.05	2.2	0.059	0.86
Yb µg/L	0.01	< 0.05	< 0.01	1.4	2.0	< 0.05	< 0.05	13	0.34	5.1
Lu µg/L		< 0.05		0.18		< 0.05	< 0.05			
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	< 0.02	< 0.05	< 0.02	< 0.05	< 0.02	< 0.05	< 0.05	0.65	0.03	1.7
W µg/L	< 0.02	< 0.05	< 0.02	< 0.05	< 0.02	< 0.05	< 0.05	< 0.02	0.03	0.61
Re µg/L	< 0.02		< 0.02		< 0.02			< 0.02	< 0.02	< 0.02
Au µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02
Tl µg/L	< 0.05	< 0.1	< 0.05	< 0.1	0.1	< 0.1	< 0.1	< 0.05	0.07	< 0.05
Pb µg/L	< 0.05	0.09	< 0.05	110	110	0.08	< 0.05	33	380	42
Bi µg/L	< 0.01	< 0.05	< 0.01	< 0.05	< 0.01	< 0.05	< 0.05	< 0.01	0.04	< 0.01
Th µg/L	< 0.005	< 0.05	< 0.005	0.33	0.69	< 0.05	< 0.05	33	0.59	14
U µg/L	< 0.005	< 0.02	< 0.005	2.5	3.4	< 0.02	< 0.02	14	0.91	16
Total Acid Soluble Concentrations										
Li µg/L	0.4	< 0.3	< 0.1	6.6	8.3	< 0.3	0.4	100	5.6	78
Be µg/L	< 0.05	< 0.2	< 0.05	0.6	1.0	< 0.2	< 0.2	3.5	0.2	4.9
B µg/L		**< 10**		**< 10**		**< 10**	**< 10**			
Na mg/L	1.5	**1.3**	0.94	**1.3**	0.93	**1.3**	**1.9**	0.62	0.83	0.77
Mg mg/L	0.50	**1.20**	0.81	**16.00**	12.00	0.96	**3.90**	150.00	12.00	180.00
Al µg/L	77.00	**290.00**	220.00	**8200.00**	20000.00	51.00	36.00	250000.00	12000.00	140000.00
Si mg/L	3.51	5.10	4.11	16.00	12.15	4.90	5.40	34.59	8.41	28.98

Sample	**FL-2**	**FM-1-1**	**FM-1-2**	**FM-2-1**	**FM-2-2**	**FM-3-1**	**FM-4-1**	**FM-5-2**	**FM-6-2**	**FM-7-2**
Total Acid Soluble Concentrations (cont.)										
P µg/L	31	< 100	77	< 100	77	< 100	< 100	340	73	1200
K µg/L	600	500	350	**2400**	1500	500	900	130	750	1400
Ca mg/L	1.3	**1900**	1.0	**24000**	18	**1900**	**11000**	130	10	100
Sc µg/L	< 0.1	< 10	< 0.1	< 10	2	< 10	< 10	17	2	12
Ti µg/L	0.8	3	1.1	< 2	5.1	< 2	< 2	37	2.6	60
V µg/L	< 0.1	< 10	< 0.1	< 10	< 0.1	< 10	< 10	5.3	0.5	2
Cr µg/L	1	< 10	< 0.5	< 10	2	< 10	< 10	4	3	< 0.5
Fe µg/L	31	0.37	80	10	7300	0.15	0.56	530000	88000	2600000
Mn µg/L	11	33	9.3	1500	1200	< 20	300	15000	1600	25000
Co µg/L	0.03	0.5	0.2	**23**	34	< 0.5	1.1	580	64	1200
Ni µg/L	< 0.1	< 1	0.2	7	8.9	< 1	1	130	9.6	180
Cu µg/L	< 0.5	**160**	21	**10000**	22000	**34**	**180**	160000	27000	270000
Zn µg/L	< 0.5	**32**	6	**7300**	8200	**27**	**380**	130000	23000	420000
Ga µg/L	< 0.02	< 0.5	< 0.02	< 0.5	0.4	< 0.5	< 0.5	< 0.02	0.77	6.2
Ge µg/L	< 0.02	< 0.2	< 0.02	< 0.2	0.06	< 0.2	< 0.2	< 0.02	0.04	< 0.02
As µg/L	< 0.2	< 0.5	< 0.2	< 0.5	< 0.2	< 0.5	< 0.5	2.8	< 0.2	< 0.2
Se µg/L	0.2	< 5	0.4	< 5	2	< 5	< 5	10	1	9.3
Rb µg/L	1.3	1.2	0.90	18	18	1.1	2.2	13	7.0	41
Sr µg/L	11	8.2	6.3	**84**	62	7.8	**38**	300	34	280
Y µg/L	0.3	0.6	0.3	27	27	0.1	0.3	190	4.3	67
Zr µg/L	< 0.05	< 0.1	< 0.05	0.2	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.1	< 0.02	< 0.1	< 0.02	< 0.1	< 0.1	0.03	< 0.02	0.4
Mo µg/L	< 0.02	< 0.1	< 0.02	< 0.1	< 0.02	< 0.1	< 0.1	0.2	< 0.02	0.3
Ag µg/L	< 0.01	< 0.05	< 0.01	< 0.05	0.06	< 0.05	< 0.05	1.3	0.09	0.4
Cd µg/L	< 0.02	< 0.1	0.03	9.3	17	< 0.1	0.8	310	56	780
In µg/L	< 0.01	< 0.05	< 0.01	0.53	1.0	< 0.05	< 0.05	34	2.7	51
Sn µg/L	< 0.05	< 1	< 0.05	< 1	< 0.05	< 1	< 1	14	< 0.05	12
Sb µg/L	< 0.02	< 0.05	< 0.02	0.08	< 0.02	< 0.05	< 0.05	1.9	0.03	0.2

