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NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Water quality and macroinvertebrate communities of Emigration and Red Butte Creeks, Salt Lake County, Utah

Introduction

Residential development in the canyons and foothills surrounding Salt Lake City, Utah, is growing at a rapid pace. Urban development typically degrades the water quality when formerly natural lands are developed. In Emigration Canyon, however, residential development is replacing land formerly used for grazing and recreation. It is not clear how this land use change has affected the water quality and biotic communities in this watershed. The water quality and macroinvertebrate communities of Emigration Creek and neighboring Red Butte Creek were examined by the U.S. Geological Survey (USGS) as part of the National Water-Quality Assessment Program (NAWQA) during summer 1999.

Significant Findings

- Water quality in Emigration Creek, which drains a residential area, is moderately degraded compared to water quality in Red Butte Creek, which drains an undeveloped area.
- The macroinvertebrate communities in upper Emigration Creek and Red Butte Creek are similar, indicating similar environmental conditions at these two sites. The middle and lower Emigration Creek sites have less taxa richness than the other sites and are dominated by a few taxa, reflecting human influence on these sites.
- Some changes in the macroinvertebrate community of Emigration Creek have occurred since 1950, but it is difficult to determine the reason for this change.

Description of Area

Emigration and Red Butte Creeks are located in adjacent canyons, to the east of Salt Lake City (fig. 1). Emigration Canyon is almost twice as large as Red Butte Canyon and has a lower stream gradient. Both creeks drain geologic formations that contribute large amounts of dissolved calcium carbonate to the water. In some areas, this calcium carbonate precipitates, causing a cement-like coating on rocks in the creek bottoms. Although present in both canyons, the coating is more prevalent in Red Butte Creek. Emigration Canyon is a residential area, while Red Butte Canyon has been protected from development.

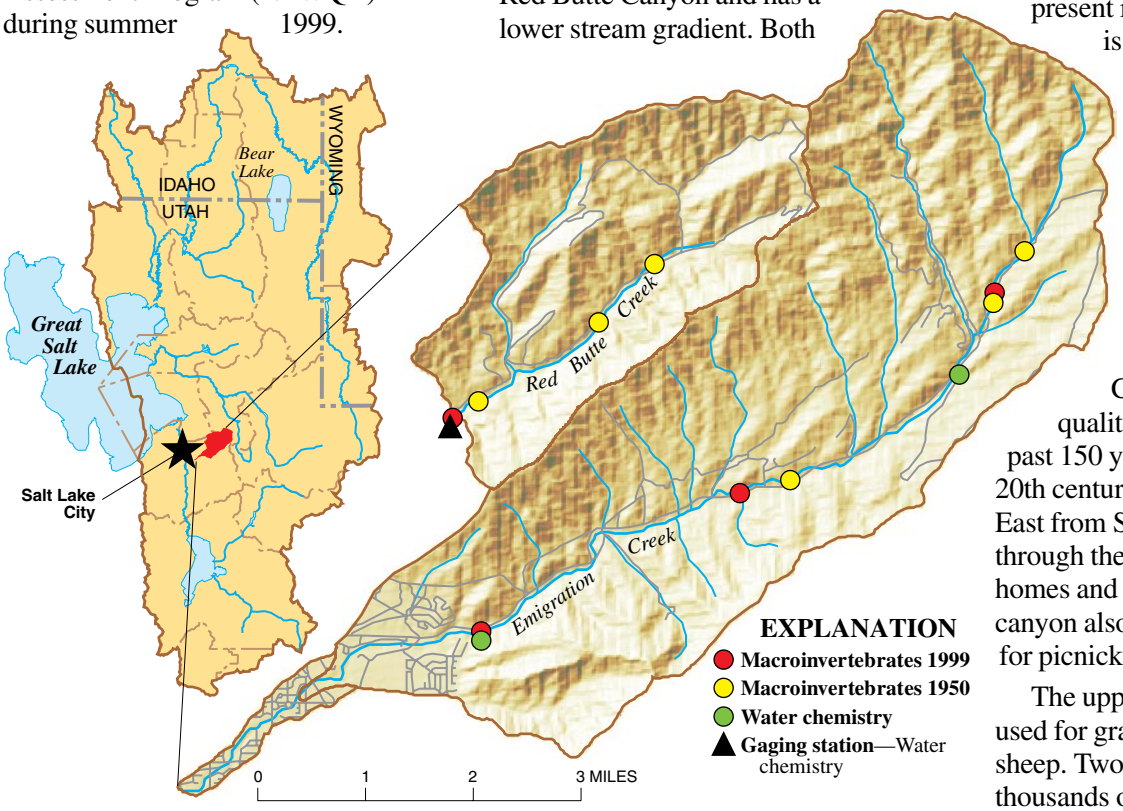

Figure 1. Location of sampling sites in Emigration and Red Butte Creeks.

