DRAFT

TMDL for *Escherichia coli (E. coli)* in the Upper Emigration Creek Watershed

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US Environmental Protection Agency, Region 8

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Executive Summary

This document addresses water quality impairments within the Upper Emigration Creek Sub-Basin through the establishment of a Total Maximum Daily Load (TMDL) for *Escherichia coli (E. coli)*. The purpose of this TMDL study is to assess watershed conditions, establish water quality endpoints, and propose effective strategies to restore the Creek's designated beneficial uses. Upper Emigration Creek, from the Salt Lake County flow gage at Rotary Park to its headwaters, was listed on Utah's 2002 Section 303(d) list of impaired waters for pathogens (Fecal Coliform). In 2006, Utah switched to *Escherichia coli (E. coli)* as the indicator species for pathogens as it provides a better indicator of human health threat.

The impaired beneficial use is infrequent contact recreational use such as wading and fishing (Class 2B). The water quality standard for 2B waters is any sample may not exceed 206 MPN per 100 mL as a 30-day geometric mean and a maximum of 668 MPN in 100 mL in one sample in a 30-day period. The 30-day geometric mean is based on no less than 5 samples equally spaced over 30 days. Data analyses show that *E. coli* concentrations and loading increase from upstream to downstream and during low flow conditions in mid to late summer.

Thus the critical season of this *E. coli* TMDL is defined by the months of July, August and September and need an *E. coli* load reduction of 71% collectively. The observed loading is higher during the summer months due to a combination of several factors including warmer water temperatures and increased activity of humans, domestic animals and wildlife. There are no point sources in the Upper Emigration Creek watershed, thus all necessary load reductions are allocated to nonpoint sources.

Previous studies suggest that the origin of nonpoint pollution in Emigration Creek may include residential waste disposal, fecal contamination from dogs and wildlife, stormwater runoff, hydrologic modifications, and groundwater seepage from old holding vaults and septic tank leach fields. Although many improvements have been implemented in the Upper Sub-Basin, exceedances of water quality standards still occur on a regular basis.

This TMDL suggests several implementation strategies. A septic system dye study is recommended to determine if effluent from leaking septic systems is contributing to the bacterial contamination in Emigration Creek, and if so, which septic systems are failing. Residents of Emigration Canyon are encouraged to participate in the EPA's Voluntary National Guidelines for Management of Onsite and Clustered Wastewater Treatment Systems. Finally, in order to better understand the degree to which various sources contribute to the *E. coli* load in Emigration Creek the contribution of human versus non-human bacterial contributions in Emigration Creek should be determined.

Utah Department of Environmental Quality
Division of Water Quality
Water Quality Protection Section

DRAFT

Upper Emigration Creek TMDL

Waterbody ID	UT16020204-012
Location	Salt Lake County
Pollutants of Concern	*Escherichia coli (E. coli)*
Impaired Beneficial Uses	Class 2B: Infrequent Contact
Current Loading Loading Capacity (TMDL) Load Reduction	5.64E13 #/day 1.62E13 #/day 4.03E13 #/day (71%)
Wasteload Allocation Load Allocation Margin of Safety	0 #/day 1.46E13 #/day 1.62E12 #/day
Defined Targets/Endpoints	1) Total maximum load as an daily average of less than 1.62E13 #/day 2) Load reduction of 4.03E13 #/day 3) Maximum water quality target of 668 MPN/100 ml and geometric mean 206 MPN/100ml
Implementation Strategy	Stakeholders will employ an iterative and adaptive approach to address all anthropogenic sources of *E. coli* loading to include failing onsite septic systems, animal waste, and stormwater runoff.
This document is identified as a DRAFT TMDL for waters in the Emigration Creek drainage and is submitted under §303d of the Clean Water Act to U.S. EPA for review and approval.	

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

1.0 PURPOSE

This document provides a review of available chemical, physical and biological information for the Upper Emigration Creek Sub-Basin in order to assess and meet the beneficial uses for the creek as defined by the Clean Water Act (CWA). Water quality, flow, and macroinvertebrate data are summarized in order to assess the current health of Emigration Creek and to identify data gaps that may exist. A review of geologic data is also included in this document to assess hydro-geomorphic contributions to water quality impairments. Geographic Information System (GIS) data has also been included to assist in the determination of stream segments and potential loading sources.

Water quality, flow, and macroinvertebrate data that is included in this review date from 1975 through the summer of 2010. The number of measurements collected at each monitoring site is varied; however, a limited number of sample stations have consistent records. Routine and intense monitoring studies have indicated that Emigration Creek has high fecal coliform levels. Although the State of Utah bacteriological standard has been changed to *Escherichia coli* (*E. coli)*, both total and fecal coliform data will be reviewed in addition to the review of *E. coli* data.

Various federal, state, and local agencies have collected physical, biological, and chemical data from Emigration Creek. The primary agencies that have collected water quality and flow data in the Emigration Creek sub-basin are: Utah Division of Water Quality (DWQ), Salt Lake City Public Utilities, Salt Lake County (SLCo) Engineering Division, University of Utah, the United States Geological Survey (USGS), Emigration Improvement District (EID) and Westminster College. All of the pertinent water quality, biological, and physical studies that have been conducted are reviewed in this assessment.

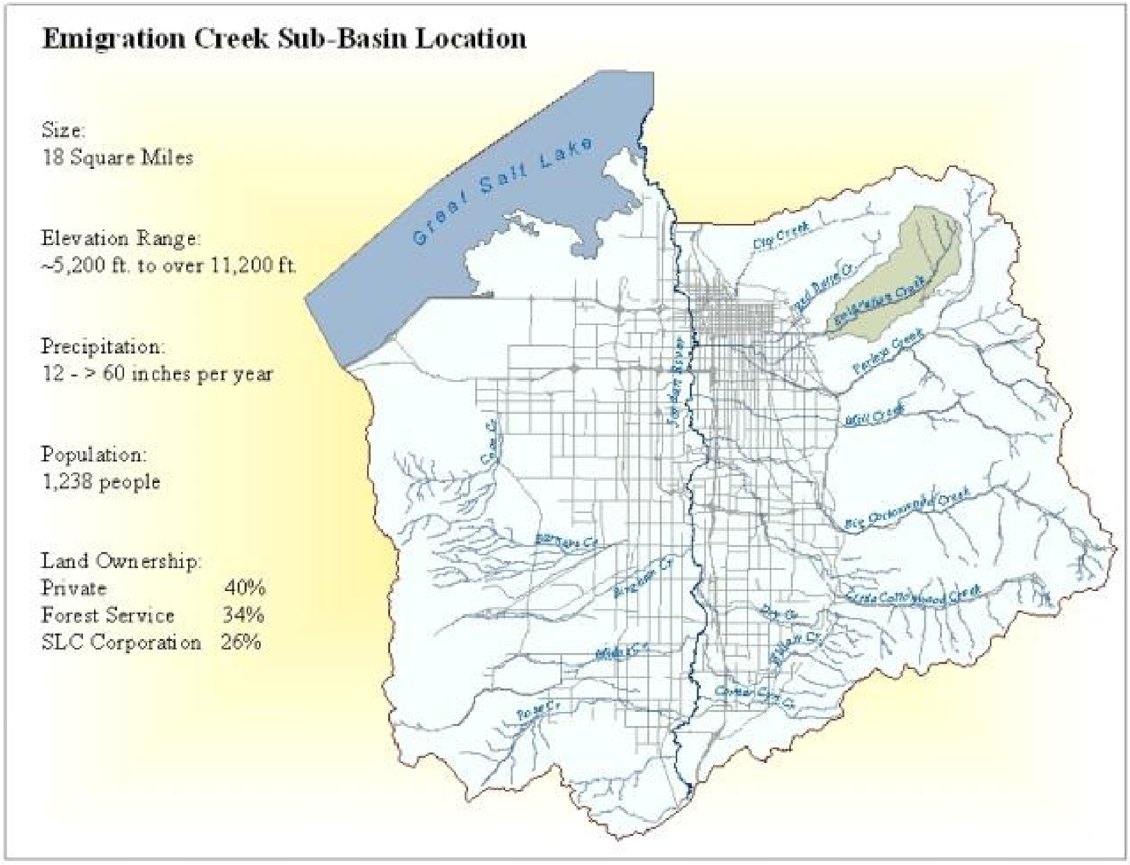
After reviewing available physical, chemical, and biological data for Emigration Creek, potential sources are identified and the critical period for load reductions are defined and discussed. The DWQ collected *E. coli* data at six (6) sample sites throughout the Upper Sub-Basin (Table 1) on a monthly basis throughout the year and on a weekly basis during the summer months. It has been determined that the data available from this sampling effort are sufficient to create load duration curves for all seasons.

Table 1. DWQ Sample Site Locations and Description.

Site Name/Description	latitude	longitude	STORET	STORET DESCRIPTION
Below Rotary Park	40º 44' 58.8"	111º 48' 33.6"	4992140	Emigration Ck at Rotary Glen Park nr Gage
Above Rotary Park	40º 45' 6.8"	111º 48' 16.1"	4992145	Emigration Ck at Rotary Glen Park
Sunnydale Rd	40º 45' 23.7"	111º 47 24.5"	4992150	Emigration Ck at Sunnydale Rd Xing
Maryfield Road	40º 45' 53.4"	111º 46' 28.0"	4992153	Emigration Ck at Maryfield Rd Xing
Maple Lane	40º 46' 28.8"	111º 44' 5.3"	4992158	Emigration Ck at Maple Lane Rd Xing
Burr Fork	40º 47' 13.5"	111º 42' 56.0"	4992162	Burr Fk ab cnfl/ Emigration Ck at Gage

2.0 GENERAL CHARACTERISTICS OF EMIGRATION CREEK SUB-BASIN

Emigration Creek Sub-Basin is located approximately 2 miles to the east of Salt Lake City (Map 1) and comprises a drainage area of 18 square miles (11,520 acres). In 1847, the Sub-Basin was the primary route used by Mormon Pioneers to enter the Salt Lake Valley and has thereby been designated a National Historic Site. Since its early notoriety as a migratory route, the sub-basin has been used for ranching, limited farming, quarrying, and summer resorts. Although initial residences were built as summer retreats, eventually these structures were converted and used for year-round residences. In addition to the Emigration Canyon Road, there is historical documentation of a railroad line that ran from the Valley floor to Pinecrest.



Map 1. Location of Emigration Creek Sub-Basin.

2.1 Emigration Creek

Emigration Creek is approximately 14 miles in length; the lower 3.7 miles of which are found in the Salt Lake Valley. The Sub-Basin has a moderate gradient (ranging between 1.2% to 3.6%), descending from 9,000 to 5,100 feet in elevation with an average gradient of 2.4%. The Creek originates in Killyon Canyon and Burr Fork and is later supplemented by water from springs in the upper basin. Small tributaries feed Emigration Creek for most of its length; however, there are two substantial intermittent tributaries - Pioneer Fork and Perkins Hollow—that enter the Creek approximately half way down the canyon. At the Sub-Basin mouth, Emigration Creek is diverted in the Mount Olivet diversion ditch (Figure 1). The average annual discharge at the mouth of the canyon ranges from 4,400 to 6,110 acre-feet per year (Wilden, 2005). The stream eventually flows into a conduit near Westminster College and is conveyed to the 1300 South conduit. Along with Red Butte and Parleys Creek, it is then conveyed to the Jordan River.

Figure 1. Mt. Olivet Diversion Ditch.

3.0 WATER QUALITY STANDARDS

3.1 Total Maximum Daily Load (TMDL)

A TMDL is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either defined implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}.$$

On a biennial basis, the DWQ develops lists of impaired waters in the state. Impaired waters are those waterbodies that currently fail to meet water quality standards established by the state. The biennial assessment conducted by DWQ is mandated under section 303(d) of the Clean Water Act and results in what is known as the 303(d) List of Impaired Waters. Subsequent to listing, the State is required to develop a Total Maximum Daily Load (TMDL) to reduce pollutant levels in impaired waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive on a daily basis and still meet water quality standards. The TMDL process consists of the following steps: 1) Review existing water quality data, 2) Identify sources and causes of pollutants, 3) Identify water quality goals, 4) Establish the amount of pollutant that can be allowed in total, 5) Allocate allowable pollutant loads to the various sources, 6) Identify and implement measures to achieve and maintain water quality standards, and 7) Monitor to assure that goals are met. The TMDL process results in load allocations to each pollutant contributor that may often result in regulatory controls and mandates.

3.2 Impairment of Emigration Creek

Emigration Creek is a 3rd order tributary of the Jordan River. The Creek was listed as impaired for high Fecal Coliform levels in 2000. With a change in State standards, the TMDL study will target *E. coli*. Monitoring efforts by DWQ, Salt Lake County 208 Water Quality Project, Salt Lake Valley Health Department (SLVHD), Salt Lake City Public Utilities, University of Utah, Salt Lake County Public Works, and USGS suggest that the origin of nonpoint pollution in Emigration Creek may include residential waste disposal, fecal contamination from dogs and wildlife, stormwater runoff, hydrologic modifications, and groundwater seepage from old holding vaults and septic tank leach fields.

3.3 Water Quality Standards and TMDL Target

The purpose of a TMDL water quality study is to establish the water quality goals and endpoints that will meet water quality standards and restore an impaired waterbody's designated beneficial uses. One of the primary components of a TMDL is the instream numeric target to evaluate attainment of water quality goals. Instream numeric targets, therefore, represent the water quality goals to be achieved by reducing pollutant loads specified in the TMDL. Numeric water quality targets associated with Emigration Creek are listed in Table 2. The targets allow for a comparison between current instream conditions and those required to support its beneficial uses. The targets are established on the basis of numeric or narrative criteria from state water quality standards. If numeric water quality standards are available, they can serve as a TMDL target. If only narrative criteria are available, a numeric target is developed to represent conditions supporting designated beneficial uses.

Table 2. Utah Division of Water Quality State Standards for Emigration Creek

State of Utah water quality criteria and pollution indicators used in Emigration Creek	
Parameter	**Beneficial Use Classification Standards**
Bacteriological	
Total Coliform(1) – Max	5,000 colonies/100 ml
Fecal Coliform(2) – Max(2)	400 colonies/100 ml
Fecal Coliform(1) – 30 Day Geometric Mean(3)	200 colonies/100 ml
E. coli – Max(2)	940 colonies/100 ml
E. coli – 30 Day Geometric Mean	206 colonies/100 ml
Physical	
Dissolved Oxygen – Minimum	5.5 mg/L
Temperature – Max	27° C
PH – Range	6.5 – 9.0
Inorganics	
Total Ammonia as N	pH dependent (see R317-2 Table 2.14.2)
Total Dissolved Solids	1,200 mg/L
Pollution Indicators	
Biochemical Oxygen Demand	5 mg/L
Total Phosphorus as P	0.05 mg/L
Total Suspended Solids(4)	35 mg/L

(1) Total and Fecal coliform are no longer included in Utah water quality standards.
(2) All sample values within a 30-day sample period compared to a threshold value. Minimum of five samples collected within 30-days, if <10 samples collected in 30 days – at least two samples must exceed criteria for impairment.
(3) Geometric mean calculated from a minimum of five samples collected within 30-days.
(4) Total Suspended Solids (TSS) are no longer used as a pollution indicator by Utah DWQ. The criterion was formerly associated with Class 3A – Cold Water Fishery.

3.4 Overview of 303(d) List

Emigration Creek and tributaries, from the flow gage at Rotary Park to headwaters, is listed on Utah's 2002 Section 303(d) list of impaired waters for pathogens (Fecal Coliform). Since 2006, Utah has used *Escherichia coli (E. coli)* instead of Fecal Coliform as the indicator species for pathogens as it provides a more accurate representation of the health threat posed by pathogenic contamination. Emigration Creek was then technically delisted in 2006 for Fecal Coliform but added to the Impaired List for exceedances in *E. coli* as show in Table 3. The beneficial use that is listed as impaired is infrequent contact recreational use such as wading and fishing (Class 2B).

Table 3. Classification of Impaired Waters in the Emigration Creek Watershed.

Name	**Year Listed**	**Impaired Beneficial Use**	**Cause of Impairment**
Emigration Creek and tributaries from Rotary Park to Headwaters	2002	2B	Pathogens (Fecal coliform)
Emigration Creek and tributaries from Rotary Park to Headwaters	2006	2B	*E. coli*

3.5 Parameter of Concern (E. coli)

The World Health Organization (WHO) reports that 80% of all sicknesses can be attributed to inadequate water supplies and poor sanitation. To ensure the protection of public health, routine monitoring and assessment programs are needed. For Utah's bacteriological monitoring program, surface waters are monitored for pathogens that originate from fecal pollution from both human and animal waste. It is not feasible to monitor for all pathogens in water, but by analyzing for certain indicator organisms, it is possible to assess potential health risks. Following the Environmental Protection Agency (EPA) guidelines, Utah samples for *E. coli* concentrations from Utah's surface waters.

The use of indicator organisms as a means of assessing the presence of pathogens in surface waters has been adopted by the WHO, EPA, and the European Union. *E. coli* are the most abundant coliform bacteria present in human and animal intestines numbering up to 1 billion per gram of feces. They are the only true fecal coliform bacteria in that their presence can be exclusively attributed to a fecal origin. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination. Common fecal contamination sources include failing septic systems, leaking sewer lines, livestock pastures, confined feedlots, wildlife, and dog parks (Benham, 2006). Pathogenic bacteria are washed into surface waters during rainfall or snowmelt or deposited directly and pose a threat to human health through incidental ingestion or contact with broken skin.

3.6 Applicable Water Quality Standards

Under the Clean Water Act (CWA), every state must adopt water quality standards to protect, maintain, and improve the quality of surface waters. These standards represent a level of water quality that will support the Clean Water Act's goals of "swimmable/fishable" waters. Water quality standards consist of three major components:

- Beneficial uses reflect how humans can potentially use the water and how well it supports those uses. Examples of beneficial uses include aquatic life support, agriculture, drinking water supply, and recreation. Every waterbody in Utah has a designated use or uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support designated beneficial uses. Numeric criteria represent the maximum concentration of a pollutant that can be in the water and still support the beneficial use of the waterbody. Narrative criteria state that all waters must be free from sludge, floating debris, oil/scum, color and odor producing materials, substances that are harmful to human, animal, or aquatic life, and nutrients in concentrations that may cause algal blooms.
- Utah's antidegradation policy (UAC R317-2-3) establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants through the Utah Pollutant Discharge Elimination System (UPDES) permitting process to demonstrate an important social or economic need.

The Utah Water Quality Board (UWQB) is responsible for establishing the water quality standards that are then enforced by the Utah Department of Environmental Quality, Division of Water Quality. Utah has numeric criteria for *E. coli* found in the Utah Administrative Code, Standards of Quality for Waters of the State R317-2. These criteria vary based on the beneficial use assignment of the waterbody (DWQ 2009). Table 4 summarizes the standards pertaining to the 303(d) listed segment in the Emigration Creek watershed.

Table 4. Water Quality Standards for Impaired Waters in the Emigration Creek Watershed.

Designated Use	**Description**	***E. coli* Geometric Mean (MPN*/100 mL)**	***E. coli* Not to Exceed (MPN*/100 mL)**
2B	Secondary Contact	206	668
3A	Cold Water Fishery	N/A	N/A

*MPN/100 mL= Most Probable Number [of colonies] per 100 mL water

Utah has two recreational beneficial use categories, frequent contact recreation (2A) with more stringent criteria for uses such as swimming, and infrequent contact recreation such as boating or wading (2B). The *E. coli* numeric standard for 2A waters is a sample may not exceed 126 MPN per 100 mL as a 30-day geometric mean and a maximum of 409 MPN per 100 mL in one sample in a 30-day period. The standard for 2B waters is a sample should not exceed 206 MPN per 100 mL as a 30-day geometric mean and a maximum of 668 MPN in 100 mL in one sample in a 30-day period. The 30-day geometric mean is based on no less than 5 samples equally spaced over 30 days.

The geometric mean is used when evaluating bacterial data and not the arithmetic mean because these data tend to span several orders of magnitude in a given data set. The geometric mean, unlike the arithmetic mean, is not influenced by outliers that might bias the data. This is helpful with bacteria because levels may vary from 10 to 10,000 fold over a given time period. It is also more appropriate than the arithmetic mean for describing exponential growth.

3.7 Utah's Listing Methodology and 303(d) Status

Surface waters designated as having a 2A or 2B recreational use in Utah are assessed for *E. coli* using the water quality standards (Table 3) and the assessment methodology presented in Figure 2.

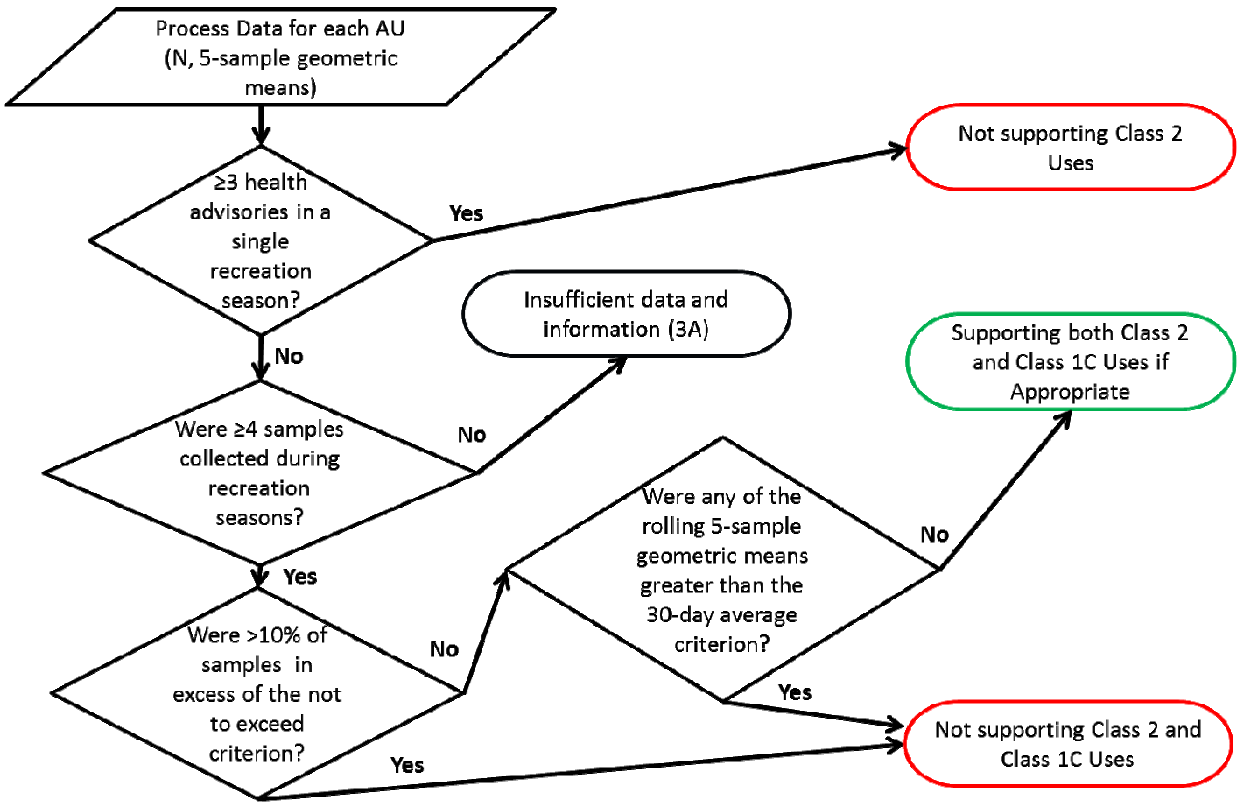


Figure 2. Assessment Methodology for E. coli Impairments.

The following rules provide an interpretation of Utah's *E. coli* criteria, depending on the number of samples collected during the most recent five years of sampling. Assessment Units (AUs) that fail to meet any of these criteria will be listed as failing to meet its designated uses on Utah's 303(d) list of impaired waters; however, exceptions may be made to these rules if a single collection event represents an outlier that biases results:

- Rule 1: For each AU with >10 samples in any recreation season, all 5-sample rolling geometric means of samples collected from May 1st through September

30th should not exceed either 126 MPN/100 mL for 2A waters or 206 MPN/100 mL for 2B waters.

- Rule 2: For each AU with >5 samples in any recreation season, no more than 10% of samples collected from May 1st through September 30th should exceed 409 MPN/100 mL for 2A waters or 668 MPN/100 mL for 1C/2B waters throughout the most recent five years.

- Rule 3: AUs with ≤4 samples in any recreation season will not be assessed for support of recreation uses. These sites will be prioritized for future sampling, particularly if limited data suggest a problem exists in the waterbody.

3.7.1 Analytical Methods

Before making any assessment decision, DWQ will first compile information on health advisories and all existing and available *E. coli* data collected from Utah's waters during the five most recent recreation seasons (May 1st through September 30th). These data are summarized by Assessment Unit (AU) as follows:

- Closures or Health Advisories: A tally of closures issued for the waterbody during each recreation season.

- Single Samples: A tally and percent of samples collected over the most recent five years that are greater than the "not to exceed" E. coli standard for the AU: 409 MPN/100 mL for 2A waters and 668 MPN/100 mL for 1C/2B waters in three years.

- Rolling Geometric Means: Calculation of 5-sample rolling geometric means and a tally of the number of times the 5-sample geometric mean exceeds the 30 day, 5-sample geometric mean criterion for the AU: 126 MPN/100 mL for 2A waters and 206 MPN/100 mL for 1C/2B waters.

Rolling geometric means are calculated by ordering all samples by date and then calculating a series of moving 5-sample geometric means, starting with the first 5 samples, then samples 2-6, then 3-7, etc. within each recreation season. In some situations, very frequent samples (more than1 per day) are collected in response to health advisories or beach closures, in such situations the geometric mean of these samples is used to represent a single collection event to avoid biasing the data set with a single spike of high *E. coli* concentrations.

3.7.2 Assessment of Recreational and Drinking Water Uses

Based on the summary of all *E. coli* data and information, an Assessment Unit (AU) will be assessed as not meeting its designated recreational uses if any of the following decision rules apply:

- Rule 1: A lake or reservoir that has ≥3 posted health advisories or beach closures during any recreation season shall be considered impaired (not supporting recreational uses). Since Emigration Creek is not a lake or reservoir this rule does not apply to it. In many cases, sites will also be designated as impaired following the other assessment rules; however, because health advisory rules are conservative by using the 5-sample, 30-day geometric mean criteria without the 10% exceedence exception— this rule captures sites with repeated moderately high *E. coli* concerns. While this rule is not explicitly required by Utah's water quality standards, DWQ believes that it is consistent with the intent of recreational use protections.

- Rule 2**:** Any AU where >10% of samples are greater than the not to exceed criterion shall be considered impaired, provided that at least one recreation season has ≥5 collection events.

- Rule 3**:** Any of the 5-sample rolling geometric mean calculations exceed the 30-day, 5-sample geometric mean criterion assigned to waters within the AU, provided that ≥10 samples were collected in the AU during any of the 5 recreation seasons evaluated. However, this rule shall not be used to make assessments if the results are biased from a single outlier.

The outcome from these impairment rules are subsequently used to place each AU with any *E. coli* data or information into 303(d) beneficial use support categories as follows:

- Insufficient Data or Information (Category 3A): Sites with ≤4 collection events in all seasons evaluated will be placed into Category 3A, provided that impairment is not suggested by the first impairment rule (≥3 health advisories); or impairment rule 3 (rolling geometric means). All 3A sites will be prioritized for future monitoring, particularly when this assessment is based on the influence of statistical outliers.

- Fully Supporting (Category 1 or 2): There is no evidence of impairment from any of the three impairment rules and there exists at least five collection events for the AU for at least one recreation season over the most recent five years.

- Not Supporting (Category 5): An AU is considered to be impaired— not meeting its recreational beneficial use — if any of the impairment rules suggest that concentrations of *E. coli* represent a threat to human health.

3.8 TMDL Endpoints

TMDL endpoints represent water quality targets. For *E. coli*, the reductions specified in the TMDL to meet the 30-day geometric mean water quality standard will ensure no sample will exceed the acute *E. coli* water quality standard based upon the current data set.

4.0 DETAILED CHARACTERISTICS OF UPPER EMIGRATION CREEK SUB-BASIN

4.1 Physical Features

Low-lying, rolling hills characterize Emigration Creek Sub-Basin with steeper mountains in the northeast section. Further down the canyon, side slopes remain moderate until the mouth, where they become narrow and steep. From the mouth, the drainage gently slopes to the west. The drainage area below the mouth of the Sub-Basin consists of lakebed terraces with very well drained soils having medium to slow runoff potential (Yonkee and Barnett, 2000).

4.1.1 Bedrock Geology

The Emigration Creek Sub-Basin is located along the western flank of the central Wasatch Mountain Range in the Middle Rocky Mountain physiographic province (SLCO, 1999). Rocks within the Sub-Basin range in age from Pennsylvanian (323 - 290 million years ago) to Cretaceous (144 - 65 million years ago) and are folded in a northeast-southwest trending syncline (U-shaped fold) (Figure 3).

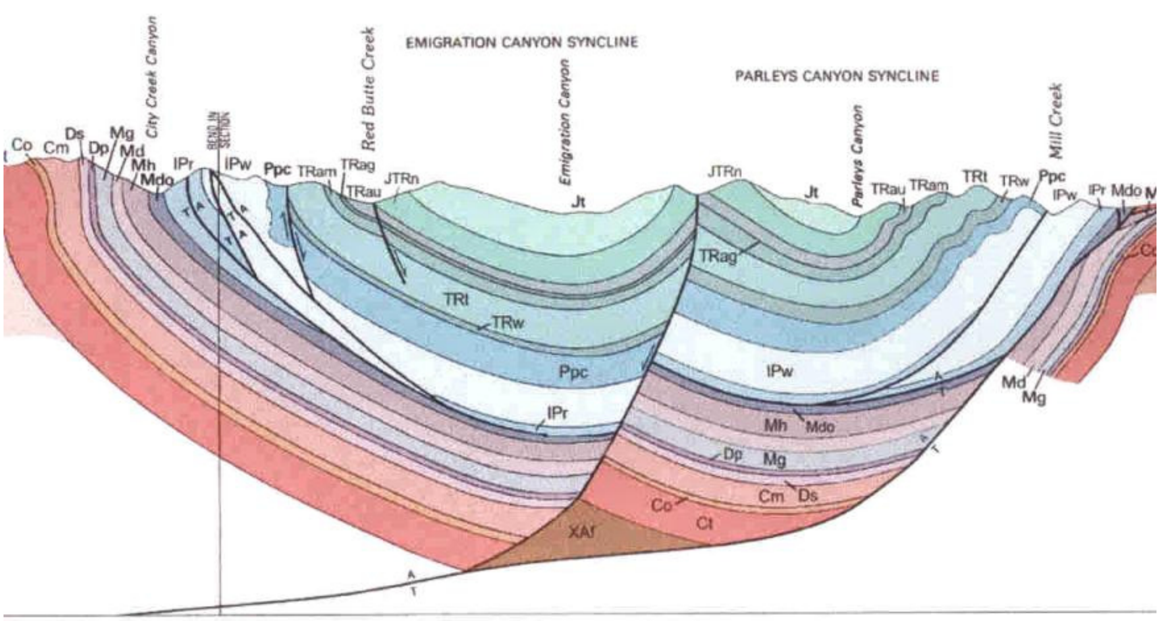
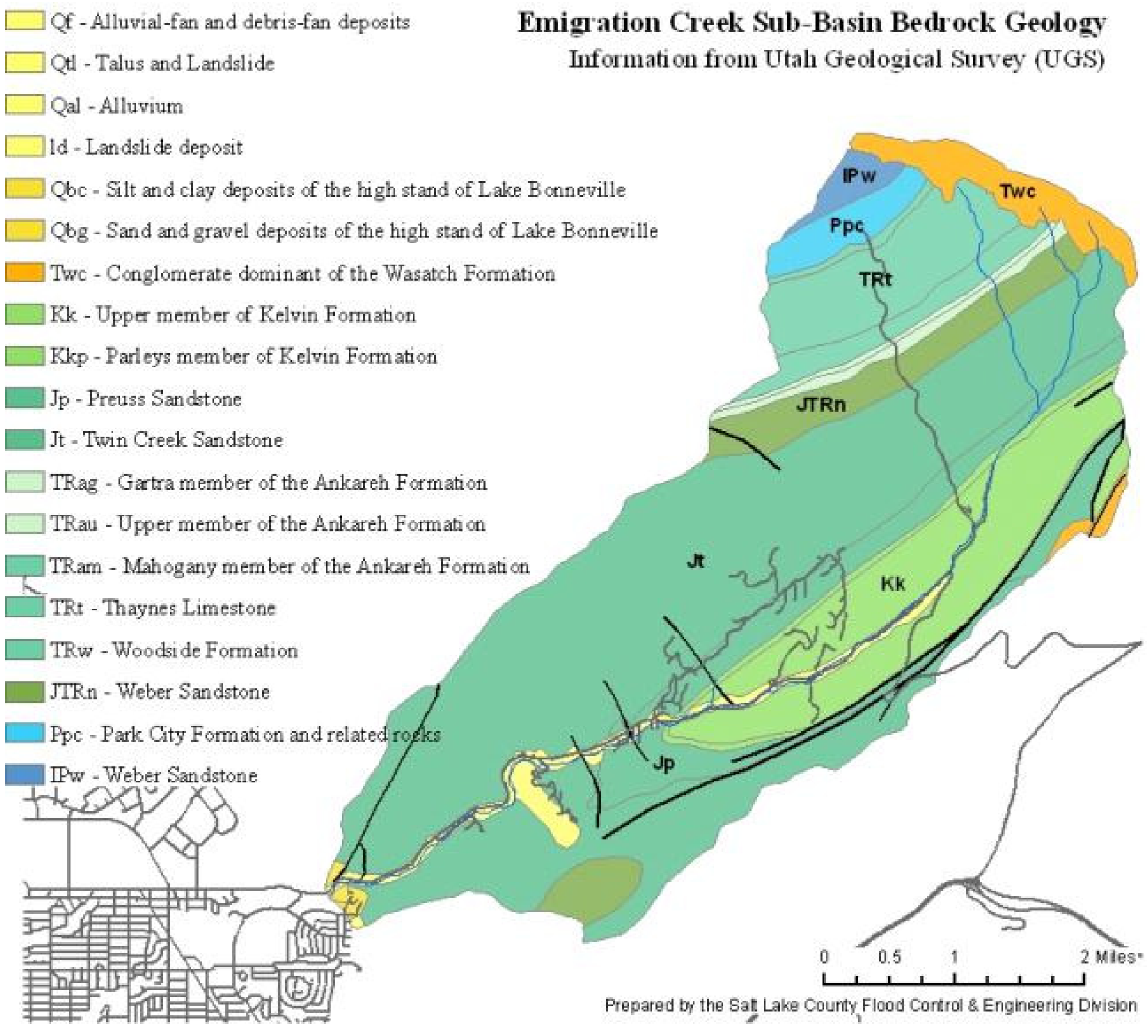


Figure 3. Emigration Creek Sub-Basin Syncline.

The Twin Creek Sandstone formation dominates the slopes of Emigration Creek Sub-Basin; whereas, the Kelvin Formation dominates the lower elevations in the upper two-thirds of the Sub-Basin. Typically, alluvial deposits are found along the majority of Emigration Creek. In the upper northeastern section of the Sub-Basin, Weber Sandstone, Thaynes Limestone, and the Park City Formation transect the Burr Fork and Killyon Canyon regions. Tertiary-age (65 - 1.8 million years ago) Wasatch Formation has covered the northeastern portion of the syncline (Map 2).



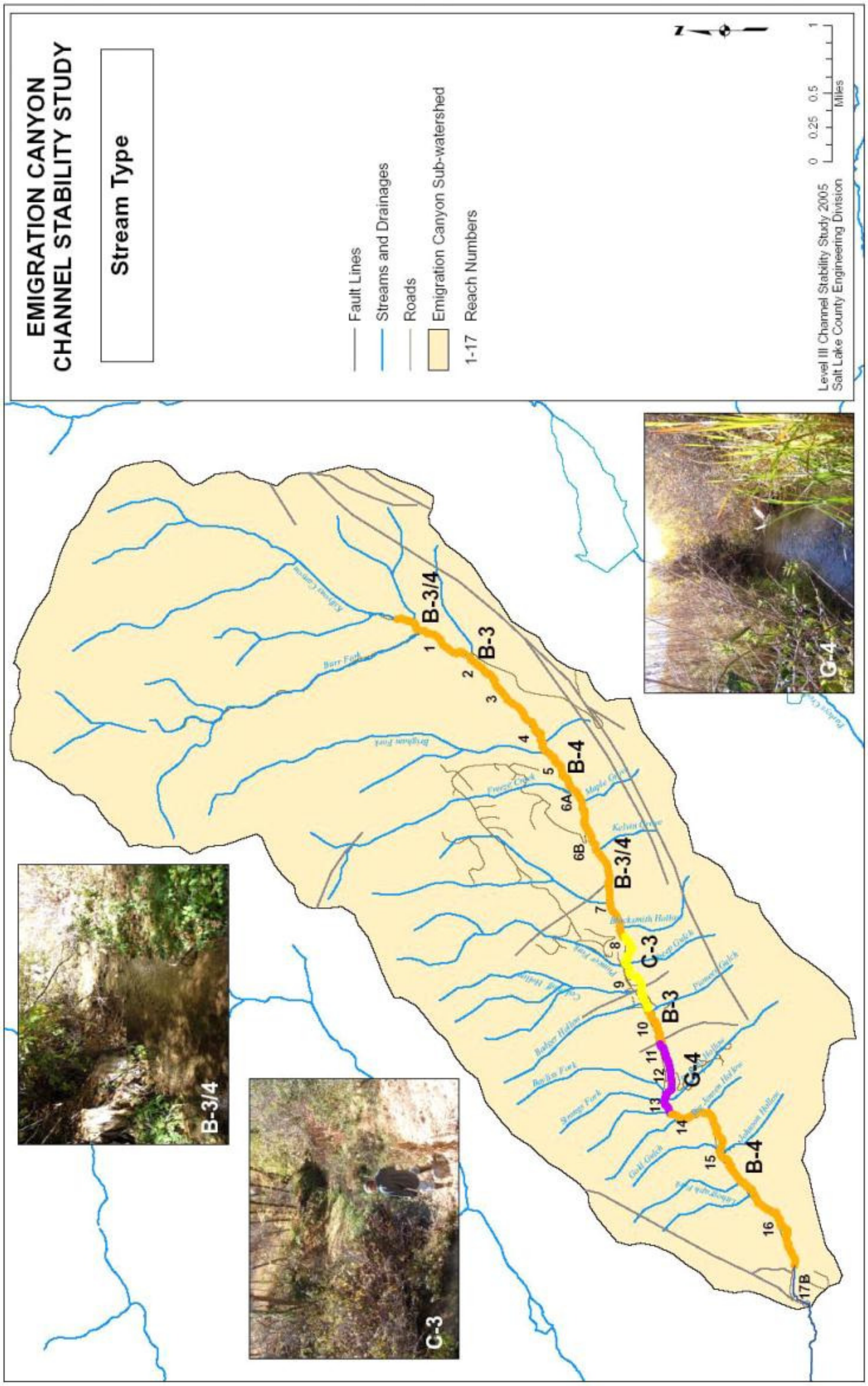
Map 2. Emigration Creek Sub-Basin Bedrock Geology.

For several reasons, the bedrock geology of Emigration Creek Sub-basin may facilitate transportation of pollutants. First, the bedrock underlying the Sub-Basin has been folded into a northeast-southwest trending syncline with unique physical properties that may impose constraints on development due to instability, moisture sensitivity, shrink/swell potential, or poor percolation characteristics (Figure 3). Second, the Twin Creek Limestone formation in the in the lower section of the Sub-Basin was strongly correlated with a decrease in flow during the October, 2005 USGS Tracer Injection study of the Creek.

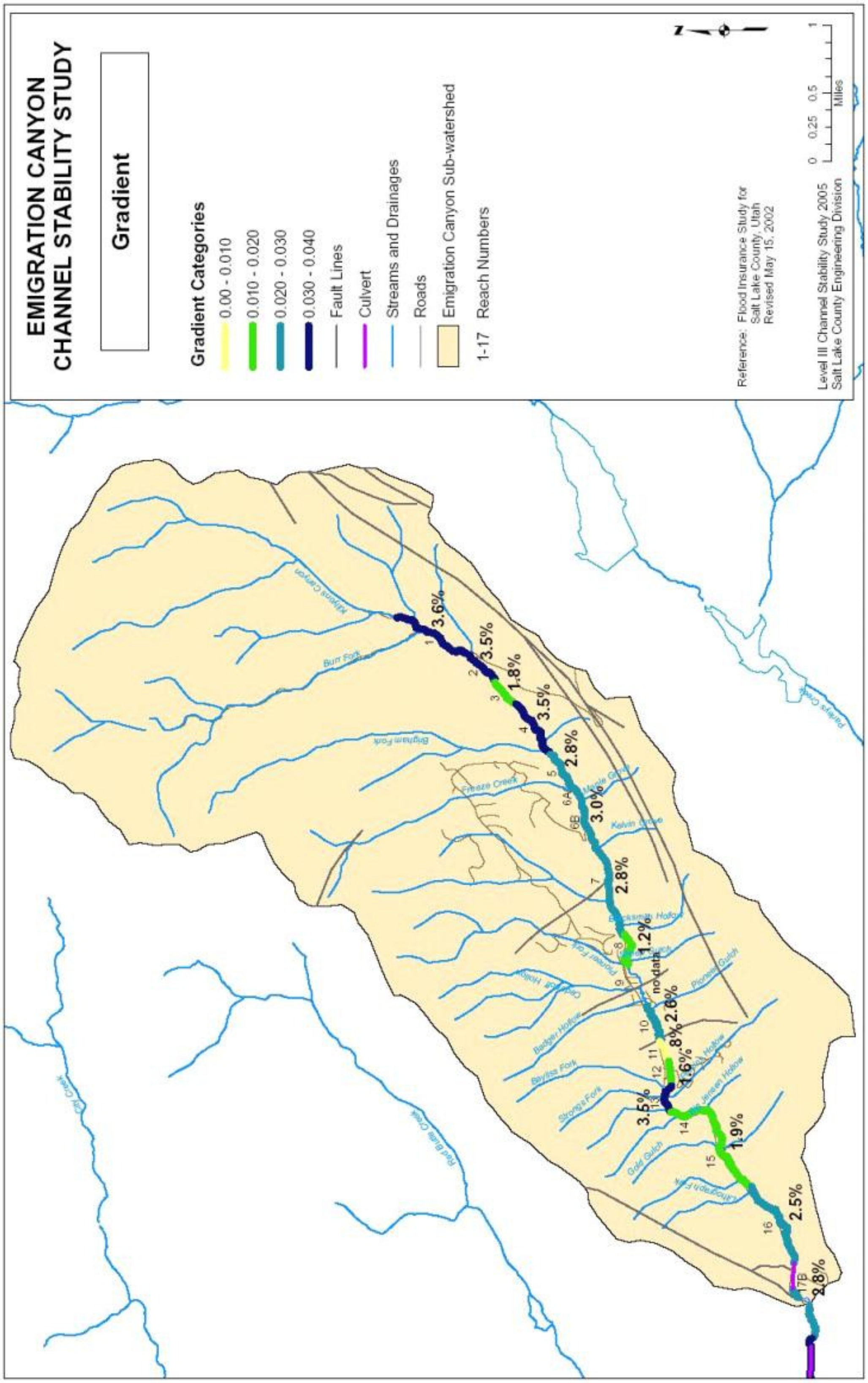
4.1.2 Level III Stream Channel Stability Evaluation of the mountain reaches of Emigration Creek—Salt Lake County 2005

In conjunction with the USGS synoptic study, Salt Lake County Water Resources Planning and Restoration Program staff conducted a level III bank stability assessment of the canyon segments of Emigration Creek in October of 2005. Additionally, an assessment was done of the Burr Fork tributary at that time. Similar to the 2001 assessment, a Pfankuch rating (Pfankuch 1975) was derived for these segments based on parameters such as: sediment supply, streambed stability, width/depth ratios, and bed features.

In this study, the majority of Emigration Creek was classified as B-3 and B-4 stream types (Map 3) that are characterized as stable, moderately entrenched and riffle dominated with "rapids" and infrequently spaced scour pools at bends or areas of constriction. The number following the stream type denotes the median particle size of channel material, 3 for cobble and 4 for gravel. Areas between Blacksmith Hollow and Pioneer Gulch, and to the stream reach near Perkins Hollow, were classified as C-3 and G-4 respectively. C type streams are characterized as low gradient, meandering, with broad well defined floodplains. G type streams are characterized as entrenched, "gully" step pool and low width/depth ratio on moderate gradients. The G-4 segment near Perkins Flat was acquired by Utah Open Lands and transferred to Salt Lake County. For mitigation purposes, and to stabilize the G stream, grade controls were installed in this section in 2007. In addition to stream type, this study examined the gradient of Emigration Creek and found that the majority of Emigration Creek has a gradient between 1.0% and 3.6% (average 2.4%) (Map 4).