Sample	FL-2	FM-1-1	FM-1-2	FM-2-1	FM-2-2	FM-3-1	FM-4-1	FM-5-2	FM-6-2	FM-7-2
Total Acid Soluble Concentrations (cont.)										
Te µg/L	< 0.1	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.5	< 0.1	< 0.1	< 0.1
Cs µg/L	< 0.01	< 0.05	< 0.01	0.62	1.5	< 0.05	< 0.05	12	1.4	17
Ba µg/L	7.7	2.1	4	13	19	0.57	4.2	2	9.8	2
La µg/L	0.2	0.74	0.3	39	41	0.13	0.37	230	5.7	140
Ce µg/L	0.4	2.0	1.0	85	170	0.40	0.50	540	12	280
Pr µg/L	0.06	0.21	0.09	10	12	< 0.05	0.09	61	1.5	34
Nd µg/L	0.25	0.79	0.37	39	49	0.15	0.40	240	6.1	140
Sm µg/L	0.05	0.15	0.07	7.9	9.3	< 0.05	0.06	45	1.2	28
Eu µg/L	0.007	< 0.05	0.02	1.2	1.4	< 0.05	< 0.05	6.9	0.36	6.9
Tb µg/L	0.005	< 0.05	0.01	1.0	1.3	< 0.05	< 0.05	6.7	0.16	3.5
Gd µg/L	0.053	0.13	0.068	7.1	8.5	< 0.05	0.06	46	1.2	26
Dy µg/L	0.054	0.11	0.063	5.5	6.6	< 0.05	0.06	36	0.92	17
Ho µg/L	0.009	< 0.05	0.01	0.91	1.2	< 0.05	< 0.05	6.7	0.18	2.7
Er µg/L	0.02	0.06	0.04	2.3	2.7	< 0.05	< 0.05	16	0.39	6.3
Tm µg/L	< 0.005	< 0.05	0.005	0.27	0.37	< 0.05	< 0.05	2.2	0.062	0.80
Yb µg/L	0.02	0.05	0.02	1.4	2.0	< 0.05	< 0.05	14	0.32	5.1
Lu µg/L		< 0.05		0.18		< 0.05	< 0.05			
Hf µg/L	< 0.05	< 0.05	< 0.05	0.13	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	< 0.02	< 0.05	< 0.02	0.10	< 0.02	< 0.05	< 0.05	0.82	0.04	2.6
W µg/L	< 0.02	< 0.05	< 0.02	< 0.05	< 0.02	< 0.05	< 0.05	< 0.02	0.03	0.62
Re µg/L	< 0.02		< 0.02		< 0.02			< 0.02	< 0.02	< 0.02
Au µg/L	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.01	0.04
Tl µg/L	< 0.05	< 0.1	< 0.05	< 0.1	0.1	< 0.1	< 0.1	< 0.05	0.07	< 0.05
Pb µg/L	< 0.05	2.8	0.2	110	110	0.62	0.14	33	360	45
Bi µg/L	< 0.01	< 0.05	< 0.01	< 0.05	0.03	< 0.05	< 0.05	0.09	0.06	< 0.01
Th µg/L	< 0.005	< 0.05	< 0.005	0.40	0.70	< 0.05	< 0.05	33	0.65	13
U µg/L	0.008	0.04	0.02	2.5	3.5	< 0.02	< 0.02	14	0.86	16

Sample	**FM-8-2**	**FM-9-2**	**FM-10-2**	**FM-11-2**	**FM-12-2**	**HCM-1-1**	**HCM-2-1**	**HCM-3-1**	**HCM-3-2**	**HCM-4-2**
Collection Date	6/17/97	6/18/97	6/18/97	6/18/97	6/18/97	9/16/96	9/12/96	9/12/96	6/19/97	6/19/97
Field Parameters										
pH	2.5	6.2	6.7	6.7	6.7	5.4	3.8	7.0	6.5	3.7
Spec. Cond. µS/cm	1.5	63.2	63.9	19.5	17.8	38	308	19	16.2	333
Water T °C	13.0	13.0	17.0	21.0	17.0	15.0	15.0	17.0	14.0	13.0
Air T °C		21.0		21.0	21.0	21.0	18.0	22.0	23.0	
Dissolved O_2 mg/L	9.0	4.5	7.0		9.0	8.0	7.0	7.0	11.0	7.0
Filter Size (µm)	0.45	0.45	0.45	0.45	0.45	0.22	0.22	0.22	0.45	0.45
Dissolved Concentrations										
Hardness $CaCO_3$ mg/L	103.0	23.0	23.6	4.3	4.6	1756.6	35041.0	3752.5	4.1	48.6
Alkalinity $CaCO_3$ mg/L		8.0	5.4	4.0	5.4	0.7		5.8	5.3	
NO_3 mg/L										
F mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	0.2
Cl mg/L	1.6	0.5	0.5	1.2	0.5	0.5	0.5	0.4	0.4	0.6
SO_4 mg/L	990	17	20	1.8	1.6	19	150	2.5	2.7	120
Li µg/L	18	1.2	0.7	0.2	0.2	1.3	9.6	< 0.3	< 0.1	8.4
Be µg/L	0.6	< 0.05	< 0.05	< 0.05	0.06	< 0.2	0.4	< 0.2	< 0.05	0.2
B µg/L						**< 10**	**< 10**	**< 10**		
Na mg/L	0.46	1.4	1.1	1.4	1.0	0.90	**1.6**	**1.1**	0.76	0.83
Mg mg/L	22.00	2.20	2.40	0.45	0.56	**1.60**	**10.00**	0.60	0.52	6.60
Al µg/L	34000.00	2.60	8.80	2.80	4.60	46.00	**2200.00**	18.00	3.30	3300.00
Si mg/L	24.31	5.61	4.49	3.32	4.35	4.20	9.90	4.50	3.55	6.54
P µg/L	180	31	28	15	37	< 100	< 100	< 100	32	29
K µg/L	1400	650	570	600	420	**1400**	**4500**	1000	530	3100
Ca mg/L	5.1	5.6	5.5	1.0	0.92	700	**14000**	**1500**	0.79	8.6
Sc µg/L	3	0.4	0.3	< 0.1	< 0.1	< 10	< 10	< 10	< 0.1	0.5
Ti µg/L	4.4	< 0.1	< 0.1	< 0.1	< 0.1	< 2	< 2	< 2	< 0.1	0.3
V µg/L	1	< 0.1	< 0.1	< 0.1	< 0.1	< 10	< 10	< 10	< 0.1	< 0.1
Cr µg/L	4	2	3	< 0.5	< 0.5	< 10	< 10	< 10	< 0.5	2
Fe^{2+} mg/L	5	0.01	0.04	0	0.02	0.02			0	0.04