Changing Land Use through Time

Activities in Emigration Canyon have affected water quality in varying ways for the past 150 years. In the early part of the 20th century, the main highway to the East from Salt Lake City was routed through the canyon, and many summer homes and cabins lined the creek. The canyon also was used by city residents for picnicking and recreation.

The upper areas of the canyon were used for grazing livestock, primarily sheep. Two times per year, hundreds of thousands of sheep were driven through

the canyon between the summer high country and winter lowland pastures. The sheep grazed on the way, denuding the hillsides of vegetation. Especially along the creek, trees, shrubs, and grasses were removed. The resulting lack of vegetation contributed to severe erosion of the hillsides in some areas. The creek likely was affected by sediment from upland erosion, trampling by livestock twice a year, and human recreation. The "sheep driveway" was eliminated in 1950, when herdsmen began using trucks to move their livestock between pastures.

Livestock grazing ended in the early 1970s, although residents still kept horses, cattle, chickens, and other animals into the late 1980s. Vegetation has grown back on the hillsides and along the creek, and the canyon's primary use today is residential. The population of year-round residents has risen sharply in the last 20 years. Most of the houses in the main canyon are close to the creek and use septic systems for water waste disposal.

In contrast, Red Butte Canyon has been largely protected from human influence for most of the 20th century, first as a drinking water source, and later as a U.S. Forest Service Research Natural Area. Natural disturbances have continued to occur, however. In 1983, a large flood caused landslides and severe erosion in the watershed, and the stream channel was reworked in some places as a result. Red Butte Creek also has been modified by the removal and subsequent reinvasion of beavers into the watershed. The USGS has operated a hydrologic benchmark station on Red Butte Creek since 1966, where stream-flow and water quality have been monitored.

Description of Studies

1999 Macroinvertebrate Survey and Water-Quality Collections

In 1999, the USGS sampled macroinvertebrates in Emigration and Red Butte Creeks. Three sites on Emigration Creek were sampled (fig. 1). The most upstream site is above the residential area of the canyon. The middle site is in a narrow area of the canyon, where most houses are very close to the creek. The lower site is near the mouth of the canyon. Habitat measurements were made at all three sites. One site in Red Butte Creek was sampled for macroinvertbrates at the USGS streamflow-gaging station (fig. 1). This site is similar in elevation to the middle site in Emigration Creek.

Photograph courtesy of Jeff Carlstrom, Emigration Canyon History Group

Emigration Canyon before 1950—Grazing of livestock removed upland vegetation, which led to gully erosion. Note in photograph below, the lower tree branches have been removed by livestock.

Photograph courtesy of Jeff Carlstrom, Emigration Canyon History Group

Emigration Canyon in 1999 is filled with residential development. Upland vegetation has grown back.

Water-chemistry data have been collected monthly by the Utah Division of Water Quality for more than 10 years at two sites in Emigration Creek (fig. 1). The lower water-chemistry site coincides with the lower macroinvertebrate site. The upper water-chemistry site is between the middle and upper macroinvertebrate sites. Water chemistry in Red Butte Creek is monitored with monthly samples collected by the USGS.

1950 Macroinvertebrate Survey

In addition to the recent data collections, a macroinvertebrate assessment of these two creeks was conducted in 1950 as part of a Masters thesis at the University of Utah (Whitney, 1951). This study sampled three sites in each creek (fig. 1), and the data were combined for an overall assessment of each creek. The study concentrated on the identification of aquatic insects. Despite changes in taxonomy and classification of many insects since 1950, the Whitney data can be compared to the 1999 USGS data.

Water Quality

Chloride

Chloride concentrations in Emigration and Red Butte Creeks illustrate that Emigration Creek is affected by humans (fig. 2). Chloride concentrations in Red Butte Creek are low throughout the year and vary little. In Emigration Creek, a spike in chloride concentrations in the winter reflects the use of road salt, which dissolves in water and runs off into the stream. Septic systems also likely contribute chloride from general household use and cause concentrations to vary throughout the rest of the year.