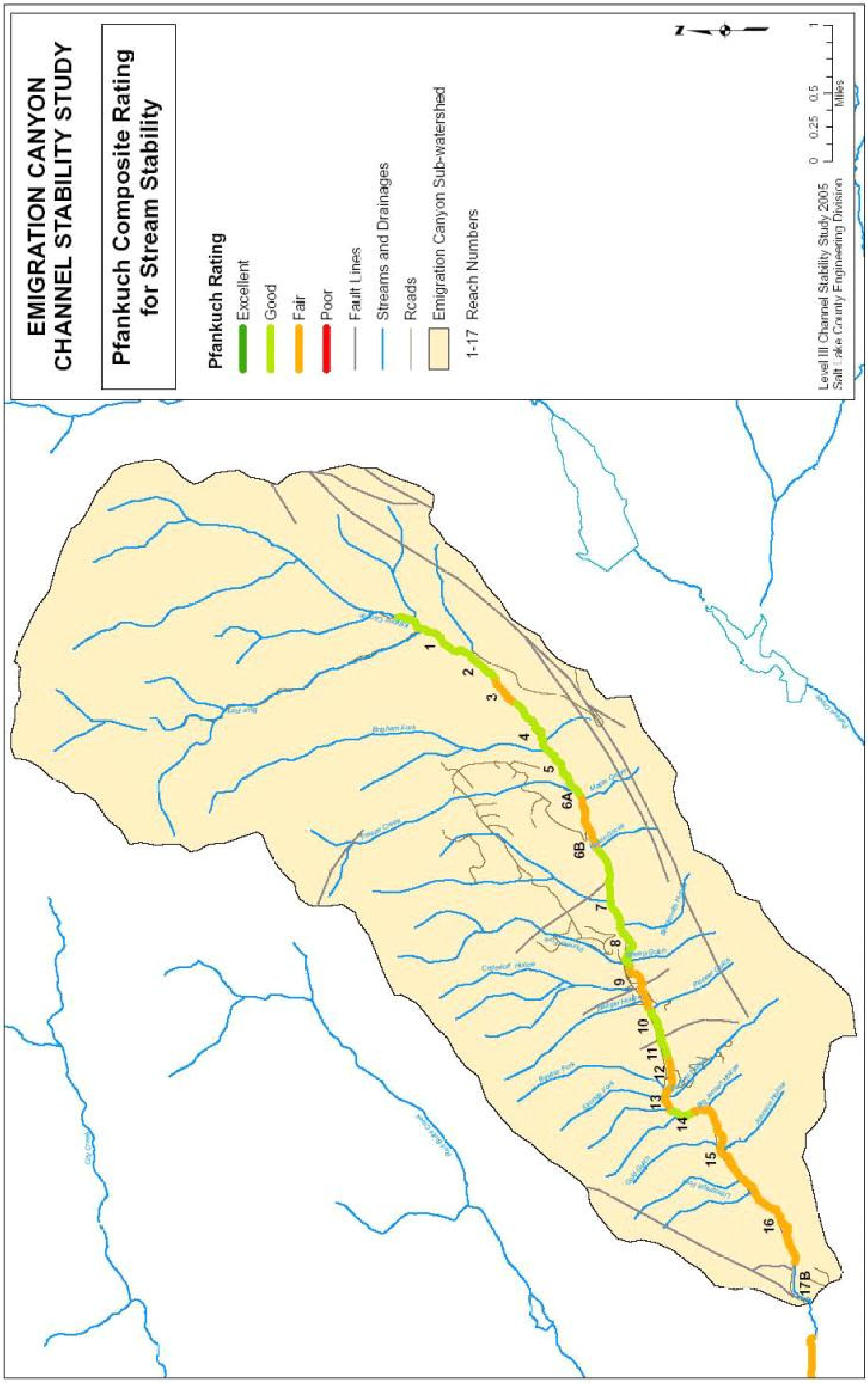
Map 3. Emigration Creek Stream Type.



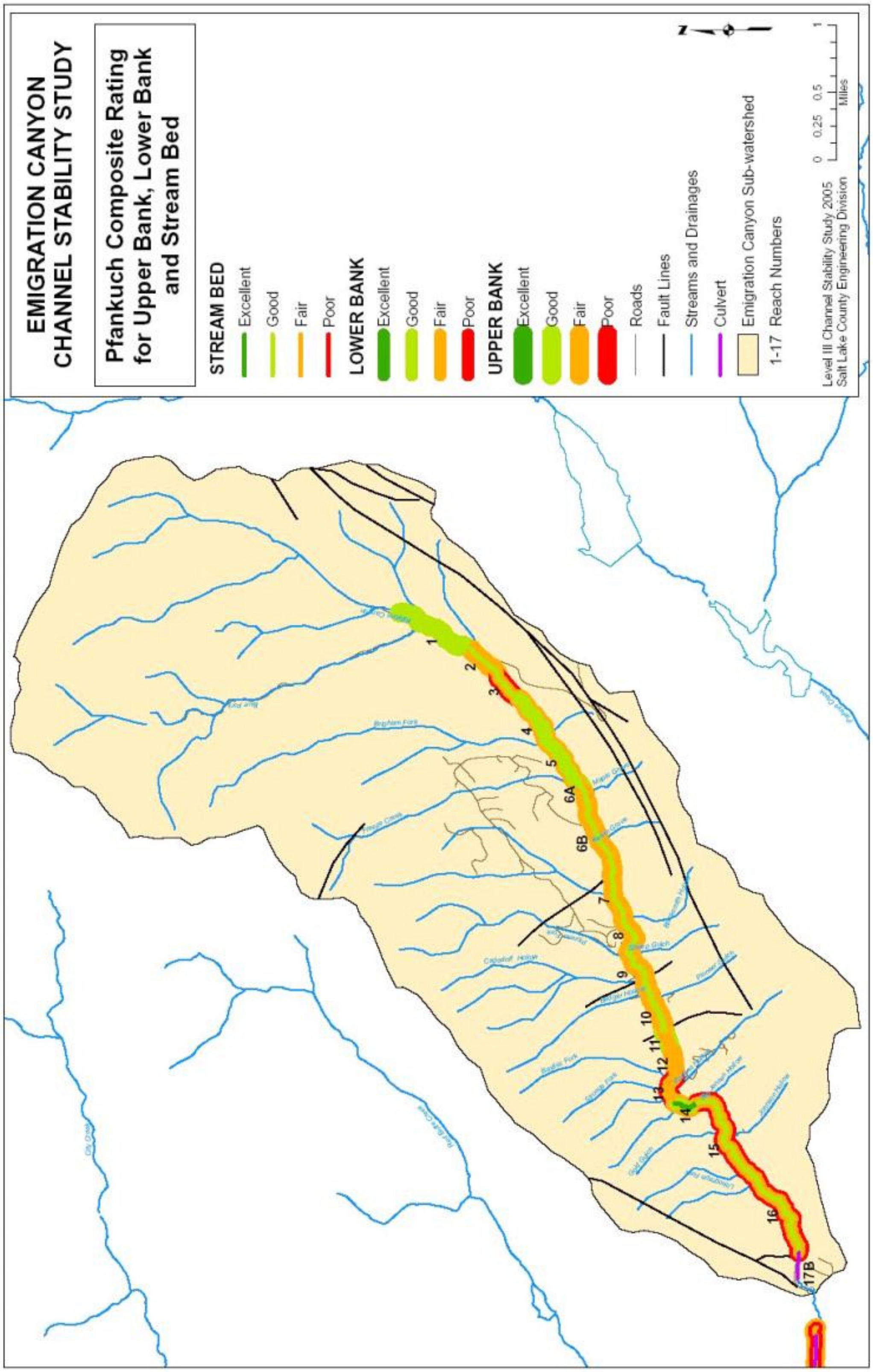
Map 4. Emigration Creek Gradient.

Stream segments in the Upper Burr Fork drainage area were classified as A-4 and A-3/4 in the 2005 assessment. As the tributary moves toward its confluence with Emigration Creek, the stream is classified as A-1 and A-2. Stream channels characterized as A type are steep, entrenched, cascading, step/pool streams that are very stable if dominated by bedrock (particle size 1) and boulders (particle size 2).

All of the mountain reaches in this study were determined to have "fair" or "good" stability ratings. There were no reaches with "excellent" or "poor" ratings. In general the "fair" conditions were found in the lower reaches of the Sub-Basin (below Perkins Hollow), and the "good" conditions were found further up Canyon (Map 5). In the lower reaches of Emigration Creek, the upper bank was found to be poor; whereas, the middle sections had fair conditions in the upper banks (Map 6). The majority of reaches had good or excellent conditions in the streambed. Alternatively, many reaches in the stream had "fair' conditions in the lower bank. A small reach between Brigham Fork and Burr Fork also had poor stability conditions in its upper bank.



Map 5. Emigration Creek Level III Composite Bank Stability Assessment.

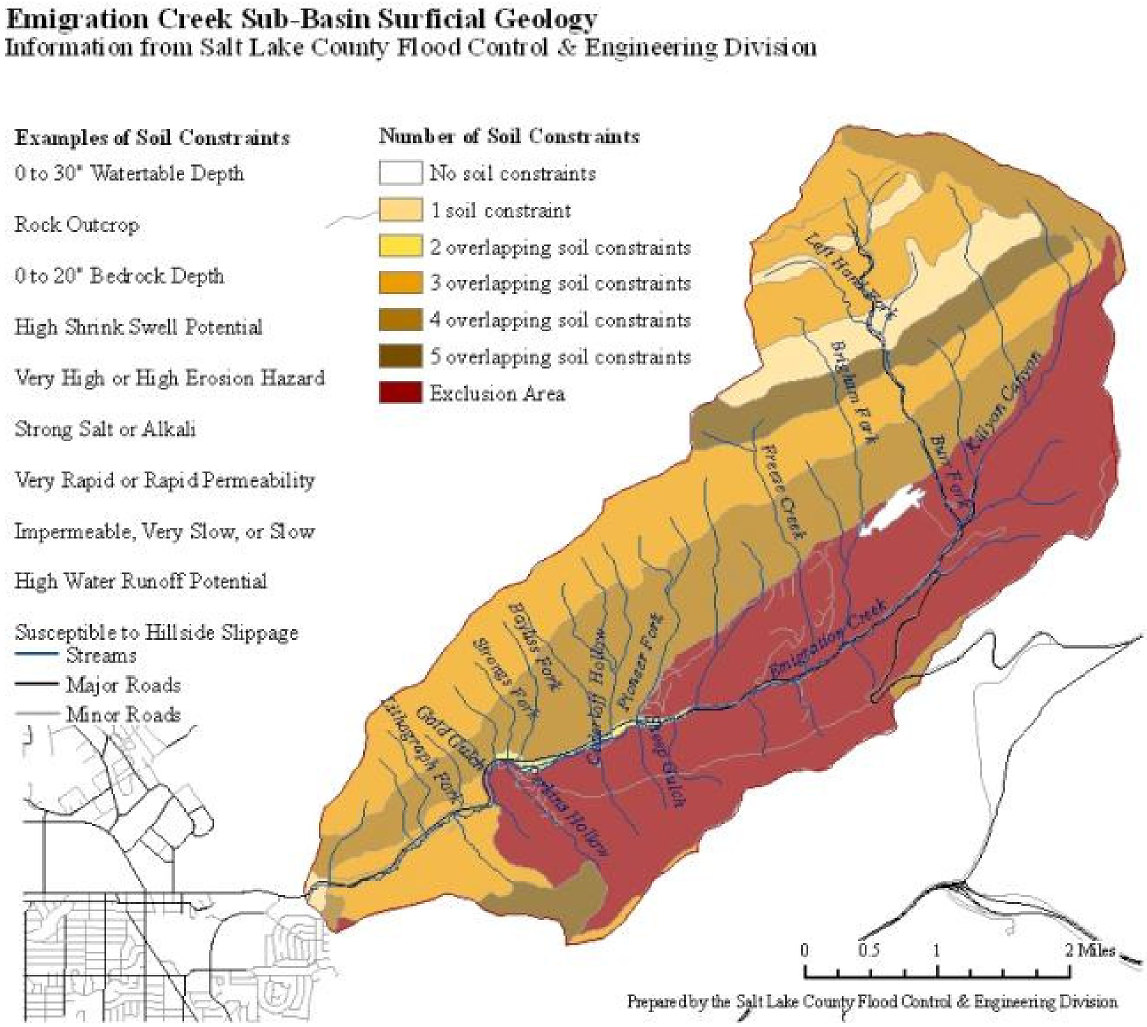


Map 6. Emigration Creek Level III Stability Assessment—Upper, Lower, and Streambed.

4.1.3 Soil

The soils within the Emigration Creek Sub-Basin consist primarily of consolidated crystalline rocks, shales, sandstones, limestone, and volcanic rock. Streamside soils consist of sand and silty alluvial soils (Glenne and West, 1981). The Summit Area Soil Survey (Soil Conservation Service, 1974) indicated that the predominant streamside soil types in Emigration Creek Sub-Basin are represented in the Harker Series. The Harker Series has the following severe constraints: 1) high shrink-swell potential, 2) very high to high erosion hazard, 3) slow to very slow permeability, 4) high water runoff potential, and 5) susceptibility to hillside slippage. Other limiting soil types (generally constrained by rock outcrop or shallow bedrock) occur in the upper reaches (Pinecrest Area) of the sub-basin. In addition to numerous constraints, these soils tend to be shallow, well drained, and derived from sedimentary rocks. Soils in the upper third of the watershed have high, or very high, erosion hazards.

The northwestern slope of the Sub-Basin typically contains between one (1) and five (5) overlapping soil constraints; whereas, the southeastern slope contains more constraints and is therefore an exclusion area. Constraints used in this assessment include: 0 to 30" water table depth, rock outcrops, 0 to 20" bedrock depth, high shrink swell potential, very high or high erosion hazard, strong salt or alkali, very rapid or rapid permeability, impermeable, very slow, or slow percolation, high water runoff potential, and susceptibility to hillside slippage (Map 7).



Map 7. Emigration Creek Sub-Basin Soil Constraints.

4.1.4 Faults

In addition to the bedrock and surficial geology's influence on hydrology in Emigration Creek Sub-Basin, three (3) major faults intersect Emigration Creek at 90º angles (Map 2). As was demonstrated through the synoptic-tracer injection study conducted by the United States Geological Survey (USGS), these faults can be associated with changes in water chemistry. The faults near Pioneer Gulch and Perkins Flat were associated with a dramatic increase in conductivity in the 2005 synoptic study.

4.1.5 General Flow

Several entities have collected flow data for Emigration Creek. The Salt Lake County

Flood Control & Engineering Division has the most extensive period of record having collected flow data annually at Rotary Park (Gage site #620) beginning in 1964 and continuing to the present (Figure 4). Hydrographs are provided for the most recent years, 1991 through 2004 in Appendix A; however, the cumulative hydrograph is shown in Figure 5. Over the last fifteen (15) years, mean flows of Emigration Creek have varied between 0 and 5 cfs between October and January. However, in mid- to late-February, flows of Emigration Creek begin to increase, and typically peak between April and May. High flows in Emigration Creek below Rotary Park varied between 4 and 52 cfs between 1991 and 2004. Relative to other creeks in Salt Lake County, Emigration Creek reaches its peak flows early in the season, and is generally the second gauged stream to peak each year. The Creek flows recede early and typically reach their yearly minimum flow in mid-September. Detailed flow information used for load allocation and analysis is found in Section 6.1.

Figure 4. Emigration Creek at Rotary Park Gage site #620.

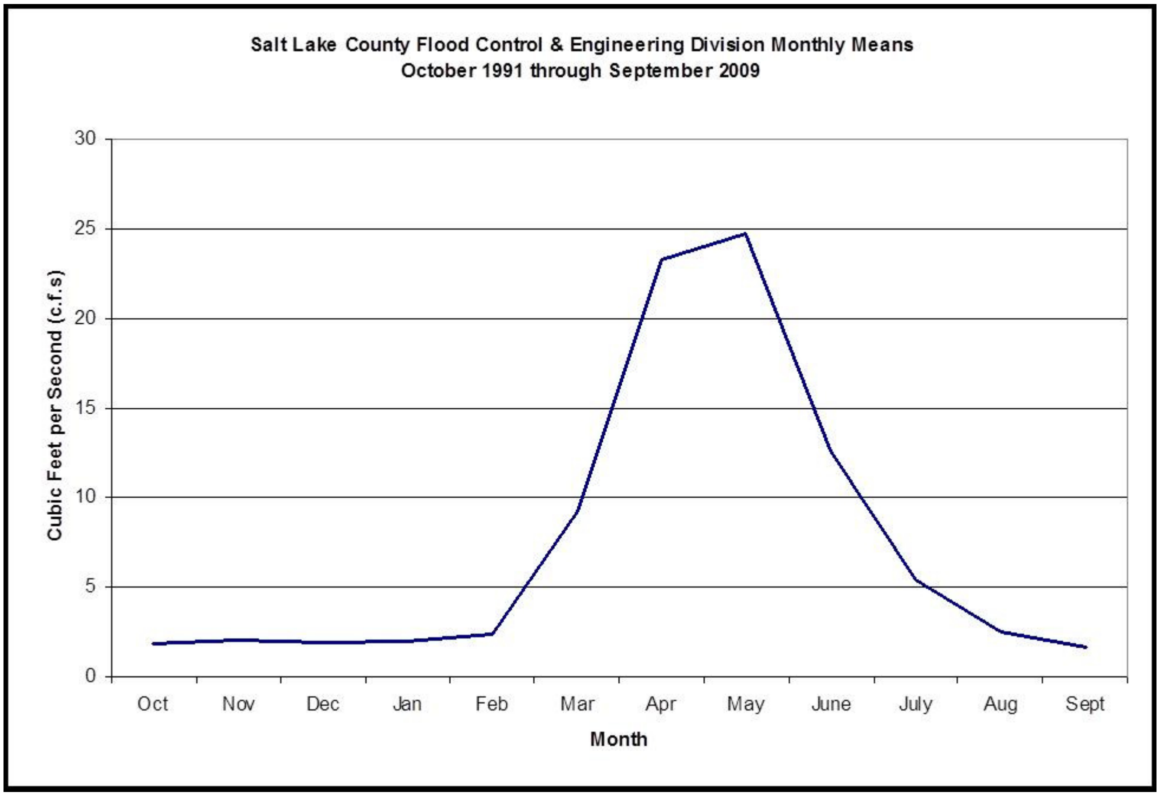


Figure 5. Mean Monthly flow rates for Emigration Creek Data Collected by Salt Lake County 1991 through 2009.

4.2 Biological Features

4.2.1 Vegetation

The Southwest Region Gap Analysis Project (SWReGAP) developed by the United States Geologic Survey (USGS) in 2004 used aerial photo-interpretation along with ground-truthing studies to classify vegetation communities. This study found twenty-one (21) distinct vegetation communities in Emigration Creek Sub-Basin (Map 8). The majority (7,618 acres, 65%) of land in Emigration Creek Sub-Basin contained Rocky Mountain Gambell Oak-Mixed Montane Shrubland vegetation communities. The next most abundant community is the Rocky Mountain Aspen Forest and Woodland (1,096 acres, 9%). The remaining nineteen (19) communities together comprised <25% (2,976 acres) of the total land area (Table 5).

Map 8. USGS Vegetation GAP Analysis (USGS, 2004).

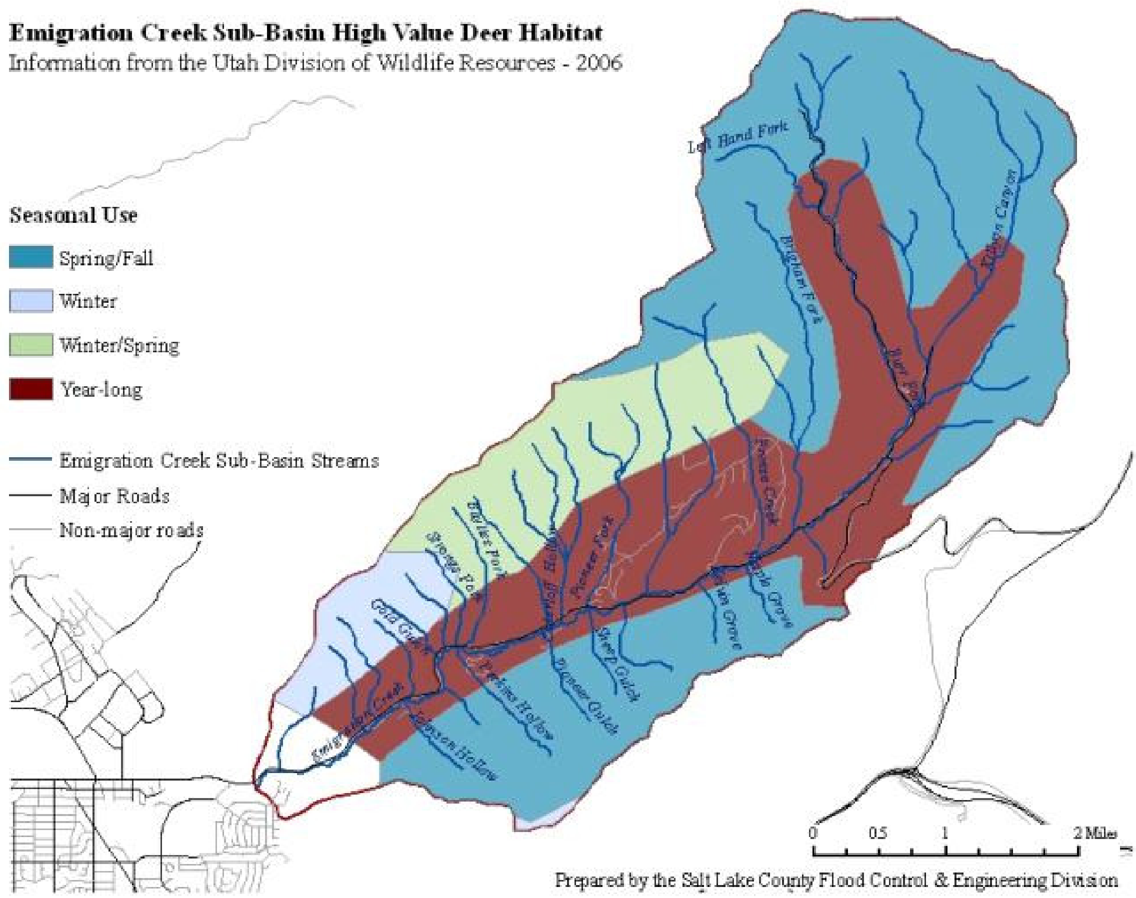
Table 5. USGS Vegetation GAP Analysis (USGS, 2004).

Vegetation Type	Total Acres	% of Sub-Basin
Rocky Mountain Gambell Oak-Mixed Montane Shrubland	7618	65
Rocky Mountain Aspen Forest and Woodland	1096	9
Inter-Mountain Montane Sagebrush Steppe	820	7
Developed – Open Space	562	5
Rocky Mountain Bigtooth Maple Ravine Woodland	386	3
Rocky Mountain montane Mesic Mixed Conifer Forest and Woodland	272	2
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	211	2
Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	194	2
Colorado Plateau Pinyon-Juniper Woodland	135	1
Southern Rocky Mountain Montane-Subalpine Grassland	89	1
Invasive Perennial Grassland	88	1
Rocky Mountain Cliff and Canyon	75	1
Rocky Mountain Subalpine Mesic Meadow	53	0
Developed, Medium – High Intensity	40	0
Inter-Mountain Basins Big Sagebrush Steppe	17	0
Inter-Mountain Basins Mountain Mahogany woodland/shrubland	11	0
Rocky Mountain Alpine-Montane Wet Meadow	10	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	6	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	3	0
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	2	0
Inter-Mountain Basins Big Sagebrush Shrubland	2	0

Field observations of vegetation communities in Emigration Creek Sub-Basin identified three (3) primary vegetation types. Scrub Oak (*Quercus berberidifolia*) and Mountain Mahogany (*Cercocarpus ledifolius*) dominated the foothill community, whereas, Maple (*Acers*), Chokecherry (*Prunus virginiana*), Western Birch (*Betula occidentalis*), Mountain Alder (*Anus incana*), and Cottonwoods (*Populus freemontii*) dominated canyon streamside communities. White Fir (*Abies concolor*), Aspen (*Populus tremuloides*), and Spruce (*Picea*) were found in the lower montane forests. On the north-facing slopes of Emigration Canyon, oak and maple were present, while the south-facing slopes were dominated by scrub oak. Along the banks of the stream, box elder, cottonwood trees, mustard, clover and grasses were observed in this semi-residential environment. The Emigration Canyon Master Plan concluded that heavy residential use of the Canyon has caused many species normally found in the lower and upper montane ecosystems to be scarce or totally displaced (SLCo, 1999).

4.2.2 Wildlife

The Utah State Division of Wildlife Resources has identified the majority of the sub-basin as "high value" habitat for Mule Deer (*Odocoileus hemionus*), Elk (*Cervus elaphus*), Cougar (*Felis concolor*), and Black Bear (*Ursus americanus*). The mouth of the canyon has been identified as "critical winter habitat" for Mule Deer (Map 9).

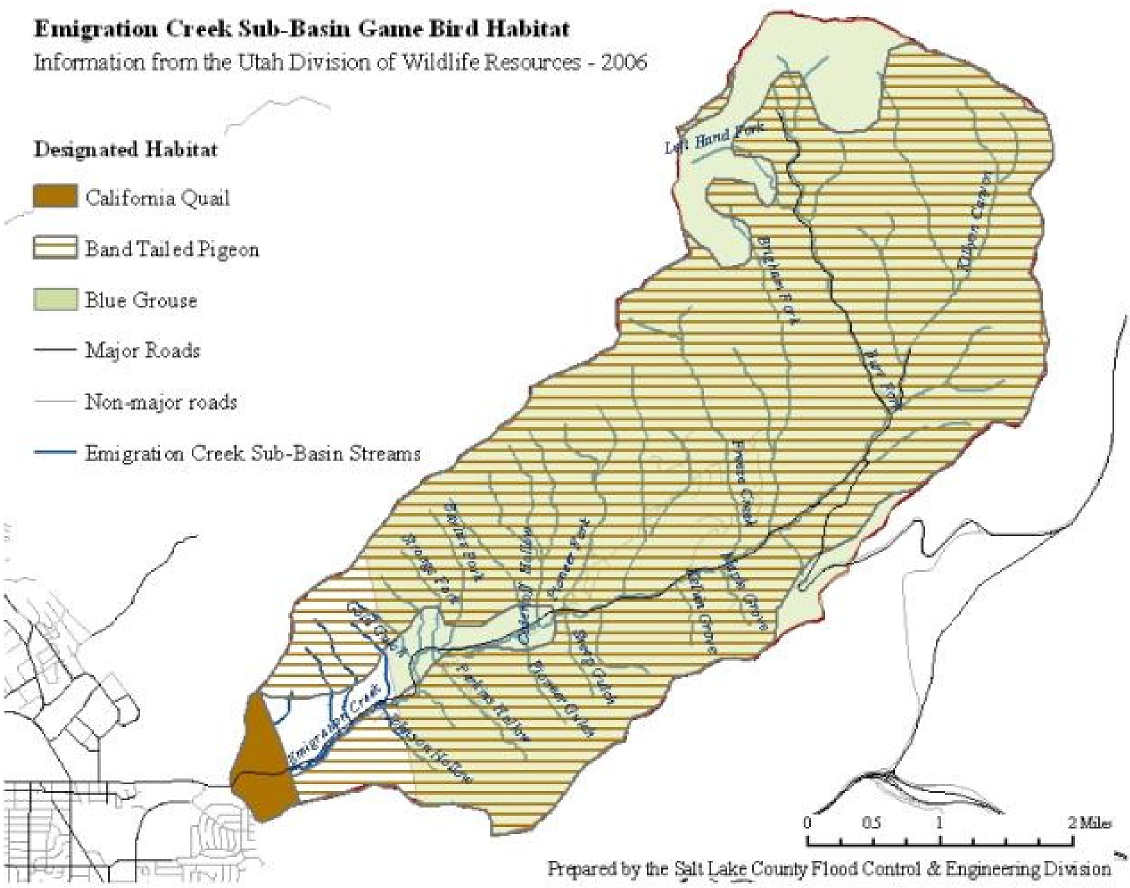


Map 9. Utah Division of Wildlife Resources Mule Deer Habitat in Emigration Creek Sub-Basin.

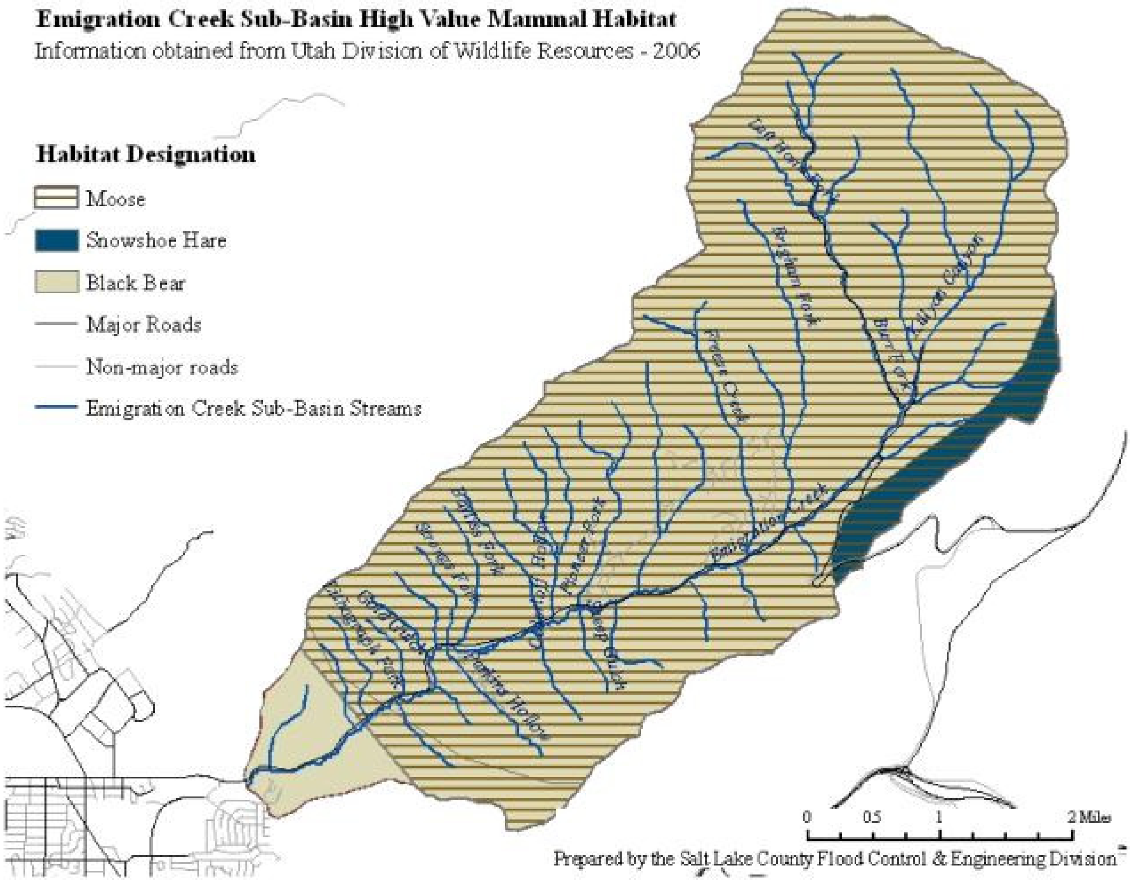
According to the Division of Wildlife Resources, game bird populations in Emigration Creek Sub-Basin include: Band Tailed Pigeon (*Columba fasciata*), Blue Grouse

(*Dendragapus obscurus*), California Quail (*Callipepla californica*), Chukar (*Alectoris chukar*), Hungarian Partridge (*Perdix perdix*), Ring Necked Pheasant (*Phasianus colchicus*), Ruffed Grouse (*Bonasa umbellus*), Sage Grouse (*Centrocercus urophasianus*), and Wild Turkey (*Meleagris gallopavo*) (Map 10).

The Utah State Division of Wildlife Resources has also observed Bighorn Sheep (*Ovis canadensis*), Moose (*Alces alces*), Mountain Goat (*Rhododendron albiflorum*) and Snowshoe Hare (*Lepus americanus*) in Emigration Creek Sub-Basin (Map 11). Sightings of beaver and sub-tropical bird species have also been documented in riparian areas of Emigration Sub-Basin. Bonneville Cutthroat Trout have been observed in the Killyon's Canyon tributary to Emigration Creek.



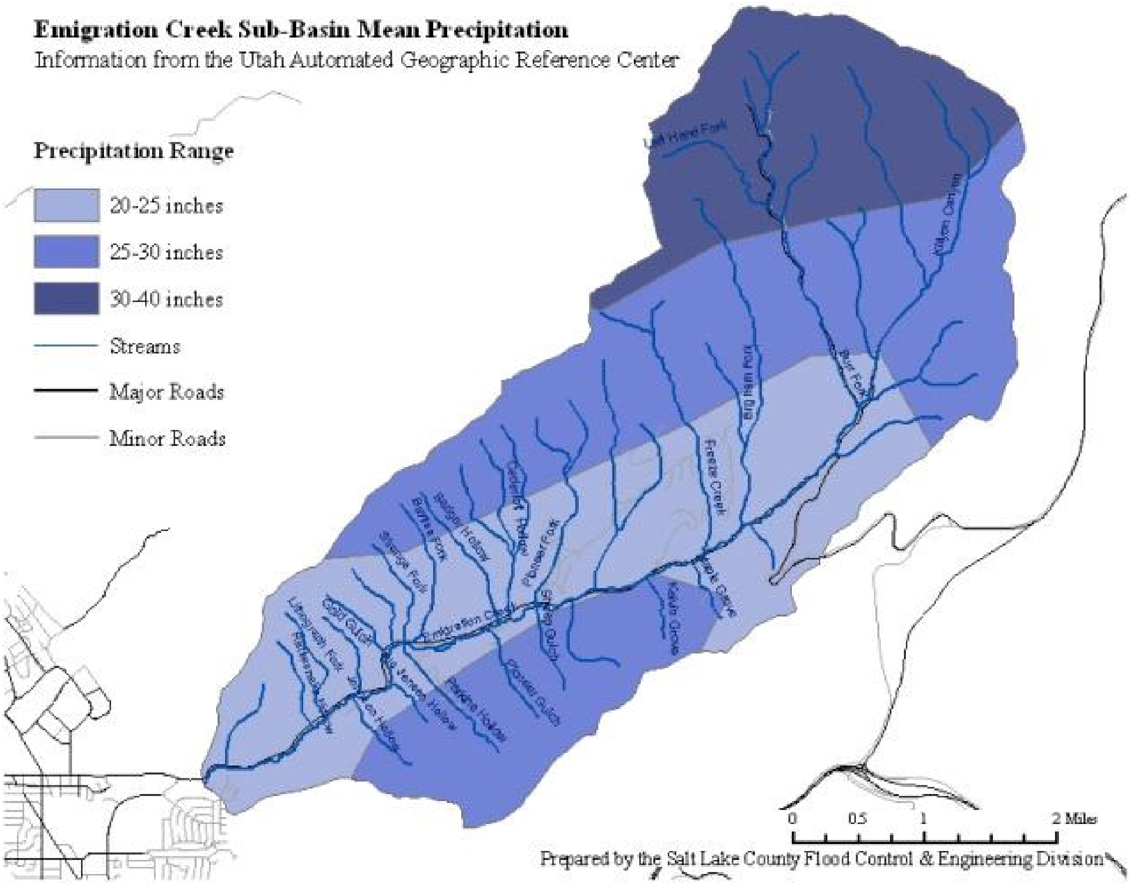
Map 10. Utah Division of Wildlife Resources Game Bird Habitat in Emigration Creek Sub-Basin.



Map 11. Utah Division of Wildlife Resources Mammal Habitat in Emigration Creek Sub-Basin.

4.3 Climate

As with other Wasatch Canyons, the majority of precipitation in Emigration Creek Sub-Basin comes in the form of snow. On average, a foot or more of snow can be found on the mountain slopes by mid-November. This snow cover typically remains until the middle of May. In Emigration Creek Sub-Basin, only 10 days per month receive > 0.10" of precipitation or more. However, 24-hour snowfalls are common and have been recorded in most winter and spring months. On an annual basis, the Sub-Basin typically receives between 20" and 40" of precipitation (Map 12). The heaviest precipitation levels typically occur in the northeastern portion of the Sub-Basin, with the lowest levels observed along the Creek at lower elevations.



Map 12. Mean Annual Precipitation in Emigration Creek Sub-Basin.

4.4 Social Features

Historically, Emigration Creek Sub-Basin was part of the Federal Sheep Driveway, where sheep were driven through the Sub-Basin to the Rio Grande Railroad station. The Sub-Basin was also used as a summer pasture for sheep. Emigration Creek Sub-Basin once had a small ski slope at Little Mountain (Figure 6). Skiers were pulled up by a towrope, which was first operated manually and then eventually by machine. Additionally, a historic railroad line ran up the canyon and was used for quarrying (Figure 7) and transportation purposes. Elsewhere in the Sub-Basin there was an ice-skating pond (near what is known as Perkins Flat), a brewery, a golf course, riding stables and a donkey rental.

Today, the entirety of Emigration Creek Sub-Basin is designated as a National Historic

Place. This designation comes from the use of this canyon by early pioneers who entered the Salt Lake Valley starting in 1847 (SLCo, 1999). Unlike other resort Sub-Basins in Salt Lake County, Emigration Creek Sub-Basin maintains a large residential population. The highway through the canyon carries considerable traffic and provides access to Parley's Canyon and East Canyon. Some hiking occurs in the Sub-Basin, but there are no developed trailheads; however, the canyon road is popular for jogging and bicycling.

Figure 6. Historic Photo of Skier.

Figure 7. Historic Photo of Quarry.

4.5 Population and Land Use

As of 1998, the population of Emigration Creek Sub-Basin was estimated at 1,238 persons in 425 households, or 2.9 persons per household, (SLCo, 1999), however currently there may be many as 535 homes. Although the Sub-Basin is located in the youngest state in the nation, residents of Emigration Creek Sub-Basin average 35.4 years of age, which is slightly over the national average of 27.1 years of age. Despite the older average age, approximately one-fourth of the Sub-Basin residents are school age children (under 18 years of age). By the year 2010, the U.S. Census Bureau estimates that the population of Emigration Creek Sub-Basin will grow to more than 2,000 persons (17.4 people per 100 acres) (Figure 8). This projection is based on an average of 18 new homes per year and the current family size of 2.9 persons per household.

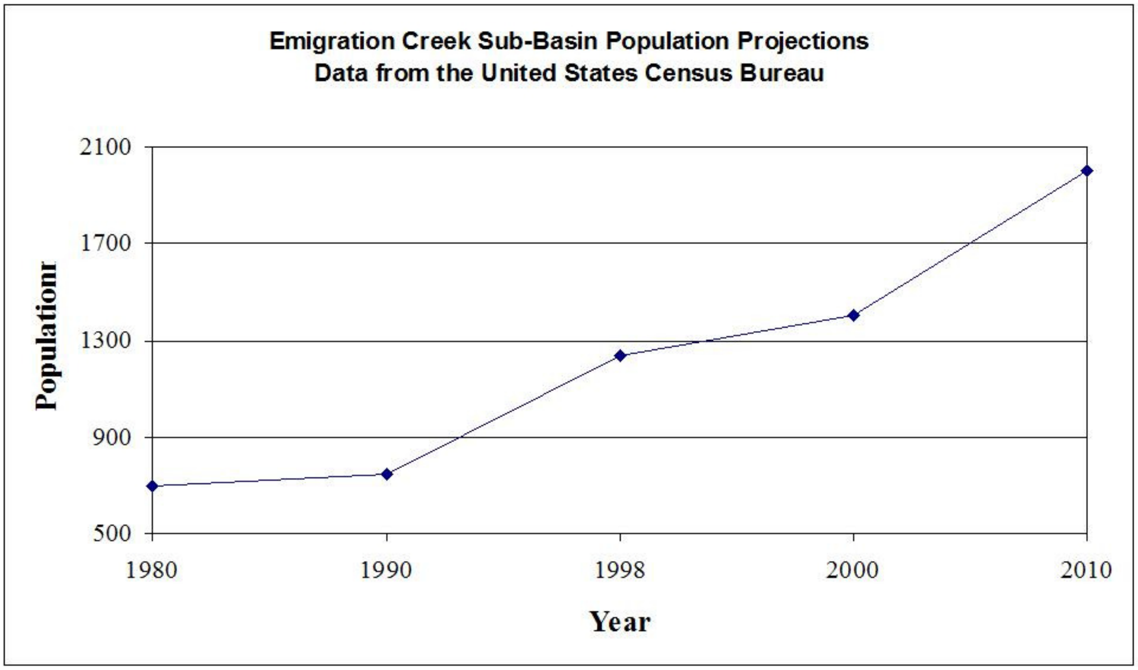


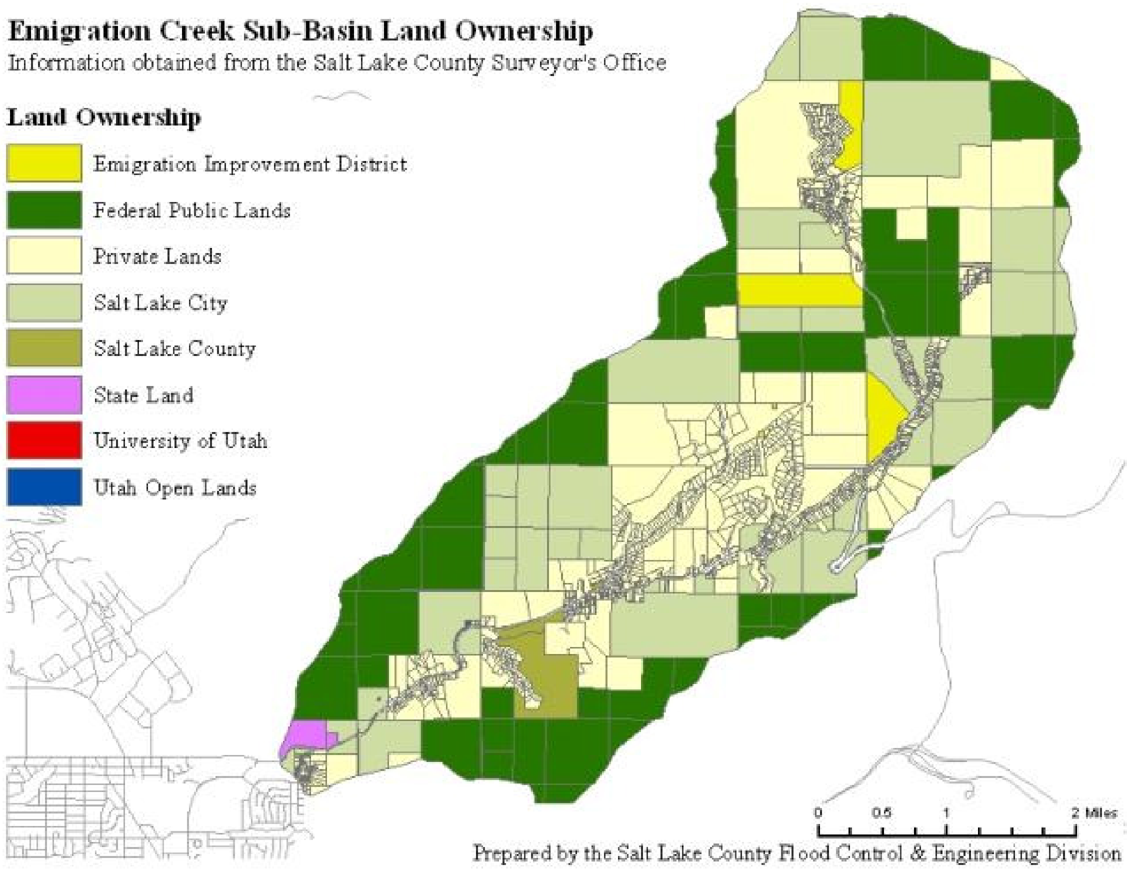
Figure 8. Population Projections for Emigration Creek Sub-Basin.

A study conducted by the Development Services Division of Salt Lake County showed that residential growth in Emigration Creek Sub-Basin has increased greatly over the last 10 years (SLCo Township Plan). Previous growth in the Sub-Basin was attributable to small scale, individual residential structures. However, within the last ten years the Sub-Basin has seen increased individual lot development, particularly within two Planned Unit Developments (PUDs), Emigration Place and Emigration Oaks. Overall, the community population has increased steadily since the late 1980's with this growth occurring mainly in the new PUDs.