Sample	**FM-8-2**	**FM-9-2**	**FM-10-2**	**FM-11-2**	**FM-12-2**	**HCM-1-1**	**HCM-2-1**	**HCM-3-1**	**HCM-3-2**	**HCM-4-2**
Dissolved Concentrations (cont.)										
Fe μg/L	100000	14	37	< 10	< 10	0.054	0.69	< 0.05	< 10	610
Mn μg/L	640	120	140	3.3	0.58	45	1300	20	0.21	820
Co μg/L	150	0.83	0.81	< 0.02	< 0.02	3.4	19	< 0.5	< 0.02	18
Ni μg/L	38	1.5	0.7	< 0.1	< 0.1	3	15	< 1	0.3	13
Cu μg/L	76000	75	86	< 0.5	< 0.5	**980**	**7900**	**60**	39	16000
Zn μg/L	12000	290	230	0.5	2	**960**	**8700**	**140**	110	11000
Ga μg/L	0.64	< 0.02	< 0.02	< 0.02	< 0.02	< 0.5	< 0.5	< 0.5	< 0.02	0.2
Ge μg/L	0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.2	< 0.2	< 0.2	< 0.02	0.03
As μg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2
Se μg/L	6.7	0.4	0.4	0.4	0.4	< 5	< 5	< 5	0.3	2
Rb μg/L	26	2.4	1.6	1.3	1.2	8.6	32	1.9	1.8	28
Sr μg/L	22	22	19	9.6	7.5	4.6	**36**	7.1	5.1	22
Y μg/L	26	0.4	0.09	0.2	0.07	2.1	35	0.3	0.06	30
Zr μg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.05	< 0.05
Nb μg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.1	< 0.1	< 0.1	< 0.02	< 0.02
Mo μg/L	0.03	0.03	< 0.02	0.02	< 0.02	< 0.1	< 0.1	0.6	< 0.02	< 0.02
Ag μg/L	0.1	0.02	0.02	< 0.01	< 0.01	< 0.05	0.24	0.06	< 0.01	0.3
Cd μg/L	36	0.5	0.50	< 0.02	< 0.02	7.6	**22**	0.5	0.3	30
In μg/L	5.4	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05	< 0.05	< 0.01	< 0.01
Sn μg/L	0.3	< 0.05	< 0.05	< 0.05	< 0.05	< 1	< 1	< 1	< 0.05	< 0.05
Sb μg/L	0.03	< 0.02	0.03	< 0.02	0.03	0.14	< 0.05	0.44	< 0.02	0.03
Te μg/L	17	< 0.1	< 0.1	< 0.1	< 0.1	< 0.5	< 0.5	< 0.5	< 0.1	< 0.1
Cs μg/L	4.2	0.02	< 0.01	< 0.01	< 0.01	0.06	0.18	< 0.05	< 0.01	0.39
Ba μg/L	4	5.7	6.4	6.1	4	7.1	19	1.4	4	25
La μg/L	11	0.3	0.1	0.2	0.05	1.3	35	0.26	0.03	26
Ce μg/L	24	0.2	0.1	0.2	0.06	1.9	60	0.37	0.06	45
Pr μg/L	3.4	0.05	0.02	0.04	0.01	0.29	8.1	0.06	< 0.01	6.1
Nd μg/L	15	0.2	0.05	0.2	0.03	1.1	32	0.24	0.03	25

Sample	FM-8-2	FM-9-2	FM-10-2	FM-11-2	FM-12-2	HCM-1-1	HCM-2-1	HCM-3-1	HCM-3-2	HCM-4-2
Dissolved Concentrations (cont.)										
Sm µg/L	3.4	0.03	0.02	0.04	< 0.01	0.22	6.5	< 0.05	0.01	4.8
Eu µg/L	0.56	0.006	< 0.005	0.009	< 0.005	< 0.05	1.1	< 0.05	< 0.005	0.83
Tb µg/L	0.76	< 0.005	< 0.005	0.005	< 0.005	< 0.05	1.1	< 0.05	< 0.005	0.87
Gd µg/L	4.4	0.052	0.01	0.03	0.007	0.26	6.7	< 0.05	0.01	5.6
Dy µg/L	4.9	0.04	0.01	0.03	0.01	0.24	5.9	< 0.05	0.01	5.0
Ho µg/L	1.0	0.009	< 0.005	0.007	< 0.005	0.05	1.1	< 0.05	< 0.005	1.0
Er µg/L	2.8	0.02	0.008	0.02	0.006	0.14	3.1	< 0.05	0.005	2.6
Tm µg/L	0.42	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	0.37	< 0.05	< 0.005	0.35
Yb µg/L	2.5	0.02	< 0.01	0.02	< 0.01	0.10	2.1	< 0.05	< 0.01	1.8
Lu µg/L						< 0.05	0.26	< 0.05		
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	0.04	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
W µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
Re µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02				< 0.02	< 0.02
Au µg/L	0.01	< 0.01	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Tl µg/L	0.76	< 0.05	< 0.05	< 0.05	< 0.05	0.1	< 0.1	< 0.1	< 0.05	0.1
Pb µg/L	83	< 0.05	< 0.05	< 0.05	< 0.05	620	280	5.6	< 0.05	510
Bi µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05	< 0.05	< 0.01	< 0.01
Th µg/L	0.11	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05	< 0.05	< 0.005	0.02
U µg/L	1.2	0.006	< 0.005	0.006	< 0.005	0.02	0.73	< 0.02	< 0.005	0.77
Total Acid Soluble Concentrations										
Li µg/L	19	1.2	0.9	0.1	< 0.1	1.4	9.4	< 0.3	0.2	8.9
Be µg/L	0.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.2	0.3	< 0.2	< 0.05	0.4
B µg/L						**< 10**	**< 10**	**< 10**		
Na mg/L	0.48	1.4	1.1	1.4	1.0	0.90	**1.5**	**1**	0.77	0.83
Mg mg/L	22.00	2.20	2.40	0.45	0.57	**1.60**	**9.70**	0.63	0.51	7.00
Al µg/L	34000.00	260.00	180.00	22.00	170.00	**200.00**	**2100.00**	**170.00**	26.00	5400.00
Si mg/L	25.24	5.61	4.58	3.32	4.39	4.30	9.50	4.30	3.51	7.48

Sample	**FM-8-2**	**FM-9-2**	**FM-10-2**	**FM-11-2**	**FM-12-2**	**HCM-1-1**	**HCM-2-1**	**HCM-3-1**	**HCM-3-2**	HCM-4-2
Total Acid Soluble Concentrations (cont.)										
P µg/L	190	68	66	17	52	< 100	< 100	< 100	25	99
K µg/L	1400	660	590	600	430	**1400**	**4400**	600	520	3200
Ca mg/L	5.2	5.7	5.7	1.1	0.94	800	**13000**	**1400**	0.78	8.6
Sc µg/L	3	0.6	0.4	< 0.1	< 0.1	< 10	< 10	< 10	< 0.1	0.9
Ti µg/L	4.3	0.8	0.2	< 0.1	1.2	< 2	< 2	4	< 0.1	42
V µg/L	1	< 0.1	< 0.1	< 0.1	< 0.1	< 10	< 10	< 10	< 0.1	0.4
Cr µg/L	4	2	2	< 0.5	< 0.5	< 10	< 10	< 10	< 0.5	3
Fe µg/L	100000	3100	920	< 10	62	0.12	0.64	0.18	< 10	8000
Mn µg/L	650	120	150	4.9	9.1	46	1300	30	11	840
Co µg/L	150	0.87	0.92	0.03	0.1	3.5	18	< 0.5	0.2	18
Ni µg/L	38	1.5	0.8	< 0.1	0.1	3	14	< 1	0.3	14
Cu µg/L	76000	150	180	< 0.5	0.7	**980**	**7600**	**93**	110	16000
Zn µg/L	12000	290	230	< 0.5	2	**960**	**8400**	**140**	130	11000
Ga µg/L	0.67	< 0.02	< 0.02	< 0.02	< 0.02	< 0.5	< 0.5	< 0.5	< 0.02	0.4
Ge µg/L	0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.2	< 0.2	< 0.2	< 0.02	0.05
As µg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2
Se µg/L	6.7	0.4	0.6	0.2	0.4	< 5	< 5	< 5	0.3	2
Rb µg/L	26	2.4	1.7	1.3	1.3	8.8	31	1.6	1.7	30
Sr µg/L	22	22	20	9.6	7.8	4.6	**34**	6.9	5.1	22
Y µg/L	27	1.5	0.76	0.3	0.3	2.3	36	0.6	0.2	32
Zr µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.1	< 0.1	< 0.1	< 0.02	< 0.02
Mo µg/L	0.02	0.04	0.03	< 0.02	< 0.02	< 0.1	< 0.1	0.1	< 0.02	< 0.02
Ag µg/L	0.06	0.03	0.02	< 0.01	< 0.01	< 0.05	0.34	< 0.05	< 0.01	0.4
Cd µg/L	36	0.50	0.53	< 0.02	< 0.02	7.8	**22**	0.2	0.4	30
In µg/L	5.3	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05	< 0.05	< 0.01	0.05
Sn µg/L	0.3	< 0.05	< 0.05	< 0.05	< 0.05	< 1	< 1	< 1	< 0.05	< 0.05
Sb µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	0.10	0.04	< 0.02