Nutrients

Nutrients are another potential concern in Emigration Creek. Septic systems can contribute substan-

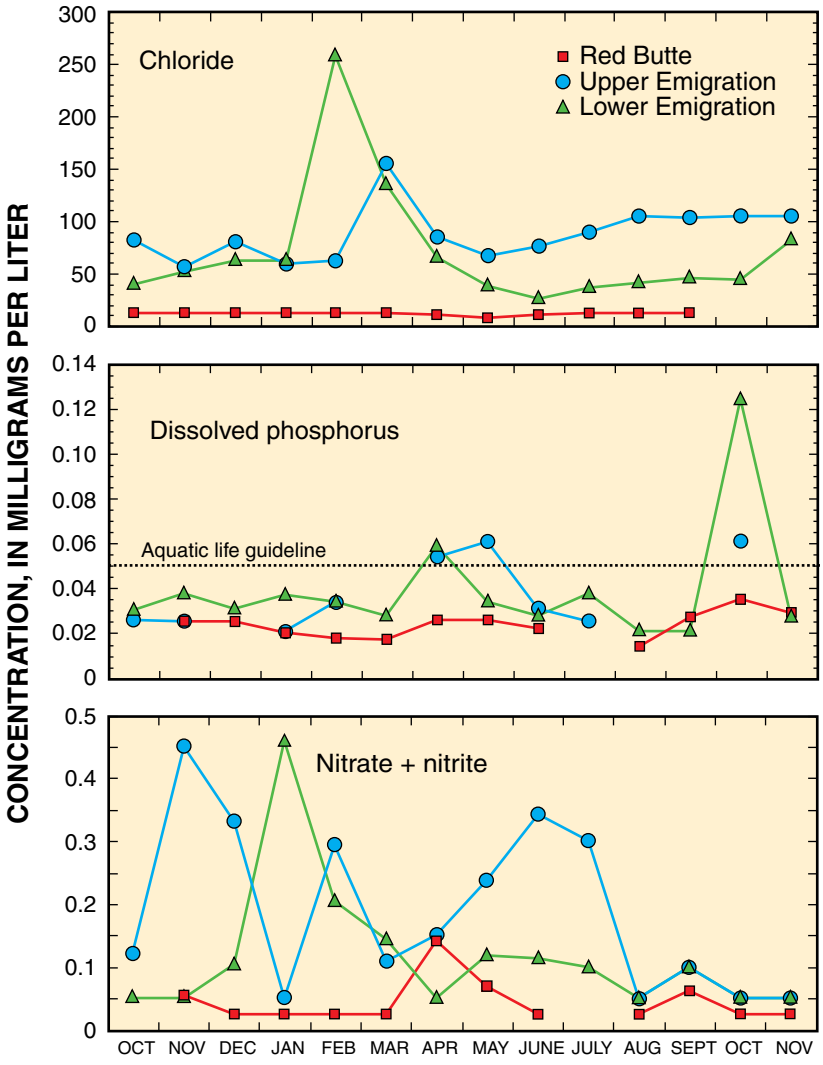

Figure 2. Chloride, dissolved phosphorus, and nitrate + nitrite concentration in Emigration and Red Butte Creeks, October 1998 to November 1999.

tial amounts of nutrients to aquatic systems, especially when they are not working properly. Concentrations of dissolved phosphorus generally were higher in Emigration Creek than Red Butte Creek in 1998 (fig. 2). Some of the concentrations in Emigration Creek exceeded State of Utah water-quality guidelines for aquatic life (0.05 milligrams per liter (mg/L)). The concentrations of inorganic nitrogen (nitrate + nitrite) also are generally higher in Emigration Creek than Red Butte Creek, but did not exceed the State of Utah water-quality guideline (4 mg/L) (fig. 2). A water-quality assessment of Emigration Creek in 1975 recorded an average nitrate concentration of 7 mg/L and phosphorus concentration of 0.5 mg/L (phosphate as P) (Templeton and others, 1975). On the basis of this study, it appears that the concentration of nutrients in Emigration Creek has decreased throughout the last 25 years; however, the effects of nutrients on aquatic life are still a concern.