Increased population growth and housing development, as well as increased Sub-Basin use by non-residents, are major concerns of the current residents. However, it is anticipated that the Emigration Creek Sub-Basin will continue to grow. Water, sanitation services, municipal services, roads, available land and conformance to all zoning and site regulations may limit Sub-Basin development.

4.5.1 Land Ownership

Of the 11,520 acres (18 square miles) in Emigration Creek Sub-Basin, 4,800 acres (40%) are privately owned. The remainder is publicly owned and managed by either the U.S. Forest Service (3,917 acres, 34%) or Salt Lake City Corporation (2,995 acres, 26%) (Map 13). Privately owned land has been developed into a variety of residential lot sizes. The portion of land that has been developed is concentrated around the main thoroughfare. Although most of the housing units in the Sub-Basin are single-family residences, approximately 30 multifamily housing units now exist in various areas in the Sub-Basin.



Map 13. Emigration Creek Sub-Basin Land Ownership.

4.5.2 Commercial Development

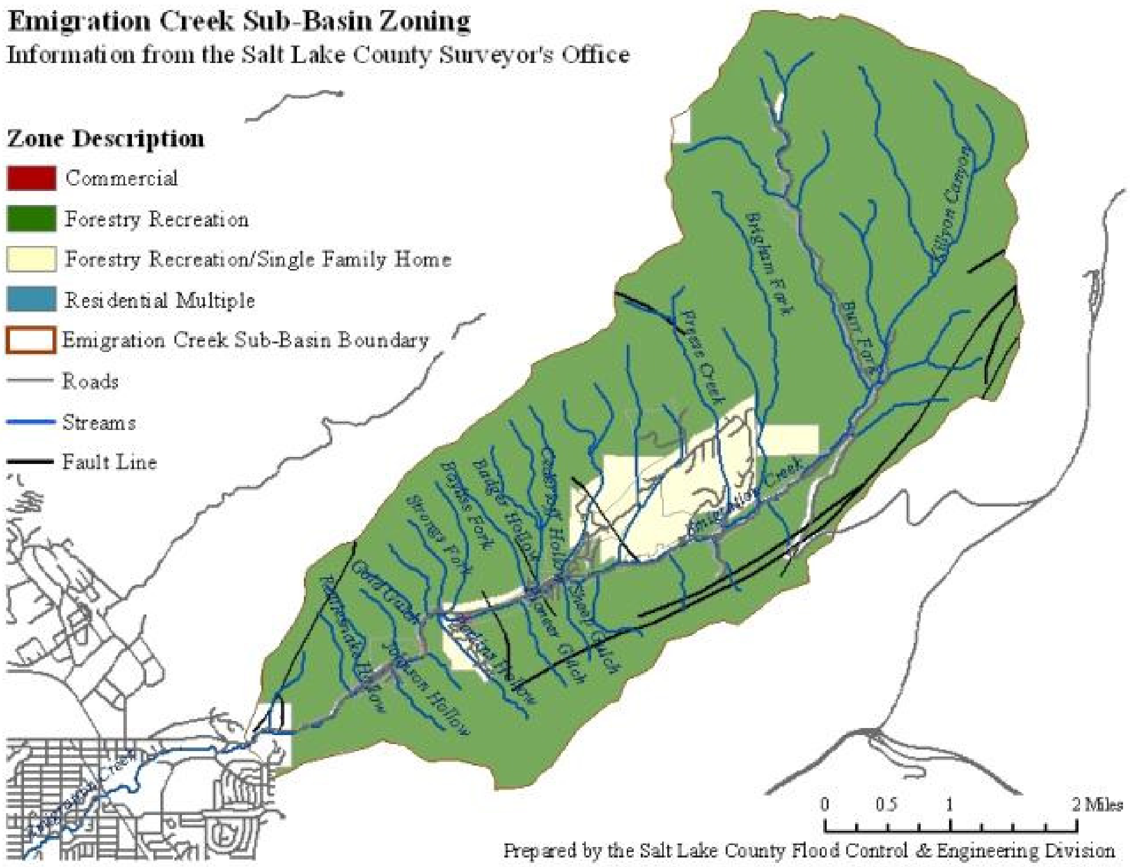
Emigration Creek Sub-Basin has limited commercial development. The existing commercial services include Ruth's Diner and the Sun & Moon Café. Property previously owned by the Sorenson Development Company was purchased by Utah Open Lands for open space preservation. It is unlikely that commercial development will expand beyond these sites due to: 1) conditions placed on the existing commercial zones, 2) the lack of commercial zoning available elsewhere in the Sub-Basin, and 3) the limited need for new commercial zoning in the Sub-Basin. In addition to the restaurants, Emigration Creek Sub-Basin is the site of Camp Kostopulos, a 15-½ acre camp run by a non-profit organization that provides recreational opportunities for people with disabilities of all ages.

Emigration Creek Sub-Basin contains many small lots-of-record (which are non-conforming to the existing zones such as FR-20). These lots have existed since the early 1900's. Most, if not all of these lots, some of which are only 25 feet wide, were originally intended to serve as camping lots. However, many of these small tent lots fall in the FR-20 zone, which requires a minimum of twenty (20) acres for newly created lots to develop a structure. One major factor, when considering the development potential of these lots, is that most of them fall within the Foothills and Canyons Overlay Zone (FCOZ). FCOZ prohibits development on slopes above 30%. This Overlay Zone establishes specific site development and design standards for the Sub-Basin that preserves the character of the mountain terrain, minimizes soil and slope instability, erosion, and stream siltation. FCOZ is discussed in Chapter 19.72 of the Salt Lake County Zoning Ordinance (Emigration Township Plan).

The Salt Lake County 208 Sub-Basin Plan and the Utah State Code have designated all land in Emigration Creek Sub-Basin as Anti-Degradation Areas that is owned or managed by the U.S. Forest Service and the Salt Lake City Corporation. Anti-Degradation status prohibits any new pollutant discharges into the water body. In addition to their Anti-Degradation status, USFS and Salt Lake City lands contain many of the trails that exist in the Sub-Basin. These trails are generally multi-use, accommodating both hiking and biking activities.

4.5.3 Zoning

Zoning was first introduced in the Emigration Creek Sub-Basin in 1951. Early zoning was for tent campsites. The Sub-Basin underwent a major rezoning to reflect appropriate land uses and lot sizes in July of 1987. Emigration Creek Sub-Basin zoning remains relatively unchanged from the 1987 adjustment. Today, the predominant zoning classifications in the Sub-Basin are FR-0.5, FR-1, FR-5, FR-20 and C-2/zc zones (Map 14).

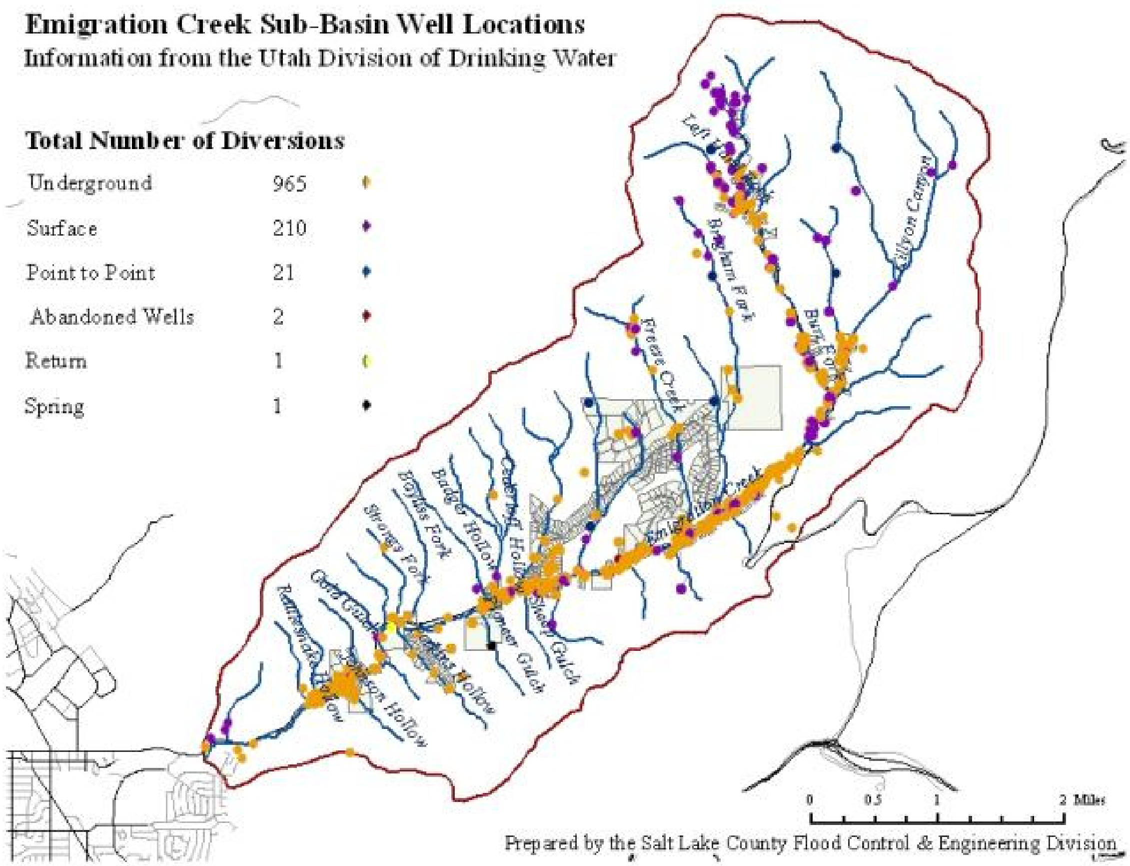


Map 14. Emigration Creek Sub-Basin Zoning.

The majority of land in Emigration Creek Sub-Basin is zoned for forestry/recreational use (97.6%), with <1% of land in Emigration Creek Sub-Basin being zoned for commercial and multi-family residential. Approximately 2.4% of land in Emigration Creek Sub-Basin has been zoned for single family units.

4.5.4 Well Locations

The Utah Division of Drinking Water (DDW) has identified a total of 1200 points of diversion in Emigration Creek Sub-Basin (Map 15). The majority, 965 sites, were identified as underground extractions or local wells and 210 of these sites are surface diversions, most of which are found in the upper reaches of Burr Fork. However, the Emigration Improvement District (EID) has put in a culinary water system; therefore some of the homes on Emigration Canyon Road have discontinued use of their wells. As can be seen from Map 15, the majority of underground diversions are along the major through-way of Emigration Canyon Road.



Map 15. Emigration Creek Sub-Basin Well Locations.

4.5.5 Salt Lake County On-site Waste Disposal Study

In 2003, as part of the Emigration Watershed Non-Point Pollution Assessment: Coliform Bacteria Water Quality Analysis, Salt Lake County published a review of septic systems in Emigration Creek Sub-Basin. In total, 326 septic systems were identified that had been installed between 1954 and 2003. Of those systems, approximately 24% were over twenty (20) years old. Fifty-two percent (52%) of the septic systems were installed in the 1990's, and only 5% were installed in the current decade. The majority of older septic systems (older than 1980) were found in the middle canyon, from Maryfield Drive to the Burr Fork confluence; however, the highest percentage (39%) of older septic systems was found in the lower canyon – from Rotary Park to Maryfield Drive. Figures 9 through 15 shows plate details for upper Emigration Canyon.

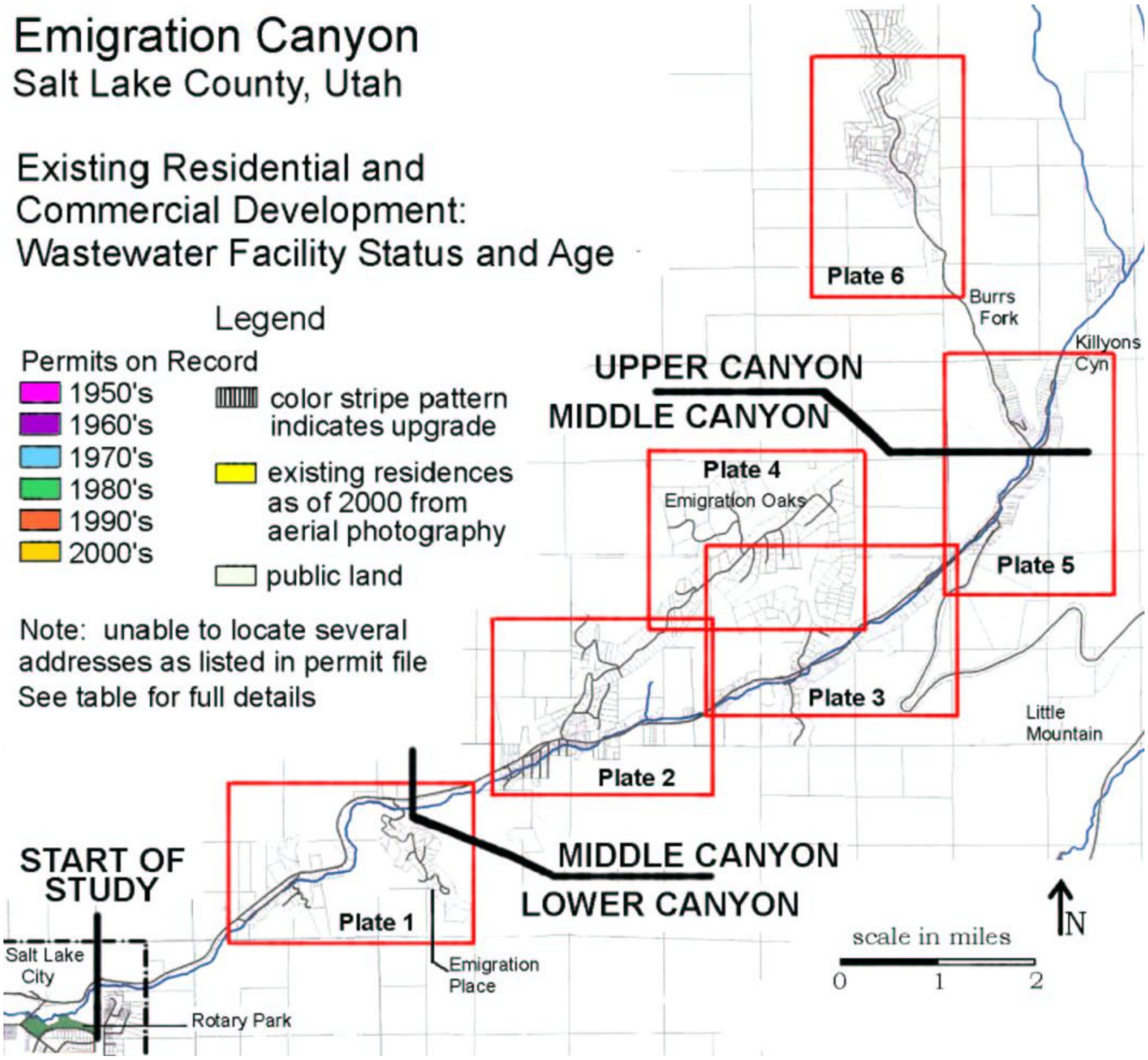


Figure 9. Plate Locations of Salt Lake County On-Site Waste Disposal Study.

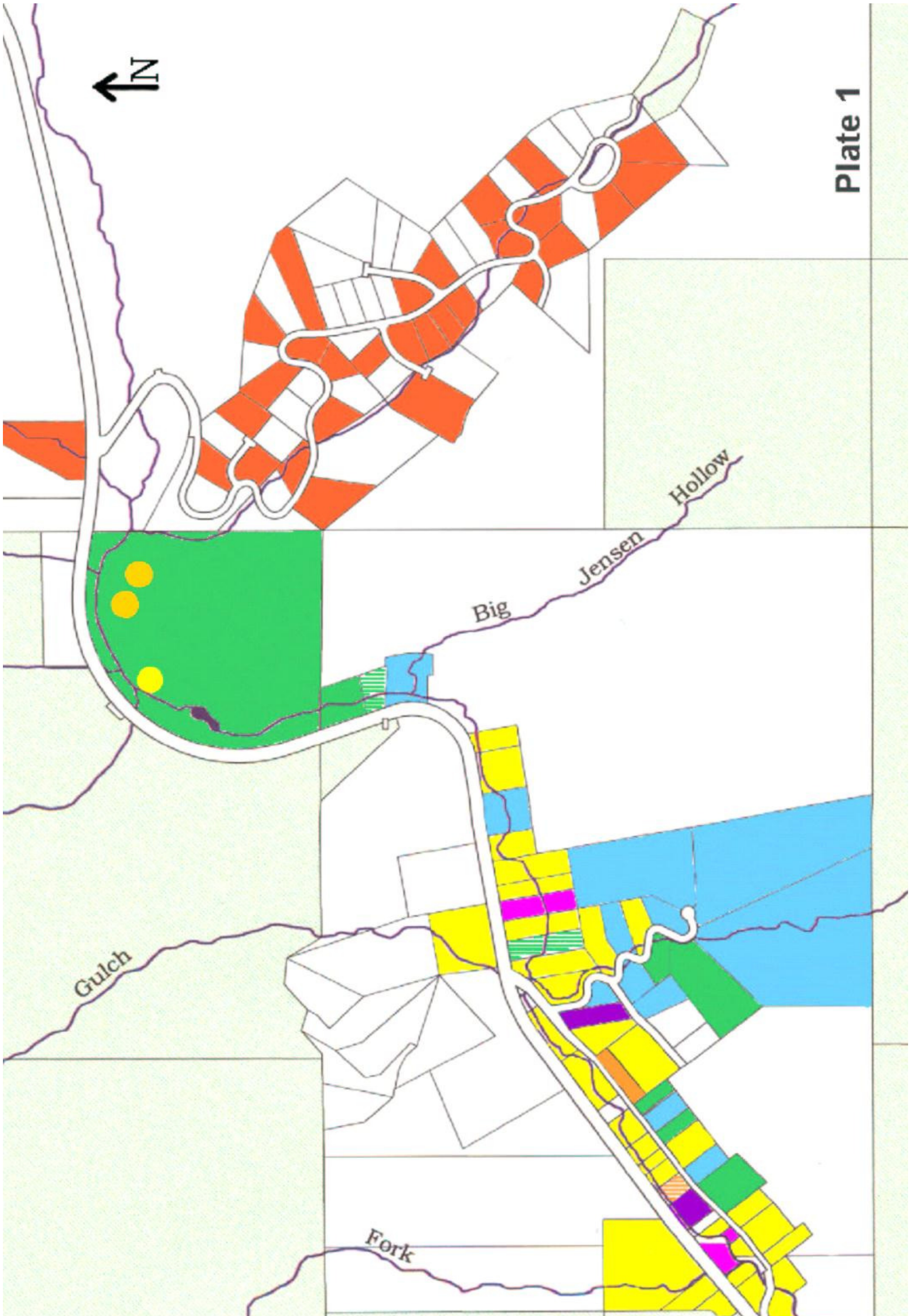


Figure 10. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 1.

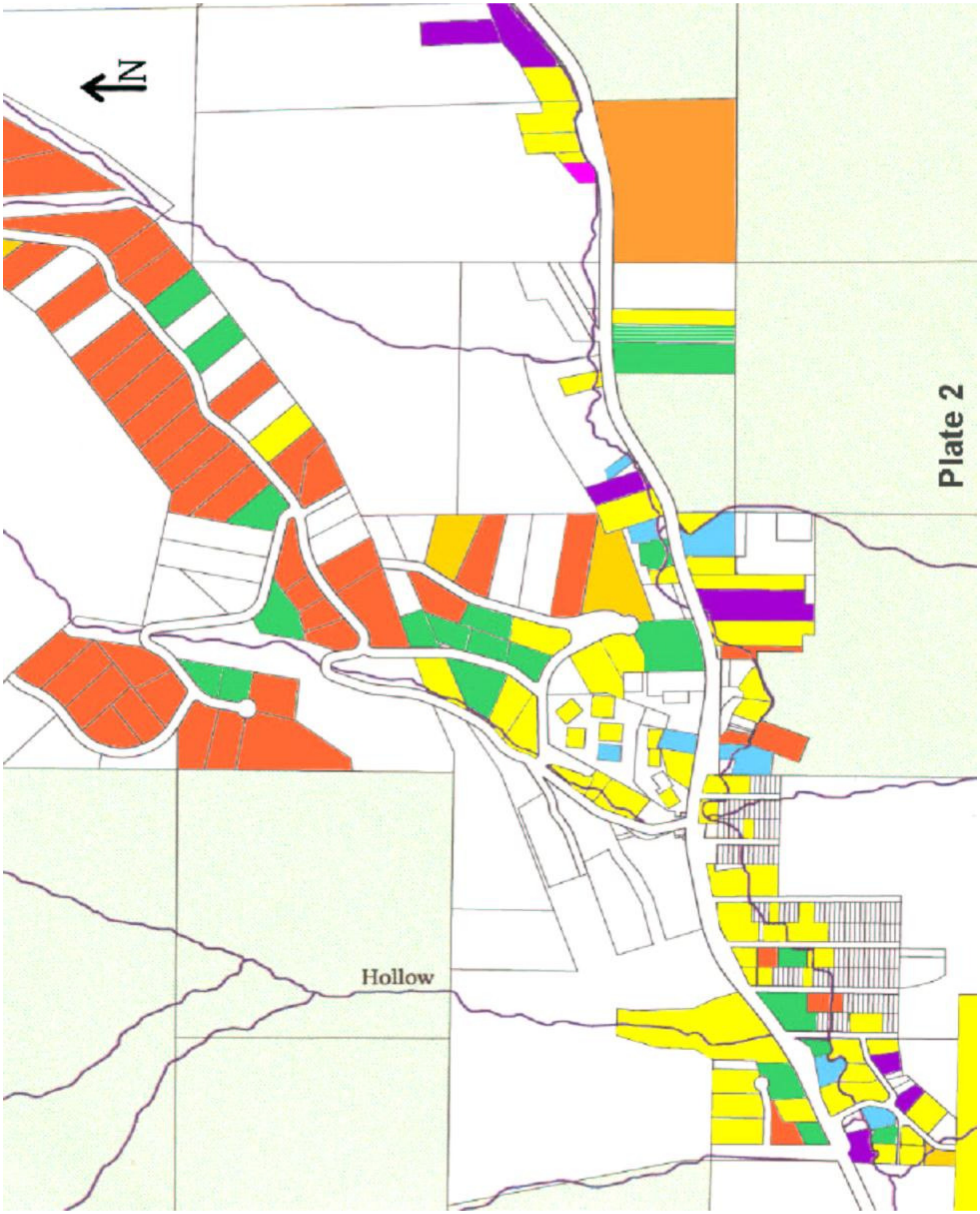


Figure 11. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 2.

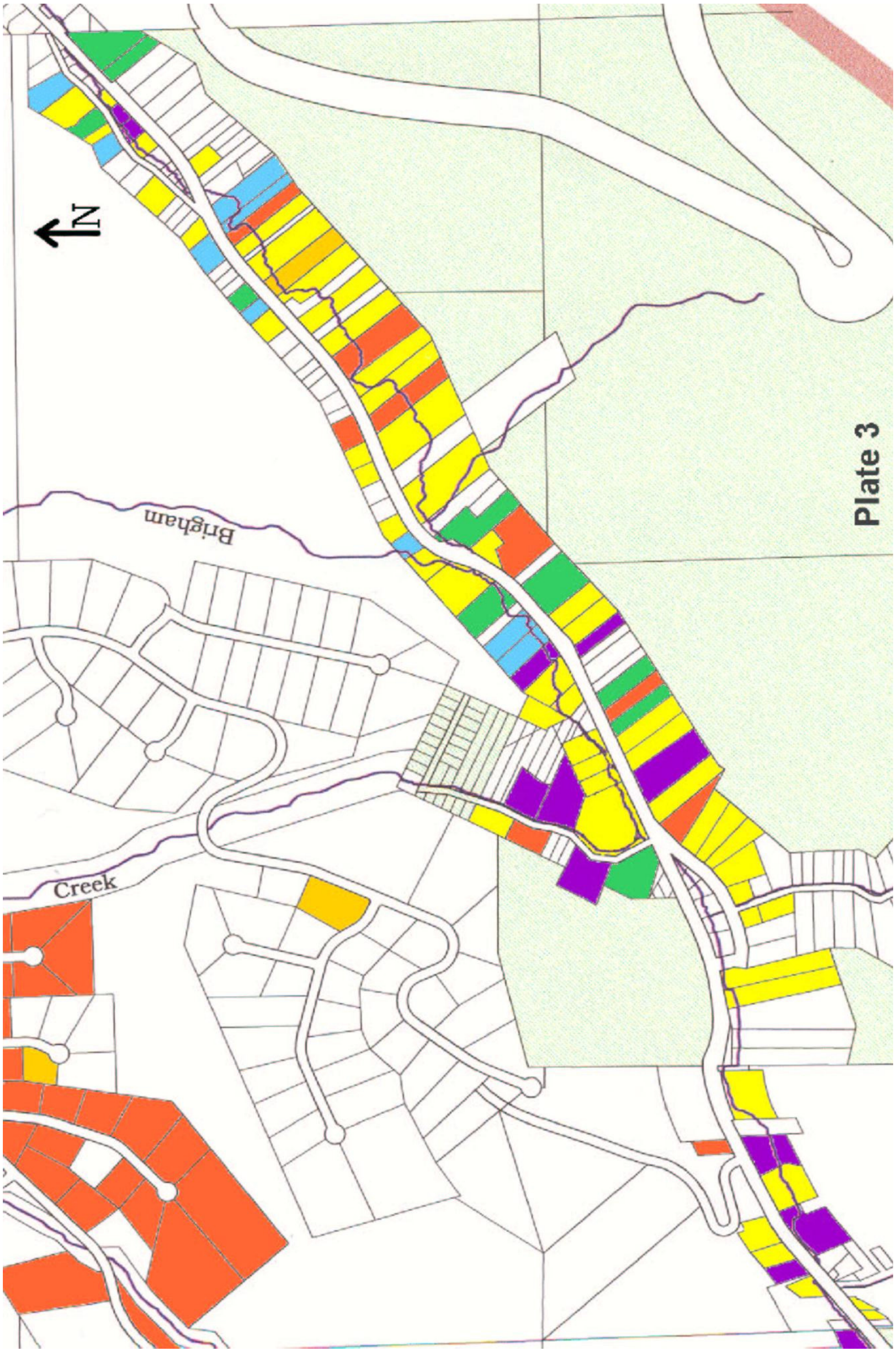


Figure 12. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 3.

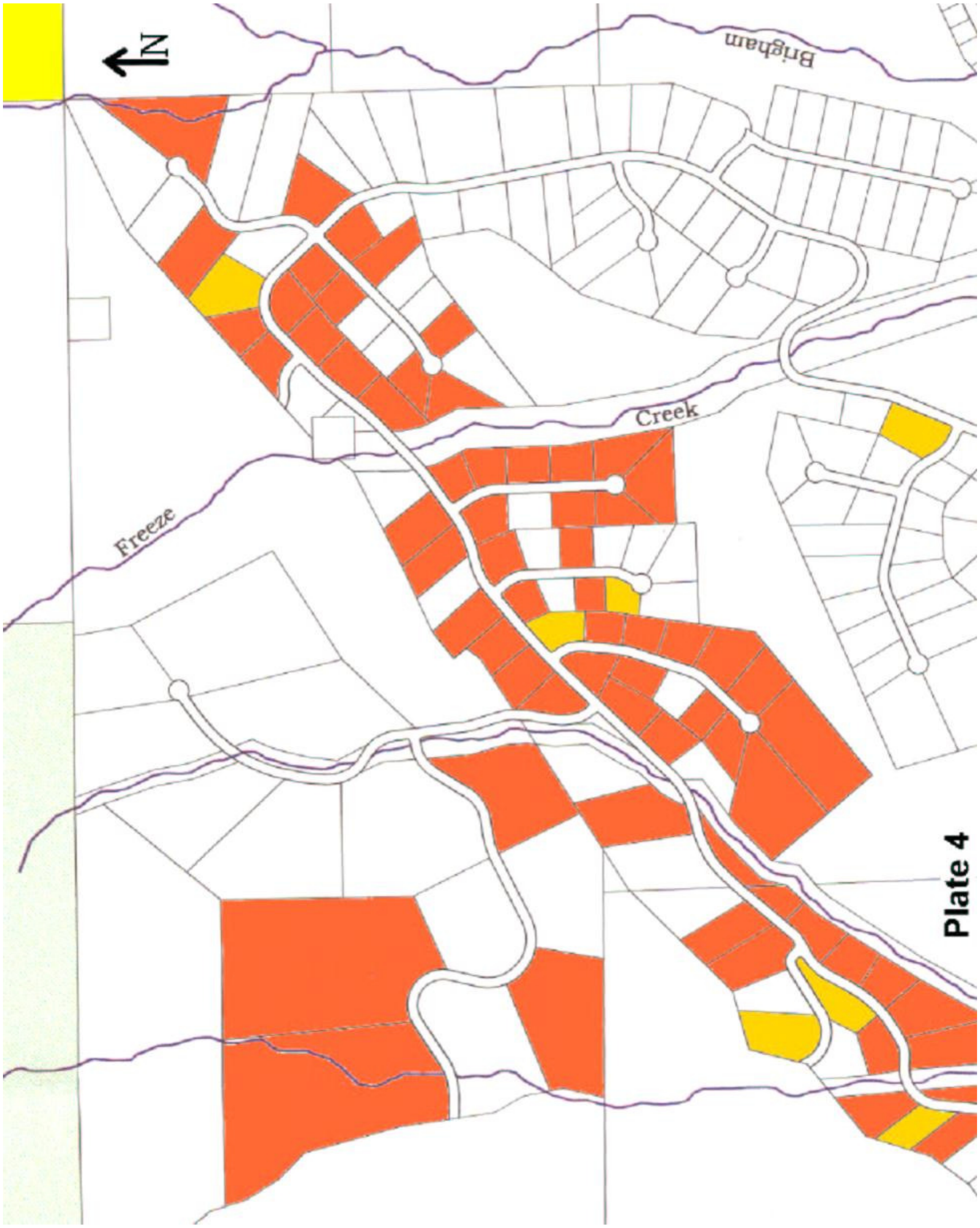


Figure 13. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 4.

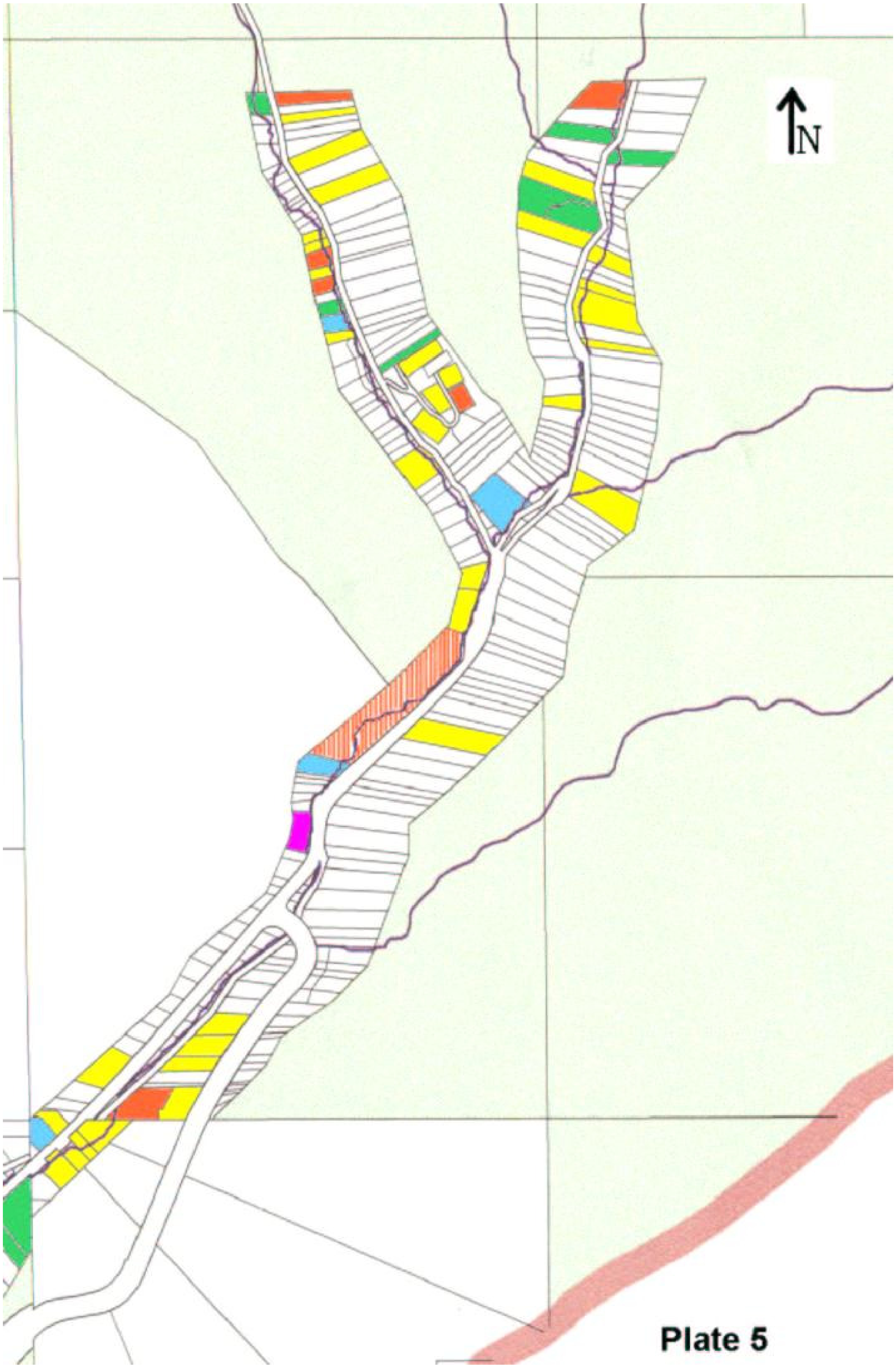


Figure 14. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 5.

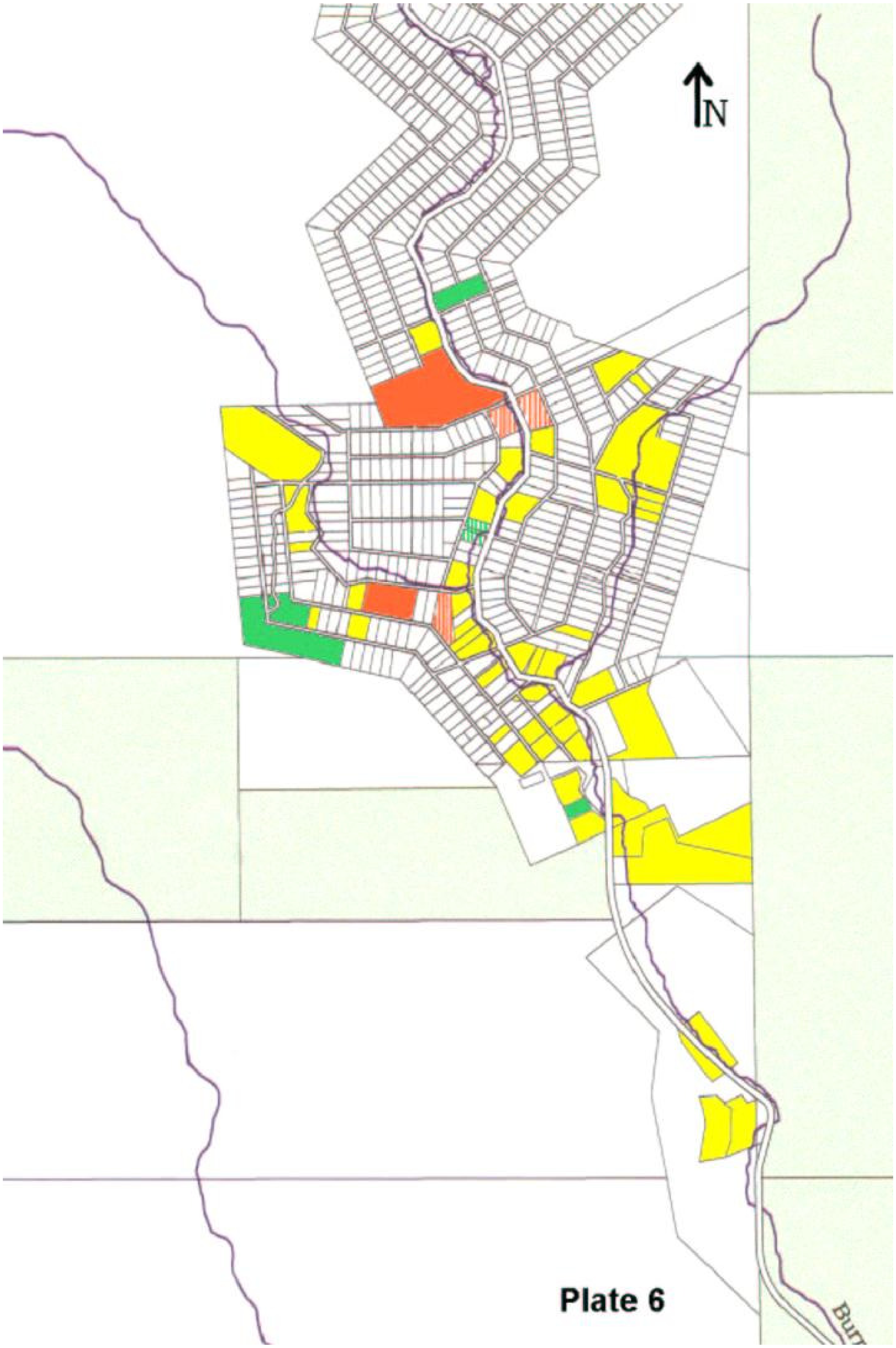


Figure 15. Salt Lake County 2003—Age of On-Site Waste Disposal Systems in Plate 6.

5.0 HISTORIC DATA ANALYSIS

5.1 Previous Water Quality Data Summaries

Water quality data has been collected for Emigration Creek beginning in 1975 and continuing through the present. Numerous parameters have been monitored; however, few have been consistently analyzed. Parameters with the greatest number of samples collected include: pH, Nitrogen, Phosphorus, Specific Conductance, Total and Fecal Coliform, and *E. coli*. The Utah DWQ has collected the majority of samples; however, Salt Lake City Public Utilities has a sample station above Rotary Park, which has been consistently sampled since 1993. Additionally, the Salt Lake County Engineering Division, the University of Utah Engineering Department, and the USGS have conducted several intense studies of Emigration Creek. Tables 6 through 9 summarize data, sources, dates of collection, and value means through the 2005 period of collection. Section 5.2 discusses more recent data used for load analyses.

Table 6. Summary of previous available water quality data for Emigration Creek.

Parameter	Dates	# Samples	Minimum	Maximum	Mean
Alkalinity (mg/l)	1975-2005	266	51	308	237
Aluminum (ug/l)	1995-2005	92 (29*)	30.3	939	66.2
Anions (mg/l)	1991-1995	140	113	935	282.5
Arsenic (ug/l)	1976-2005	113 (8*)	Not detect	1.97	1.22
Barium (ug/l)	1991-2005	111 (98*)	Not detect	146	81.32
Bicarbonate (mg/l)	1975-2005	267	62	376	288.2
BOD (mg/l)	1976-1979	13	1	1	1
Boron (ug/l)	1975-2005	8	18	88.4	51.65
Cadmium (ug/l)	1991-2005	111 (3*)	Non detect	8.2	4.06
Calcium (mg/l)	1975-2005	267	32.1	140	89.02
Carbon dioxide (mg/l)	1975-2005	274	0	160	5.69
Carbonate (mg/l)	1991-2005	262	0	11	0.54
Cation (mg/l)	1991-1999	140	67	342	155.2
Chloride (mg/l)	1975-2005	267	3.5	750	97.3
Chromium (ug/l)	1976-2005	112 (28*)	2	864	42.8
COD (mg/l)	1991	2	Non detect	Non detect	Non detect
Copper (ug/l)	1976-2005	112 (4*)	10	28	17.7
DO (mg/l)	1976-1979	9	5.5	10.4	8.2
Flow (cfs)	1992-2003	152 (14**)	0	59.95	7.2
Fluorides (mg/l)	1975-1976	5	0.13	0.32	0.21
Hardness (mg/l)	1975-2005	267	138.1	504	307.4
Hydroxide (mg/l)	1991-	262	0	0	0

	2005				
Iron (ug/l)	1975-2005	(57*)	10	661	97
Lead (ug/l)	1976-2005	112 (2)	3.8	20	11.9
Magnesium (mg/l)	1975-2005	267	3.5	39.4	20.7
Manganese (ug/l)	1976-2005	113 (94*)	3	90.7	21.2
Mercury (ug/l)	1991-2005	111 (1*)	Non detect	Non detect	Non detect
Nickel (ug/l)	1975-2005	6 (2*)	5	20	12.5
Nitrogen (mg/l)	1975-2005	520 (260*)	0.0149	1.14	0.21
pH	1975-2005	524	6.5	8.9	8.25
Phosphorus (mg/l)	1975-2005	427 (359*)	0.008	0.55	0.044
Potassium (mg/l)	1975-2005	268 (220*)	1	4	1.53
Selenium (ug/l)	1976-2005	114 (3*)	0.5	1.7	0.97
Silica (mg/l)	1975-1976	5	11	15	13
Silver	1991-2005	111	Non detect	Non detect	Non detect
Sodium (mg/l)	1975-2005	267	5.1	233	56.2
TDS (mg/l)	1975-2005	267	190	1,056	497.5
TSS (mg/l)	1976-2005	273 (220*)	0	471.3	25.5
Specific Conductance (umho/cm)	1975-2005	438	260	1,800	806.9
Sulfur (mg/l)	1975-2005	267 (261*)	13.4	247.4	59.8
Temperature (°C)	1976-2005	258	0	26.9	7.6
Turbidity (NTU)	1975-2005	267	0.087	254	9.5
Zinc (ug/l)	1975-2005	112 (1*)	Non detect	10	

*Number of samples with values
**Number of 0 cfs measurements recorded

Table 7. *E. coli* (MPN/100 ml) Data for Emigration Creek. (2003-2005)
(Includes Salt Lake City Public Utilities, Salt Lake County, and Garrick Wilden data) Total of 334 samples, 326 have values, 49 recorded as 0 MPN, 81 of the samples had values >206 MPN.

Month	N	0 MPN	TNTC*	>206 MPN	Minimum	Maximum	Mean
January	4	2	0	0	0	50	17.5
February	5	1	0	0	0	60	17.2
March	8	3	0	0	0	60	26.3
April	16	7	2	2	0	TNTC	13.6
May	15	7	0	1	0	240	50
June	57	5	0	2	0	920.8	63.8
July	74	5	1	34	0	TNTC	367
August	81	7	0	32	0	1,850	276.5
September	3	3	0	9	0	697	123.4
October	6	3	0	1	0	1,020	185
November	5	4	0	0	0	0	4
December	2	2	0	0	0	0	0
Total	326	49	3	81			

*Too Numerous To Count

Table 8. Total Coliform (MPN/100ml) for Emigration Creek. (1976 – 2005)
(Includes Salt Lake City Public Utilities, Salt Lake County, DEQ, and Garrick Wilden data). Total of 753 samples, 752 have values, 1 was recorded as 0 MPN, 89 of the samples had values >5,000 MPN.

Month	N	0 MPN	TNTC*	>5,000 MPN	Minimum	Maximum	Mean
January	14	1	0	1	0	>600	58.4
February	14	0	0	2	10	>400	80.1
March	21	0	0	0	6	>1,000	114.3
April	36	0	1	14	12	TNTC	152.8
May	68	0	0	0	10	3,000	326.1
June	137	0	0	21	10	24,196	2,621.4
July	137	0	1	5	16	TNTC	2,496.4
August	135	0	0	45	4	11,199	1,230.6
September	65	0	0	0	1	2,800	588.1
October	93	0	0	0	2	2,300	357.1
November	25	0	0	0	20	2,300	308.6
December	7	0	0	1	10	800	165.4
Total	752	1	2	89			

*Too Numerous To Count

Table 9. Fecal Coliform (MPN / 100 ml) for Emigration Creek. (1976-2006)
(Includes Salt Lake City Public Utilities, Salt Lake County, DEQ, and Garrick Wilden data). Total of 598 samples, 598 have values, 21 recorded as 0 MPN, 63 of the samples had values >400 MPN.

Month	N	0 MPN	TNTC*	>400 MPN	Minimum	Maximum	Mean
January	14	3	0	0	0	30	10.1
February	14	3	0	0	0	46	8.9
March	20	3	0	0	0	120	24.95
April	35	2	0	2	0	400	50.6
May	66	1	0	2**	0	3,000	113.4
June	86	0	0	5	2	5,600	187.8
July	73	1	1	8	0	TNTC	176.9
August	102	2	0	23	0	3,030	279.5
September	63	2	0	11	0	2,460	218.1
October	93	2	0	11	0	2,460	218.1
November	25	0	0	1	1	500	39.6
December	7	2	0	0	0	106	29
Total	598	21	1	63			

* Too Numerous To Count
**Not QA/QC'ed

5.2. Other Water Quality Studies Review

The Salt Lake County Engineering Division, the University of Utah Engineering Department, and the USGS have conducted several intense studies of Emigration Creek. The following is a review of water quality studies that have been conducted for Emigration Creek.