Sample	FM-8-2	FM-9-2	FM-10-2	FM-11-2	FM-12-2	HCM-1-1	HCM-2-1	HCM-3-1	HCM-3-2	HCM-4-2
Total Acid Soluble Concentrations (cont.)										
Te µg/L	14	< 0.1	< 0.1	< 0.1	< 0.1	< 0.5	< 0.5	< 0.5	< 0.1	2.0
Cs µg/L	4.2	0.02	< 0.01	< 0.01	< 0.01	0.05	0.19	< 0.05	< 0.01	0.49
Ba µg/L	4	5.6	6.5	6.0	5.0	7.3	19	2.2	4	29
La µg/L	11	1.0	0.72	0.2	0.4	1.4	36	0.67	0.1	29
Ce µg/L	24	1.3	1.0	0.3	0.69	2.6	61	1.2	0.2	56
Pr µg/L	3.4	0.30	0.20	0.06	0.09	0.35	8.3	0.15	0.03	7.1
Nd µg/L	15	1.3	0.81	0.29	0.36	1.3	32	0.66	0.1	29
Sm µg/L	3.4	0.27	0.2	0.05	0.07	0.29	6.6	0.11	0.03	5.5
Eu µg/L	0.58	0.050	0.03	0.01	0.01	< 0.05	1.1	< 0.05	0.006	0.92
Tb µg/L	0.79	0.04	0.03	0.008	0.01	0.06	1.1	< 0.05	0.005	0.93
Gd µg/L	4.4	0.31	0.17	0.054	0.076	0.32	6.7	0.15	0.03	5.9
Dy µg/L	5.0	0.25	0.12	0.04	0.070	0.31	6.1	0.12	0.02	5.6
Ho µg/L	1.0	0.050	0.03	0.009	0.01	0.06	1.1	< 0.05	0.006	1.1
Er µg/L	2.9	0.12	0.068	0.02	0.04	0.16	3.0	0.06	0.02	2.7
Tm µg/L	0.42	0.02	0.01	< 0.005	0.005	< 0.05	0.37	< 0.05	< 0.005	0.36
Yb µg/L	2.5	0.09	0.06	0.02	0.03	0.11	2.0	< 0.05	0.01	2.0
Lu µg/L						< 0.05	0.25	< 0.05		
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
W µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
Re µg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02				< 0.02	< 0.02
Au µg/L	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01
Tl µg/L	0.66	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.05	0.1
Pb µg/L	83	0.4	0.2	< 0.05	< 0.05	660	280	1.2	0.07	590
Bi µg/L	0.06	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05	< 0.05	< 0.01	0.02
Th µg/L	0.12	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05	< 0.05	< 0.005	1.3
U µg/L	1.2	0.04	0.02	0.008	0.01	0.04	0.74	< 0.02	< 0.005	1.1

Sample	**HCM-5-2**	**HCM-6-2**	**HCM-7-2**	**HHS-1**	**HHS-1-R1**	**HHS-R1-2**	**NPS-66**	**NPS-72**	**NPS-74**	**NPS-75**
Collection Date	6/19/97	6/19/97	6/19/97	9/22/94	9/10/96	6/22/97	6/23/97	6/23/97	6/23/97	6/23/97
Field Parameters										
pH	3.8	6.4	4.5	4.6	4.8	4.8	6.7	6.6	6.8	5.1
Spec. Cond. µS/cm	264	97.5	97.6	40.9	26	23.1	18.2	14.7	22	17.5
Water T °C	13.0	13.0	15.0	15.0	14.6	15.2	15.0	14.0	13.0	12.0
Air T °C			23.0	19.0	19.0	22.0	23.0	19.0		
Dissolved O_2 mg/L	7.0		9.0	0.3	1.5	5.5	9.0	9.0	9.0	9.0
Filter Size (µm)	0.45	0.45	0.45	0.45	0.22	0.45	0.45	0.45	0.45	0.45
Dissolved Concentrations										
Hardness $CaCO_3$ mg/L	37.6	16.9	18.0	6.9	3752.4	4.6	5.3	4.0	7.0	4.0
Alkalinity $CaCO_3$ mg/L		3.0	0.0	1.9	2.4	0.0	1.1	0.9	2.1	0.0
NO_3 mg/L						2.0	2.8	2.3	2.4	2.9
F mg/L	0.1	0.1	< 0.1	<0.05	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cl mg/L	0.6	0.5	0.4	0.62	0.4	0.4	0.5	0.4	0.5	0.5
SO_4 mg/L	94	36	37	10	7.4	5.3	3.3	2.2	4	3.5
Li µg/L	7.3	4.2	3.5	2.5	1.1	1.9	0.5	< 0.1	0.5	1.0
Be µg/L	0.3	0.2	0.2	<0.2	< 0.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
B µg/L				**<50**	**< 10**					
Na mg/L	0.74	1.1	0.76	0.45	0.40	0.26	0.51	0.54	0.54	0.30
Mg mg/L	5.20	2.30	2.50	0.82	0.58	0.57	0.45	0.30	0.56	0.49
Al µg/L	3200.00	< 0.01	1400.00	120.00	**0.18**	470.00	66.00	93.00	70.00	250.00
Si mg/L	6.08	8.41	4.49	**1.20**	1.10	0.93	1.87	1.87	1.87	0.93
P µg/L	21	20	22	**<500**	< 100	< 1	5	17	18	< 1
K µg/L	2700	1700	1400	**<1000**	200	100	270	320	160	110
Ca mg/L	6.5	3.0	3.1	**1.4**	**1500**	0.92	1.4	1.1	1.9	0.80
Sc µg/L	0.5	0.7	0.3	2	< 10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ti µg/L	0.2	< 0.1	< 0.1	<2	< 2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
V µg/L	< 0.1	< 0.1	< 0.1	<0.2	< 10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cr µg/L	2	2	2	<0.4	< 10	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Fe^{2+} mg/L	0.1	8.3	0	4.5	0.1	0.03	0.01	0.03	0.01	0.02