Coliform Bacteria

Coliform bacteria have been monitored by Salt Lake Public Utilities in Emigration Creek, but not in Red Butte Creek. Emigration Creek has had a historic problem with high coliform counts caused by livestock and pets, as well as old cesspools and leaking septic systems. During the 1970s and 80s, counts exceeding the domestic source water limit of 5,000 (no.) total coliform per 100 milliliter (ml) were recorded (Glenne and West, 1981). In monthly samples collected during 1993–98, the count in 15 percent of the samples exceeded 200 per 100 ml for fecal coliform, the standard for recreational use. No samples exceeded 2,000 fecal coliform per 100 ml, the domestic source water limit (Florence Reynolds, Salt Lake Public Utilities, oral commun., 1998). However, coliform concentrations in the 1990s were higher in Emigration Creek than in other Wasatch Front streams (Red Butte Creek was not measured).

Macroinvertebrates

Richness and Abundance, 1999

The richness of macroinvertebrates (number of species) varied among sites (fig. 3). Richness was greatest at the upper Emigration site (60 species) and the Red Butte site (52 species). The lower Emigration site had about half as many species (29) and the middle site had an intermediate number (39 species). Taxa present at the upper site but missing from the lower were from all orders and of varying tolerance values. A reduction in taxa richness is often associated with perturbation of the stream. It indicates the stream is not as capable of supporting a wide variety of organisms because of some environmental condition, such as water quality, habitat, or food resources. A high richness would be expected at

Photograph by Stephen Porter, 2000

Sampling for macroinvertebrates.

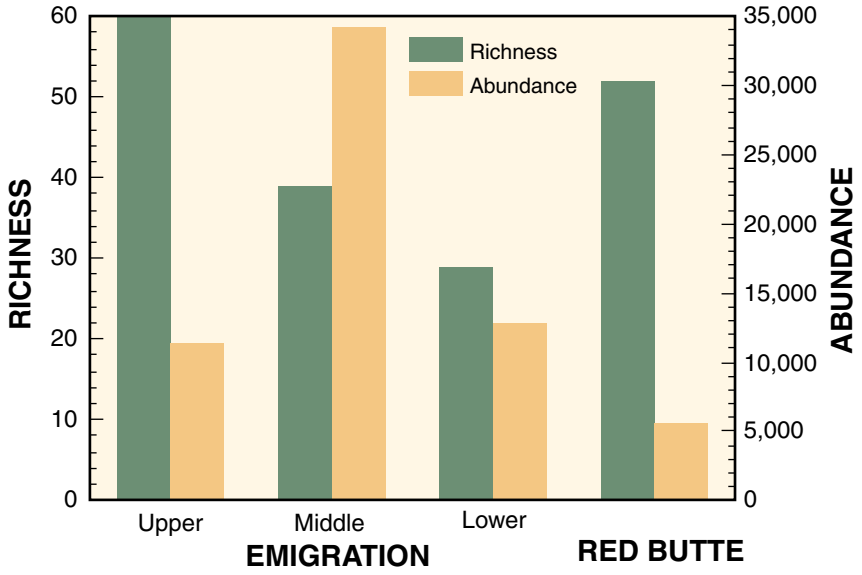

Figure 3. The richness (number of species) and abundance (number of individuals) of macroinvertebrates in Emigration and Red Butte Creeks, summer 1999.

undisturbed sites, such as Red Butte Creek. The upper Emigration site had even higher richness than Red Butte, indicating the environmental conditions at this site also supported a taxonomically rich community. The lower Emigration site had only half as many species, indicating a probable decline in environmental conditions.

The abundance (total number of organisms) of macroinvertebrates also differed between the two streams (fig. 3). The middle Emigration site was dominated by black fly larvae (Simuliidae), which account for 58 percent of the abundance. These organisms can reach very high abundances where stream conditions are right for them, including stable substrates and abundant particulate food sources in the water column. Abundant particulate food could be an effect of nutrient enrichment in the stream. Red Butte Creek had about half the total abundance of the upper and lower Emigration sites. This could result from several factors. First, the heavy calcium carbonate deposits in Red Butte Creek made sampling more difficult than in Emigration Creek, so sampling could have been less representative in Red Butte Creek. Second, the calcium carbonate deposits in Red Butte Creek reduce interstitial space available in the substrate, thus reducing food retention in the stream and abundance with it. Alternatively, the slight enrichment of nutrients in Emigration Creek could be supporting a more productive aquatic system, leading to a higher abundance.