5.2.1 Pollution Mitigation in Emigration Canyon (Glenne and West, 1981)

In 1981, Glenne and West published a coliform model that they developed for Emigration Creek Sub-Basin (Bard and Glenne, 1981). In this study, the Canyon was divided into sixteen (16) sections based on flow regime. This study used bacterial decay rates as well as travel time through various media to assess the source of high coliform and TSS levels in Emigration Creek. Significant findings from this study include:

- An estimated 87% of coliform in Emigration Creek Sub-Basin were from surficial human and domestic animal use
- Only 5% of the coliform were thought to have originated from underground

disposal systems

- The upper portion of the Canyon yields proportionally the largest flow
- Rotary Park showed ~60% higher flows than the Burr Fork confluence
- 40% of wells were shown to have higher coliform levels than drinking water standards
- There were relatively low coliform levels coming in at the lower portion of the Canyon
- Concentration levels were highest in August
- Coliform loads were highest in June
- August coliform levels showed a sharper decrease near the mouth of the canyon than the model predicted
- The model under-estimated loads from Kilyon Canyon
- June provided the best agreement between observed and predicted coliform levels

5.2.2 Emigration Canyon General Plan

Background information regarding history, land use, and population can be derived from the 1999 General Plan for Emigration Canyon (SLCo, 1999). This plan characterized the canyon in detail and then proceeded to delineate various characteristics (e.g. environmental quality, transportation, open space and recreation, natural hazards, and land use policies) associated with the Canyon. The Plan concluded with an implementation protocol to be observed in order to assist Salt Lake County and Emigration Canyon residents with future growth. In characterizing the groundwater system of Emigration Canyon, the general plan states, "The continued reliance on septic systems may seriously impede the long-term preservation of groundwater quality."

5.2.3 Water Quality and Macroinvertebrate Communities of Emigration and Red Butte Creeks, Salt Lake County, Utah (USGS, 2000)

In December of 2000, the USGS published a fact sheet reviewing both chemical and biological data for Emigration Creek. This study compared macroinvertebrate data collected in 1950 with macroinvertebrate data that was collected in 1999. This study examined three (3) sites in Emigration Creek Sub-Basin for habitat and macroinvertebrate community composition and one (1) site in Red Butte (Figure 16).

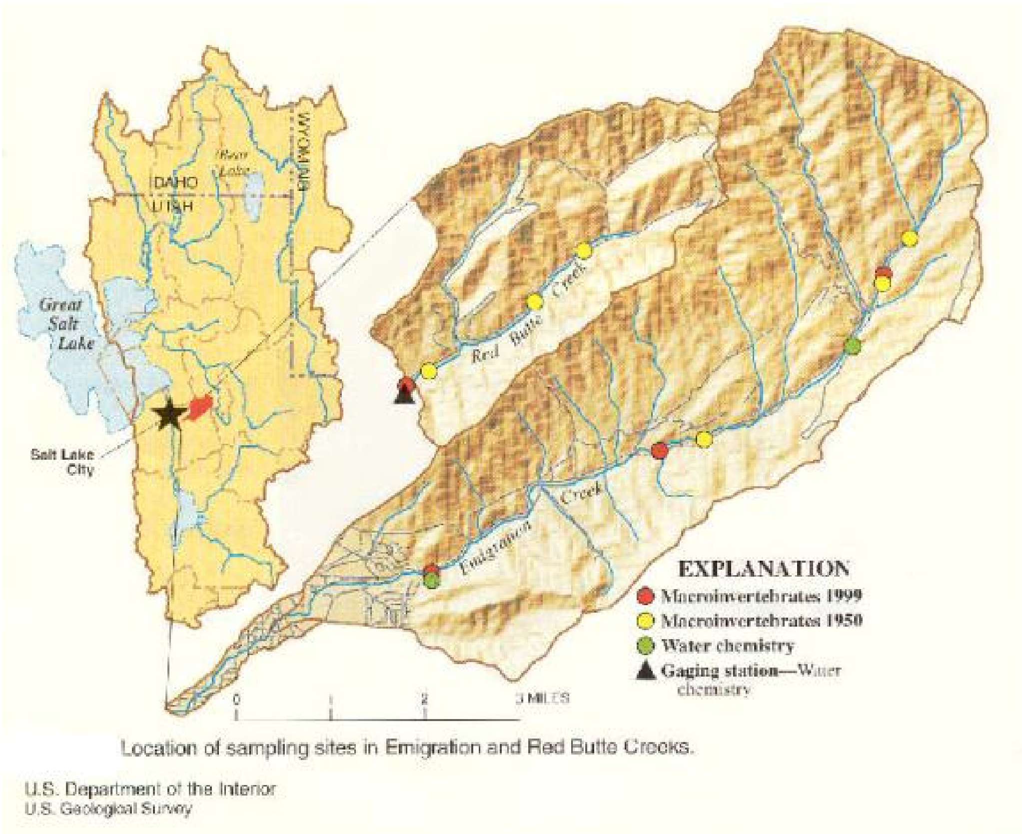


Figure 16. Sample Locations for USGS Macroinvertebrate Assessment.

This study found that macroinvertebrate concentrations in both the Upper Emigration and Red Butte Creek sites were similar in both 1950 and 1999. Significantly, the Middle and Lower regions of Emigration Creek had less taxa than the site in Red Butte Creek Sub-Basin and had a lower richness rating (Figure 17).

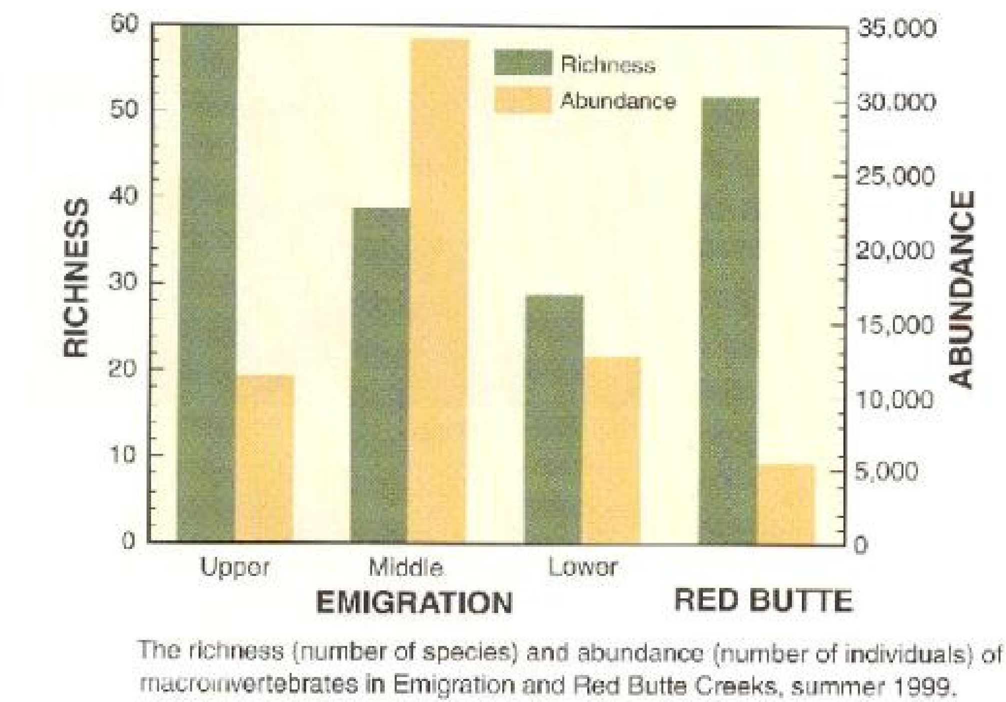


Figure 17. Macroinvertebrate Richness and Abundance for Emigration and Red Butte Creeks.

In addition to concentration, the USGS study examined tolerance levels of the macroinvertebrate communities in both Emigration and Red Butte Creek Sub-Basins. In 1999, lower Emigration Creek supported macroinvertebrates with moderate tolerance to pollution levels. The upper Emigration and Red Butte sites were shown to have the highest percentage of intolerant taxa, thus implying superior water quality at these sites. Additionally, this study suggested a general shift from pollution intolerant to pollution tolerant macroinvertebrates in all sites between 1950 and 1999.

Finally, chloride data was collected for Emigration Creek Sub-Basin (Figure 18). The findings of the study suggest that Emigration Creek is affected by humans from on-site disposal systems. However, a spike in chloride concentrations in the winter may have been due to the use of road salt for snow removal.

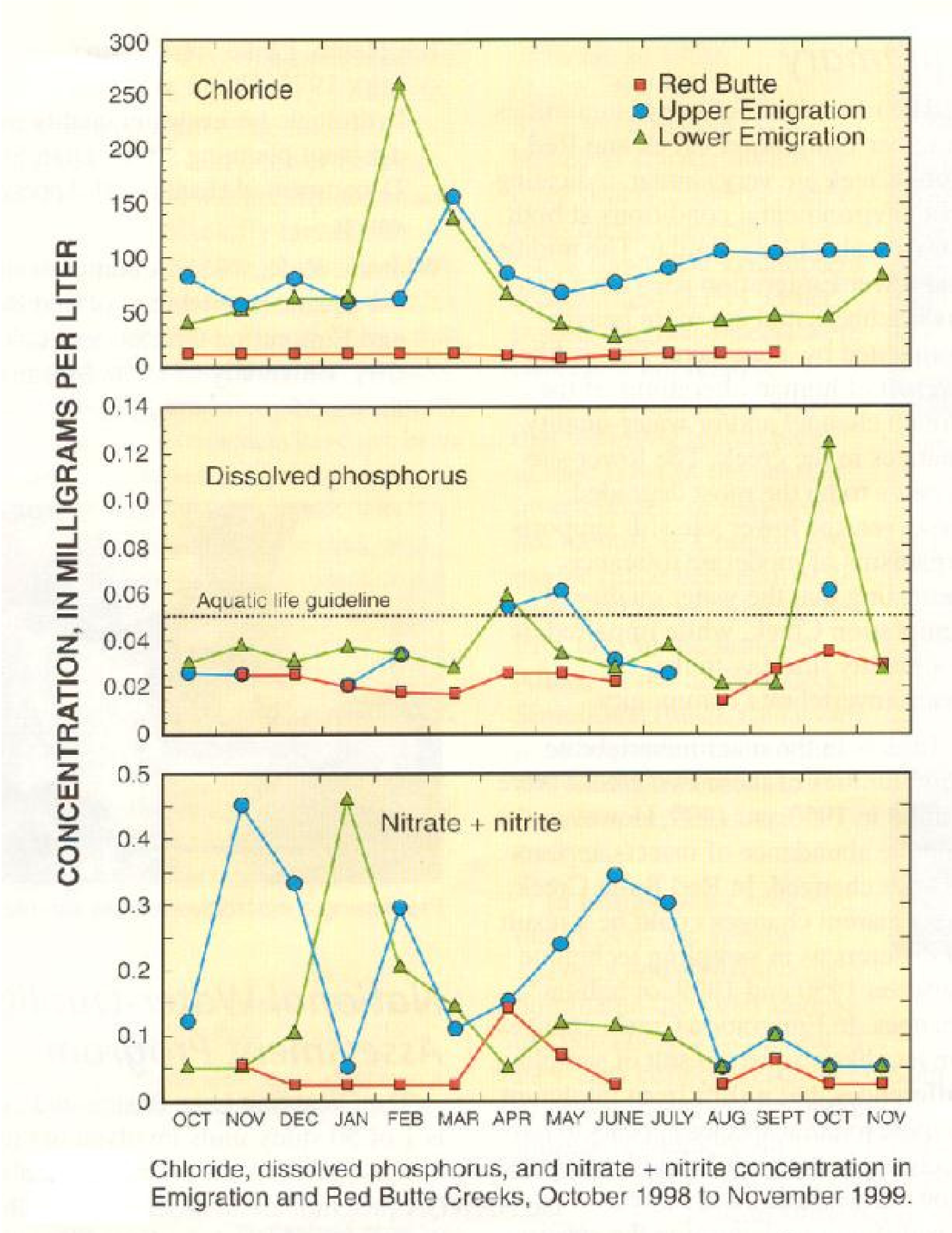


Figure 18. Chloride and Nutrient Data from 1999 USGS Macroinvertebrate Study.

5.2.4 Level III Stream Channel Stability Evaluation and Restoration Alternatives For Emigration Creek near Perkins Hollow (SLCo, 2001)

Based on a bank stability methodology authored by Pfankuch for the United States Forest

Service (USFS) in the 1970's, the Salt Lake County Engineering Division conducted a level III stream channel stability evaluation of a segment of Emigration Creek near Perkins Hollow in the summer of 2001 (Figure 19). Of the ten (10) stream reaches identified in this study, only two (2) rated as having predominantly excellent stability conditions (Figure 19). Three (3) reaches were rated as predominantly good, and three (3) reaches were rated predominantly fair. The remaining two (2) reaches were rated as predominantly poor. The varied conditions result from such factors as: pool and riffle ratios, debris, landform bank slopes, mass wasting, bank rock content, cutting and deposition, aquatic vegetation, and vegetative bank protection. Management alternatives that were suggested as a result of this study included: the re-establishment of a beaver population, the installation of vortex rock weirs, the installation of log vortex weirs, and the installation of cobble/gravel weirs. In 2007, Salt Lake County Flood Control & Engineering Division installed rock weirs in the Perkins Flat segment of Emigration Creek.

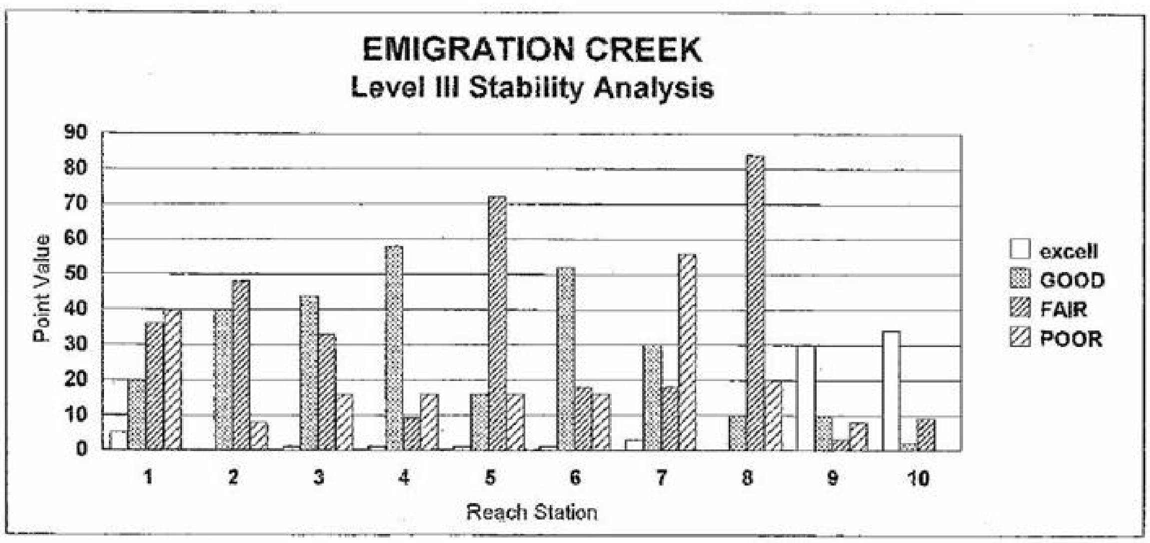
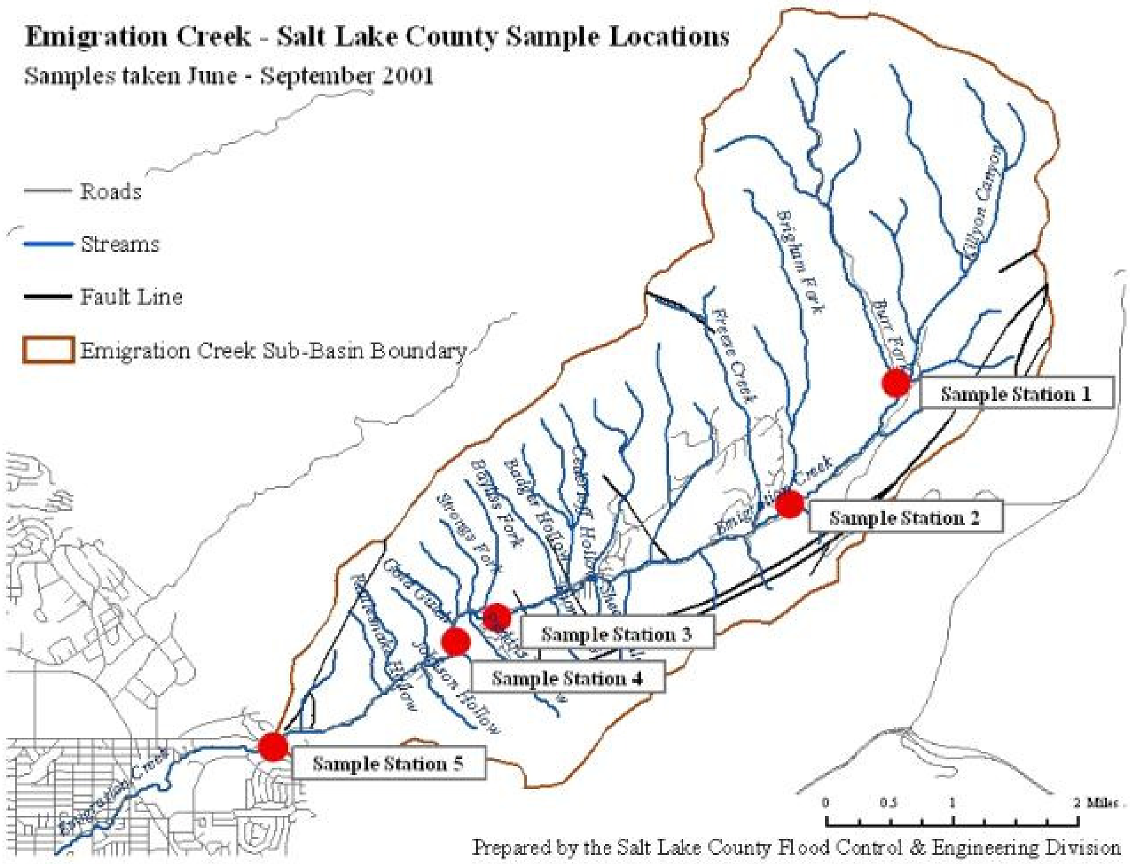


Figure 19. Level III Bank Stability Assessment of Perkins Flat Reaches.

5.2.5 Emigration Watershed Non-Point Pollution Assessment: Coliform Bacteria Water Quality Analysis (SLCo, 2001)

Between May and November of 2001, the Salt Lake County Engineering Division conducted an intense study of Emigration Creek using five (5) sample locations (Map

16). Samples were collected weekly for 23 weeks, and were taken three (3) times each sample day to assess diurnal variance in water quality. Parameters that were analyzed included: Temperature, Conductivity, Total and Fecal Coliform, and Stream Flow.



Map 16. Salt Lake County 2001 Sample Sites.

5.2.6 Temperature and Conductivity

In the Salt Lake County study, temperatures varied between 0.5º and 24º C and were consistently highest in the evening hours (Figure 20). Seasonal temperatures peaked in early August. Conductivity levels varied between 0.463 and 1.34 and peaked in the morning hours at all five (5) sample sites. Overall, conductivity levels were highest at the Mayfield and Santa Fe sampling sites (Figure 21).

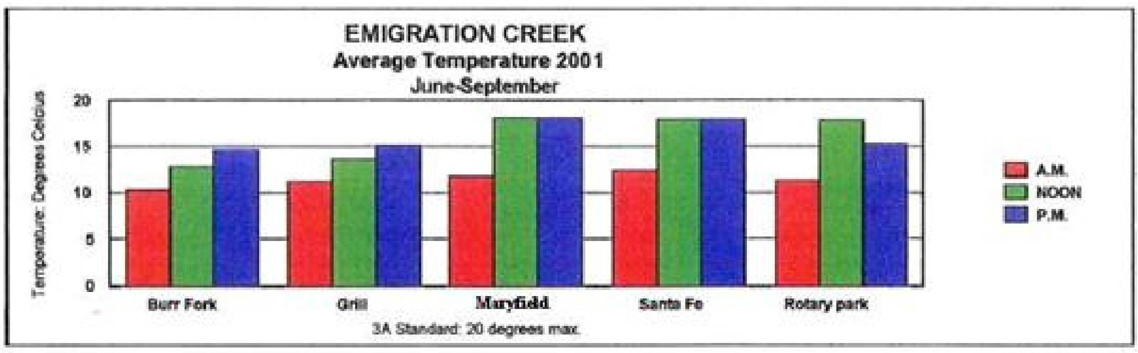


Figure 20. Salt Lake County 2001—Mean Monthly Temperature.

Conductivity measurements that were taken as part of this 2001 study show minor diurnal variation. At all five sample sites, the highest conductivity levels were observed in the morning hours (Figure 21). At four of the five sites, conductivity levels were lowest in the evening hours.

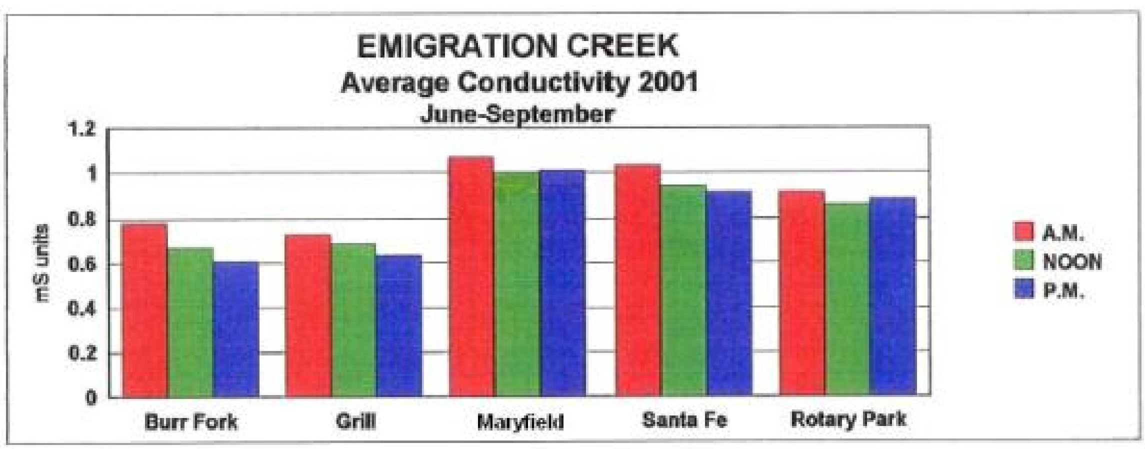


Figure 21. Salt Lake County 2001—Mean Monthly Conductivity.

Geographically, conductivity was relatively low in the upper reaches of Emigration Creek (Burr Fork and the Grill) and showed a sharp increase at Maryfield Drive. Beyond Maryfield Drive, conductivity levels decreased slowly to Rotary Park. Although geographic and diurnal patterns were observed, it is important to note that the overall geographic and diurnal fluctuations were relatively minor with the low mean levels of ~0.5 mS and the high mean levels of ~1.05 mS.

5.2.7 Salt Lake County 2001—Total Coliform

Seasonal mean total coliform concentrations, observed by Salt Lake County in 2001, varied between 566 cfu/100 mL and 1,375 cfu/100 mL, with the highest mean observed at Burr Fork (Figure 22). The total coliform concentrations decreased from the upper to the lower reaches of Emigration Creek.

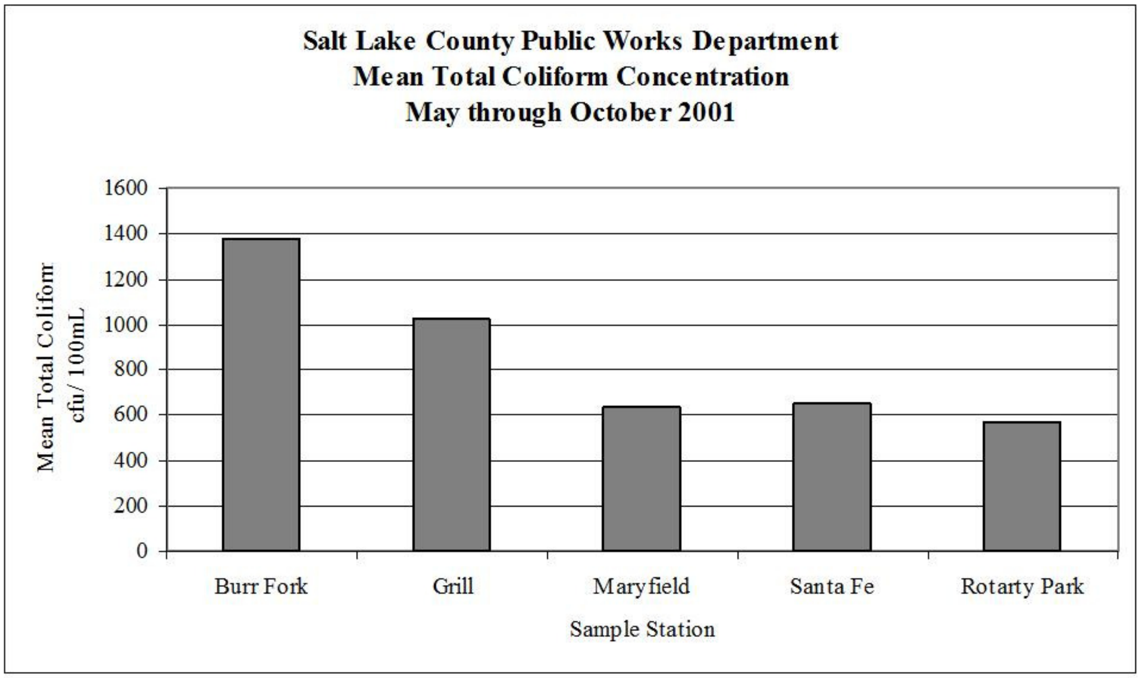


Figure 22. Salt Lake County 2001—Mean Total Coliform Concentrations.

In order to assess diurnal patterns, total coliform levels were analyzed for AM, Noon, and PM hours at all five (5) sample locations. Diurnal patterns were similar to overall mean patterns with the highest concentration levels being observed in the upper reaches with a steady decline with distance and time (Figure 23). In general, total coliform levels were highest in the AM hours—reaching a mean high of 1521 cfu/100 mL at Burr Fork. The lowest mean diurnal level was observed for noon measurements at Rotary Park (462 cfu/100 mL).

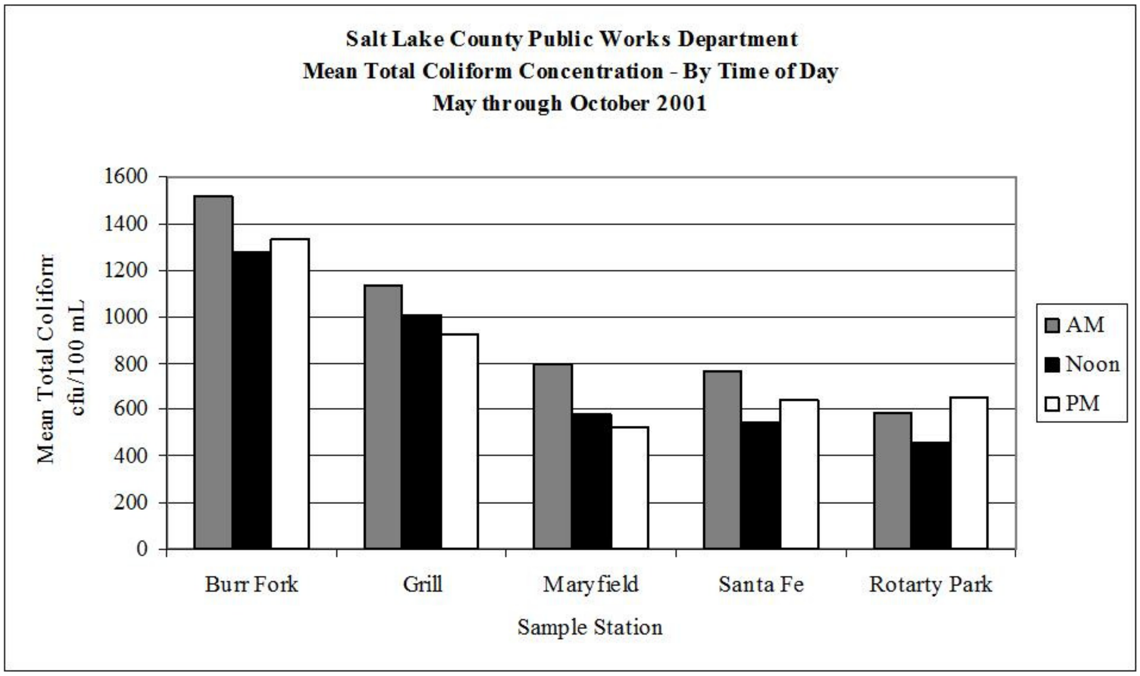


Figure 23. Salt Lake County 2001—Mean Diurnal Total Coliform Concentrations.

Mean monthly coliform concentrations observed in this study varied between 407 cfu/100 mL and 1161 cfu/100 mL, with the highest levels observed again in August (Figure 24). The lowest total coliform levels were observed in November.

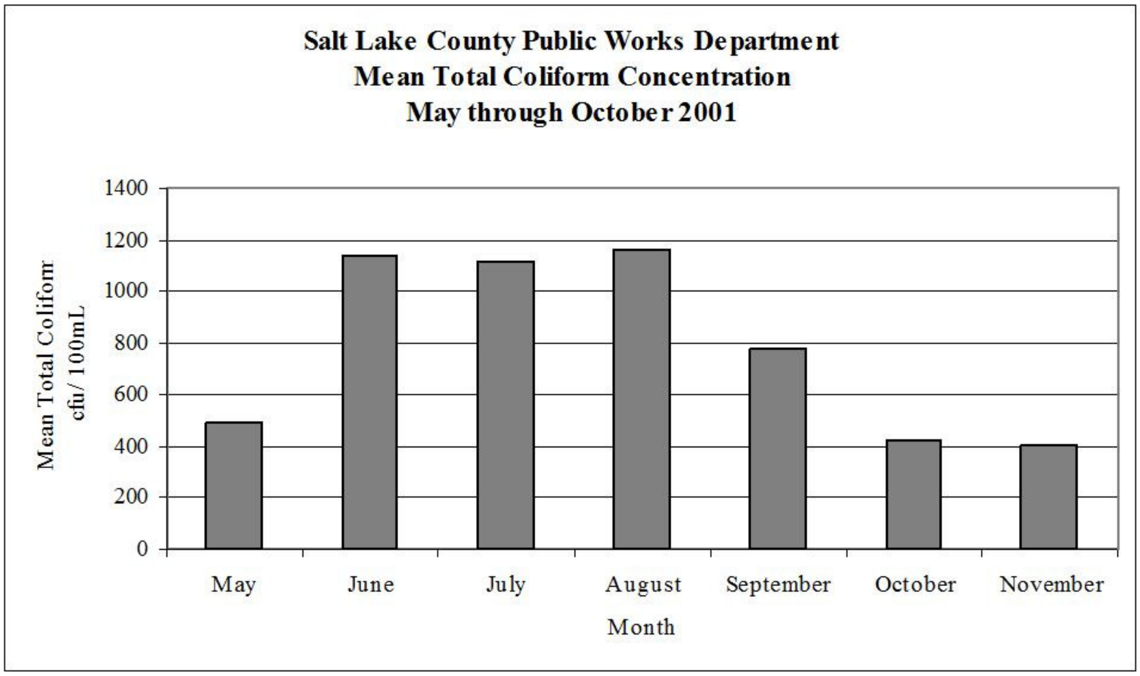


Figure 24. Salt Lake County 2001—Mean Monthly Total Coliform Concentrations.

5.2.8 Salt Lake County 2001 Study—Fecal Coliform

Mean seasonal fecal coliform levels ranged between 196 and 276 cfu/100 mL in the Salt Lake County study. In contrast to total coliform concentrations, the highest mean fecal coliform concentration was observed at Rotary Park and the lowest level was observed at Maryfield Drive (Figure 25).

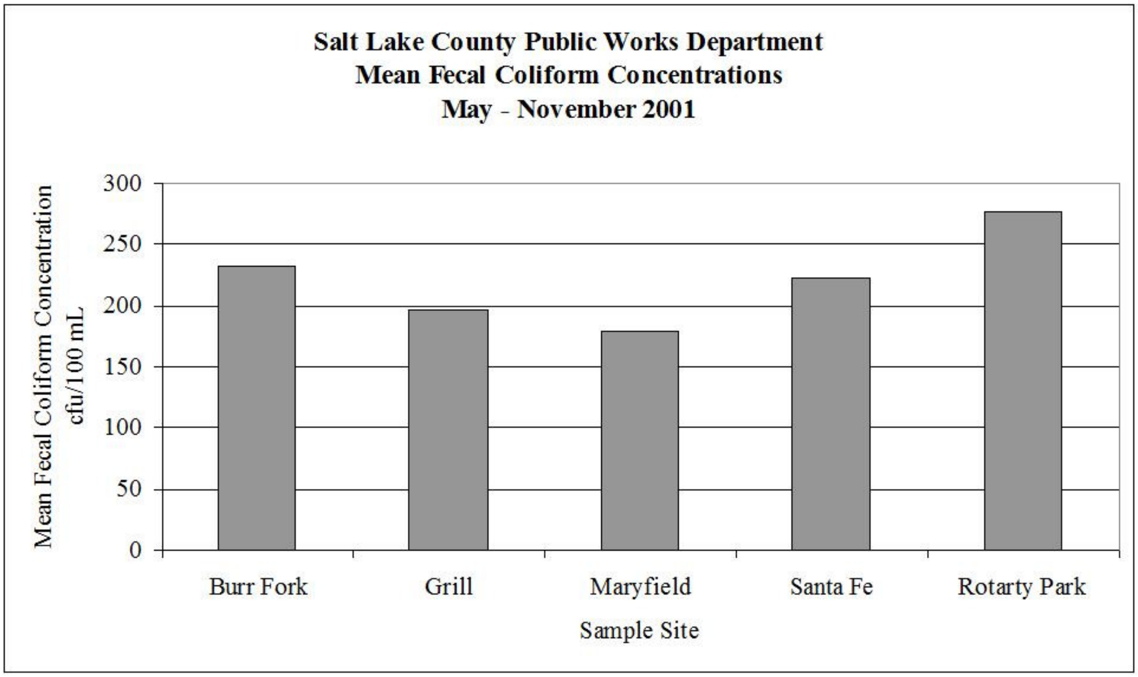


Figure 25. Salt Lake County 2001— Mean Fecal Coliform Concentrations.

Similar to total coliform concentrations, fecal coliform levels were highest in the morning and evening hours (Figure 26); however, in contrast to total coliform, a more extreme diurnal pattern was observed for fecal coliform with the greatest variation between sites occurring in the PM hours. The observed fecal coliform mean for the AM hours varied between 236 cfu/100 mL (Maryfield) and 329 cfu/100 mL (Rotary Park). Fecal coliform means observed in the noon samples varied between 148 cfu/100 mL (Rotary Park) and 173 cfu/100 mL (Burr Fork). Evening means varied between 143 cfu/100 mL (Maryfield) and 354 cfu/100 mL (Rotary Park) with a nearly 2.5 fold variation in coliform concentrations between sample sites along Emigration Creek.

Fecal concentration levels observed by Salt Lake County in 2001 varied between 53 cfu/100 mL and 355 cfu/100 mL, with the highest monthly mean being observed in August and the lowest levels observed in November (Figure 27). Significantly, these findings are consistent with other studies; specifically, the mean monthly fecal coliform concentration in Emigration Creek is typically highest in August.

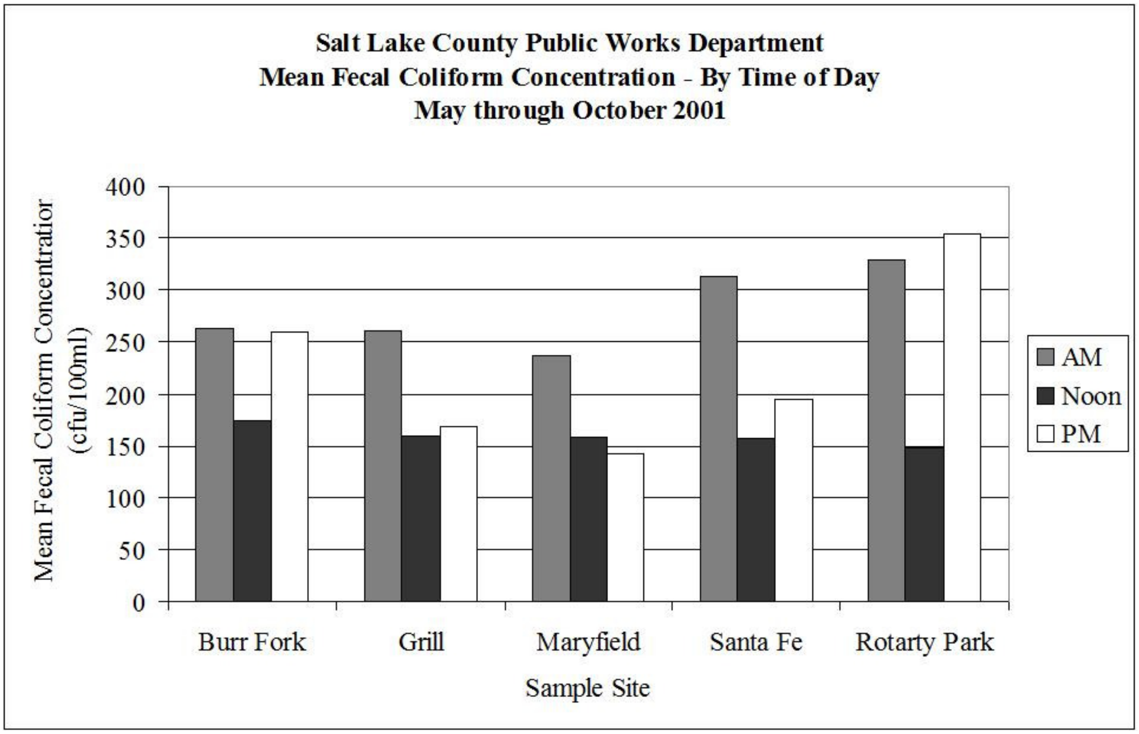


Figure 26. Salt Lake County 2001—Mean Diurnal Fecal Coliform Concentrations.

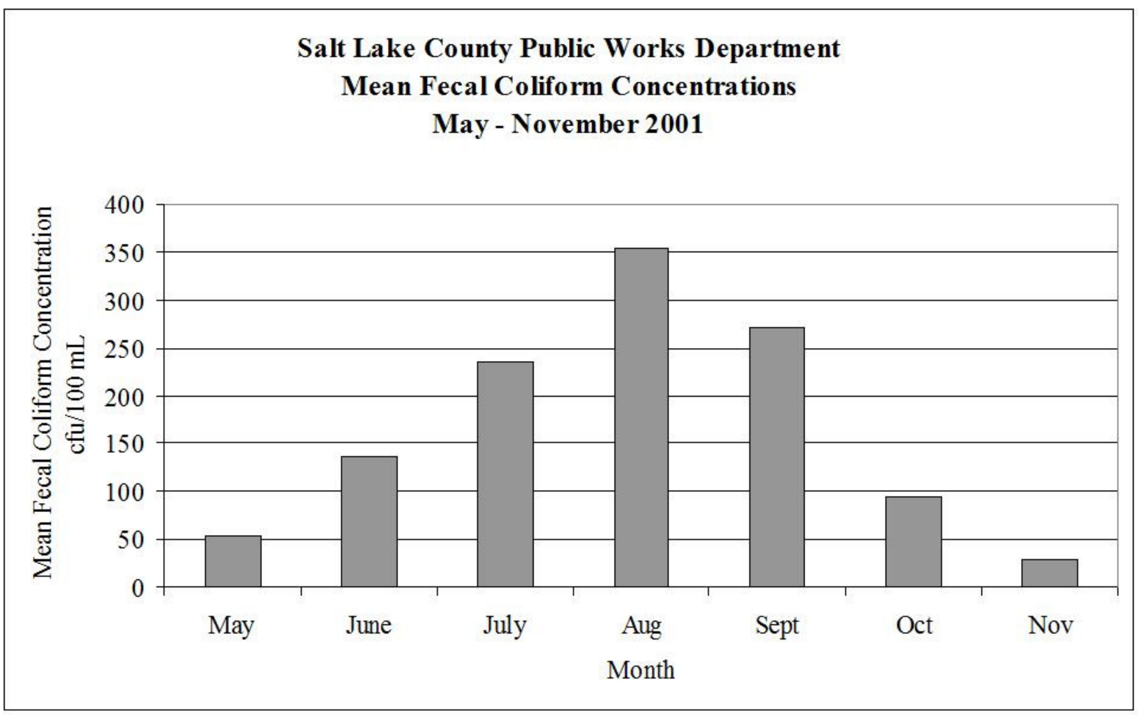
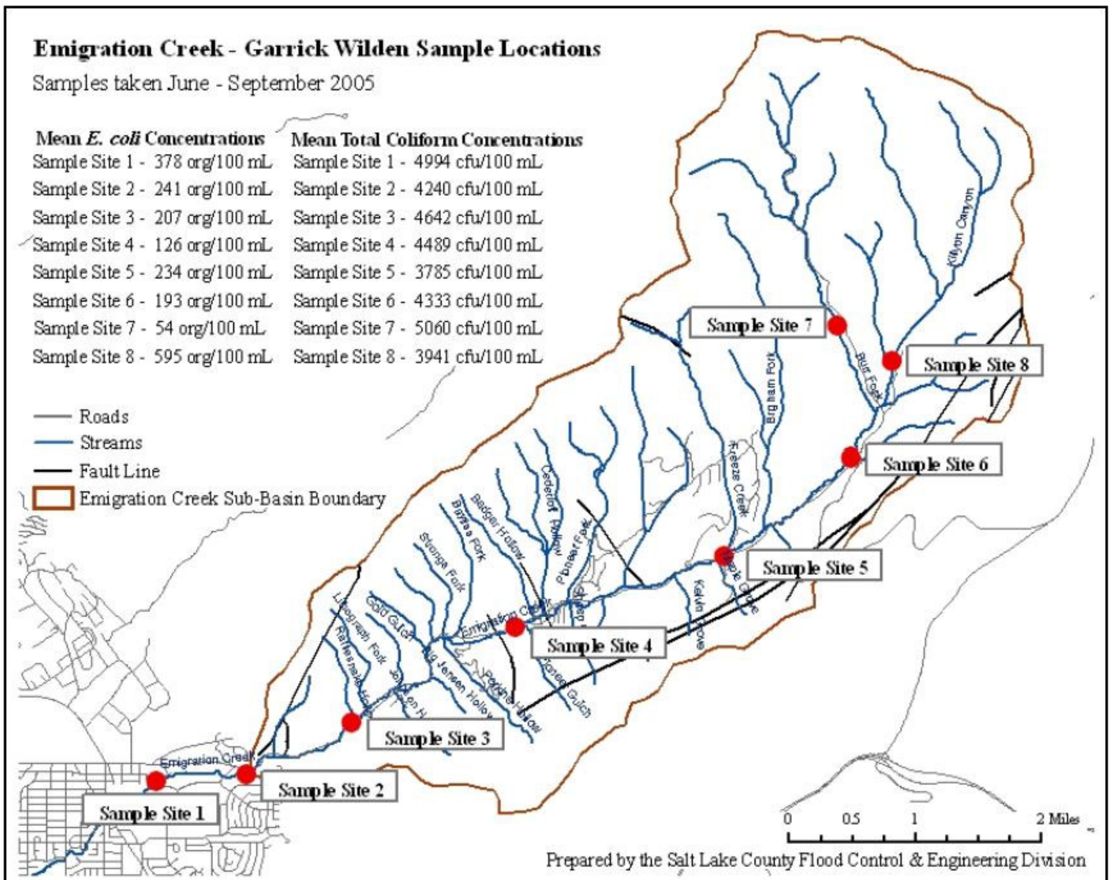


Figure 27. Salt Lake County 2001— Mean Fecal Coliform Concentrations.

5.2.9 Loading and Attenuation of Fecal Indicator Bacteria in Emigration Creek (Wilden 2005)

Garrick Wilden, a graduate student in the Civil Engineering Department at the University of Utah, conducted a two-part study of Emigration Creek Sub-Basin between June and October of 2005. This study collected weekly grab samples from eight (8) sample locations for 16 weeks (Map 17) and analyzed these samples for Total Coliform, *E. coli*, Enterococci, Nitrate, and Ammonia. In addition to a seasonal assessment, samples were collected twice daily to capture diurnal fluctuations in Emigration Creek.