Sample	**HCM-5-2**	**HCM-6-2**	**HCM-7-2**	**HHS-1**	**HHS-1-R1**	**HHS-R1-2**	**NPS-66**	**NPS-72**	**NPS-74**	**NPS-75**
Dissolved Concentrations (cont.)										
Fe µg/L	360	7800	270	6200	< 0.05	14	< 10	< 10	< 10	< 10
Mn µg/L	640	160	260	160	190	98	0.67	0.66	1.2	20
Co µg/L	15	1.7	5.8	3.4	2.6	2.0	< 0.02	< 0.02	0.02	0.4
Ni µg/L	11	3.9	5.1	1.8	4	2.6	0.4	0.2	0.6	1.3
Cu µg/L	13000	< 0.5	3800	1.1	2.2	2	< 0.5	< 0.5	< 0.5	< 0.5
Zn µg/L	8500	1700	3200	<10	20	20	2	1	3	6
Ga µg/L	0.2	0.05	0.07	<0.1	< 0.5	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ge µg/L	0.03	< 0.02	< 0.02	<0.2	< 0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
As µg/L	< 0.2	< 0.2	< 0.2	5.8	< 0.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Se µg/L	2	0.3	1		< 5	0.3	0.3	0.3	0.2	0.3
Rb µg/L	25	16	13	0.6	0.5	0.4	1.0	1.5	0.86	0.50
Sr µg/L	18	18	10	4.8	3.8	3.2	8.3	8.9	9.5	3.9
Y µg/L	27	6.6	9.1	0.1	0.4	0.4	0.2	0.2	0.2	0.3
Zr µg/L	< 0.05	< 0.05	< 0.05	<0.1	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.02	< 0.02	<0.1	< 0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Mo µg/L	< 0.02	< 0.02	< 0.02	<0.3	< 0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ag µg/L	0.3	0.02	0.09	<0.1	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cd µg/L	25	< 0.02	8.6	<0.4	< 0.1	0.1	< 0.02	< 0.02	0.05	< 0.02
In µg/L	< 0.01	< 0.01	< 0.01		< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sn µg/L	< 0.05	< 0.05	< 0.05	<0.4	< 1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Sb µg/L	0.02	0.03	0.03	1	0.12	< 0.02	< 0.02	0.04	< 0.02	< 0.02
Te µg/L	< 0.1	< 0.1	< 0.1	<0.9	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cs µg/L	0.36	0.1	0.1		< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ba µg/L	26	8.1	14	4.4	2.6	5.6	7.2	8.5	6.3	5.0
La µg/L	24	8.4	8.6	0.9	0.71	0.81	0.2	0.2	0.4	0.67
Ce µg/L	42	11	16	2.1	2.1	2.3	0.2	0.1	0.2	0.69
Pr µg/L	5.6	0.91	2.2	0.2	0.21	0.20	0.05	0.05	0.09	0.2
Nd µg/L	23	3.3	8.8	0.8	0.80	0.87	0.22	0.2	0.35	0.57

Sample	HCM-5-2	HCM-6-2	HCM-7-2	HHS-1	HHS-1-R1	HHS-R1-2	NPS-66	NPS-72	NPS-74	NPS-75
Dissolved Concentrations (cont.)										
Sm µg/L	4.3	0.39	1.7	0.1	0.12	0.1	0.03	0.04	0.07	0.1
Eu µg/L	0.75	0.072	0.29	<0.1	< 0.05	0.02	0.008	0.005	0.01	0.02
Tb µg/L	0.80	0.088	0.28	<0.1	< 0.05	0.01	< 0.005	< 0.005	0.007	0.01
Gd µg/L	5.0	0.67	1.7	0.2	0.12	0.12	0.03	0.03	0.057	0.075
Dy µg/L	4.6	0.49	1.6	<0.1	0.08	0.077	0.03	0.03	0.04	0.052
Ho µg/L	0.92	0.11	0.32	<0.1	< 0.05	0.01	< 0.005	< 0.005	0.007	0.01
Er µg/L	2.3	0.24	0.78	<0.1	< 0.05	0.03	0.009	0.01	0.02	0.02
Tm µg/L	0.31	0.02	0.11	<0.1	< 0.05	0.005	< 0.005	< 0.005	< 0.005	< 0.005
Yb µg/L	1.6	0.08	0.58	<0.1	< 0.05	0.04	0.01	0.01	0.02	0.02
Lu µg/L					< 0.05					
Hf µg/L	< 0.05	< 0.05	< 0.05	<0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	< 0.02	< 0.02	< 0.02	<0.1	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
W µg/L	< 0.02	< 0.02	< 0.02	<0.2	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Re µg/L	< 0.02	< 0.02	< 0.02	<0.1		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Au µg/L	< 0.01	< 0.01	< 0.01	<0.1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Tl µg/L	0.1	< 0.05	< 0.05	<0.6	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Pb µg/L	420	< 0.05	72	<0.6	0.32	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Bi µg/L	< 0.01	< 0.01	< 0.01	<0.6	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Th µg/L	0.008	< 0.005	< 0.005	<0.5	< 0.05	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U µg/L	0.73	0.04	0.23	<0.1	0.02	0.02	< 0.005	< 0.005	0.006	0.007
Total Acid Soluble Concentrations										
Li µg/L	7.7	4.0	3.6	2.6	1.2	1.6	0.4	0.4	0.6	1.1
Be µg/L	0.4	0.2	0.2	<0.2	< 0.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
B µg/L				**<50**	**< 10**					
Na mg/L	0.74	1.1	0.76	0.42	0.30	0.26	0.52	0.54	0.52	0.31
Mg mg/L	5.40	2.30	2.50	0.82	0.58	0.57	0.46	0.31	0.56	0.49
Al µg/L	4400.00	< 0.01	1600.00	140.00	**0.19**	730.00	190.00	130.00	91.00	260.00
Si mg/L	6.54	8.41	4.44	**1.20**	1.10	0.93	1.87	1.87	1.87	0.93