Dominance and Tolerance, 1999

Mayflies in the genus Baetis and midges in the genus *Micropsectra* (Chironomidae) dominated the upper Emigration and Red Butte sites (table 1). These two groups accounted for 52.8 percent and 43.5 percent of the total abundance at these sites, respectively. The middle and lower Emigration sites were dominated by *Baetis* mayflies and *Simulium sp.* (black fly larvae). These two genera accounted for 79.4 percent and 84.8 percent of the total abundance at these sites. The more even distribution of taxa at the upper Emigration and Red Butte sites is indicative of a healthy community. In contrast, the middle and lower Emigration sites were heavily dominated by a few taxa. At the lower Emigration site, more than three-quarters of the sample consisted of *Baetis* mayflies, a tolerant genus, and all other taxa groups made up less than one-quarter. This indicates that there was a change in conditions between the sites that allowed a few taxa to dominate at the lower sites. This change is most likely a result of the effect of humans on the stream.

The upper Emigration and Red Butte sites had a higher percentage of intolerant taxa than the other two sites. At upper Emigration, 18 percent of the individuals collected belonged to intolerant taxa groups; at Red Butte, 12 percent; middle Emigration, 7.5 percent; and lower Emigration, 2 percent. The lower percentage of intolerant taxa at the middle and lower Emigration sites is another indicator of impaired water quality at these sites.

Because the Red Butte site is a minimally impacted watershed, it can be used as a reference site for Emigration Creek. The macroinvertebrate community at upper Emigration was similar in richness, dominance, and tolerance to the Red Butte site, indicat-

Photograph by Jim Carter

Simulium sp.—Black fly larvae.

Photograph by Jim Carter

Baetis sp.—Mayfly nymphs.

ing that environmental conditions at this site were similar to those at Red Butte. The middle Emigration site had a lower richness value (fig. 3) and was heavily dominated by *Simulium* (black fly larvae), an intermediate tolerance genus. However, some of the organisms supported at this site were intolerant. This indicates that there have been some human impacts at the site that modified the community structure, but the impacts have not been severe. The lower Emigration site, however, had lower richness, was heavily dominated by one taxa, and supported few intolerant organisms. This site is the most heavily impacted of the sites examined.

Comparison of Macroinvertebrates in 1950 and 1999

Several differences in methods used for the macroinvertebrate surveys in 1950 and 1999 make comparison difficult. In 1950, identification of macroinvertebrates was biased to aquatic insects in three orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT). Other insects and non-insects were collected, but relative abundances indicate either that sampling techniques missed most of the smaller invertebrates, or they were not identified. Comparisons can be made between 1950 and 1999 by examining the EPT taxa in the samples. Although not an EPT taxa, Simuliidae (black fly larvae) is an important taxa in the 1999 sample, and was therefore included in this analysis.

Photograph by Jim Carter

Chironomid—Midge.

Photograph by Jim Carter

Hydropsychidae—Caddisfly larvae.

In Emigration Creek, the mayflies of the genera *Epeorus* and *Ephemerella* dominated the 1950 sample (38 percent and 24 percent of EPT taxa collected) (table 2). Both of these genera are intolerant of impaired conditions. In 1999, *Epeorus* was collected at the middle and upper Emigration sites, but in much lower abundances (1.3 percent for the two sites combined). The genus *Ephemerella* has been split into two genera since 1950, *Ephemerella* and *Drunella*, and *Drunella* was collected in 1999, also at lower abundances than in 1950 (less than 1 percent). The dominant EPT taxa in 1999 were Baetidae (75 percent) and Nemouridae (a stonefly, 13 percent). The change in dominance of the sample in Emigration Creek indicates a shift from intolerant taxa, such as *Ephemerella*, to more tolerant taxa, such as *Baetis*. Because the insects involved occur in similar habitats and are similar in size, the change in dominance is not likely to be caused by differences in sampling technique.

The dominant EPT insects in Red Butte Creek in 1950 were caddisflies of the family Hydropsychidae (48 percent of sample) and mayflies in the family Baetidae (40 percent) (table 2). In 1999, Hydropsychidae were 4 percent of the sample collected and Baetidae were 73 percent. Simuliidae (black flies) were rarely collected in 1950 (only 1.5 percent of all taxa collected for both Emigration and Red Butte Creeks), while in 1999 this family was much more prevalent (7 to 58 percent of total taxa in Emigration and 18 percent in Red Butte).