1) Golf Course	5) 4800 Bridge (As of year 2009 6300 Bridge)
2) Rotary Park	6) Salt Lake City Weir
3) Sunnydale Lane	7) Burr Fork
4) Upper Meadow	8) Killyons Canyon

Map 17. Garrick Wilden 2005—Sample Site Locations.

5.2.9.1 Garrick Wilden 2005—Flow Assessment

Generally, Wilden found that the flows in Emigration Creek increase with time and distance downstream. Monthly mean flows ranged from slightly over 0 cfs in September to nearly 14 cfs in June (Figure 28). This finding is consistent with other studies that have shown Emigration Creek to have a particularly early spring runoff, usually between early April and May. Notably, spring runoff was particularly high in the spring of 2005 and caused several landslides in this Sub-Basin. However, flows measured at Rotary Park were similar to flow regimes in other years.

Wilden observed an increase in enterococci, total coliform, nitrate, chloride, and flow between sample stations five (5) and four (4). There was no observed surface inflow in this region; therefore, the increase in flow is most likely due to groundwater discharge. An increase in stream flow was also observed between sampling stations three (3) and two (2). This increase in flow was again thought to be attributable to groundwater discharge.

5.2.9.2 Garrick Wilden 2005—*E. coli* Assessment

Wilden's study found that mean *E. coli* concentrations for the study period generally increased from upstream to downstream and ranged between 54 org/100 mL and 595 org/100 mL (Figure 29). However, in contrast to this general pattern, high levels of *E. coli* were observed at the Burr Fork sample site. Overall, in the lower reaches of the Creek substantial bacteriological increases were observed.

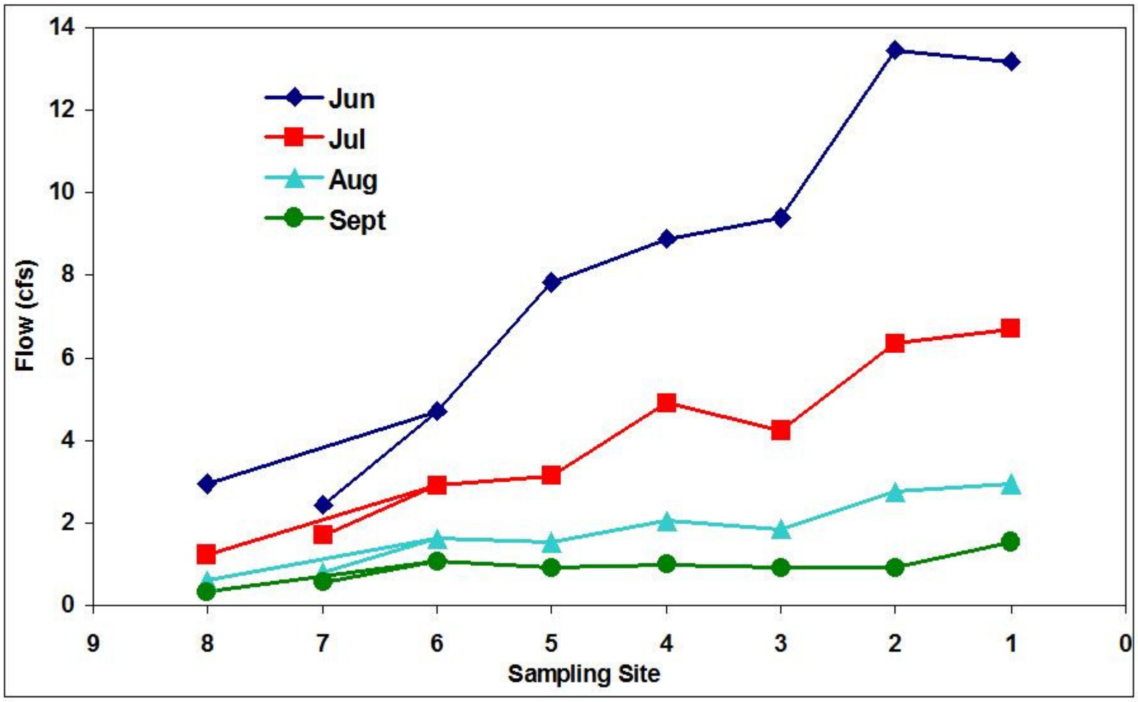


Figure 28. Garrick Wilden 2005—Mean Monthly Flow Data for Emigration Creek.

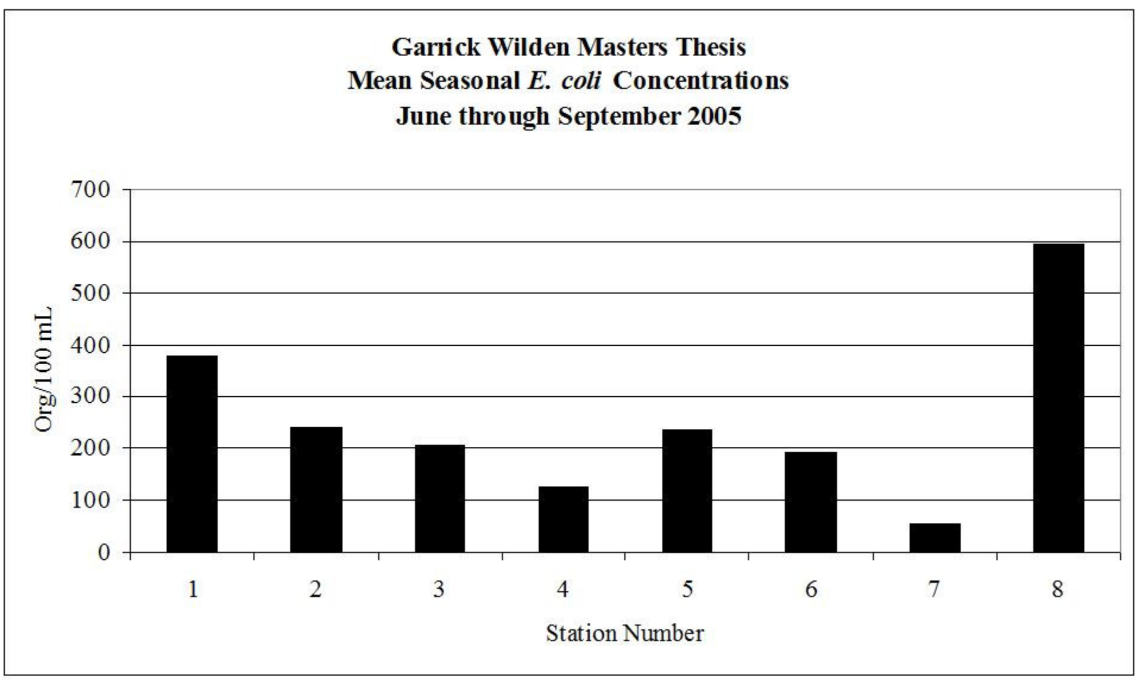


Figure 29. Garrick Wilden 2005—Mean Seasonal *E. coli* Concentrations.

Diurnally, *E. coli* concentrations were higher in morning hours versus the evening hours at all eight (8) of Wilden's sample sites (Figure 30). This is similar to both of the patterns for total and fecal coliform observed in the other diurnal study of Emigration Creek (SLCo, 2005). Causes of this diurnal impact will be assessed in the source identification element of this TMDL study.

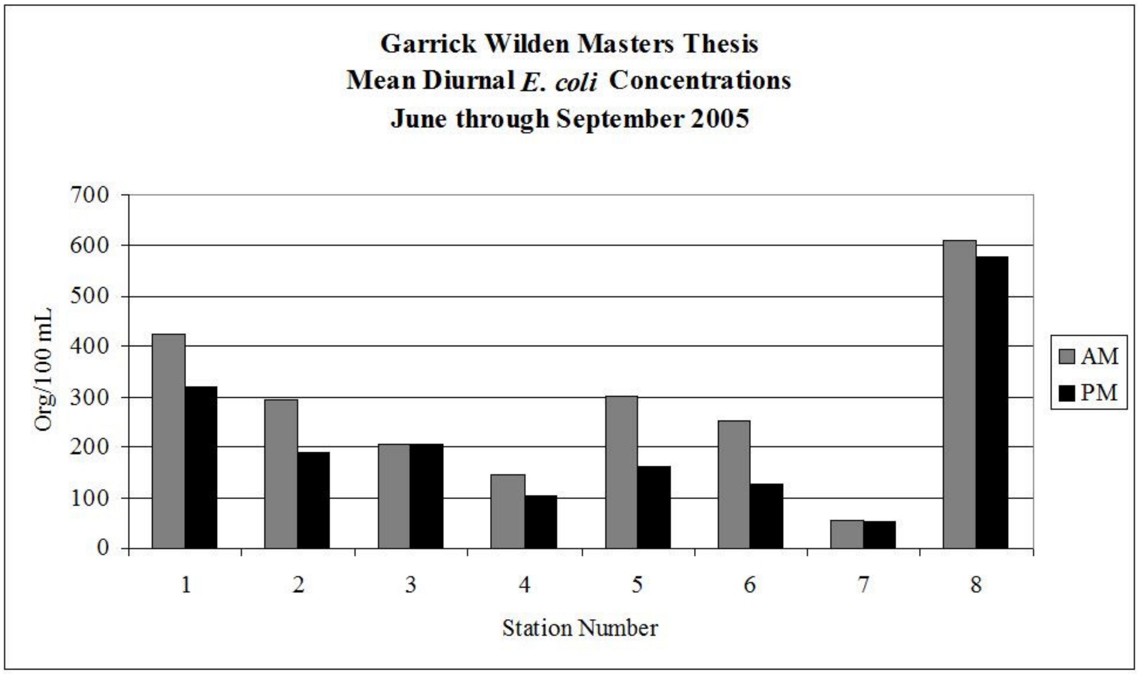


Figure 30. Garrick Wilden 2005—Mean Diurnal *E. coli* Concentrations.

The monthly geometric means for the eight (8) sample sites in Wilden's study showed more variance between months than between sites (Figure 31). Geometric means for July were the highest with August corresponding at several sample locations. The most consistently low month was June. Interestingly, the lower flows of September revealed a decrease in mean *E. coli* concentrations between sample sites five and four.

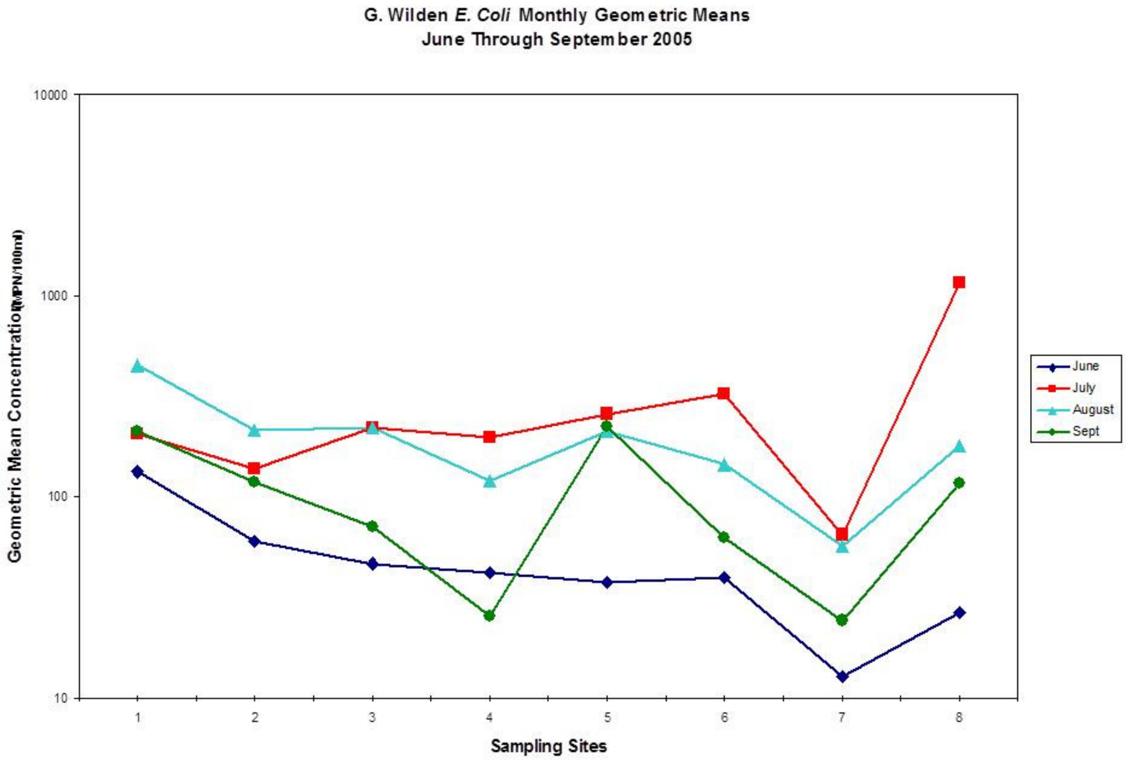


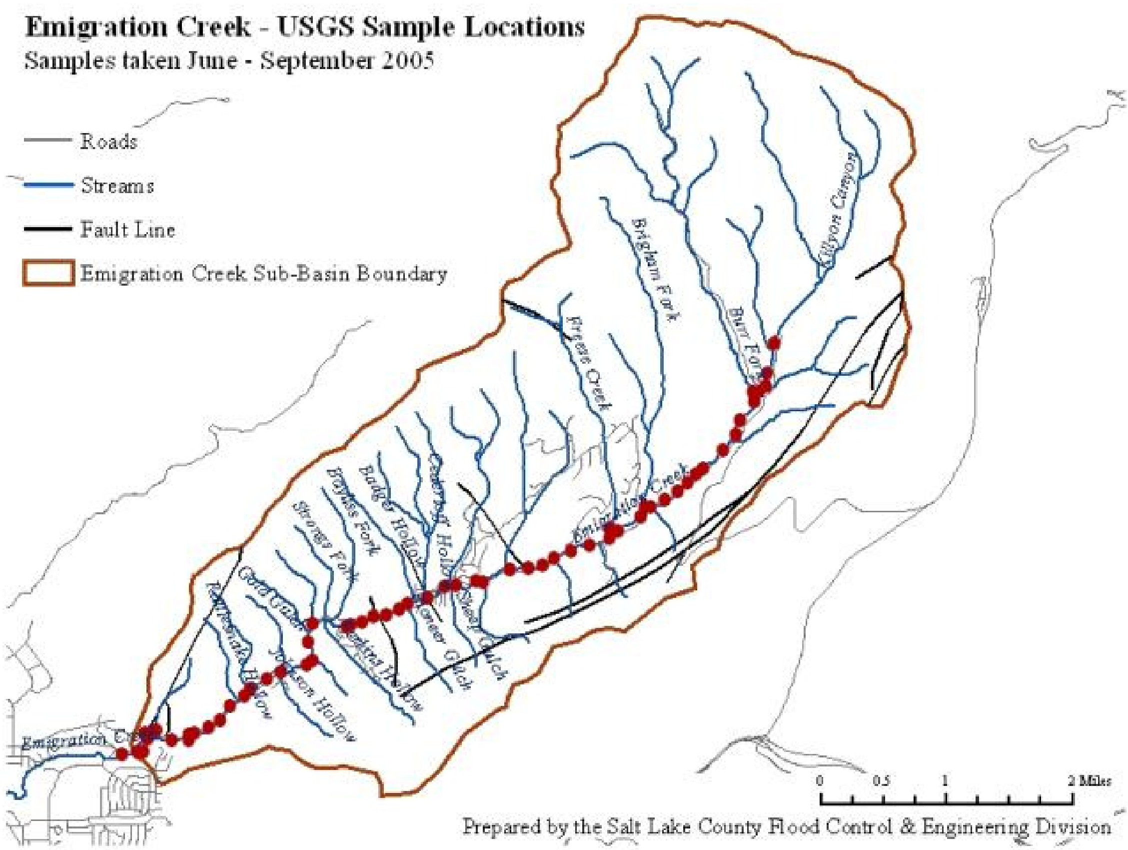
Figure 31. Garrick Wilden 2005—Monthly Geometric Mean *E. coli* Levels for Emigration Creek.

5.2.9.3 Garrick Wilden 2005—Bacterial Fate and Transport Assessment

The bacterial fate and transport portion of this study estimated an attenuation rate of 5.14 day^{-1}, which is much greater than other published loss rates. A speculated reason for this high attenuation rate is filtration by flow through streambed sediments. Due to the high attenuation rate, it is anticipated that several loading segments/sources must necessarily exist.

5.2.10 Principal Locations of Major-Ion, Trace-Element, Nitrate, and *Escherichia coli (E. coli)* Loading to Emigration Creek, September 2005

In September of 2005, the USGS conducted a synoptic tracer-injection study of Emigration Creek to quantify mass loading of major ions, trace elements, nitrate, and *E. coli*. As part of this study, the hydrologic setting of Emigration Creek was established when Sodium Bromide was injected upstream of Burr Fork. Subsequently, the downstream dilution rate was observed to establish "a detailed spatial profile of stream discharge" (Map 18). This study established that within the first 8,092 m (8,849 yd) of the study reach, Emigration Creek is a typical gaining stream. However, at 10,024 m (10,962 yd), Emigration Creek experienced a significant decrease in flow. This decrease may be attributable to a corresponding change in geologic formations from the Preuss Sandstone to the Twin Creeks Limestone (Kimball, 2005). As was explored by Kimball, the limestone is extremely fractured and may allow abundant infiltration. Downstream from the 10,024 m (10,962 yd) mark, there was an increase in discharge. This increase occurred despite the piping of Emigration Tunnel Spring and may be attributable to the inflow of Wagner Spring, two (2) unnamed springs, and the remaining water from Emigration Tunnel Spring (Figure 32).



Map 18. USGS 2005—Sample Sites.

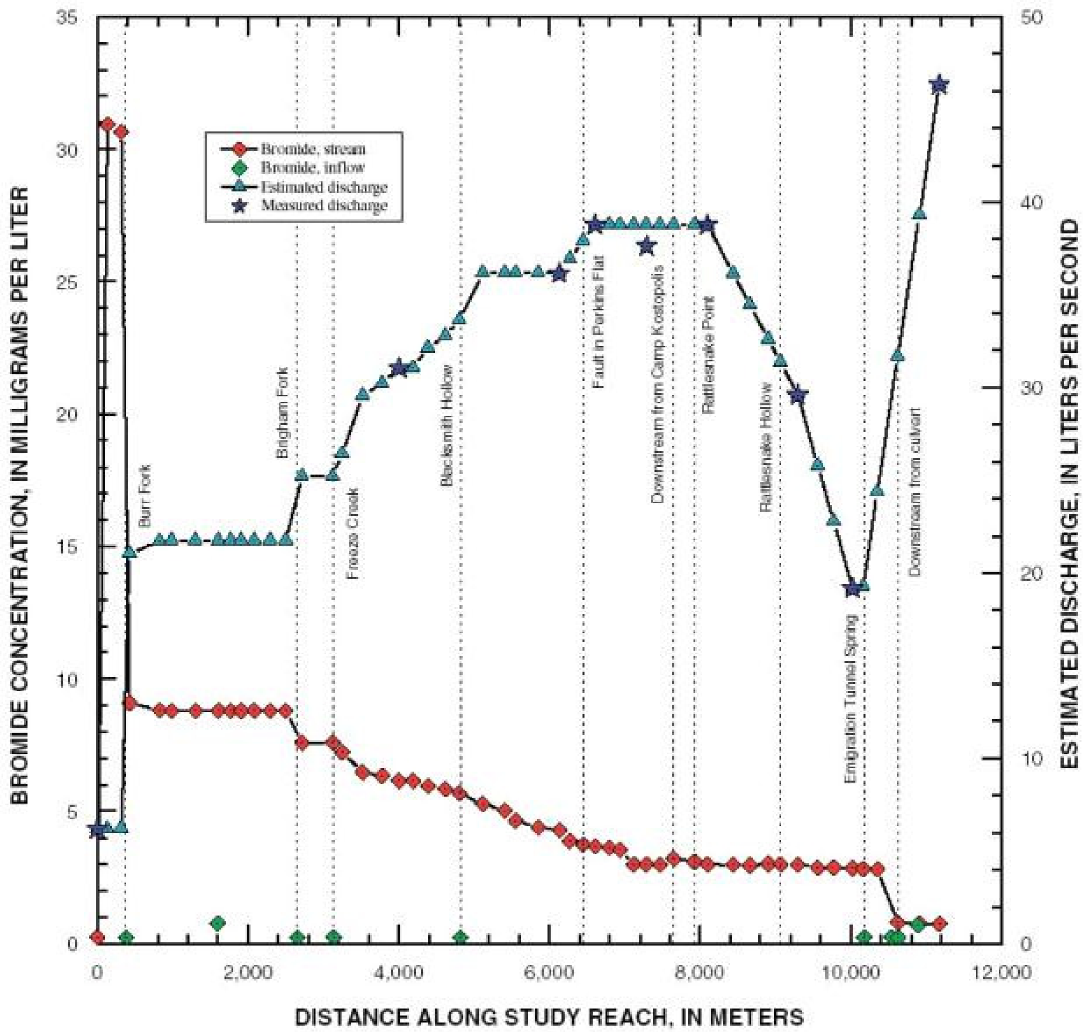


Figure 32. USGS 2005—Flow Data.

This study found increases of *E. coli* loading below Burr Fork, Brigham Fork, Blacksmith Hollow, Perkins Flat, and Camp Kostopolus (Figure 33). Generally, downstream changes in chemistry and loadings corresponded to locations where stream discharge increased. Interestingly, Lithium loadings were observed in Burr Fork, Brigham Fork, Maple Grove, Blacksmith Hollow, and Emigration Tunnel Spring. In Emigration Creek, Lithium only comes from anthropogenic sources. Therefore, the USGS study concluded that loading of nitrate and *E. coli* occurred independently of major ions and trace elements.

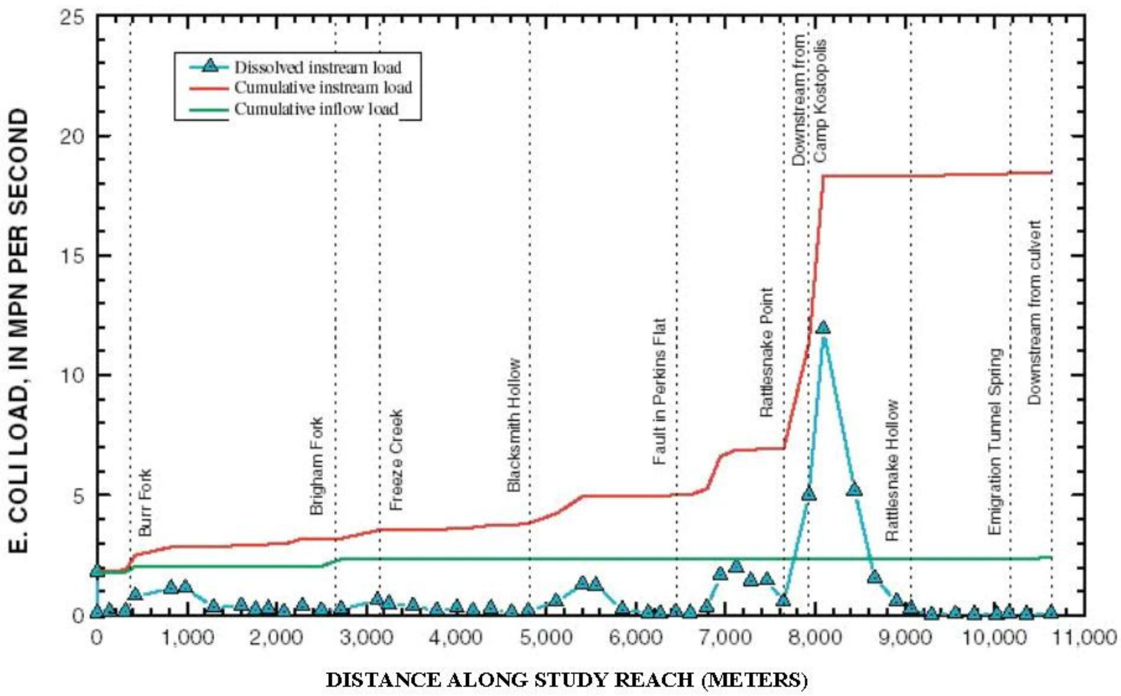


Figure 33. USGS 2005—*E. coli* Loads.

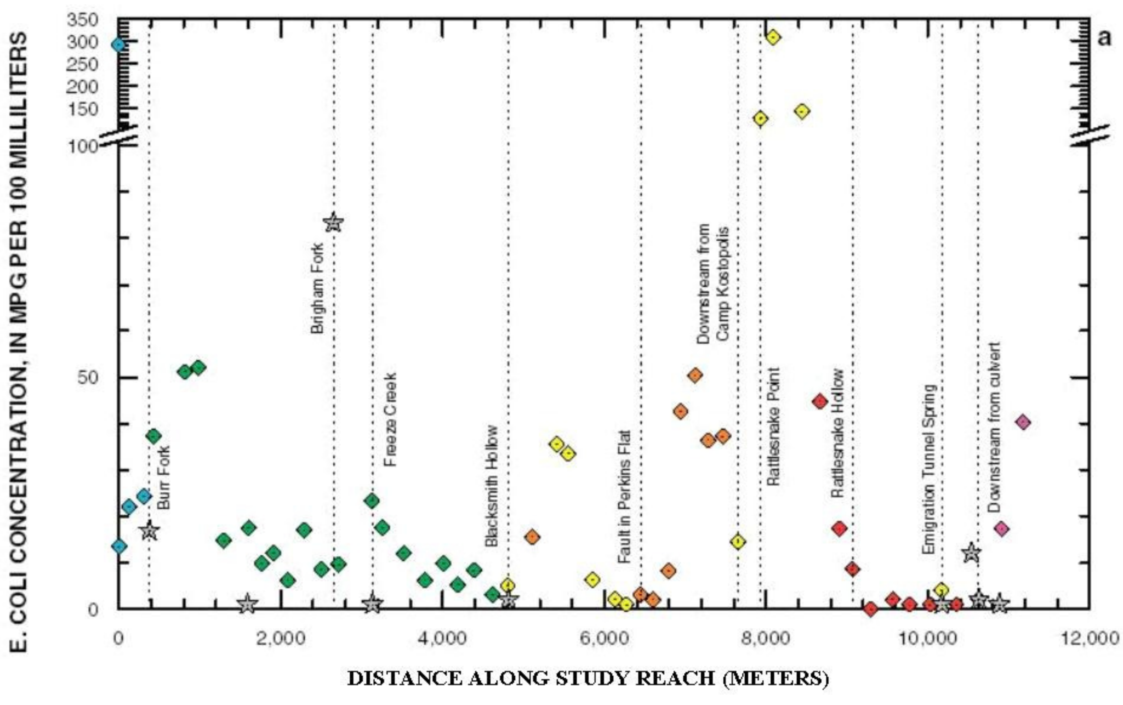


Figure 34. USGS 2005—*E. coli* Concentrations.

5.3 Other Bacteriological Studies and Data

Salt Lake City Public Utilities Department has been monitoring coliform concentrations of Emigration Creek above Rotary Park beginning in 1993 through the present. Although sampling frequency varies for this dataset, typically, samples have been taken monthly at a minimum for both total and fecal coliform.

5.3.1 Salt Lake City—Total Coliform

The highest total coliform concentrations are present in July and August (Figure 35). Mean July and August concentrations exceeded 300 cfu/100 mL; whereas, October through February levels were typically between 90 and 160 cfu/100 mL.

5.3.2 Salt Lake City—Fecal Coliform

As with total coliform, fecal coliform has been collected above Rotary Park beginning in 1993 and continuing through the present. The mean fecal coliform concentrations were highest in July (179 cfu/100 mL) and were lowest in February (9 cfu/100 mL) (Figure 36).

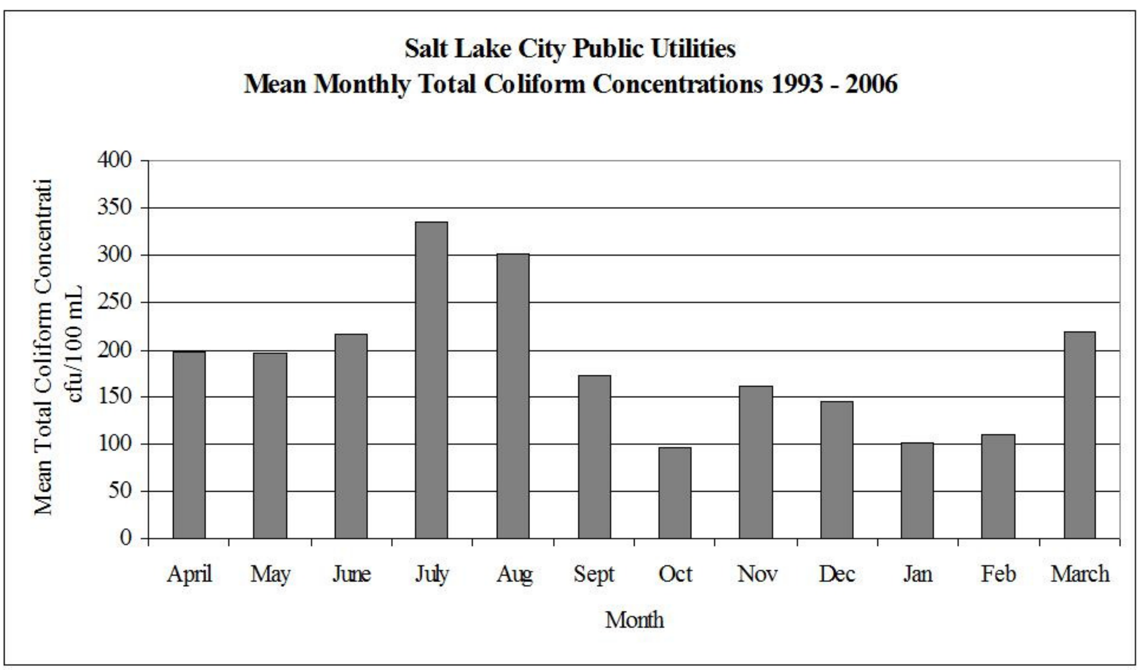


Figure 35. Salt Lake City—Mean Monthly Total Coliform Concentrations.

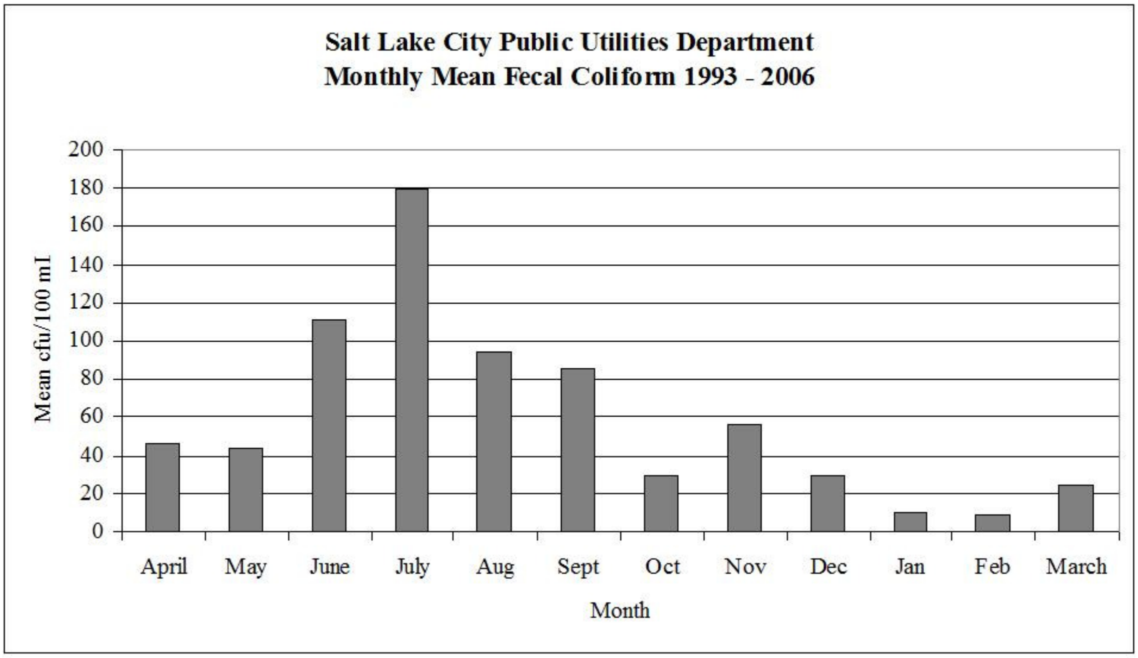


Figure 36. Salt Lake City—Mean Monthly Fecal Coliform Concentrations.

5.3.3 Salt Lake City—*E. coli* Coliform

With the adjustment of State standards in 2004, fecal coliform has been replaced with *E. coli* as the primary pathogenic indicator for 2B waters. The Salt Lake City Public Utilities Department began monitoring monthly *E. coli* levels at their Rotary Park sample location in 2003; however, the majority of data has been collected for the summer months (April through August). The Salt Lake City data shows that the arithmetic mean monthly *E. coli* levels varied between 0 org/100 mL (December) and 367 org/100 mL (July) (Figure 37). Notably, *E. coli* levels appear to fluctuate much more than either total or fecal coliform.

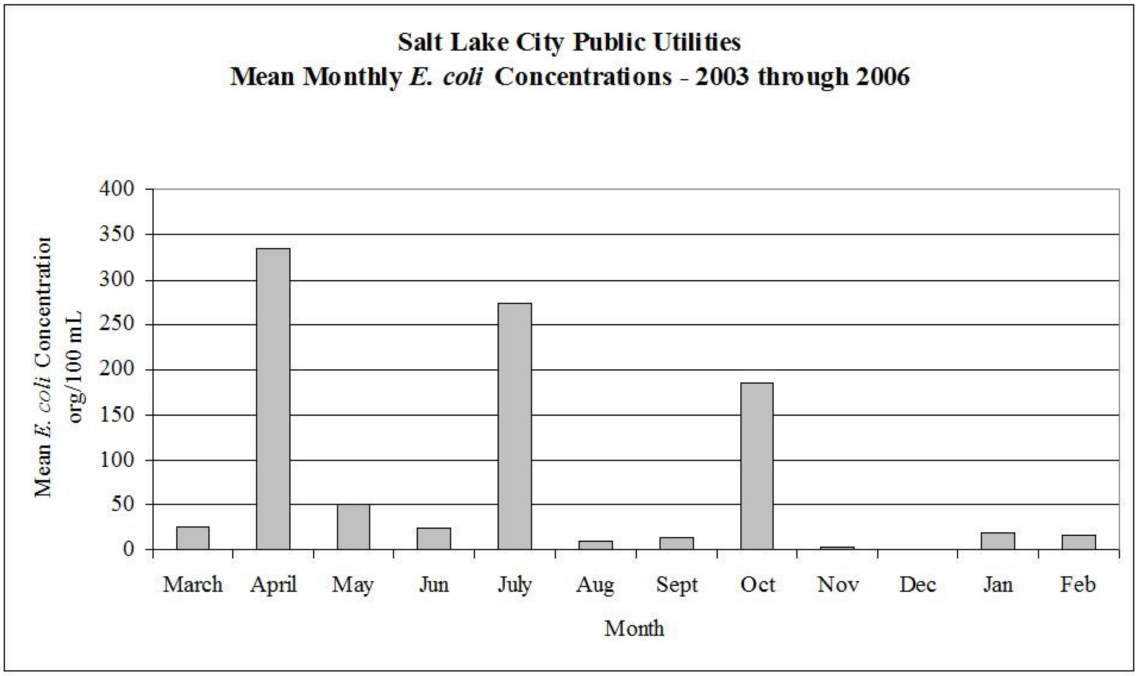
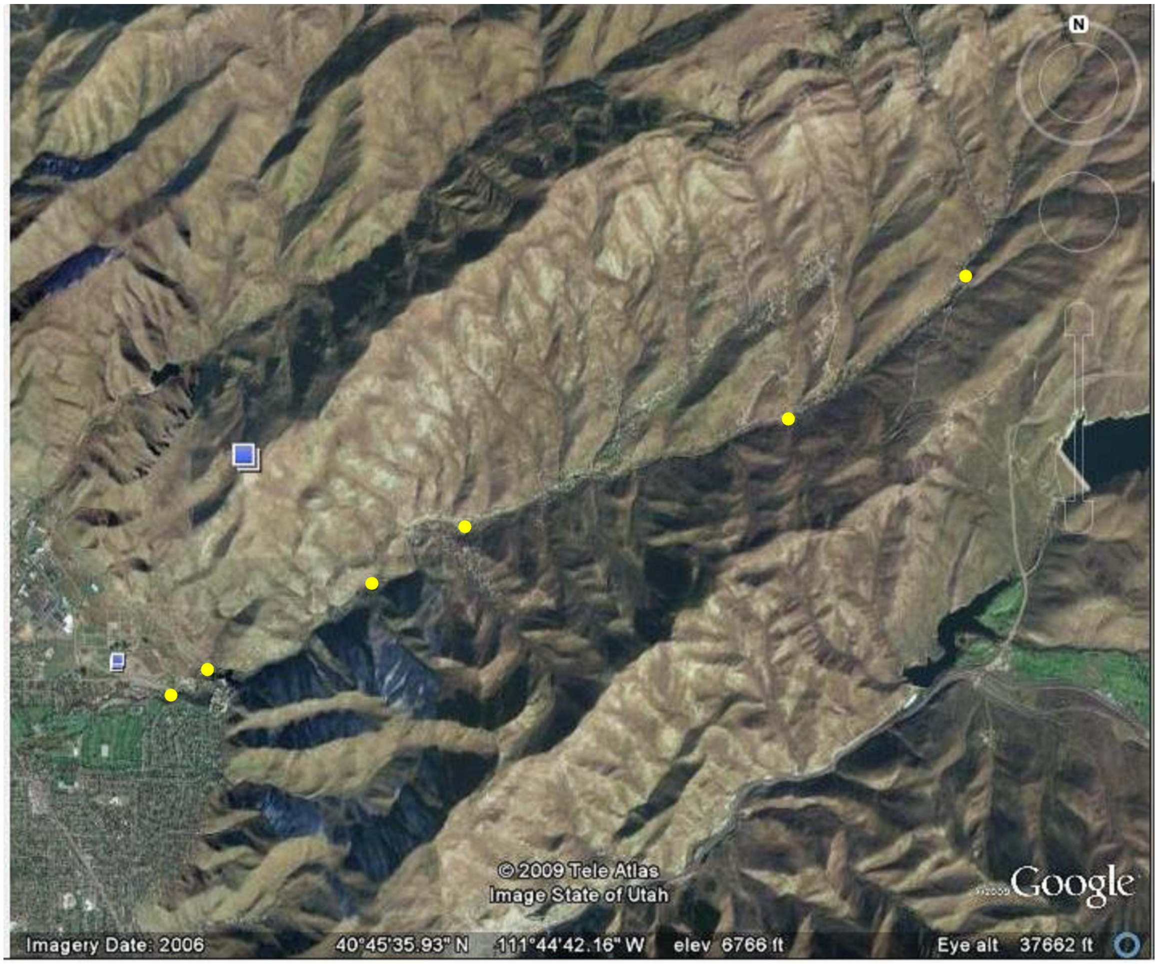


Figure 37. Salt Lake City—Mean Monthly *E. coli* Concentrations.

5.4 Emigration Canyon Microbial Source Tracking (MST)

In Summer 2008, Dr. Ramesh Goel, an Assistant Professor in the Civil and Environmental Engineering Department at University of Utah, conducted a microbial source tracking (MST) study of Emigration Canyon to qualitatively determine if Emigration Creek was receiving any fecal contamination from humans. Since fecal contamination of surface waters can result from numerous sources of fecal pollution including human sewage, manure from livestock and pets, indigenous wildlife and stormwater runoff, it is important to identify the source of the fecal contamination. Fecal contamination from humans is more dangerous because it indicates the possible presence of pathogenic bacteria. The goal of MST is to match the microbe from a polluted site with the source of contamination (discriminating between human and non-human sources of fecal contamination) and determine the origin of fecal pollution.



Map 19. MST sampling sites (yellow dots) along the study reach in Emigration Creek, Utah.

MST methods can be divided into two broad categories: (1) library-dependent and (2) library- independent. Library-dependent methods are complex, labor intensive and geographically specific, whereas, library-independent methods have no time and geographic restraints. They are primarily based on nucleic acid techniques arising from the field of molecular microbial ecology such as developing host-specific strains that are then characterized to identify host-specific genetic or phenotypic markers.

With this study, a one-liter grab sample of free-flowing water was collected from six different locations on Emigration Creek (Map 19). The method used in this study relied on DNA extraction followed by a polymerase chain reaction (PCR) based library-independent method, to differentiate between human and nonhuman sources of fecal contamination.

The study results show that all the locations, with the exception for the month of July, showed the presence of human fecal contamination (Figure 38). This finding shows that Emigration Creek is receiving anthropogenic fecal contamination, which could be resulting from leaking septic systems.

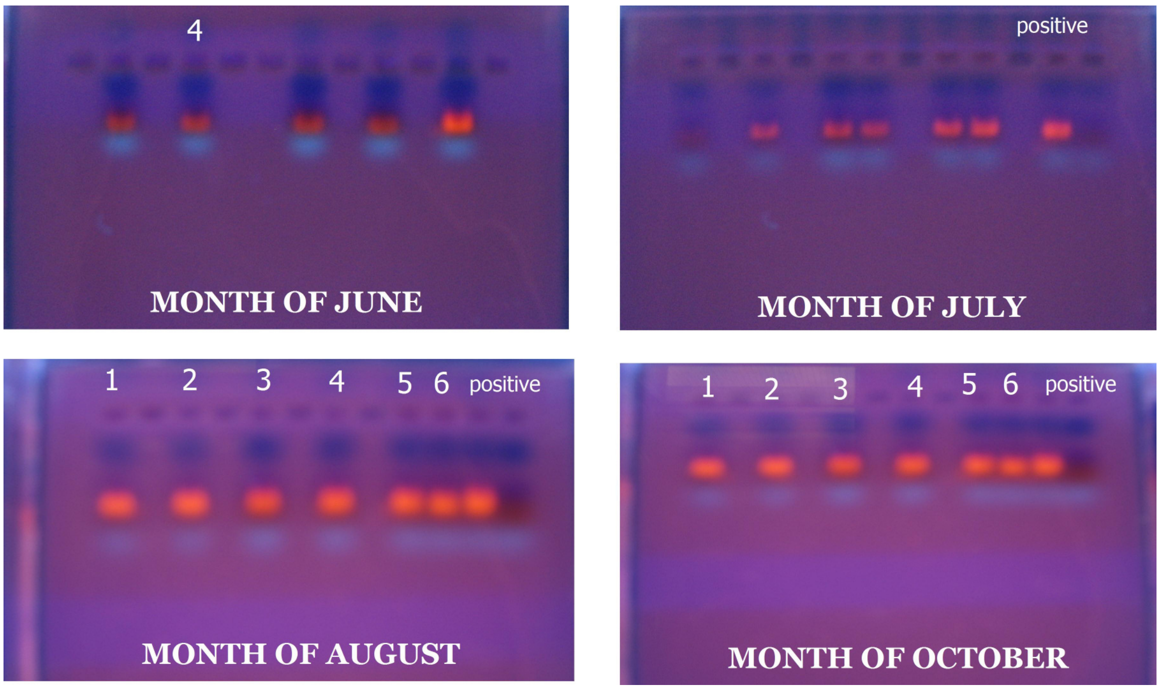


Figure 38. Agarose gel pictures depicting PCR products from DNA attained over the sampling period.

6.0 UDWQ RECENT DATA INVENTORY AND REVIEW FOR TMDL

Water quality data for the Emigration Creek Sub-Basin were obtained from DWQ and Salt Lake County from 2007 through 2009. This section provides a description of available *E. coli* data and analyses conducted to understand the current water quality conditions in the watershed. Water quality data has been collected by both DWQ and Salt Lake County at six stations located in the Upper Emigration Sub-Basin, however only one station has continuous flow data (Emigration Creek Below Rotary Park). *E. coli* samples were collected from 2007-2010 at these six stations. See Map 18 for the locations of DWQ monitoring stations in the Upper Emigration Creek Sub-Basin.

Flow data was obtained from Salt Lake County Public Works Department's gage located at the mouth of Emigration Creek Canyon at Rotary Park. Flow is recorded daily from 2001 to the present. This continuous flow data was used in the development of the TMDL. Section 4.1.6 discusses the flow data in depth.

6.1 Recent Flow Data

While general flow characteristics of Emigration Creek are discussed in Section 4.1.5, this section details recent flow information and data used in the analyses and load allocations for the TMDL.