Sample	HCM-5-2	HCM-6-2	HCM-7-2	HHS-1	HHS-1-R1	HHS-R1-2	NPS-66	NPS-72	NPS-74	NPS-75
Total Acid Soluble Concentrations (cont.)										
P µg/L	120	19	71	**<500**	< 100	29	17	21	14	< 1
K µg/L	2900	1700	1500	**<1000**	200	110	280	320	160	110
Ca mg/L	6.5	3.1	3.1	**1.3**	**1500**	0.93	1.4	1.1	1.9	0.79
Sc µg/L	0.8	0.8	0.3	2	< 10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ti µg/L	23	< 0.1	0.8	<2	< 2	1.1	0.6	< 0.1	< 0.1	< 0.1
V µg/L	0.3	< 0.1	< 0.1	<0.2	< 10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cr µg/L	3	2	2	<0.4	< 10	0.7	< 0.5	< 0.5	0.6	< 0.5
Fe µg/L	3200	8000	2400	6500	< 0.05	230	46	16	13	< 10
Mn µg/L	660	160	260	160	190	110	6.6	2.1	2.4	20
Co µg/L	15	1.7	5.8	3.4	2.5	2.2	0.1	0.03	0.04	0.5
Ni µg/L	12	3.9	5.0	2.1	4	2.7	0.5	0.3	0.6	1.3
Cu µg/L	13000	< 0.5	3800	1.4	1.8	5	< 0.5	< 0.5	< 0.5	0.6
Zn µg/L	8500	1700	3200	<10	18	20	2	0.8	2	5
Ga µg/L	0.3	0.05	0.08	<0.1	< 0.5	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ge µg/L	0.04	< 0.02	0.02	<0.2	< 0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
As µg/L	< 0.2	< 0.2	< 0.2	6.3	< 0.5	0.3	< 0.2	< 0.2	< 0.2	< 0.2
Se µg/L	2	0.3	1		< 5	0.3	0.3	0.2	0.2	< 0.2
Rb µg/L	26	16	13	0.6	0.5	0.4	1.1	1.5	0.86	0.50
Sr µg/L	18	18	9.9	4.4	3.8	3.2	8.5	9.0	9.5	3.9
Y µg/L	29	7.5	9.1	0.1	0.4	0.56	0.2	0.2	0.2	0.3
Zr µg/L	< 0.05	< 0.05	< 0.05	<0.1	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.02	< 0.02	<0.1	< 0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Mo µg/L	< 0.02	< 0.02	0.02	<0.3	< 0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ag µg/L	0.2	0.02	0.07	<0.1	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cd µg/L	25	< 0.02	8.6	<0.4	< 0.1	0.1	< 0.02	< 0.02	< 0.02	0.02
In µg/L	0.03	< 0.01	0.01		< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sn µg/L	< 0.05	< 0.05	< 0.05	<0.4	< 1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Sb µg/L	< 0.02	< 0.02	< 0.02	<0.2	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample	**HCM-5-2**	**HCM-6-2**	**HCM-7-2**	**HHS-1**	**HHS-1-R1**	**HHS-R1-2**	**NPS-66**	**NPS-72**	**NPS-74**	**NPS-75**
Total Acid Soluble Concentrations (cont.)										
Te μg/L	2.4	< 0.1	< 0.1	<0.9	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cs μg/L	0.41	0.1	0.1		< 0.05	0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ba μg/L	27	8.0	14	4.1	2.4	5.7	7.4	8.3	6.2	5.2
La μg/L	26	8.9	8.6	0.9	0.74	1.2	0.5	0.2	0.5	0.71
Ce μg/L	50	12	16	2.4	2.0	4.4	0.4	0.2	0.3	0.77
Pr μg/L	6.3	1.2	2.2	0.3	0.20	0.31	0.1	0.05	0.1	0.2
Nd μg/L	26	4.4	8.9	1.2	0.81	1.3	0.40	0.23	0.40	0.60
Sm μg/L	5.0	0.57	1.7	0.2	0.14	0.24	0.07	0.04	0.05	0.1
Eu μg/L	0.83	0.11	0.28	<0.1	< 0.05	0.04	0.01	0.009	0.008	0.01
Tb μg/L	0.84	0.13	0.27	<0.1	< 0.05	0.02	0.006	0.006	0.007	0.01
Gd μg/L	5.4	0.92	1.8	0.2	0.10	0.20	0.070	0.04	0.056	0.088
Dy μg/L	5.0	0.67	1.6	<0.1	0.08	0.10	0.03	0.03	0.04	0.059
Ho μg/L	0.98	0.15	0.31	<0.1	< 0.05	0.02	0.008	0.005	0.006	0.008
Er μg/L	2.4	0.34	0.78	<0.1	< 0.05	0.050	0.02	0.01	0.02	0.02
Tm μg/L	0.34	0.03	0.11	<0.1	< 0.05	0.006	< 0.005	< 0.005	< 0.005	< 0.005
Yb μg/L	1.7	0.1	0.62	<0.1	< 0.05	0.04	0.01	0.01	0.01	0.02
Lu μg/L					< 0.05					
Hf μg/L	< 0.05	< 0.05	< 0.05	<0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ta μg/L	< 0.02	< 0.02	< 0.02	<0.1	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
W μg/L	< 0.02	< 0.02	< 0.02	<0.2	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Re μg/L	< 0.02	< 0.02	< 0.02	<0.1		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Au μg/L	< 0.01	< 0.01	< 0.01	<0.1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Tl μg/L	0.1	< 0.05	< 0.05	<0.6	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Pb μg/L	480	< 0.05	86	<0.6	0.16	0.3	< 0.05	< 0.05	< 0.05	< 0.05
Bi μg/L	0.04	< 0.01	< 0.01	<0.6	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Th μg/L	0.58	< 0.005	0.006	<0.5	< 0.05	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U μg/L	0.96	0.05	0.24	<0.1	< 0.02	0.05	0.01	0.008	0.005	0.01

Sample	**NPS-237**	**RTN-1**	**RTN-3**	**SCLF-1**	**SUG-1**	**STYX-1**	**STYX-1-R1**	**STYX-R1-2**	**STYX-2**
Collection Date	6/23/97	6/21/97	6/21/97	9/21/94	9/21/94	9/22/94	9/10/96	6/22/97	9/22/94
Field Parameters									
pH	4.7	4.6	7.0	7.8	5.0	5.9	6.0	6.2	4.9
Spec. Cond. µS/cm	19.2	30.1	14.2	21.4	286	15.5	16.3	24.1	15.54
Water T °C	16.0	18.0	15.5	16.0	13.0	10.0	11.5	12.0	10.0
Air T °C	19.0	28.0	24.0	24.0	19.0	18.0	19.0	20.0	19.0
Dissolved O_2 mg/L	7.0	8.0	9.0	8.0	6.0	10.0	9.0	9.0	8.0
Filter Size (µm)	0.45	0.45	0.45	0.45	0.45	0.45	0.22	0.45	0.45
Dissolved Concentrations									
Hardness $CaCO_3$ mg/L	3.3	4.0	3.5	6.2	49.4	5.8	3502.6	5.0	6.7
Alkalinity $CaCO_3$ mg/L	0.0	0.0	2.9	5.7	0.0	3.1	0.9	0.0	3.0
NO_3 mg/L	2.2							2.4	
F mg/L	< 0.1	< 0.1	< 0.1	<0.05	0.16	<0.05	< 0.1	< 0.1	<0.05
Cl mg/L	0.4	0.6	0.5	0.37	0.55	0.43	0.4	0.5	0.43
SO_4 mg/L	3.2	8	2.3	4.3	103	3.1	2.8	2.8	3.5
Li µg/L	0.8	3.1	0.3	0.5	7.4	0.8	< 0.3	0.9	1.1
Be µg/L	0.08	0.2	< 0.05	<0.2	<0.2	<0.2	< 0.2	< 0.05	<0.2
B µg/L				**<50**	**<50**	**<50**	**< 10**		**<50**
Na mg/L	0.36	0.71	0.89	0.91	0.91	0.41	0.40	0.32	0.44
Mg mg/L	0.33	0.74	0.38	0.60	6.00	0.57	0.63	0.63	0.59
Al µg/L	350.00	630.00	6.80	10.00	1100.00	10.00	13.00	21.00	20.00
Si mg/L	1.40	4.49	4.07	**3.9**	**7.4**	**1.20**	1.40	1.40	**1.20**
P µg/L	2	17	22	**<500**	**<500**	**<500**	< 100	< 1	**<500**
K µg/L	120	430	460	**<1000**	**3100**	**<1000**	200	110	**<1000**
Ca mg/L	0.79	0.4	0.79	**1.5**	**9.9**	**1.4**	**1400**	0.98	**1.7**
Sc µg/L	< 0.1	< 0.1	< 0.1	3.4	4.4	2	< 10	< 0.1	2
Ti µg/L	< 0.1	< 0.1	< 0.1	<2	3	<2	< 2	< 0.1	<2
V µg/L	< 0.1	< 0.1	< 0.1	<0.2	<0.2	<0.2	< 10	< 0.1	<0.2
Cr µg/L	< 0.5	1	< 0.5	<0.4	<0.4	<0.4	< 10	1	<0.4
Fe^{2+} mg/L	0.08	0	0.01	0.01	0.25	0	0	0	0