Differences in the abundance of these caddisflies and black flies could be from differences in sampling technique or a change in available habitat. Both of these insects are filter feeders and require a specific stream velocity range, at which they tend to have a clumped distribution. The sampling locations in 1950 and 1999 may have differed enough to favor one or the other. Also, because the black fly larvae are small compared to the other aquatic insects, use of a larger mesh net could have greatly reduced the number of black flies collected. Alternatively, the habitat could have changed, making the required stream velocity for black flies more common and for caddisflies less common. Baetidae mayflies are important in Red Butte Creek in both the

Table 1. Dominant macroinvertebrate taxa in Emigration and Red Butte Creeks, 1999

[Percentage of total abundance of all taxa for the top two dominant taxa. Total is the sum of the top two]

Taxa	Percentage of all taxa
Upper Emigration	
Baetis sp.	45.8
Micropsectra sp.	7.0
Total	**52.8**
Middle Emigration	
Simulium sp.	57.8
Baetis sp.	21.6
Total	**79.4**
Lower Emigration	
Baetis sp.	76.4
Simulium sp.	8.4
Total	**84.8**
Red Butte	
Baetis sp.	25.9
Micropsectra sp.	17.6
Total	**43.5**

Table 2. Dominant Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in Emigration and Red Butte Creeks, in 1950 and 1999

[NC, not collected; <, less than]

Taxa	Percentage of EPT taxa	
Emigration[1]	**1950**	**1999**
Epeorus sp.	38	1.3
Ephemerella sp.	24	[2]< 1
Baetidae	6	75
Nemouridae	3	13
Red Butte		
Hydropsychidae	48	4
Baetidae	40	73
Nemouridae	NC	10

[1] The middle and upper Emigration sites from 1999 were combined. The lower site was excluded because this elevation was not sampled in 1950.

[2] *Drunella sp.* was collected. The genus *Ephemerella* was split into *Epemerella* and *Drunella* after 1950, so the taxa collected in 1999 could be the same genus or a different one.

1950 and 1999 surveys, although their dominance among EPT taxa was higher in 1999. Overall, 8 out of 12 genera collected in 1950 also were collected in 1999, indicating a similar community between the 2 years. However, some differences in dominance are apparent, which could reflect sampling differences or a change in habitat.

In the 1950 survey, samples were not collected from elevations as low as in the lower Emigration site, so no comparison was made with this site. Eighty percent of the insect genera collected in 1950 in Emigration Creek were recollected in 1999. As with Red Butte Creek, the community appears to be similar in composition in 1950 and 1999. However, a shift in the dominance of genera does appear to have occurred in Emigration Creek. This could be a result of water quality or habitat changes, but without information about those attributes in 1950, it is difficult to say why changes may have occurred.

Summary

The macroinvertebrate communities in upper Emigration Creek and Red Butte Creek are very similar, indicating that environmental conditions at both sites are also likely similar. The middle and lower Emigration sites have less taxa richness and are more heavily dominated by a few taxa. This is likely a result of human alterations of the stream channel and/or water-quality changes in the creek. The lower site appears to be the most degraded. However, the lower site still supports organisms of moderate tolerance, indicating that the water quality of Emigration Creek, while impaired, is not greatly limiting to the macroinvertebrate community.

Insects in the macroinvertebrate communities of these two creeks were similar in 1950 and 1999. However, the relative abundance of insects appears to have changed. In Red Butte Creek, the apparent changes could be a result of differences in sampling technique between 1950 and 1999, or habitat changes. In Emigration Creek, changes are less likely to be a result of sampling differences, but a shift from intolerant to more tolerant species appears to have occurred at the middle and lower sites. However, with the available information, it is difficult to determine the specific reason for this shift.

The water quality of Emigration and Red Butte Creeks differs both organically and inorganically. Coliform bacteria are a water-quality concern in Emigration Creek. Inorganic chemistry differs between the two creeks, on the basis of chloride and nutrient concentrations, and some enrichment of nutrients is indicated.

References

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Processing a macroinvertebrate sample.

National Water-Quality Assessment Program

The Great Salt Lake Basins study unit is 1 of 50 study units involved in the USGS NAWQA program. The goals of the NAWQA program are to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to gain a better understanding of the natural and human factors that affect the quality of these resources. The study design balances the unique assessment requirements of individual hydrologic systems with a nationally consistent design structure that incorporates a multi-scale, interdisciplinary approach.

Information on the NAWQA Program can be obtained from:

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— By Elise Giddings