Salt Lake County Public Works Department manages the continuous flow gage used in the TMDL analysis for the Upper Emigration Creek Sub-Basin. The Emigration Creek at Rotary Park (Gage site #620) is located at the mouth of Emigration Canyon at the south end of Rotary Glen Park. This site is at the same location as DWQ's monitoring station 4992140 Emigration Creek below Rotary Park. This gage has been active since 1979. The historical maximum daily flow was 146 cfs on May 31, 1983 and the historical peak flow was 148 cfs on May 28, 1983. The estimated flood stage is 1.95 ft and flood flow is 120 cfs. Flow data can be found online on Salt Lake County Public Works webpage.

Flow measurements used in the TMDL calculations were taken from 2007-2010. This data is displayed in Figure 39. This graph shows higher flow near the beginning of spring, which corresponds to the early runoff period for Emigration Creek. The flow then drops during the fall and winter months. The highest recorded flow recorded, 50 cfs, in this time period was on April 21, 2009.

This gage and monitoring station was used exclusively in the TMDL calculations for several reasons. First, since this site is located at the farthest downstream monitoring site in the Upper Emigration Sub-Basin, it is used as the compliance point. When water quality standards are met at this location, the standard is most likely to be met everywhere upstream. Secondly, this location has daily flow data, which is critical in the TMDL analysis for the Load Duration Curve in Section 7.2.

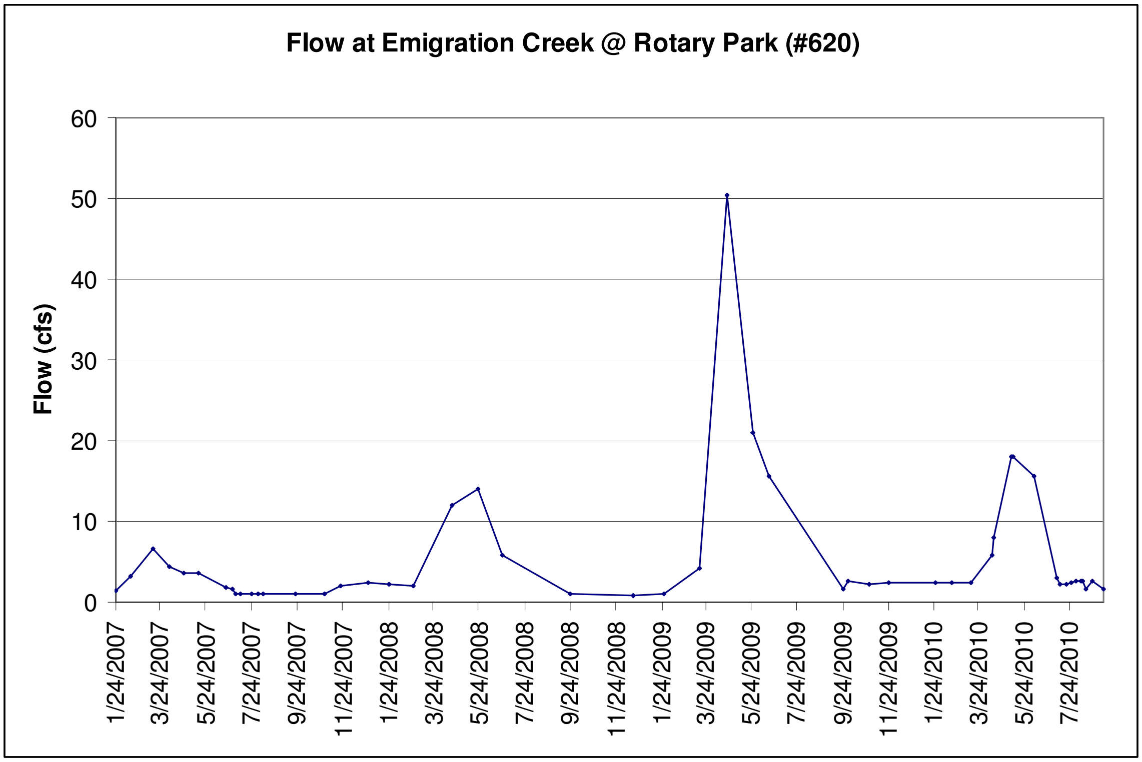
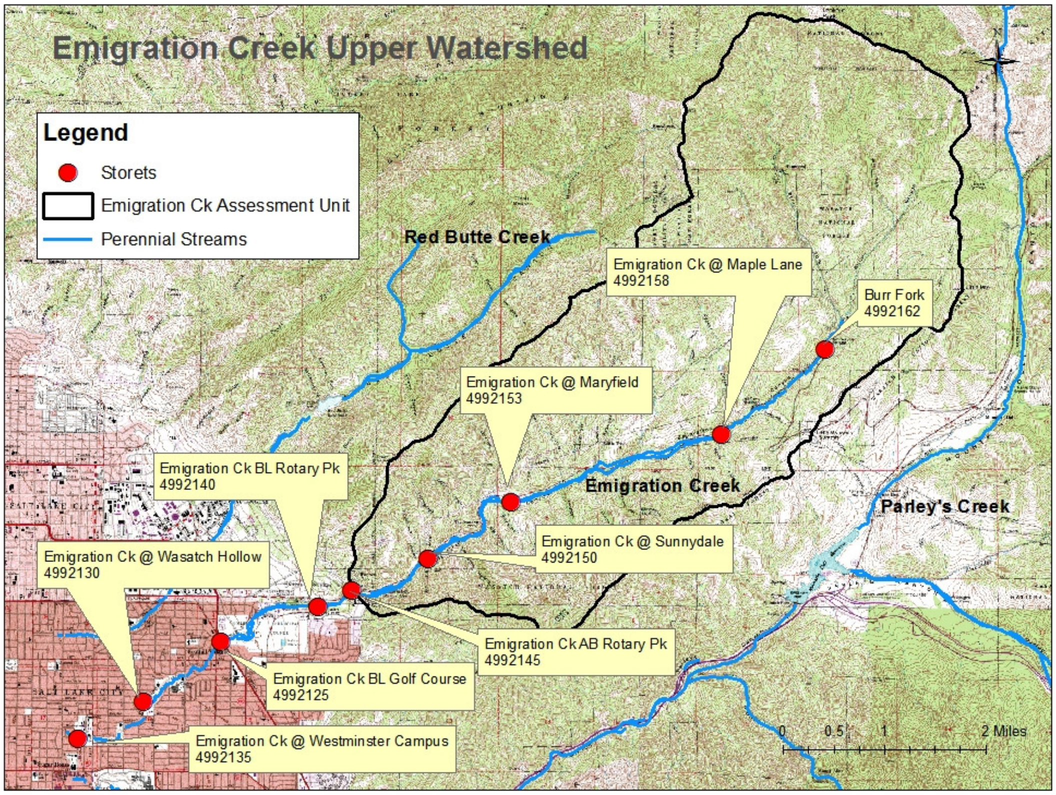


Figure 39. Flow (cfs) recorded at Emigration Creek at Rotary Park from 2007-2010.

6.2 Water Quality Data

Of the six DWQ water quality stations in the Upper Emigration Creek Sub-Basin, only one site, 4992410 Emigration Creek below Rotary Park, was used in the 2006 303(d) listing. Map 20 shows all the locations of the DWQ monitoring stations located in the Lower and Upper Emigration Creek Sub-Basins.



Map 20. DWQ Monitoring Stations Located in the Emigration Creek Watershed.

Per Utah's Assessment Methodology (Section 3.7.2), *E. coli* collected only during the defined recreational season was used to determine if Emigration Creek's secondary contact recreational use was impaired due to high *E. coli* levels. The recreational period is defined by when the greatest threat to human health would occur, during the warmer months of May through September. *E. coli* samples collected outside the recreational period were used to determine the critical season for the Emigration Creek TMDL.

Summary statistics for all nine monitoring sites taken during the entire year are presented in Table 10. Table 11 displays *E. coli* data collected only during the recreational period. Both tables cover the period of 2007 to 2010.

Table 10. Summary of *E. coli* Data (MPN/100 mL) for DWQ Monitoring Stations in Emigration Creek Yearly from 2007 to 2010.

Station ID	Station Description	# Samples	Geometric Mean	Min	Max	First Sample	Last Sample
4992162	Burr Fork	35	16.1	<1.0	2,419.6	01/27/2007	09/07/2010
4992158	Emigration Ck @ Maple Lane	29	17.3	1.3	260.3	01/24/2007	06/16/2009
4992153	Emigration Ck @ Maryfield	33	43.4	1.6	868.1	01/27/2007	09/07/2010
4992150	Emigration Ck @ Sunnydale	20	71.9	1.8	1,748.5	01/24/2007	06/16/2009
4992145	Emigration Ck Above Rotary Park	47	13.4	<1.0	1,286.6	01/24/2007	08/23/2010
4992140	Emigration Ck Below Rotary Park	53	54.9	<1.0	2,419.6	01/24/2007	09/07/2010

Table 11. Summary of *E. coli* Data (MPN/100 mL) during Recreational Season for DWQ Monitoring Stations in Emigration Creek from 2007 to 2010.

Station ID	Station Description	# Samples	Geometric Mean	Min	Max	First Sample	Last Sample
4992162	Burr Fork	20	22.7	<1.0	222.4	05/15/2007	09/07/2010
4992158	Emigration Ck @ Maple Lane	13	46.8	5.1	260.3	05/15/2007	06/16/2009
4992153	Emigration Ck @ Maryfield	19	73.7	9.7	516.6	05/15/2007	09/07/2010
4992150	Emigration Ck @ Sunnydale	10	353.6	30.2	1,748.5	05/15/2007	06/16/2009
4992145	Emigration Ck Above Rotary Park	26	42.0	<1.0	1,286.6	05/15/2007	08/23/2010
4992140	Emigration Ck Below Rotary Park	29	217.0	24.4	2,419.6	05/15/2007	09/07/2010

6.3 Water Quality Analysis

DWQ and Salt Lake County have been collecting *E. coli* data monthly at these sites from 2007 to the present. Using the Idexx Colilert Quanti-Tray method of analysis, the minimum detection limit is > 1.0 MPN/100 mL and the maximum detection limit is 2419.6 MPN/100 mL. MPN stands for Most Probable Number and is analogous with Colony Forming Units (CFUs).

Figures 40 through Figure 45 display *E. coli* concentrations over time at each monitoring site in the Emigration Creek Sub-Basin comparing data between the defined recreation seasons. The graphs are ordered from upstream to downstream. The graphs show the *E. coli* concentration is higher during the summer (recreation season) than in winter months (non recreation season). Two monitoring sites, Sunnydale and Below Rotary Park, have the highest concentrations of *E. coli* in the Upper Emigration Creek Sub-Basin. Both sites exceed the acute “Not To Exceed” standard numerous times during the recreation season. *E. coli* concentrations are also higher below Rotary Glen Park (4992140) than above (4992145). This is most likely due to heavy public use and off-leash dog activity in the park. Rotary Park Glen is owned and maintained by Salt Lake City Department of Public Service Parks Division. These graphs also show the critical period defined for the TMDL and will be discussed in Section 7.3.

The three monitoring stations downstream of Rotary Park located in the Lower Emigration Creek Sub-Basin have higher levels of *E. coli* than the compliance point at Rotary Park (see Tables 10 and 11). Thus, *E. coli* concentrations increase from upstream to downstream. Preliminary data from these three stations indicates that the Lower Emigration Creek Sub-Basin will be listed on the 2012 303(d) list for *E. coli* exceedances. A separate TMDL will address the lower section of Emigration Creek once the 2012 303(d) is approved by EPA.

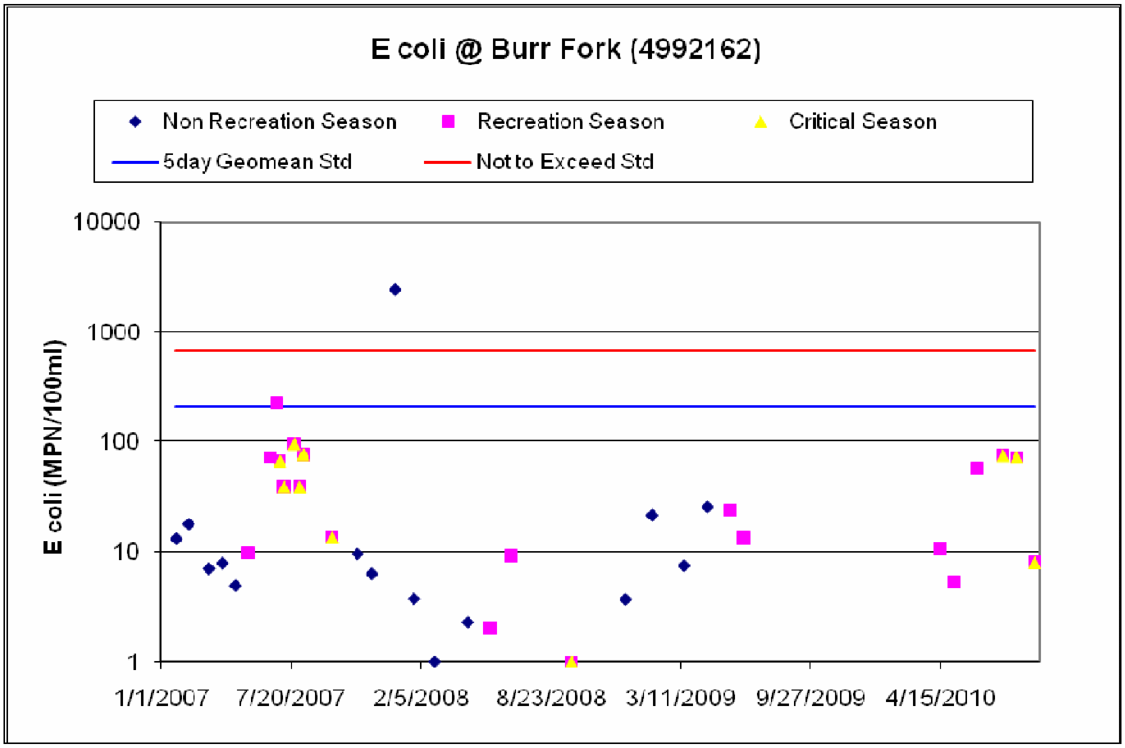


Figure 40. *E coli* Concentration (MPN/100 mL) at Burr Fork (4992162).

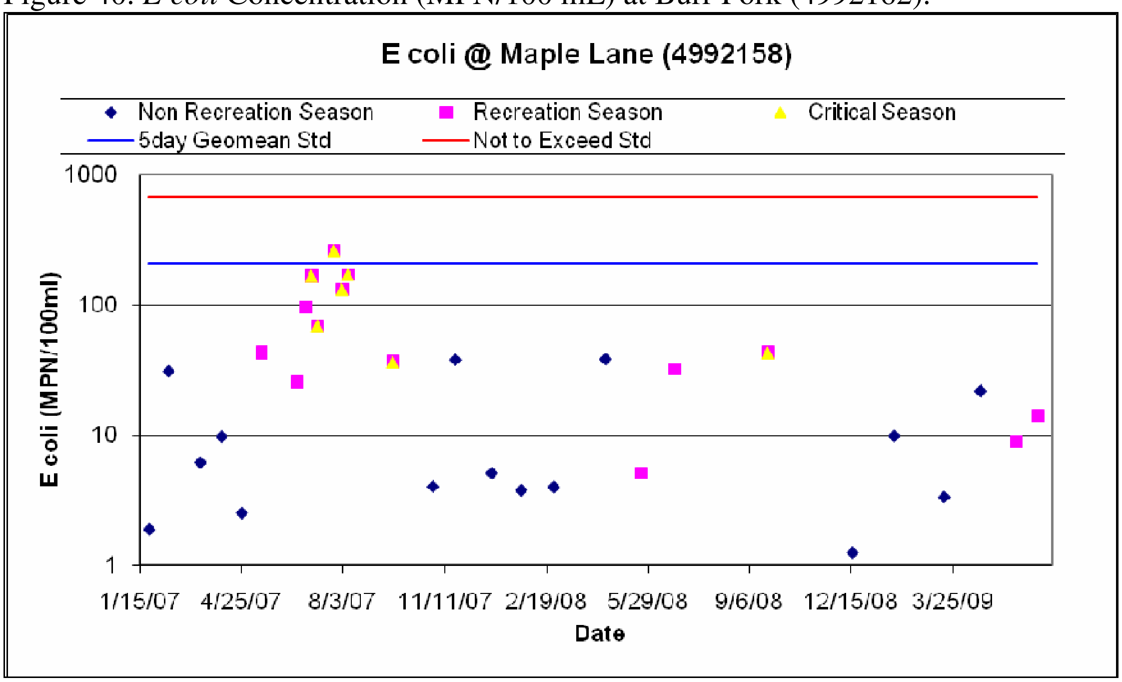


Figure 41. *E coli* Concentration (MPN/100 mL) at Emigration Creek at Maple Lane (4992158).

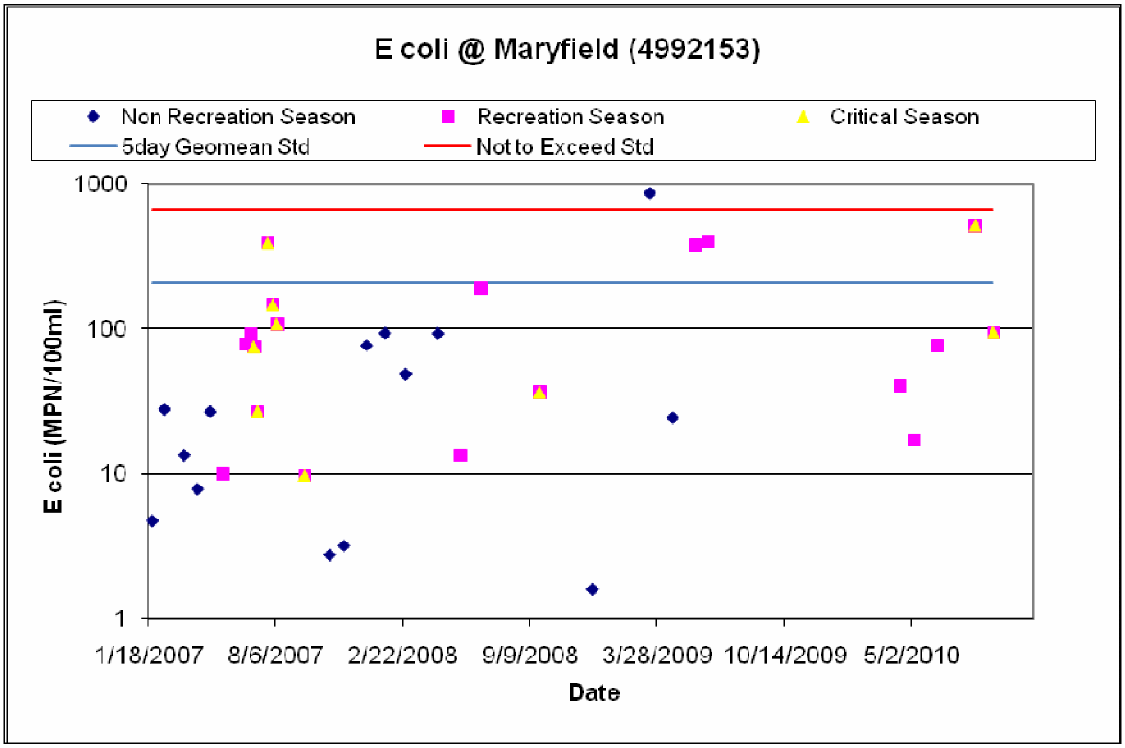


Figure 42. *E coli* Concentration (MPN/100 mL) at Emigration Creek at Maryfield Rd (4992153).

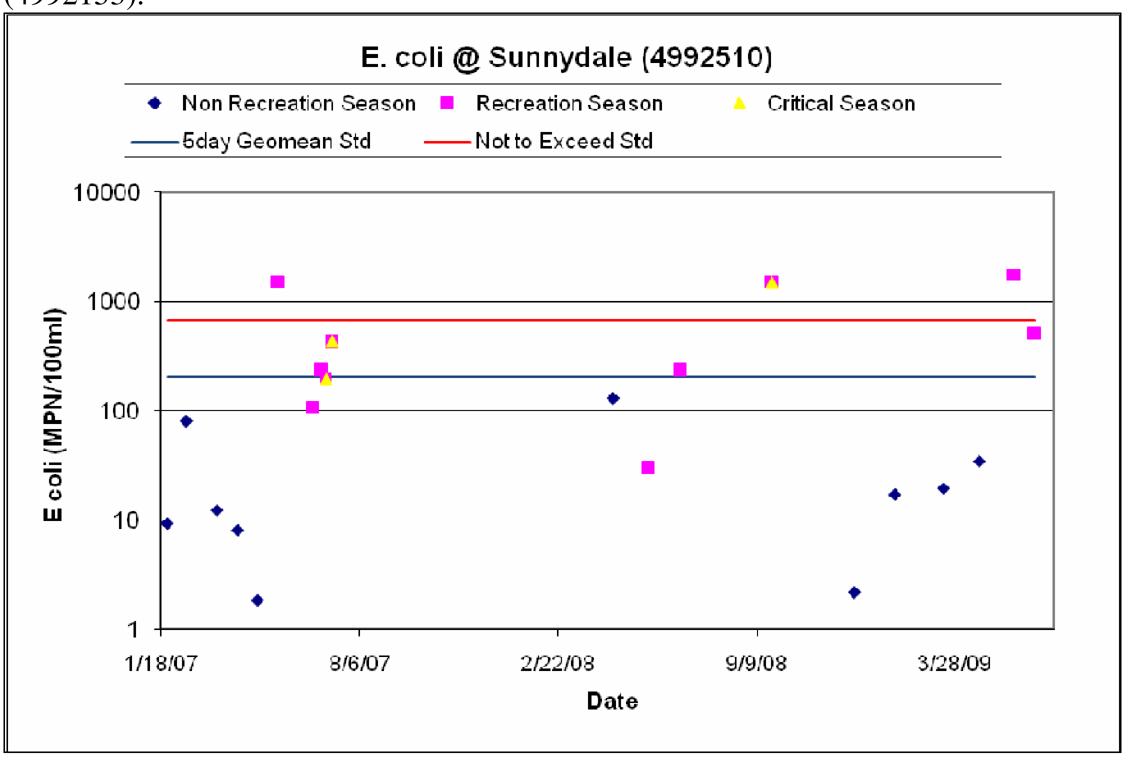


Figure 43. *E coli* Concentration (MPN/100 mL) at Emigration Creek at Sunnydale Rd (4992150).

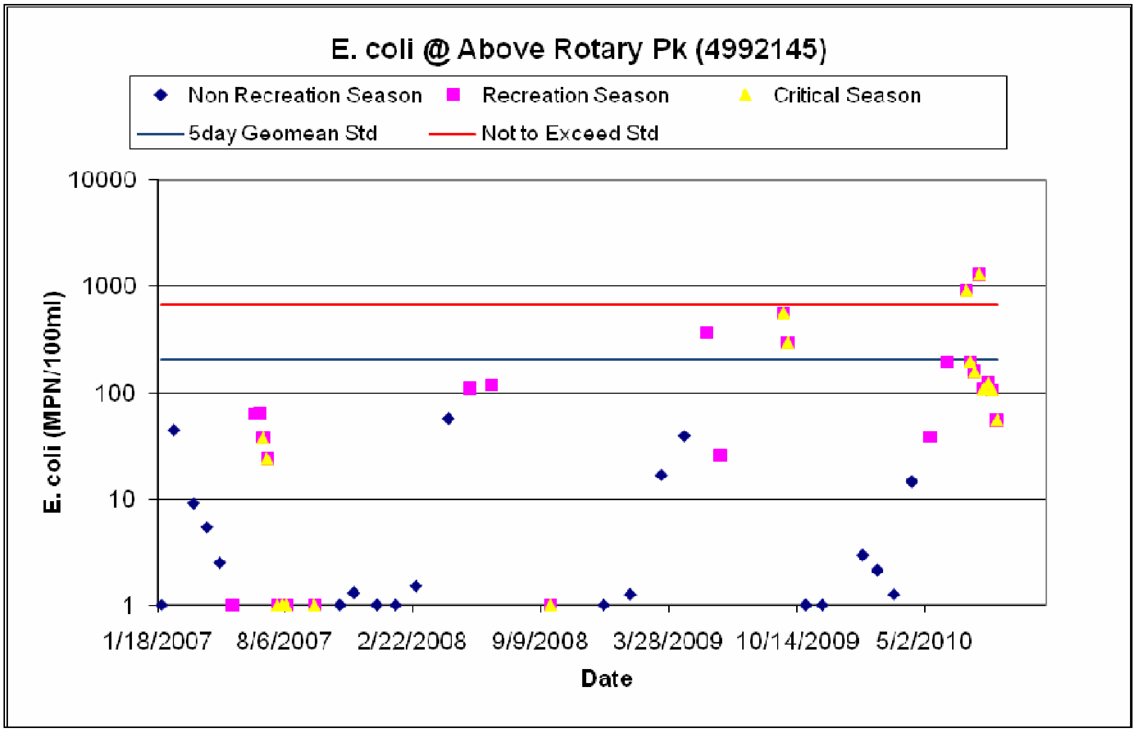


Figure 44. *E coli* Concentration (MPN/100 mL) at Emigration Creek above Rotary Park (4992145).

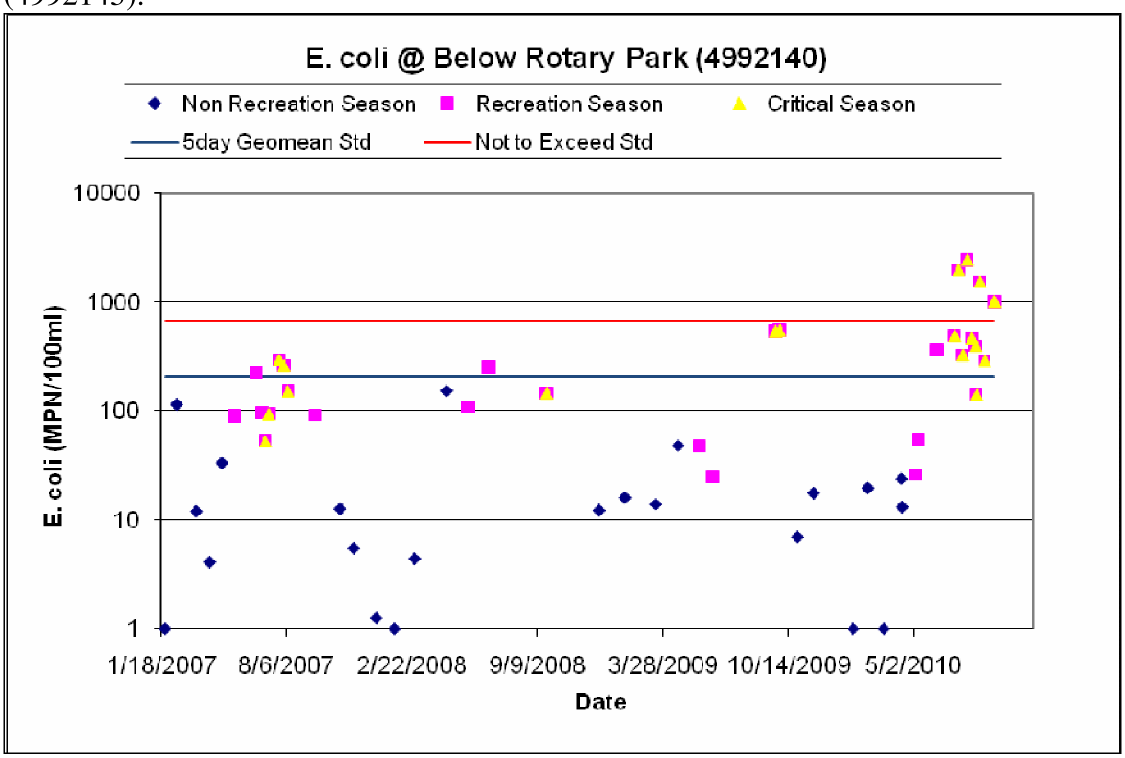


Figure 45 *E coli* Concentration (MPN/100 mL) at Emigration Creek below Rotary Park (4992140).

6.3.1 Water Quality Assessment

Assessments of water quality monitoring station 4992140 (Emigration Creek below Rotary Park) was used in the assessment of beneficial use support, which led to the listing of Emigration Creek as impaired due to *E. coli* in 2006. The reason why this site was chosen for assessment was because it is the farthest downstream monitoring station in the upper sub-basin and thus serves as a point of compliance. This monitoring station was also used in the analysis of the TMDL. Three years of data were used in the assessment of Upper Emigration Creek Sub-Basin. Data were compared against both the chronic 5-day geometric mean and the acute not to exceed water quality standards for *E. coli*. The remaining five sites located upstream and three sites downstream are used to characterize the impairments in Emigration Creek Sub-Basin.

Since the Upper Emigration Creek Sub-Basin has greater than ten samples collected in one recreational period, the assessment rule is that all of the 5-day rolling geometric means collected during the recreational season should not exceed 206 MPN/100 mL. If greater than five samples were collected during one recreation season, the assessment rule is that no more than 10% of samples collected from May 1st to September 30th should exceed 668 MPN/100 mL. Table 12 summarizes the *E. coli* data gathered during the recreational season below Rotary Park (4992140).

Table 12. Assessment of *E. coli* Data During Recreation Seasons Below Rotary Park (4992140) between 2007 and 2010.

Recreation Season Year	# Samples	Geometric Mean Per Recreation Season (MPN/100mL)	# Violations of Geometric Mean Std (206 MPN/100 mL)	% Violations of Geometric Mean Std (206 MPN/100 mL)
2007	9	129.1	0	0%
2008	3	157.9	N/A*	N/A*
2009	4	135.5	N/A*	N/A*
2010	13	386.6	3	33%

*Fewer than 5 samples collected during recreation season thus no 5-day rolling geometric means could be calculated.

The four recreation seasons, 2007 through 2010, were evaluated using the assessment methodology previously discussed. In 2007, there were a total of nine samples collected from May 2007 through September 2007. The 5-day rolling geometric mean was calculated and showed there were no violations of the 206 MPN/100 mL standard. There were not enough samples (less than five) in the recreational seasons of 2008 and 2009 to properly assess, thus data collected in 2008 and 2009 was not used in the assessment. There were a total of 13 samples collected during the 2010 recreation season of which 33% of the 5-day rolling geometric means violated the water quality standard.

The 5-day *E. coli* geometric means were also used to evaluate spatial and temporal water quality trends in the impaired reach. A 5-day period was used in order to evaluate the *E. coli* water quality standard (as discussed in Section 3.3). Figure 46 shows the observed 5-day geometric mean of *E. coli* at Emigration Creek below Rotary Park (4992140) through time compared to the 5-day Geometric Mean Standard of 206 MPN/100 mL.

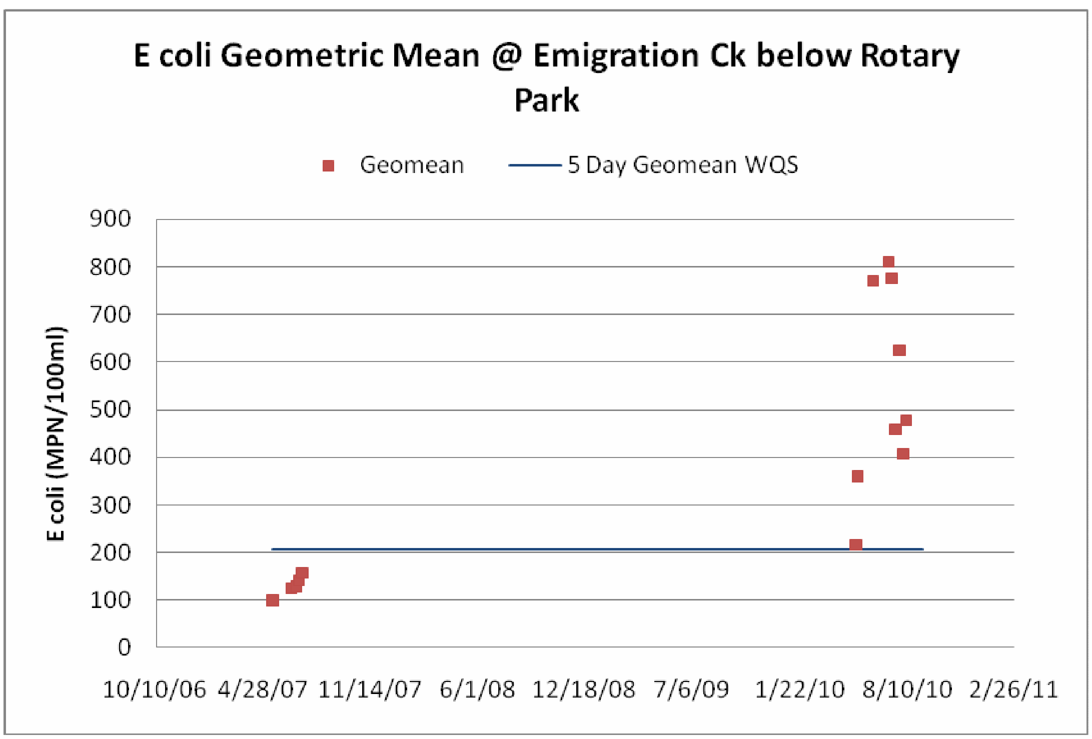


Figure 46. 5-day Geometric Mean of *E. coli* at Emigration Creek below Rotary Park.

6.4 Seasonal Variations in E. coli and Flow

This section presents the monthly variation in *E. coli* and flow data from the DWQ water quality monitoring stations, in particular Emigration Creek below Rotary Park (4992140). Figures 47 through 52 present the monthly average *E. coli* concentrations and flow. Data for these figures are found in Table 13. Note that the flow data presented here is instantaneous and not continuous data. Continuous flow data was recorded by the Salt Lake County flow gage and was used in a Load Duration Analysis discussed later (Section 7.2). These mean flow measurements are only used to aid in the hydrologic characterization of the Upper Emigration Creek Sub-Basin.

At Burr Fork (4992162) the average monthly flow and *E. coli* concentrations are elevated during the summer months; however in December *E. coli* levels are highest while flows are lower. When elevated levels of *E. coli* are observed with higher flows, the source is considered to be primarily non-point in nature, i.e. dependent on overland runoff. Emigration Creek at Maple Lane (4992158) and Emigration Creek at Maryfield (4992153) have higher flows in the spring months, which is consistent with spring runoff. Both of these sites also have high levels of *E. coli* during the summer months when flow is low. The graphs (Figures 18 and 19) show the *E. coli* levels could be diluted from the high flows during runoff and then increase with decreasing flow in the summer. This scenario is typical of a constant source of pollution that is not dependent on flow, such as point sources septic systems.

Emigration Creek at Sunnydale (4992150) has high levels of *E. coli* associated with low flows; however, limited data is available in this reach during the summer months for flow and for *E. coli* in the fall months. A synoptic monitoring survey is scheduled in the summer of 2011 (Appendix A) to address the high *E. coli* concentrations during low flows to determine if discrete sources exist in this particular reach. Emigration Creek above Rotary Park (4992145) and below Rotary Park (4992140) both have an increase in flow in the spring months associated with snow melt. However, *E. coli* concentrations are highest in the summer months (June-September) when flows decrease. This relationship between low flow and high *E. coli* concentrations is typically observed under constant source loads such as failing septic systems and pet waste.

Table 13. Monthly average *E. coli* Concentrations (MPN) in the Upper Emigration Creek Sub-Basin.

Month	Burr Fork	Emigration Ck @ Maple Lane	Emigration Ck @ Maryfield	Emigration Ck @ Sunnydale	Emigration Ck Above Rotary Park	Emigration Ck Below Rotary Park
January	17	4	21	13	1	2
February	4	11	37	81	5	21
March	7	5	108	15	6	5
April	8	12	29	29	13	26
May	7	13	30	430	35	58
June	45	32	133	235	75	136
July	63	144	92	289	85	377
August	60	150	201	201	21	332
September	5	39	32	1,505	20	330
October	10	4	3	N/A	1	9
November	6	38	3	N/A	1	10
December	95	3	11	2	1	4

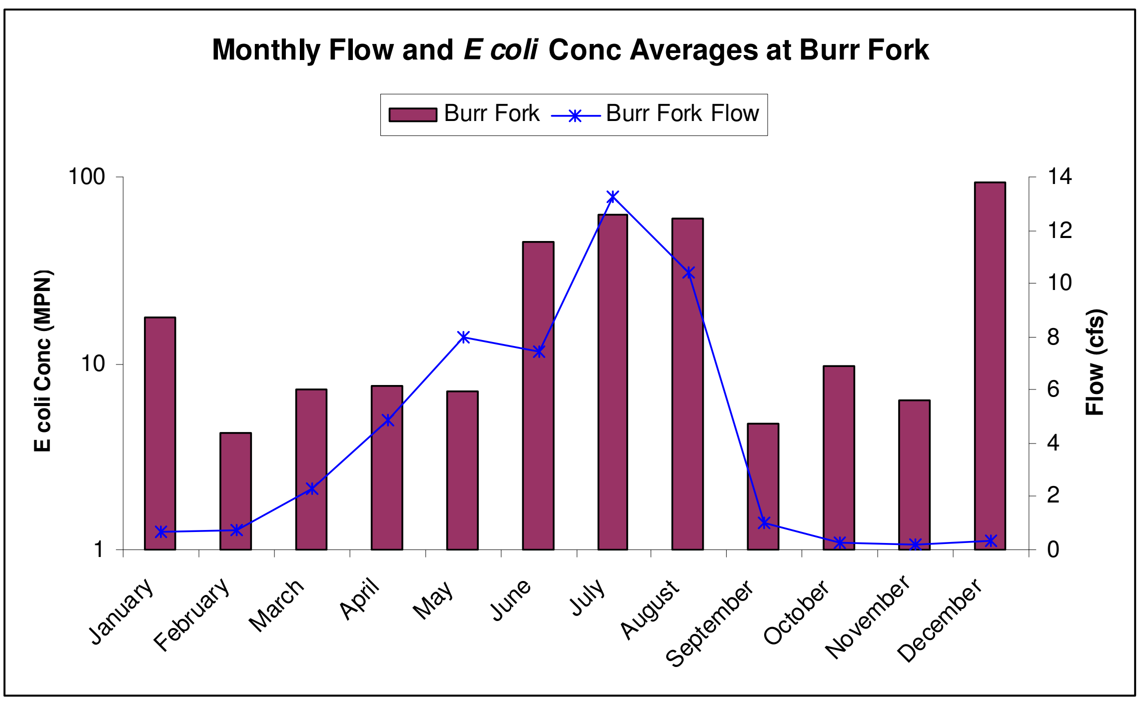


Figure 47. Average Monthly *E. coli* and Flow Data at Burr Fork (4992162).

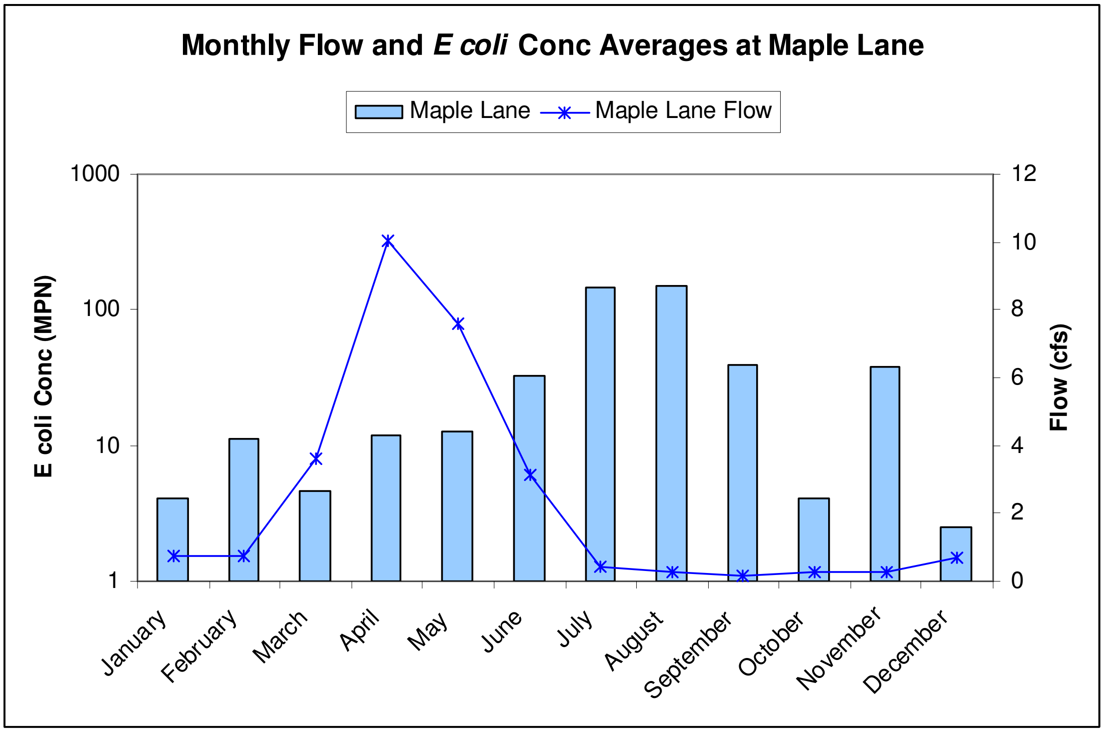


Figure 48. Average Monthly *E. coli* and Flow Data at Emigration Creek at Maple Lane (4992158).

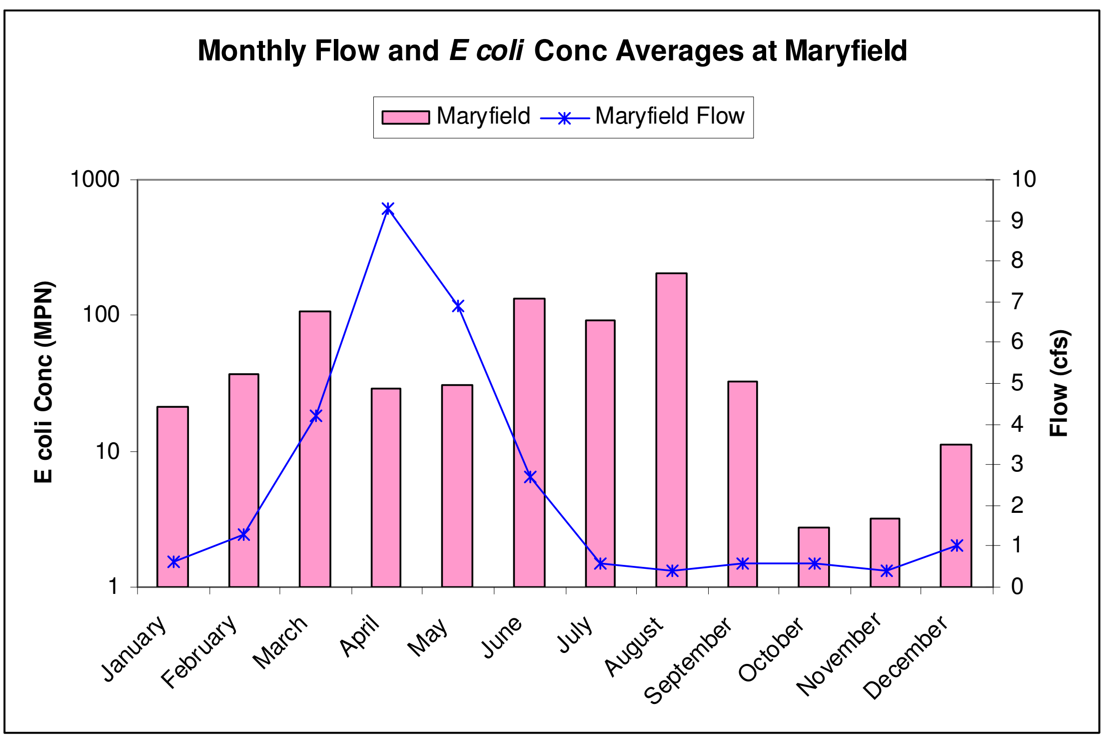


Figure 49. Average Monthly *E. coli* and Flow Data at Emigration Creek at Maryfield (4992153).