Sample	NPS-237	RTN-1	RTN-3	SCLF-1	SUG-1	STYX-1	STYX-1-R1	STYX-R1-2	STYX-2
Dissolved Concentrations (cont.)									
Fe µg/L	24	< 10	< 10	30	580	65	< 0.05	< 10	10
Mn µg/L	22	26	0.51	11	760	2.8	< 20	2.4	13
Co µg/L	0.4	1.1	< 0.02	0.20	15.00	<0.1	< 0.5	0.03	0.1
Ni µg/L	0.9	2.3	< 0.1	0.5	7.7	1.2	2	1.6	1.8
Cu µg/L	0.8	0.6	< 0.5	150	5700	0.8	< 0.5	< 0.5	1.3
Zn µg/L	6	21	1	250	6000	<10	4.4	6	<10
Ga µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.5	< 0.02	<0.1
Ge µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	< 0.2	< 0.02	<0.2
As µg/L	< 0.2	< 0.2	< 0.2	<1	<1	<1	< 0.5	< 0.2	<1
Se µg/L	0.4	0.3	0.3				< 5	0.2	
Rb µg/L	0.59	4.6	1.5	1.8	25	0.3	0.3	0.4	0.4
Sr µg/L	5.3	3.6	8.0	7.4	28	4.1	3.7	3.6	4.1
Y µg/L	0.4	0.99	0.05	0.4	31	0.2	0.2	0.2	0.2
Zr µg/L	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	< 0.1	< 0.05	<0.1
Nb µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.1	< 0.02	<0.1
Mo µg/L	< 0.02	< 0.02	< 0.02	<0.3	0.6	<0.3	< 0.1	< 0.02	<0.3
Ag µg/L	< 0.01	< 0.01	< 0.01	<0.1	0.4	<0.1	< 0.05	< 0.01	<0.1
Cd µg/L	0.07	< 0.02	< 0.02	0.7	18	<0.4	< 0.1	0.03	<0.4
In µg/L	< 0.01	< 0.01	< 0.01				< 0.05	< 0.01	
Sn µg/L	< 0.05	< 0.05	< 0.05	<0.4	<0.4	<0.4	< 1	< 0.05	<0.4
Sb µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	0.10	< 0.02	<0.2
Te µg/L	< 0.1	< 0.1	< 0.1	<0.9	<0.9	<0.9	< 0.5	< 0.1	<0.9
Cs µg/L	< 0.01	0.2	< 0.01	<0.1	0.3		< 0.05	< 0.01	
Ba µg/L	6.3	4	5	4.8	22	3.6	0.58	4	3.3
La µg/L	0.76	0.3	0.03	0.3	25	0.2	0.28	0.2	0.3
Ce µg/L	0.73	0.61	0.03	0.56	54	0.4	0.27	0.2	0.4
Pr µg/L	0.2	0.09	< 0.01	0.1	8.5	<0.1	0.06	0.05	<0.1
Nd µg/L	0.64	0.42	< 0.01	0.4	34	0.4	0.28	0.24	0.3

Sample	NPS-237	RTN-1	RTN-3	SCLF-1	SUG-1	STYX-1	STYX-1-R1	STYX-R1-2	STYX-2
Dissolved Concentrations (cont.)									
Sm µg/L	0.1	0.09	0.01	<0.1	6.4	<0.1	< 0.05	0.04	<0.1
Eu µg/L	0.02	0.04	< 0.005	<0.1	0.9	<0.1	< 0.05	< 0.005	<0.1
Tb µg/L	0.01	0.02	< 0.005	<0.1	7.1	<0.1	< 0.05	0.005	<0.1
Gd µg/L	0.10	0.15	0.006	<0.1	1.1	<0.1	< 0.05	0.04	<0.1
Dy µg/L	0.066	0.17	0.009	<0.1	5.8	<0.1	< 0.05	0.02	<0.1
Ho µg/L	0.01	0.04	< 0.005	<0.1	1.4	<0.1	< 0.05	0.005	<0.1
Er µg/L	0.03	0.10	0.007	<0.1	2.6	<0.1	< 0.05	0.01	<0.1
Tm µg/L	0.005	0.01	< 0.005	<0.1	0.4	<0.1	< 0.05	< 0.005	<0.1
Yb µg/L	0.02	0.1	< 0.01	<0.1	1.8	<0.1	< 0.05	< 0.01	<0.1
Lu µg/L							< 0.05		
Hf µg/L	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	< 0.05	< 0.05	<0.1
Ta µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.05	< 0.02	<0.1
W µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	< 0.05	< 0.02	<0.2
Re µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1		< 0.02	<0.1
Au µg/L	0.01	< 0.01	< 0.01	<0.1	<0.1	<0.1	< 0.01	0.01	<0.1
Tl µg/L	< 0.05	< 0.05	< 0.05	<0.6	<0.6	<0.6	< 0.1	< 0.05	<0.6
Pb µg/L	< 0.05	< 0.05	0.08	<0.6	270	<0.6	< 0.05	< 0.05	<0.6
Bi µg/L	< 0.01	< 0.01	< 0.01	<0.6	<0.6	<0.6	< 0.05	< 0.01	<0.6
Th µg/L	< 0.005	< 0.005	< 0.005	<0.5	<0.5	<0.5	< 0.05	< 0.005	<0.5
U µg/L	0.01	< 0.005	< 0.005	<0.1	0.6	<0.1	< 0.02	< 0.005	<0.1
Total Acid Soluble Concentrations									
Li µg/L	0.8	3.4	0.2	0.4	8.1	1	< 0.3	1.0	1.4
Be µg/L	< 0.05	0.2	< 0.05	<0.2	0.4	<0.2	< 0.2	< 0.05	<0.2
B µg/L				**<50**	**<50**	**<50**	**< 10**		**<50**
Na mg/L	0.35	0.72	0.89	0.86	0.84	0.41	0.40	0.32	0.32
Mg mg/L	0.33	0.75	0.40	0.59	6.30	0.58	0.63	0.64	0.60
Al µg/L	360.00	630.00	300.00	20.00	1100.00	10.00	15.00	160.00	20.00
Si mg/L	1.40	4.49	4.16	**3.9**	**2.40**	**1.20**	1.40	1.40	**1.20**

Sample	**NPS-237**	**RTN-1**	**RTN-3**	**SCLF-1**	**SUG-1**	**STYX-1**	**STYX-1-R1**	**STYX-R1-2**	**STYX-2**
Total Acid Soluble Concentrations (cont.)									
P µg/L	4	18	36	**<500**	**<500**	**<500**	< 100	7	**<500**
K µg/L	120	430	480	**<1000**	**3100**	**<1000**	100	110	**<1000**
Ca mg/L	0.78	0.4	0.79	**1.4**	**9.3**	**<1**	**1400**	0.99	**1.4**
Sc µg/L	< 0.1	< 0.1	< 0.1	3.2	4	2	< 10	< 0.1	2
Ti µg/L	< 0.1	< 0.1	5.1	<2	4	<2	< 2	< 0.1	<2
V µg/L	< 0.1	< 0.1	< 0.1	<0.2	<0.2	<0.2	< 10	< 0.1	<0.2
Cr µg/L	< 0.5	0.8	< 0.5	<0.4	<0.4	<0.4	< 10	0.8	<0.4
Fe µg/L	33	< 10	96	30	660	10	< 0.05	54	20
Mn µg/L	23	27	8.7	12	810	3.2	< 20	11	13
Co µg/L	0.4	1.1	0.1	0.40	17	<0.1	< 0.5	0.1	0.2
Ni µg/L	0.8	2.2	0.2	0.6	8.3	1.6	2	1.6	1.1
Cu µg/L	0.6	0.5	< 0.5	160	6400	<0.4	< 0.5	1	1.1
Zn µg/L	5	20	0.9	240	6700	<10	4.2	6	<10
Ga µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.5	< 0.02	<0.1
Ge µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	< 0.2	< 0.02	<0.2
As µg/L	< 0.2	< 0.2	< 0.2	<1	<1	<1	< 0.5	< 0.2	<1
Se µg/L	0.4	0.3	0.4				< 5	0.4	
Rb µg/L	0.58	4.6	1.7	1.8	26	0.4	0.3	0.4	0.3
Sr µg/L	5.3	3.6	8.4	6.8	29	4.3	3.7	3.6	4
Y µg/L	0.4	0.98	0.4	0.6	34	0.2	0.2	0.62	0.2
Zr µg/L	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	< 0.1	< 0.05	<0.1
Nb µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.1	< 0.02	<0.1
Mo µg/L	< 0.02	< 0.02	< 0.02	<0.3	<0.3	<0.3	< 0.1	< 0.02	<0.3
Ag µg/L	< 0.01	< 0.01	< 0.01	<0.1	0.4	<0.1	< 0.05	< 0.01	<0.1
Cd µg/L	0.08	< 0.02	< 0.02	0.6	19	<0.4	< 0.1	0.2	<0.4
In µg/L	< 0.01	< 0.01	< 0.01				< 0.05	< 0.01	
Sn µg/L	< 0.05	< 0.05	< 0.05	<0.4	<0.4	<0.4	< 1	< 0.05	<0.4
Sb µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	< 0.05	< 0.02	<0.2

Sample	NPS-237	RTN-1	RTN-3	SCLF-1	SUG-1	STYX-1	STYX-1-R1	STYX-R1-2	STYX-2
Total Acid Soluble Concentrations (cont.)									
Te µg/L	< 0.1	< 0.1	< 0.1	<0.9	<0.9	<0.9	< 0.5	< 0.1	<0.9
Cs µg/L	< 0.01	0.2	0.01	<0.1	0.3		< 0.05	< 0.01	
Ba µg/L	5.8	4	6.1	4.3	24	3.4	0.47	4	3.7
La µg/L	0.81	0.3	0.4	0.3	26	0.2	0.29	0.77	0.3
Ce µg/L	0.79	0.61	0.75	0.59	56	0.4	0.29	0.81	0.4
Pr µg/L	0.2	0.09	0.1	<0.1	8.4	<0.1	0.06	0.22	0.1
Nd µg/L	0.72	0.47	0.44	0.4	33	0.3	0.30	0.96	0.4
Sm µg/L	0.1	0.09	0.08	0.1	6.8	<0.1	< 0.05	0.2	<0.1
Eu µg/L	0.02	0.04	0.02	<0.1	0.8	<0.1	< 0.05	0.03	<0.1
Tb µg/L	0.01	0.03	0.01	<0.1	7.8	<0.1	< 0.05	0.02	<0.1
Gd µg/L	0.11	0.14	0.081	<0.1	1.2	<0.1	< 0.05	0.16	<0.1
Dy µg/L	0.067	0.19	0.075	<0.1	6.4	<0.1	< 0.05	0.093	<0.1
Ho µg/L	0.01	0.03	0.02	<0.1	1.3	<0.1	< 0.05	0.02	<0.1
Er µg/L	0.03	0.10	0.05	<0.1	3.1	<0.1	< 0.05	0.04	<0.1
Tm µg/L	< 0.005	0.02	0.005	<0.1	0.3	<0.1	< 0.05	0.007	<0.1
Yb µg/L	0.03	0.1	0.03	<0.1	2	<0.1	< 0.05	0.03	<0.1
Lu µg/L							< 0.05		
Hf µg/L	< 0.05	< 0.05	< 0.05	<0.1	<0.1	<0.1	< 0.05	< 0.05	<0.1
Ta µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1	< 0.05	< 0.02	<0.1
W µg/L	< 0.02	< 0.02	< 0.02	<0.2	<0.2	<0.2	< 0.05	< 0.02	<0.2
Re µg/L	< 0.02	< 0.02	< 0.02	<0.1	<0.1	<0.1		< 0.02	<0.1
Au µg/L	< 0.01	< 0.01	< 0.01	<0.1	<0.1	<0.1	< 0.01	< 0.01	<0.1
Tl µg/L	< 0.05	< 0.05	< 0.05	<0.6	<0.6	<0.6	< 0.1	< 0.05	<0.6
Pb µg/L	< 0.05	< 0.05	< 0.05	0.8	260	<0.6	< 0.05	< 0.05	<0.6
Bi µg/L	< 0.01	< 0.01	< 0.01	<0.6	<0.6	<0.6	< 0.05	< 0.01	<0.6
Th µg/L	< 0.005	< 0.005	< 0.005	<0.5	<0.5	<0.5	< 0.05	< 0.005	<0.5
U µg/L	0.02	0.006	0.01	<0.1	0.7	<0.1	< 0.02	0.008	<0.1