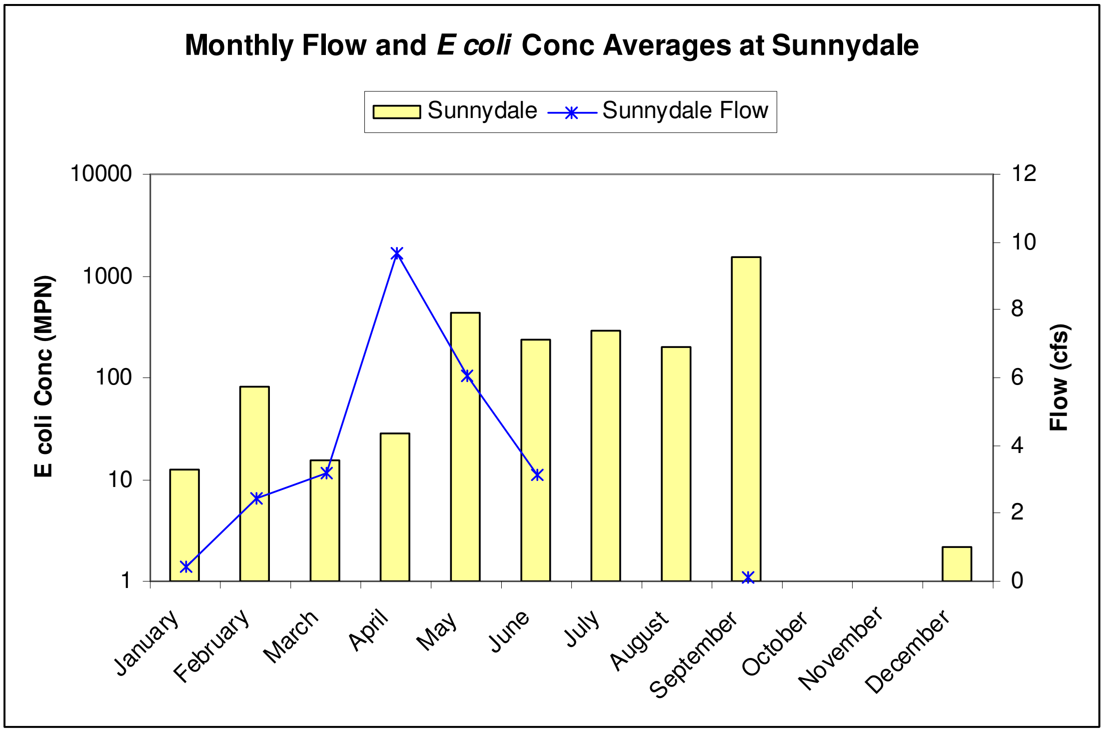


Figure 50. Average Monthly *E. coli* and Flow Data at Emigration Creek at Sunnydale (4992150).

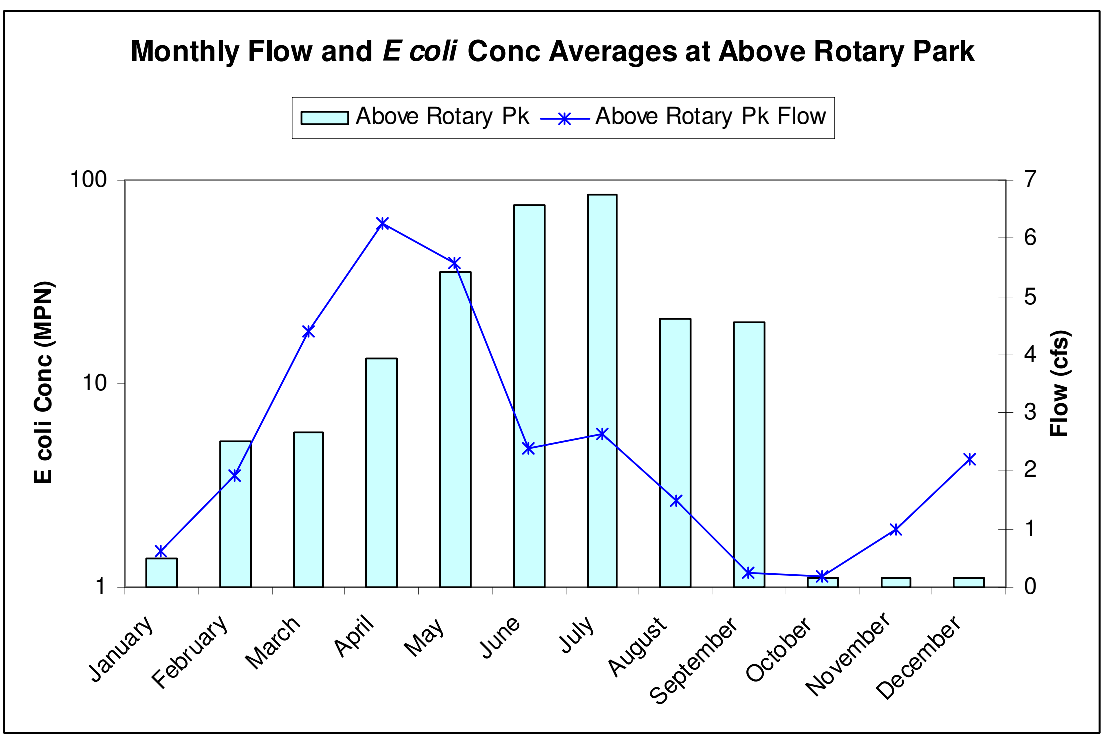


Figure 51. Average Monthly *E. coli* and Flow Data at Emigration Creek above Rotary Park (4992145).

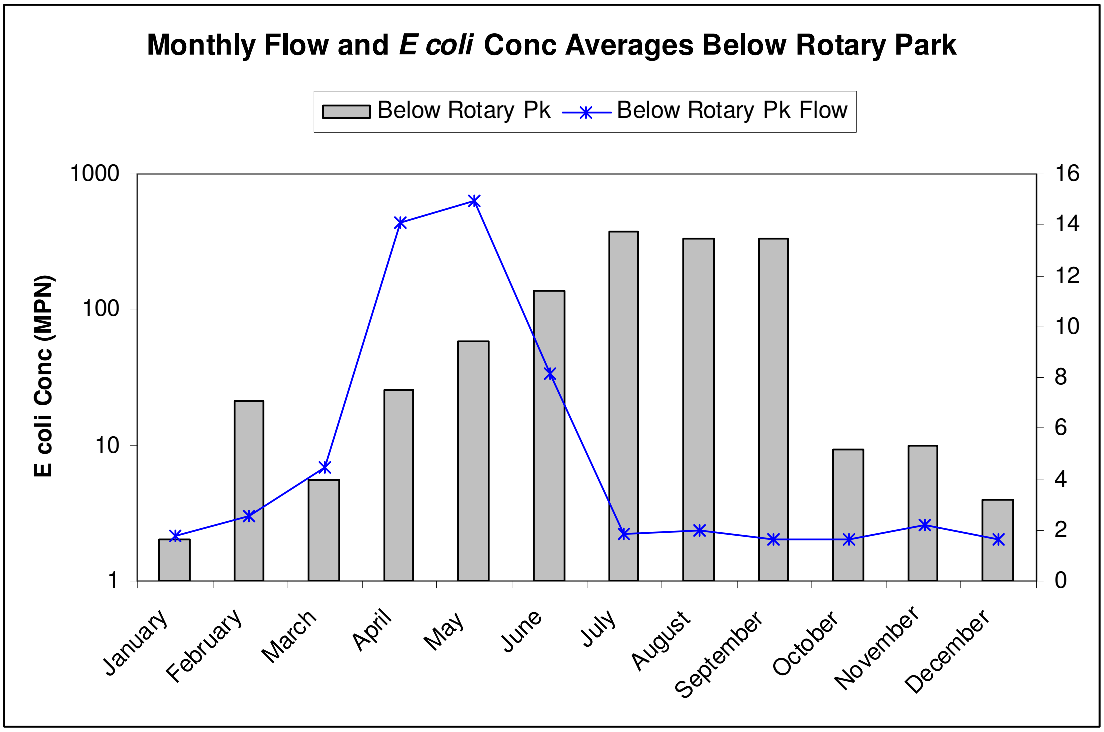


Figure 52. Average Monthly *E. coli* and Flow Data at Emigration Creek below Rotary Park (4992145).

7.0 TECHNICAL APPROACH

The guiding principle in developing this TMDL is that it is based on rigorous scientific analysis, reasonable and acceptable assumptions, and uses the best available data. Establishing a relationship between the in-stream water quality targets and source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant load and the response in water quality concentrations is necessary to evaluate the loading capacity of the receiving waterbodies.

A TMDL water quality study calculates the total amount of a pollutant that can be assimilated by the receiving water while still meeting water quality standards. The *E. coli* TMDL for Emigration Creek is expressed on a mass-loading basis. Figure 55 summarizes the *E. coli* load capacity, defined by the water quality standard and average flows, and observed loads at each sampling location within the Upper and Lower Emigration Creek Sub-Basins. At the compliance point for the Upper Sub-Basin, Emigration Creek below

Rotary Park (4992140), the load capacity is higher than observed loads implying that no reduction is needed when the entire data set is compiled. However, water quality standards must be met throughout the year, especially during the recreation season so additional analyses are required to define the critical season when standards are exceeded and impairment occurs (see Section 7.3).

7.1 Calculation of Loading Capacity and Existing Load

The loading capacity is the amount of pollutant that can be assimilated by a waterbody while still meeting water quality standards, thus protecting the waterbody's designated beneficial uses. It is calculated by multiplying the water quality standard, the corresponding flow, and a conversion factor. The existing load is the amount of pollution that is observed in the river at the time of sample collection. It is calculated by multiplying the pollutant concentration, flow, and a conversion factor. If the existing load exceeds the loading capacity, the beneficial use is impaired and loading must be reduced. The loading capacity is equivalent to the Total Maximum Daily Load (TMDL) and is allocated among the identified sources including wasteload allocations (point sources), load allocations (nonpoint sources), and a margin of safety.

7.2 Load Duration Curve

A Load Duration Curve (LDC) was calculated for the Emigration Creek below Rotary Park (4992140) monitoring site that compares existing water quality conditions and the conditions required to meet water quality standards. It also identifies the allowable and existing loads, uses data for all flow and loading conditions, and provides insight into critical conditions. LDCs are well suited for analysis of periodic monitoring data collected by grab samples.

The calculation included the following steps:

1. Available flow data was used to generate a flow frequency table that consisted of ranking all the observed flows from the smallest observed flow to the greatest observed flow and plotting all the values to create a flow duration curve.
2. The flow duration curve was translated into a load duration curve by multiplying each flow by the water quality standard and plotting the results. This curve represents the loading capacity for each observation.
3. Each observed value was then converted to a daily load by multiplying the sample concentration by the corresponding observed flow.
4. The difference between the observed load and loading capacity for each flow regime quantifies the necessary load reductions during critical conditions. Both observed loads and loading capacities for each flow regime were then graphed.
5. Loads plotted above the load duration curve represent exceedances of the loading capacity. Loads plotted below the curve represent compliance with standards and represent allowable daily loads.

The load duration curve approach identifies the major issues contributing to the impairment and differentiates between various types of sources. Loads that plot above the allowable load curve in the 1-10% flow ranges (rare high flow conditions) represent hydrologic conditions of extreme flooding. Loads plotting above the curve between the 10-60% flow ranges likely reflect precipitation driven contributions (nonpoint sources). Those plotting above the curve in 70-90% flow ranges are indicative of constant discharge sources. Loads that plot above the curve in greater than 90% of all recorded flows reflect hydrologic conditions of extreme drought.

Observed flows from January 2007 to September 2010 were ranked in order of magnitude and each flow was assigned a percentile that reflects the chance of a flow greater than or equal to it. Each flow was then multiplied by the 206 MPN/100 mL standard to calculate a corresponding maximum loading limit for each flow. The individual lines were plotted to present a loading capacity line by flow percentile, as shown in Figure 53.

Figure 54 summarizes the observed loading and loading capacity under each flow regime for this watershed. During high, moist, and low flow conditions no reduction in *E. coli* loading is needed; however, under the mid-range and dry conditions a 47% and 57% reduction is needed, respectively. Given the seasonal influence on the observed *E. coli* loading, a seasonal TMDL is warranted.

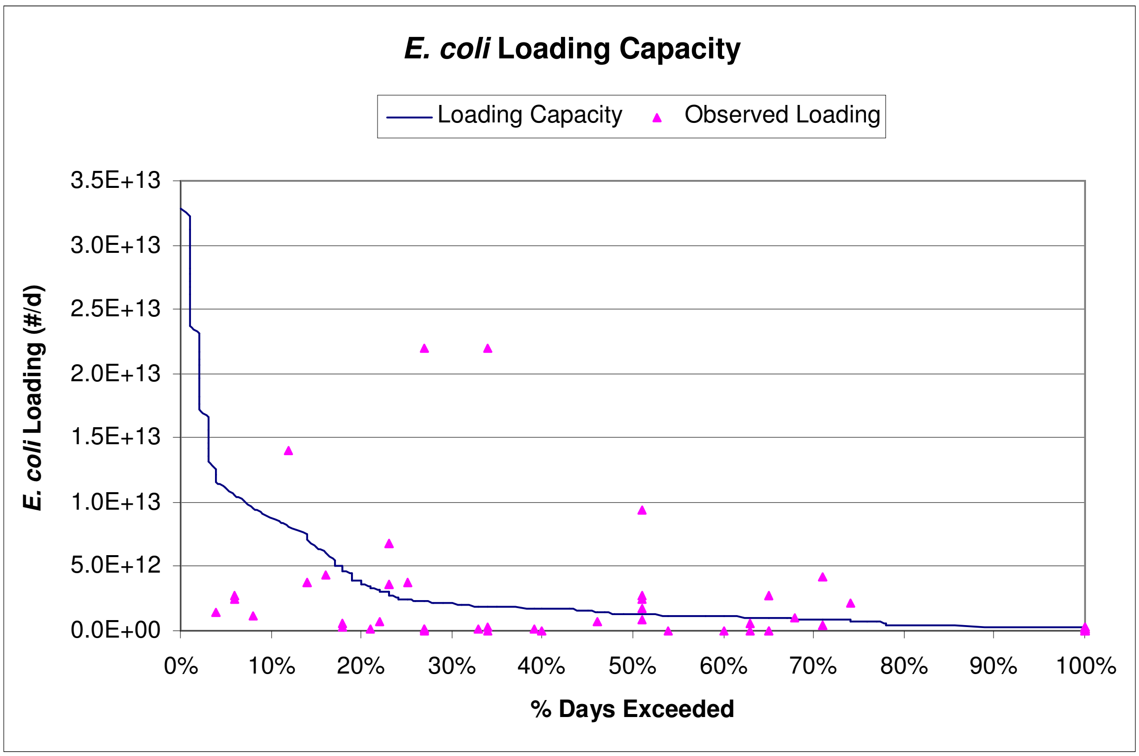


Figure 53. *E. coli* Load Duration Curve Below Rotary Park (Station 4992140).

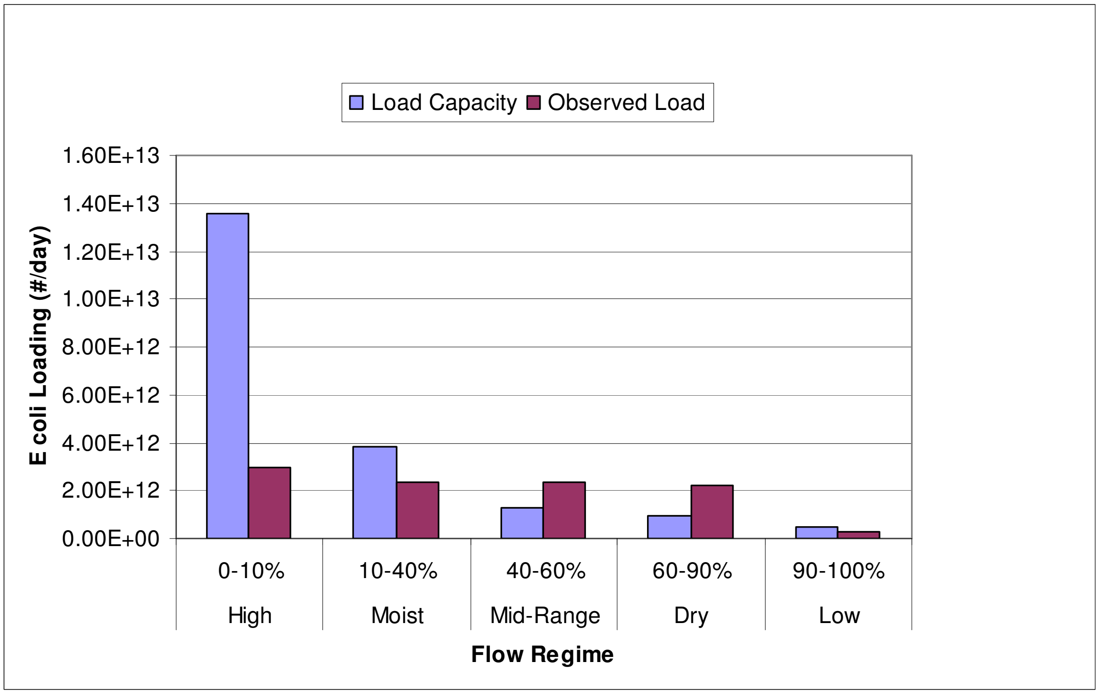


Figure 54. *E. coli* Load Capacity and Observed Loads Below Rotary Park (Station 4992140).

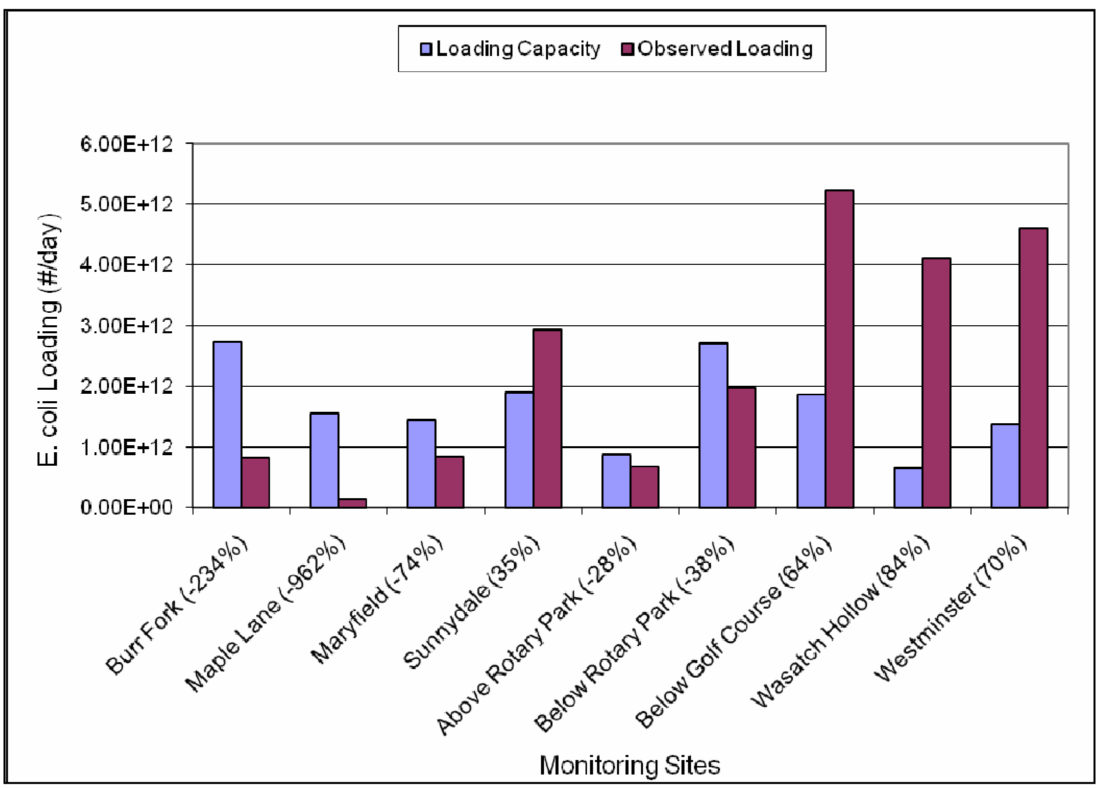


Figure 55. E. coli Loading Capacity and Existing Loading in Emigration Creek.

Loads of *E. coli* were then evaluated on a monthly basis to determine if certain months were critical, particularly during the defined recreational period of May through September. Results showed that the months of July, August, and September need reductions of 83%, 53%, and 62% respectively. Section 7.3 further explains the analysis of seasonality for this TMDL. Thus the critical season of this *E. coli* TMDL is defined by these three months and need a reduction of 71% collectively. Table 14 and Figure 56 shows the E. coli TMDL for Upper Emigration Creek Sub-Basin including the observed loading, loading capacity, and the load allocation (loading capacity minus an explicit 10% MOS). Figure 57 shows the observed loading, loading capacity, and percent reduction needed for all monitoring sites in the Emigration Creek Sub-Basin during the critical season of July through September.

Table 14. *E. coli* TMDL (#/day) Summary for Upper Emigration Creek.

	July (n=4)	August (n=7)	September (n=5)	Collective (n=16)
Observed Load	3.08E13	1.52E13	1.05E13	5.64E13
Loading Capacity (TMDL)	5.09E12	7.06E12	4.03E12	1.62E13
Load Reduction	2.57E13	8.12E12	6.46E12	4.03E13
% Load Reduction	83%	53%	62%	71%
MOS (10%)	5.09E11	7.06E11	4.03E11	1.62E12
WLA	0	0	0	0
LA	4.58E12	6.35E12	3.63E12	1.46E13

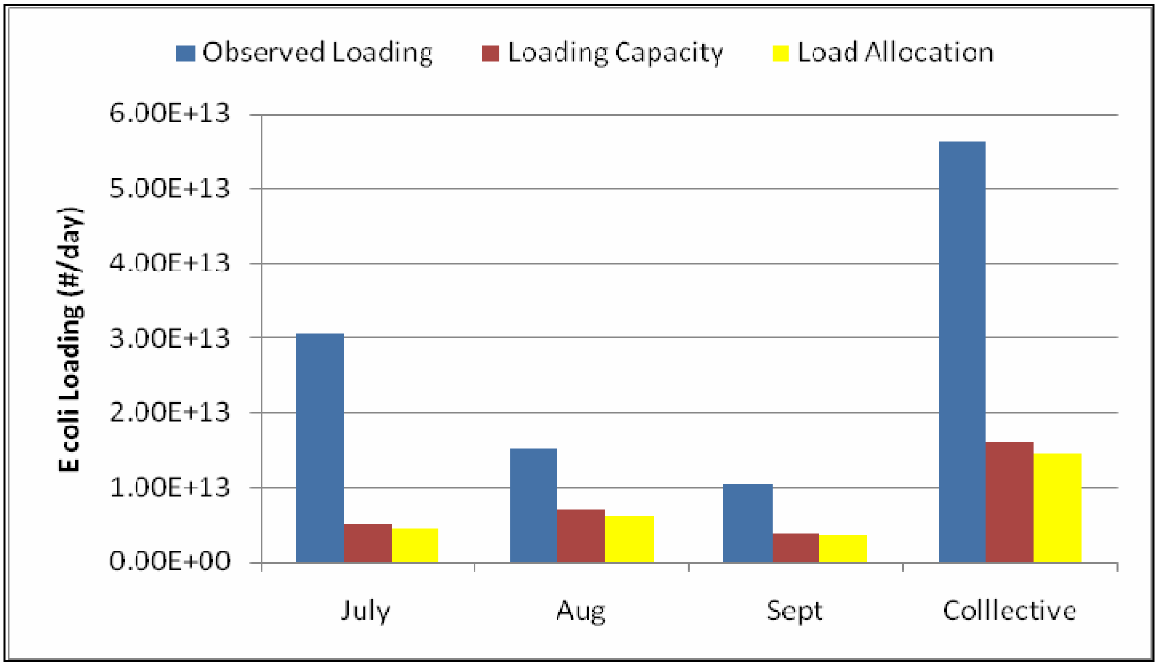


Figure 56. *E. coli* TMDL (#/day) Summary for Upper Emigration Creek

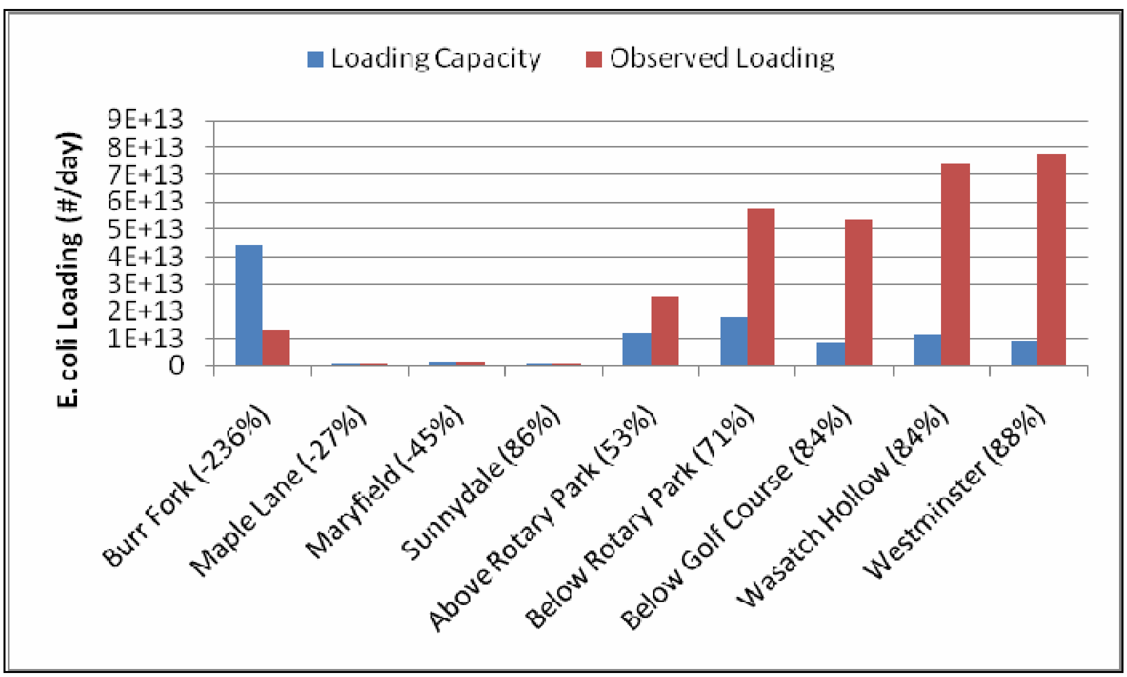


Figure 57. Observed *E. coli* Loading (#/day) and Loading Capacity at all Monitoring Sites in Emigration Creek Watershed During Critical Season.

7.3 Seasonality

E. coli loads were calculated on a monthly basis to evaluate the variation in observed and allowable loads throughout the year as shown in Figure 58. The observed loading is higher during the summer months due to a combination of several factors including warmer water temperatures and increased activity of humans, domestic animals and wildlife. Seasonal load allocations help identify periods of impairment and aid clean up efforts by prioritizing the timeframes in which they need to occur.

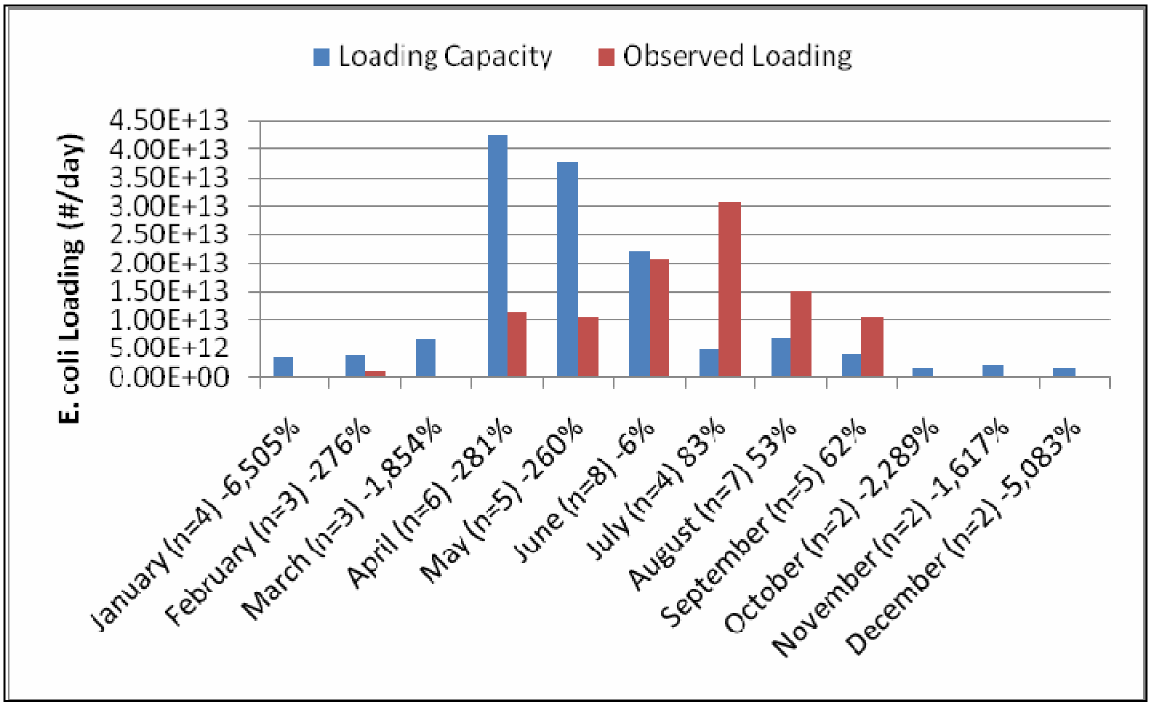


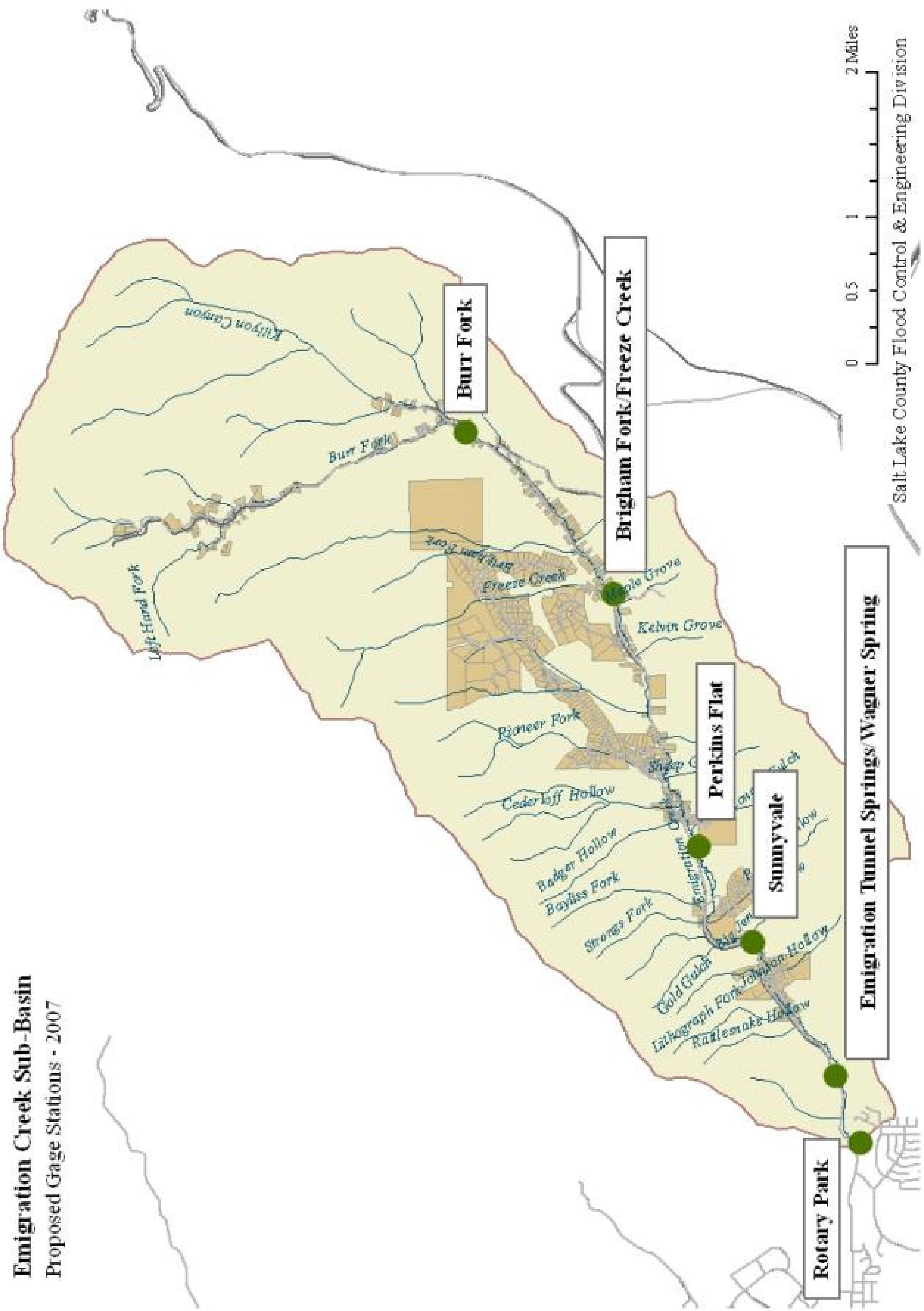
Figure 58. Monthly Observed *E. coli* Loading and Loading Capacity at Emigration Creek below Rotary Park. (Percentages denote magnitude of required load reductions, negative values denote no load reduction is required.)

8.0 DATA GAP ASSESSMENT

8.1 Emigration Creek Flow

The October, 2005 synoptic study conducted by the USGS identified a unique hydro-geological characteristic of Emigration Creek where a large proportion of flow seeps into the shallow alluvial aquifer at Rattlesnake Point and then re-emerges downstream near

Rotary Park. In the USGS study, the decline was attributed to the limestone bedrock formation in this section of the Canyon. An earlier study conducted in 2001 suggested that the water coming into the infiltration tunnel of Emigration Spring was over 50 years old (Manning, 2001). In order to clarify the unique flow regime found in Emigration Creek Sub-Basin, it is suggested that stage discharge recorders be installed at four (4) sites along the Creek (Map 21). In addition to the installation of these recorders, it is suggested that the Burr Fork Parshall flume be re-installed. By monitoring flow data at these six (6) sites, including the established flow gauge at Rotary Park, seasonal, diurnal, and geographic relationships may be better understood.



Map 21. Proposed Gaging Sites for Emigration Creek.

9.0 IMPLEMENTATION PLAN

The goal of a TMDL water quality study is to identify the sources of water quality impairment, quantify the load reductions necessary to support the waterbody's beneficial uses and ultimately lead to reductions in pollutant loading from controllable sources. Pollutant reduction is often best accomplished through an iterative process, particularly when addressing diffuse sources such as septic systems and domestic animal waste and when stakeholder support and involvement is critical for success (Lynnhaven 2004). An iterative process of public outreach, implementation of control measures, monitoring and evaluation leads to greater stakeholder support for maintaining and expanding water quality improvement efforts.

Implementation of pollution controls will focus on the most cost effective and potentially successful projects first, while mapping out the steps to implement future projects. The effectiveness of water quality improvement projects can be improved by clarifying the following items to stakeholders before projects start:

- Water quality goals
- Date of expected project start up and expected time required to attain water quality standards
- Measurable goals or milestones
- Cost
- Legal or regulatory controls

9.1 Best Management Practices

The following Best Management Practices (BMPs) have been demonstrated to improve water quality in streams affected by high *E. coli* concentrations. These BMPs are not presented in any order of priority and their effectiveness will be evaluated as part of the monitoring and evaluation phases of the iterative implementation process:

1. Improve/Increase Streamside Vegetated Buffers

- Animals and humans are discouraged from entering vegetated area once it is established. The area between the vegetated buffer and stream filters bacteria from runoff from adjacent land. Usually, buffers must be 35 feet wide on average to be eligible for any state or federal cost share money (Looney Creek 2007).

2. Analysis of Septic Systems
    - Reducing *E. coli* loading from human sources due to failing septic systems should be a priority because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems (Lynnhaven 2004).
    - Failing septic systems should be identified and corrected. To a certain degree, some of these systems can be reasonably assumed to be failing and for this reason, a portion of the *E. coli* loading in the watershed may be attributed to failure of septic systems and illicit discharges of sewage (Boulder Creek 2011).

3. Human-Related Impacts
    - Controlling urban wash-off from parking lots and roads
    - Street sweeping
    - Drainage ditch bank stabilization
    - Drainage structure maintenance
    - Enforcement of storm sewer discharge ordinance
    - BMP inspections (ponds, dry ponds, infiltration ponds, stormwater treatment devices) (Lynnhaven 2004).
    - Stormwater BMPs: Incorporation of low impact development (LID) (Boulder Creek 2011)

4. Streamside Fencing
    - Eliminates direct defecation in the stream and prevent the trampling of the stream banks (Looney Creek 2007).

5. Pet Litter Control Programs
    - Improperly discarded domestic animal and pet waste is a potential source of bacteria to Emigration Creek.
    - Educating homeowners and park users of cleaning up after their pet(s), along with posting signs, supplying pick-up bags for dog feces and trash cans in public dog walking areas ((Looney Creek 2007).

6. Outreach/Education Programs
    - As a source control technique, education and outreach can function as pollution prevention or the *'first line of defense'* to reduce or eliminate the amount of bacteria washed from surfaces (Boulder Creek 2011).
    - Implementation actions such as municipal incentives can be used to encourage proper irrigation and landscaping that can significantly reduce runoff and overland flow that tends to wash bacteria into the creek.
    - Provide resources to expand educational programs focused on proper pet waste management. (Boulder Creek 2011).
    - Encourage and facilitate public education of homeowners, homeowner associations and park users through distribution of educational materials, an Adopt a Waterway Program or "Scoop the Poop" type program http://anchoragecreeks.org/pages/scoopthepoop_about.php (Lynnhaven 2004).

9.2 Future Monitoring: General

Follow-up monitoring is required to ensure implementation efforts result in the attainment of water quality standards. The Utah Division of Water Quality (DWQ), in collaboration with Salt Lake County and other stakeholders, will continue to collect *E. coli* samples within the Emigration Canyon Sub-Basin to evaluate the effectiveness of pollution control efforts. This data will be made available through the Utah Division of Water Quality's website at www.waterquality.utah.gov.

In addition to *E. coli* data, it is suggested that stage discharge recorders be installed at six (6) sample sites (Map 20). Although flow data collected by Salt Lake City Public Utilities has been collected in all months of the year, winter data tend to be limited in frequency, often being collected only once a month.

A septic system dye study is also recommended to determine if effluent from failing septic systems is contributing to the bacterial contamination in Emigration Creek, and if so, which septic systems are failing. Dye tests will be prioritized based on the septic system's age and its proximity to Emigration Creek and its tributaries in conjunction with the Salt Lake Valley Health Department (SLVHD). The dye tests will be coordinated through the Emigration Improvement District (EID). The EID was formed in 1968 for the purpose of providing water and sewer services to the canyon; however the EID decided against installing a canyon-wide sanitary sewer system (SLCo, 2009).

9.3 Future Monitoring: E. coli Synoptic Monitoring

Emigration Creek was listed on the Utah 2006 303(d) list as being impaired due to *E. coli*. DWQ is required to develop and implement a TMDL study for *E. coli*. Data analyses show that *E. coli* concentrations and loading increase from upstream to downstream and the critical season is during low flow conditions in mid to late summer. However, in the middle reach of Emigration Creek near Sunnydale Road, *E. coli* concentrations are elevated based on data collected from January 2007 through June

2009. Further investigation is needed to isolate potential sources, particularly in this section of Emigration Creek. This monitoring plan outlines a study to be conducted in the summer of 2011 to assess *E. coli* sources in the Emigration Creek watershed.

9.3.1 Objectives

1. To characterize *E. coli* concentrations and loads in critical reaches of Emigration Creek.

2. To evaluate potential sources of *E. coli* loading, especially in the Sunnydale reach and below the Rotary Park reach of Emigration Creek.

9.3.2 Products

1. Quality-assured monitoring synoptic survey of *E. coli* data for the critical summer period from Emigration Creek.

2. A report detailing major findings of the study.

9.3.3 Background

Emigration Creek is located in the northeast corner of Salt Lake County in the Wasatch Mountains. Upper Emigration Creek Sub-Basin extends from the headwaters down to the Salt Lake County gage station in Rotary Glen Park. It has a drainage area of 18.2 square miles comprised of moderately steep mountain slopes with an elevation range from 5,000 to 8,900 feet. The major land-use is primarily residential with limited commercial. The Lower Emigration Creek watershed starts below the gage station at Rotary Park and extends down to where Emigration Creek is piped below Westminster College near 1100 East. It consists of a drainage area of approximately 18 square miles and major land uses are primarily residential with limited commercial.

Emigration Creek is a perennial stream with tributary flows from Killyon and Burr Fork canyons along with several ephemeral mountain streams. It is eventually piped underground and flows into the Jordan River. The upper watershed is listed on the 2006 303(d) list for not meeting its secondary contact recreational beneficial use due to high concentrations of *E. coli*. Recent data shows that the lower basin will be listed on the 2012 303(d) list for *E. coli* as well.

Unstable stream banks, lack of corridor preservation, on-site waste disposal systems, and urban development pressures in the floodplain add stress to the Emigration Creek watershed. Part of the TMDL development process is source identification. A synoptic monitoring plan will aid in the identification of direct sources and reaches of elevated *E. coli* loading.

9.3.4 Synoptic Monitoring Survey

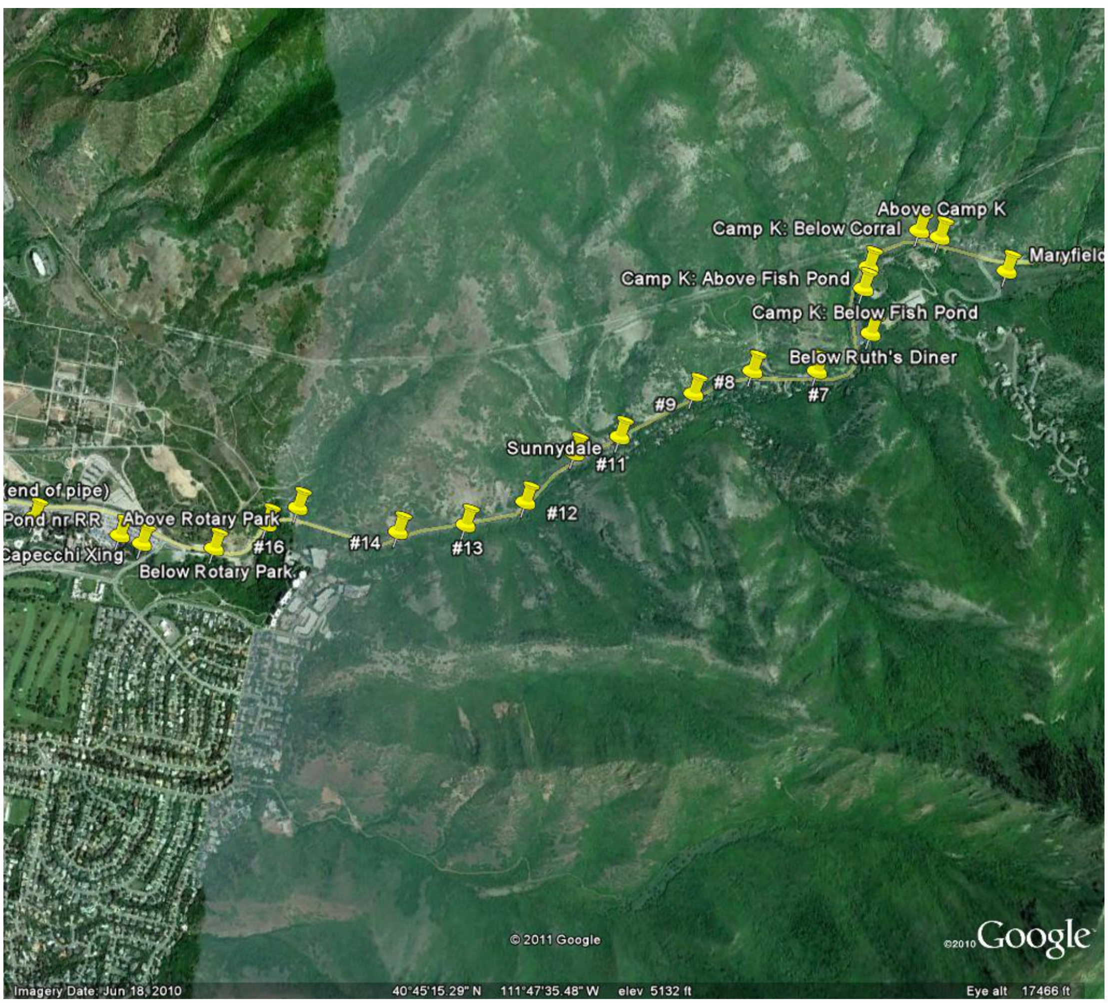
A synoptic monitoring plan is a comprehensive water quality survey designed to provide a snapshot of the bacterial levels in the Emigration Creek watershed. The survey collects surface water grab samples during baseflow hydrologic conditions at selected stations within a watershed. It involves collecting multiple samples nearly simultaneously to display concurrent conditions, as they exist within the watershed. The synoptic information is an effective tool used by watershed managers to identify stream reaches that will benefit the most from the implementation of BMPs.

The synoptic monitoring survey for the upper and lower Emigration Creek watershed will be conducted in July, August, and September 2011. See Table 15 for proposed monitoring dates. Sampling sites are spaced intensively at approximately 1,000 feet intervals from the DWQ Maryfield monitoring site down to where it is piped below Westminster campus. Figures 59 and 60 detail the locations for the synoptic monitoring survey, with two surveys to be completed on each study segment on consecutive days for three months. Any and all pipes, outfalls, and tributaries flowing during the time of collection will also be sampled. A minimum of thirty-six sites will be sampled.

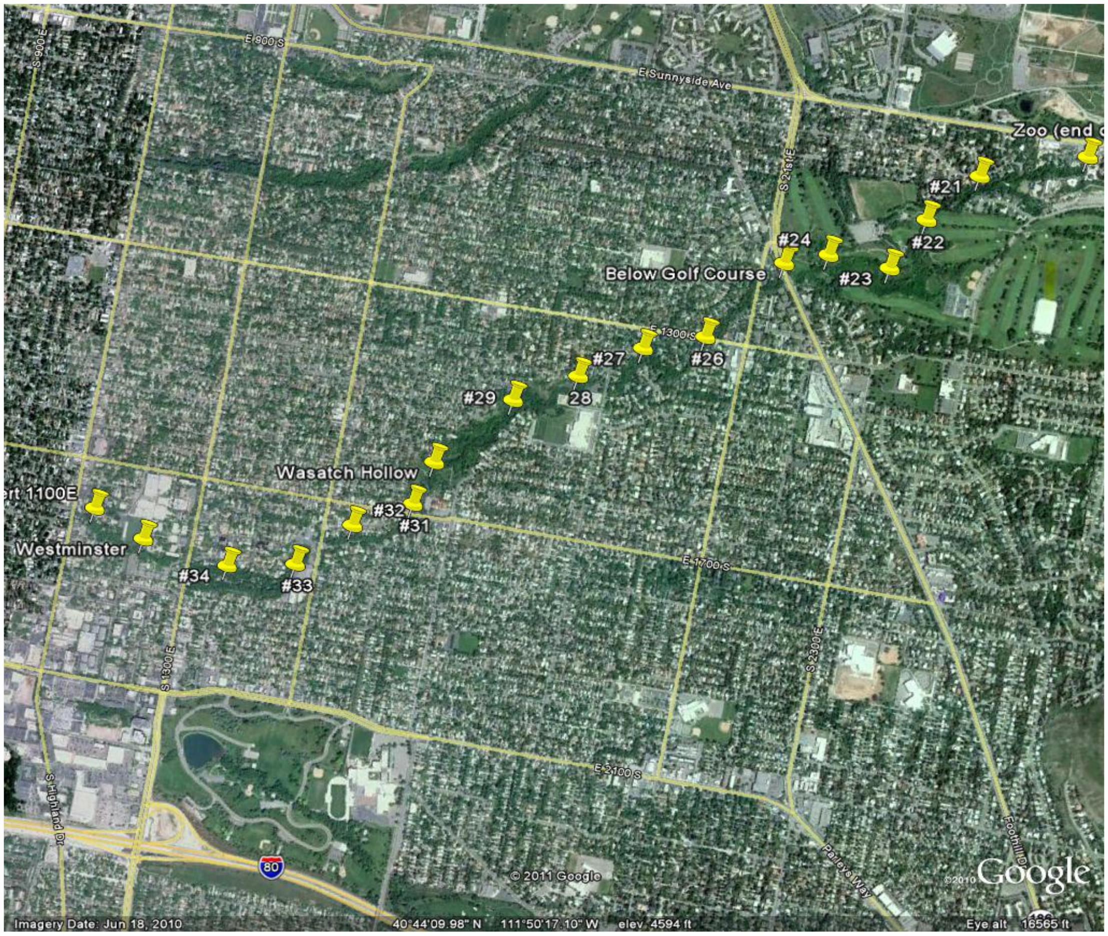
Samples will be collected as per DWQ's *E. coli* Field Collection Strategy Standard Operating Procedure (SOP) and will be processed according to the Quantification SOP. Duplicates will be taken at each site and blanks will be collected at the start of every field day. Three teams of two persons will collect samples simultaneously in their designated reaches working upstream.

9.3.5 Data Summary

Water quality data for the Emigration Creek watershed were obtained from DWQ and Salt Lake County. There are three monitoring stations in the Lower Emigration Creek watershed before the creek is piped underground at the 1300 SW Collection System along with Parley's Creek and Red Butte Creek which eventually flows into the Jordan River. *E. coli* samples were collected from 2007-2011 in the Upper Emigration Creek watershed and in 2009-2011 in the Lower Emigration Creek watershed. All nine sites will be sampled for *E. coli* and flow on a monthly basis in 2011 by Salt Lake County.



Map 22. Upper Emigration Creek Synoptic Sites.



Map 23. Lower Emigration Creek Synoptic Run Sites.

9.3.6 Collaboration

DWQ will work with Salt Lake County to collect *E. coli* samples and take flow measurements. Salt Lake County has been working with DWQ in the Emigration Creek Watershed since 2005 and is a key partner in this effort.

Table 15. Synoptic Study Timeline.

Date	Action
May 3, 2011	Tour Hogle Zoo and Camp Kostopulos to identify possible sources.
June 29, 2011	Tour watershed to finalize synoptic monitoring locations.
July 27-28, 2011	Synoptic monitoring
August 22-23, 2011	Synoptic monitoring
September 19-20, 2011	Synoptic monitoring
October 2011	Final Synoptic Monitoring Report Due

9.4 Public Involvement

Public involvement for the Emigration Creek Total Maximum Daily Load (TMDL) was initially achieved through meetings with the Emigration Improvement District (EID), which has been meeting monthly since it was formed in June 1968 by action of the Salt Lake County Commission. Facilitation and coordination of the meetings were achieved through the Jordan River Watershed Council (JRWC). Emigration Creek Stakeholders include:

- Emigration Improvement District (EID)
- Salt Lake City Public Works
- Salt Lake Valley Health Department (SLVHD)
- Salt Lake City Parks & Recreation (Rotary Park)
- Hogle Zoo
- Camp Kostopulos

Stakeholders played an integral role by contributing data as well as providing knowledge of the physical and social aspects of the Upper Emigration Creek Sub-Basin. Stakeholders also helped with informing the general public and local community about the TMDL and concerns regarding Emigration Creek.

Public education and involvement is critical to the success of the implementation of the Emigration Creek TMDL. An informational brochure on the Emigration Creek TMDL was distributed to the Emigration Canyon Community Firewise Days on June 11th, 2011 and also the Emigration Canyon Community Council Meeting on June 14th, 2011. Furthermore, DWQ and Salt Lake County has offered to present information and answer questions on the Emigration TMDL to the Emigration Community as requested by the Emigration Canyon Community Council.

Public comment for the TMDL was solicited with a public notice on July 18, 2011 via the Salt Lake Tribune Newspaper, Deseret Morning News, Utah Division of Water Quality (DWQ) website (www.waterquality.utah.gov), Jordan River Watershed Council (JRWC) listserv and the Salt Lake County Watershed Planning & Restoration Program website (www.watershed.sloc.org). Through the JRWC, a Public Meeting was held on June 30th, 2011 at the Salt Lake County Government Building to present the TMDL to the public, answer questions and solicit comments. A copy of the presentation as well as meeting minutes was posted on the Salt Lake County Watershed Planning & Restoration Program website followed by a 30-day public comment period and XXX comments were received.

Generally the public comments submitted during the 30-day public comment period focused on……The issue of funding mechanisms of the maintenance and repairs of failing septic systems was a common concern.

9.5 Recommendations

A septic system dye study is recommended to determine if effluent from leaking septic systems is contributing to the bacterial contamination in Emigration Creek, and if so, which septic systems are failing. The DWQ would like to perform dye tests on such septic systems, in conjunction with the Salt Lake Valley Health Department (SLVHD) and ideally on a volunteer basis of the homeowners. The volunteer dye tests would be coordinated through the Emigration Improvement District (EID). The EID was formed in 1968 for the purpose of providing water and sewer services to the canyon; however the EID decided against installing a canyon-wide sanitary sewer system (SLCo, 2009).

Residents of Emigration Canyon are encouraged to participate in the Environmental Protection Agency's Voluntary National Guidelines for Management of Onsite and Clustered Wastewater Treatment Systems. This guidance is to help enhance the performance and reliability of septic systems through improved management programs by institutionalizing the concept of management.

Five management models for septic systems (Table 16) are provided as conceptual approaches with increasing levels of control as sensitivity of the environment and complexity of the treatment system increases. Each model consists of 13 critical elements that describe activities to be performed to achieve the management goal. The purpose of the models are to provide a guide to match the needed management controls to the potential public health and water quality risks presented by decentralized systems in a particular area. The models are flexible so that programs can be customized by substituting elements of one program into another to accommodate local needs, practices, and conditions. The models help ensure the accountability and competency of regulators and service providers through certification and continuing education, owners through education and/or inspection requirements, and third-party managers through contract and permit stipulations to achieve their goals. The "best" model program for a community is not necessarily in the higher levels, but rather is the model that provides the most appropriate management controls for the potential risks (EPA 2003).

Table 16. EPA Management Models for Septic Systems.

Management Models for Septic Systems	
Management Model 1	"Homeowner Awareness" specifies appropriate program elements and activities where treatment systems are owned and operated by individual property owners in areas of low environmental sensitivity. This program is adequate where treatment technologies are limited to conventional systems that require little owner attention. To help ensure that timely maintenance is performed the regulatory authority mails maintenance reminders to owners at appropriate intervals.
Management Model 2	"Maintenance Contracts" specifies program elements and activities where more complex designs are employed to enhance the capacity of conventional systems to accept and treat wastewater. Because of treatment complexity, contracts with qualified technicians are needed to ensure proper and timely maintenance.
Management Model 3	"Operating Permits" specifies program elements and activities where sustained performance of treatment systems is critical to protect public health and water quality. Limited-term operating permits are issued to the owner and are renewable for another term if the owner demonstrates that the system is in compliance with the terms and conditions of the permit. Performance-based designs may be incorporated into programs with management controls at this level.
Management Model 4	"Responsible Management Entity (RME) Operation and Maintenance" specifies program elements and activities where frequent and highly reliable operation and maintenance of decentralized systems is required to ensure water resource protection in sensitive environments. Under this model, the operating permit is issued to an RME instead of the property owner to provide the needed assurance that the appropriate maintenance is performed.

Management Model 5	"RME Ownership" specifies that program elements and activities for treatment systems are owned, operated, and maintained by the RME, which removes the property owner from responsibility for the system. This program is analogous to central sewerage and provides the greatest assurance of system performance in the most sensitive of environments.

The DWQ has the authority to regulate septic systems through Utah Administrative Code R317-4 Onsite Wastewater Systems, R317-5 Large Underground Wastewater Disposal Systems and R317-11 Certification Required to Design, Inspect and Maintain Underground Wastewater Disposal Systems, or Conduct Percolation and Soil Tests for Underground Wastewater Disposal Systems. The rules require construction plan review and permitting for on-site septic systems. The rules also require certification of Onsite System Professionals to design, inspect and maintain underground wastewater disposal systems.

Additionally, local county health departments have the authority to regulate septic systems per Utah Code Annotated Section 26A-1-121(1). The SLVHD regulates on-site wastewater disposal systems in incorporated and unincorporated area of Salt Lake County through Health Regulation #13, which states onsite wastewater disposal systems shall be maintained in a manner that prevents the surfacing of sewage, the creation of a nuisance, a public health hazard, or a menace to fish or wildlife.

Finally, in order to better understand the degree to which various sources contribute to the *E. coli* load in Emigration Creek the relative percentage of human versus non-human bacterial contributions in Emigration Creek should be determined. In 2008, Dr. Ramesh Goel of the University of Utah completed a library-independent Microbial Source Tracking study on Emigration Creek. The findings show that Emigration Creek is receiving anthropogenic fecal contamination. However, with the use of real-time Polymerase Chain Reaction analysis, it is possible to quantify the human versus non-human presence of bacterial contamination. Utah's water quality standards however make no distinction between sources of *E. coli* for attainment of water quality standards, therefore the standard is applicable regardless of the source of *E. coli*.

The final Emigration Creek TMDL submitted to EPA will meet all the Minimum Submission Requirements and will ultimately reduce the pollutant loading to Emigration Creek to adequately meet the water quality standards for *E. coli*. Ideally this will be accomplished with a collaborative and coordinated effort of the abovementioned agencies and organizations.

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APPENDIX A ACRONYMS AND ABBREVIATIONS

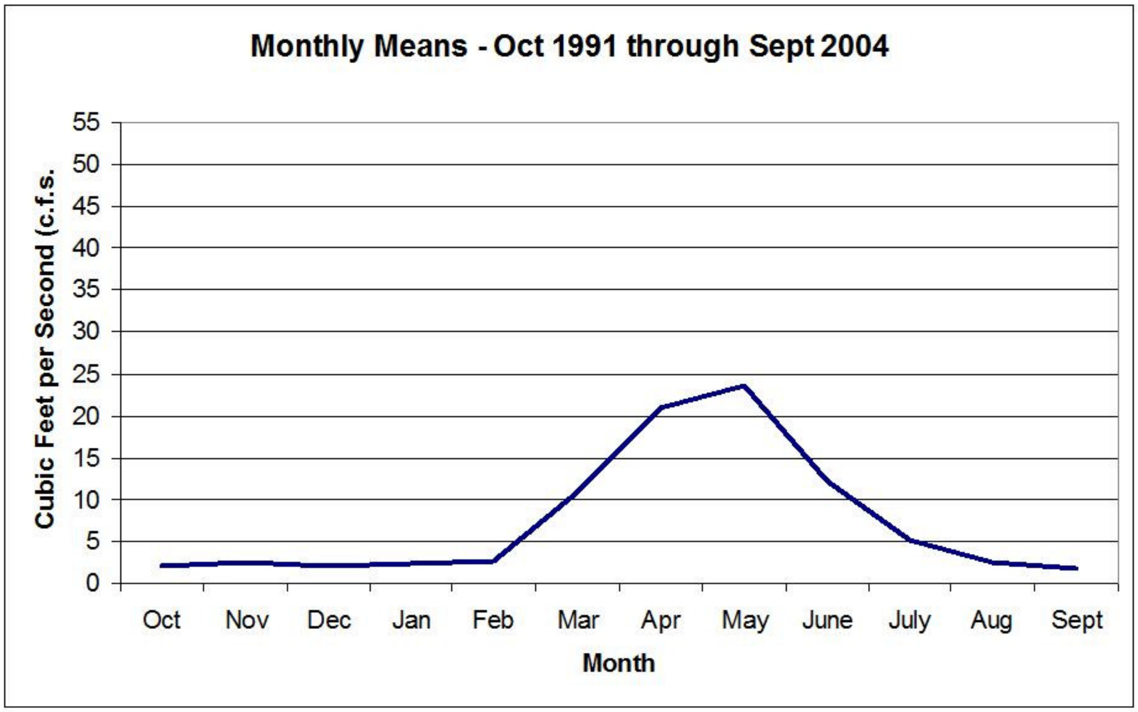
AU	**Assessment Unit**
BMP	Best Management Practice
BN	Barney's Creek
BOD	Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CFU	Colony Forming Unit
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DAQ	Division of Air Quality
DEQ	Utah Department of Environmental Quality
DO	Dissolved Oxygen
DWQ	Utah Division of Water Quality
DWR	Utah Division of Wildlife Resources
DWRe	Utah Division of Water Resources
E. coli	Escherichia coli
EID	Emigration Improvement District
EMC	Event Mean Concentration
EPA	U.S. Environmental Protection Agency
FCOZ	Foothill & Canyons Overlay Zone
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System
HOA	Home Owners Associations

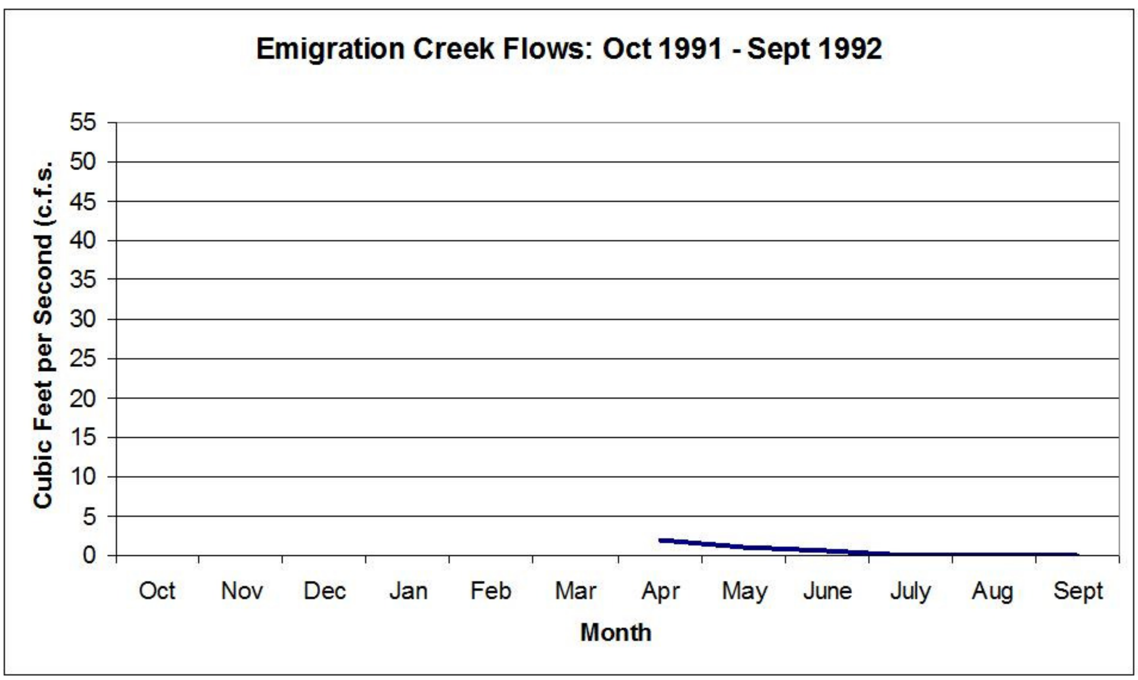
JR	Jordan River Corridor
JRWC	Jordan River Watershed Council
MCL	Maximum Contaminant Levels
mg/L	Milligrams per Liter
MOS	Margin of Safety
MST	Microbial Source Tracking
ND	non-detect
N/A	Not Applicable
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PCR	Polymerase Chain Reaction
ppm	parts per million
PUDs	Planned Unit Developments
RME	Responsible Management Entity
SLCo	Salt Lake County
SLCPU	Salt Lake City Public Utilities
SLVHD	Salt Lake Valley Health Department
SOP	Standard Operating Procedure
T.Cu	Total Copper
T.Pb	Total Lead
T.Zn	Total Zinc
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Toxic Organic Compounds

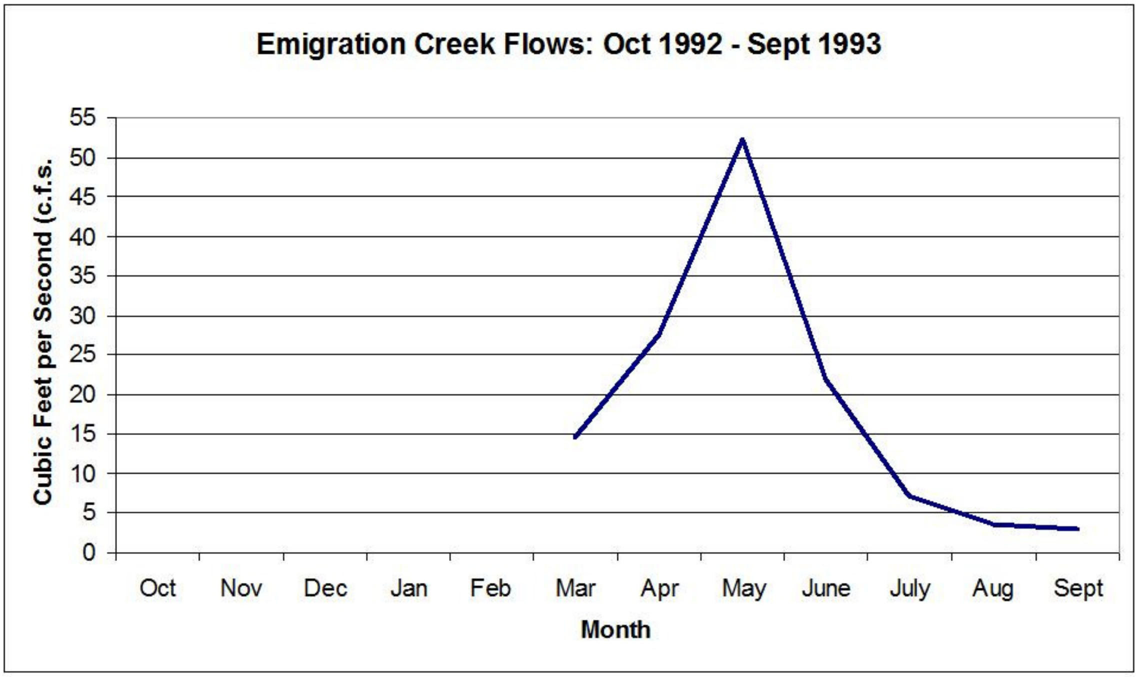
TP	Total Phosphorus
TSS	Total Suspended Solids
UAC	Utah Administrative Code
UCA	Utah Code Annotated
UPDES	Utah Pollutant Discharge Elimination System
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Service
UWQB	Utah Water Quality Board
WHO	World Health Organization

APPENDIX B STREAM FLOW DATA

Data is collected at Salt Lake County's gage #620 which is managed by Salt Lake County Flood Control and Engineering Division.







Emigration Creek Flows: Oct 1992 - Sept 1993
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
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20
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10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
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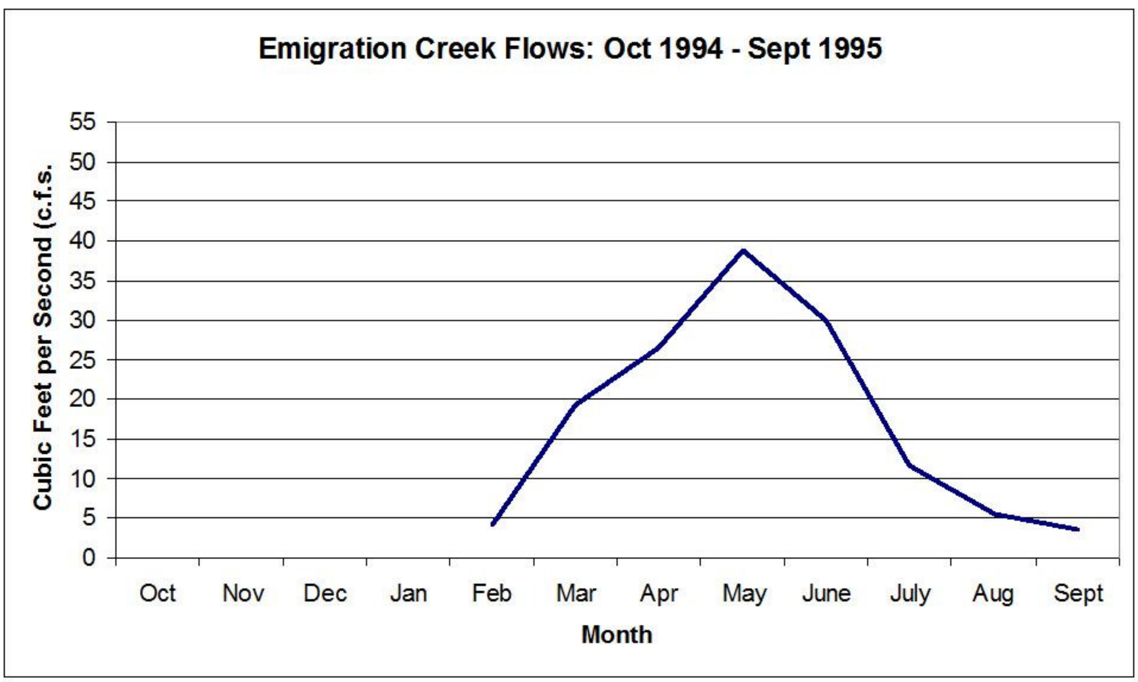
June
July
Aug
Sept
Month



Emigration Creek Flows: Oct 1994 - Sept 1995
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
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5
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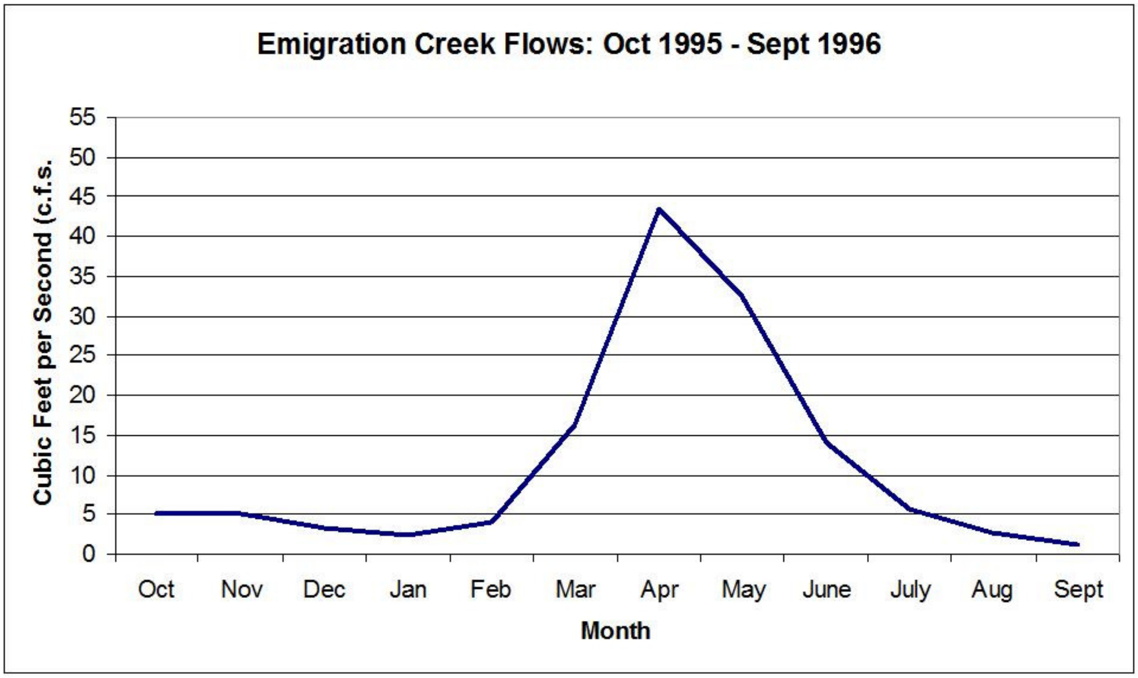
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month


Emigration Creek Flows: Oct 1995 - Sept 1996
Cubic Feet per Second (c.f.s.
0
5
10
15
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Oct
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Dec
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Feb
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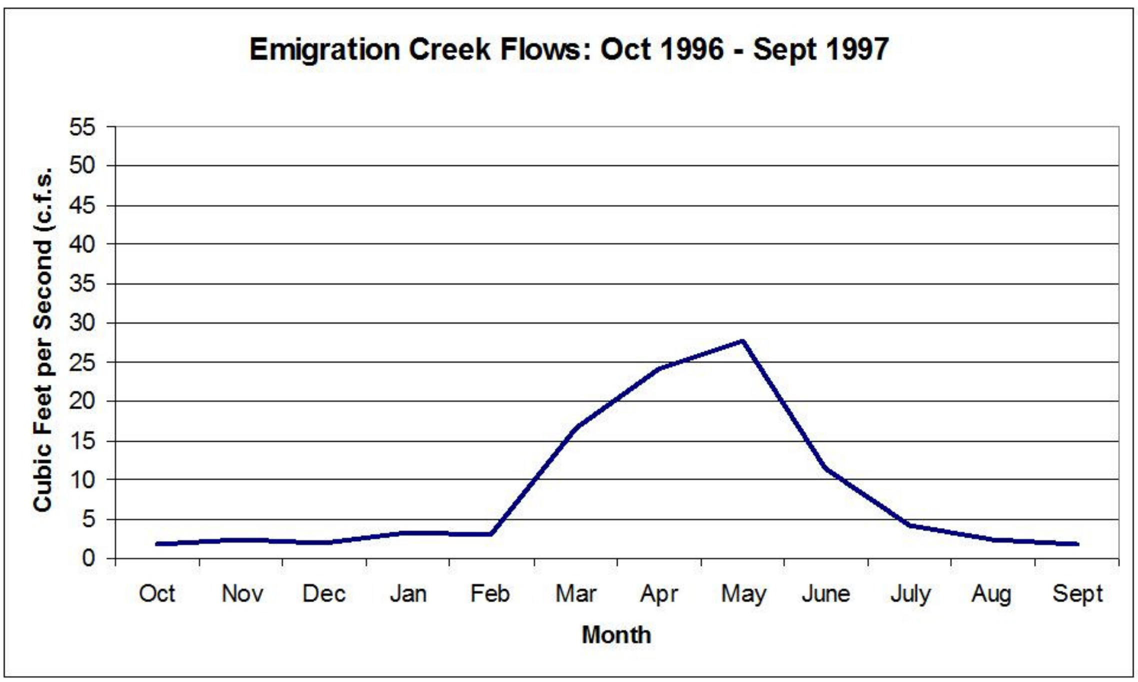
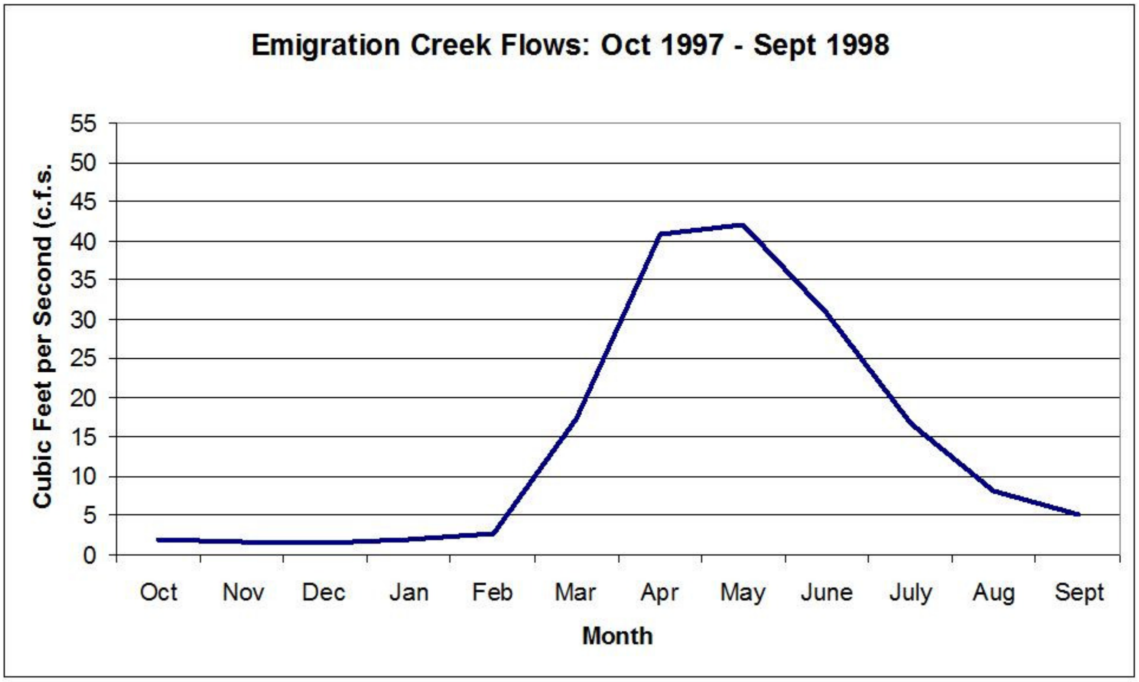
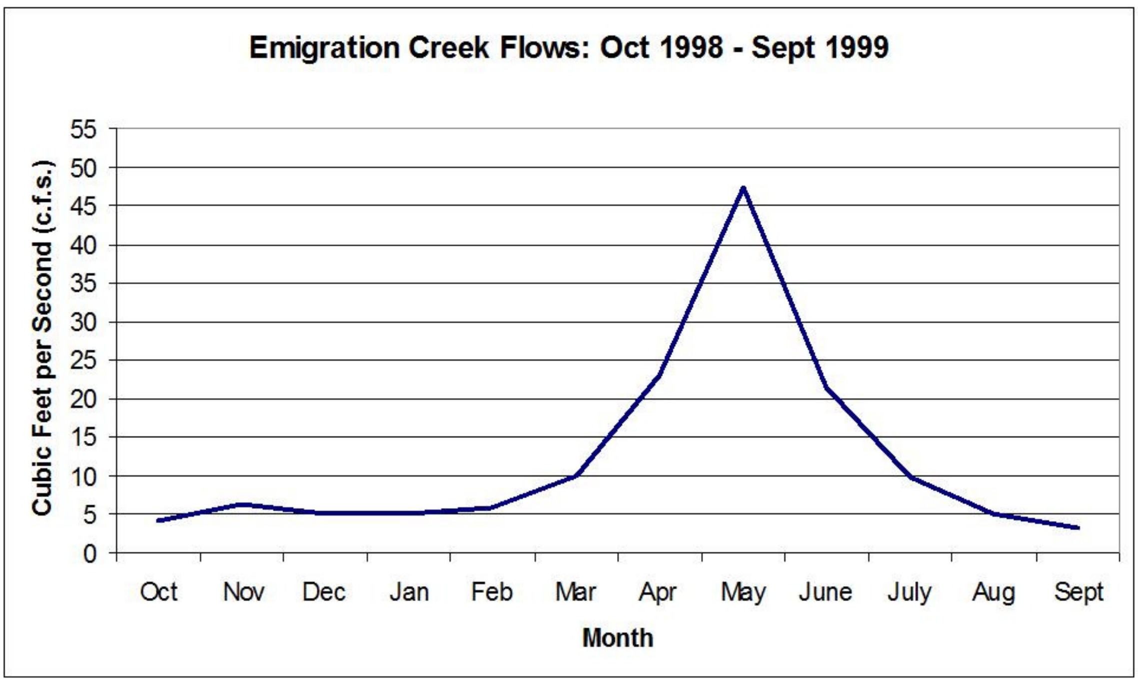
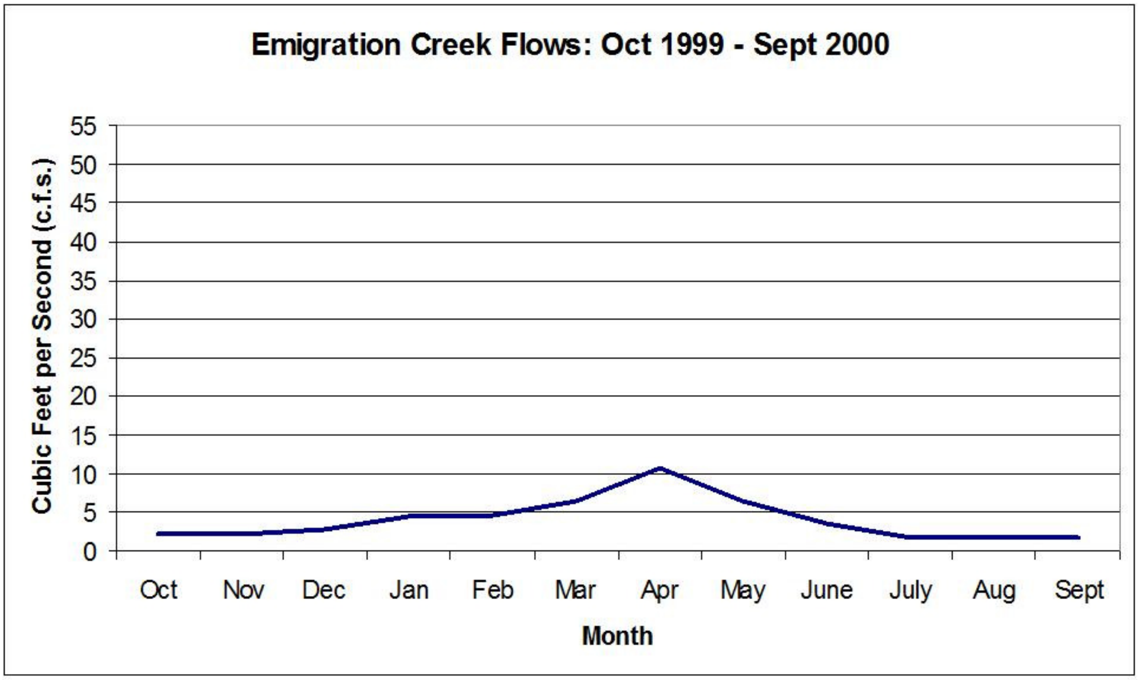
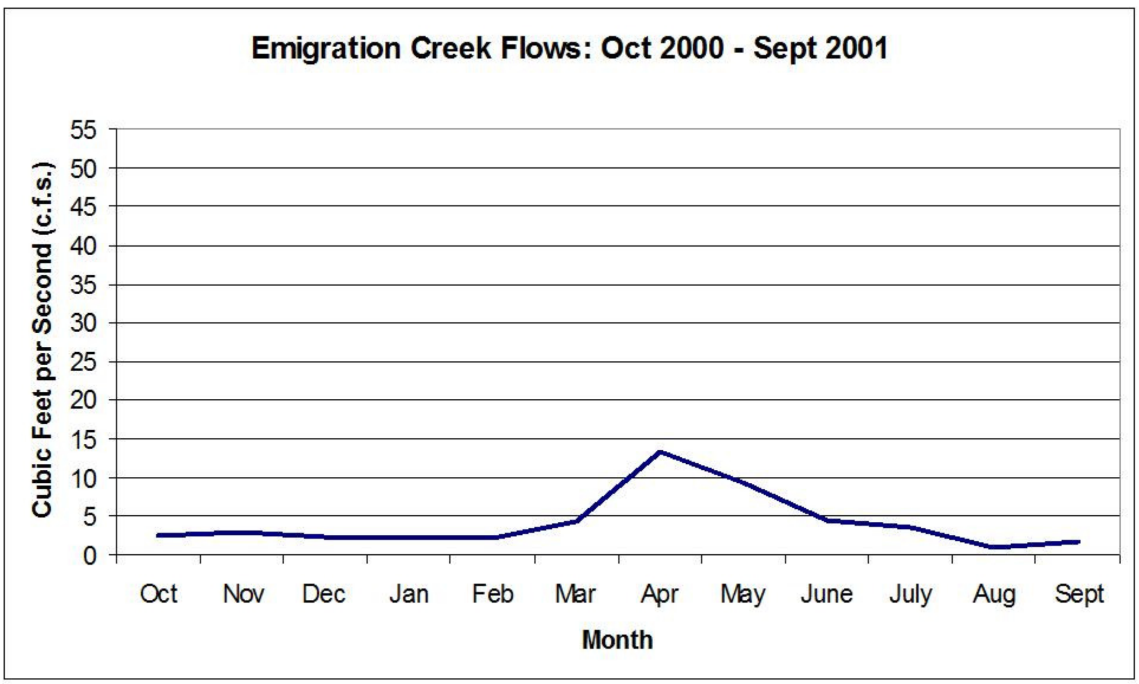
Month

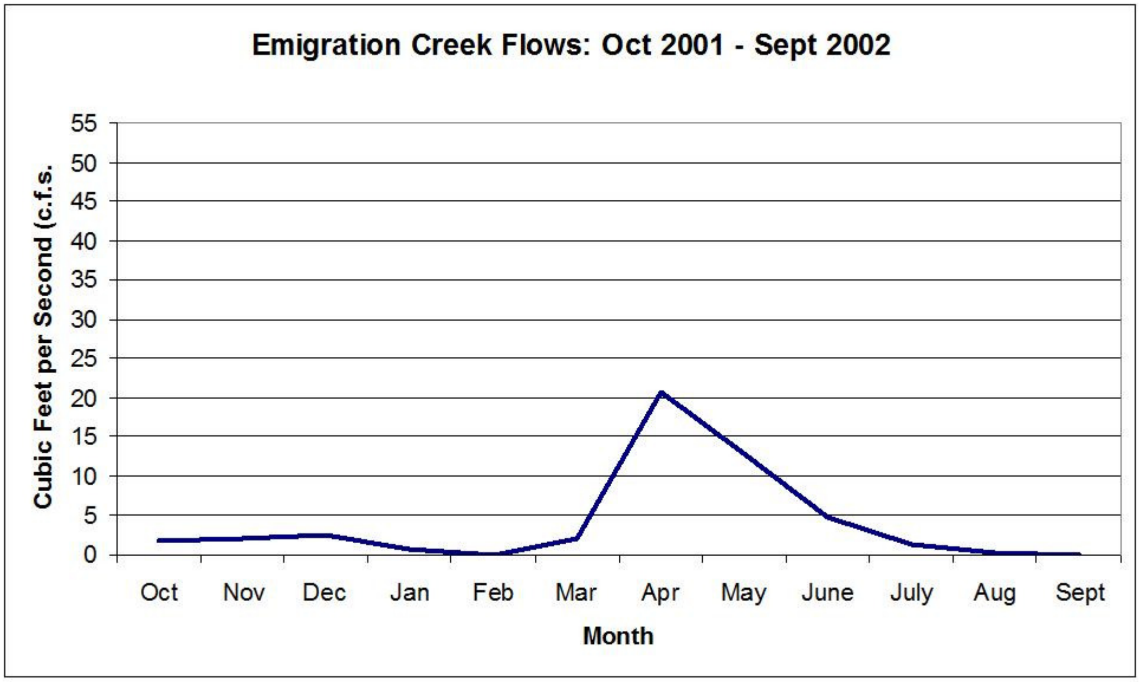

Emigration Creek Flows: Oct 1996 - Sept 1997
Cubic Feet per Second (c.f.s.
0
5
10
15
20
25
30
35
40
45
50
55
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

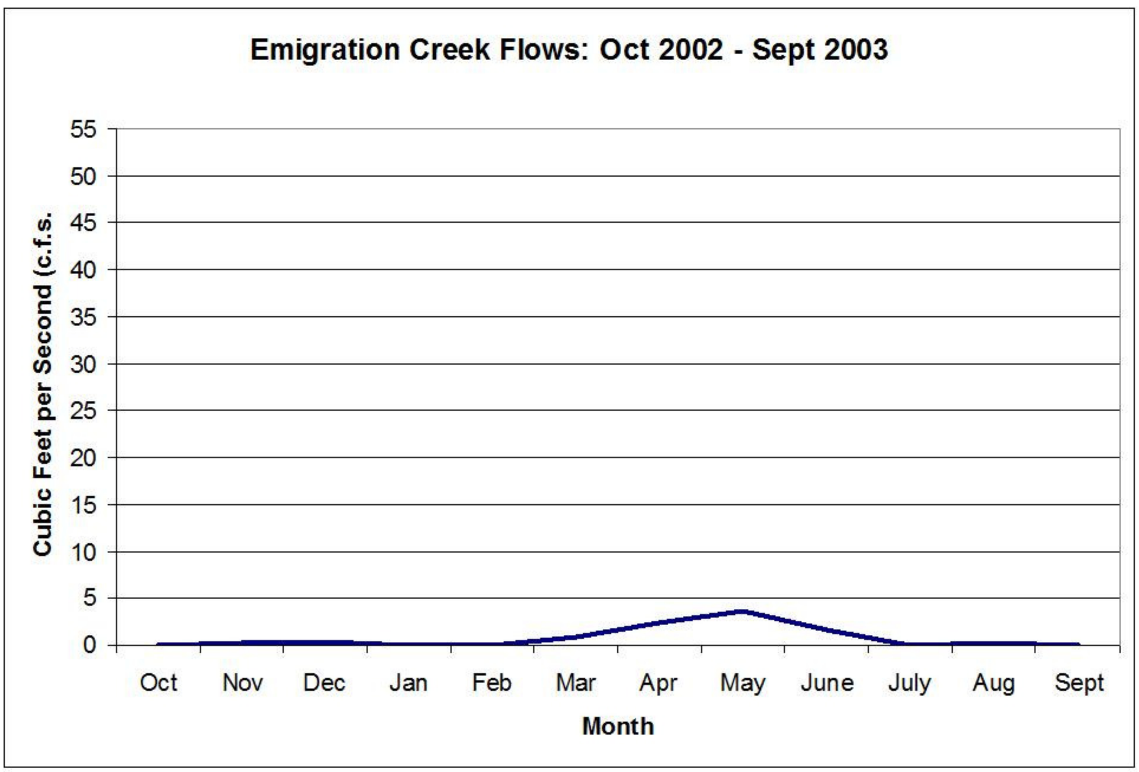

Emigration Creek Flows: Oct 1997 - Sept 1998
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

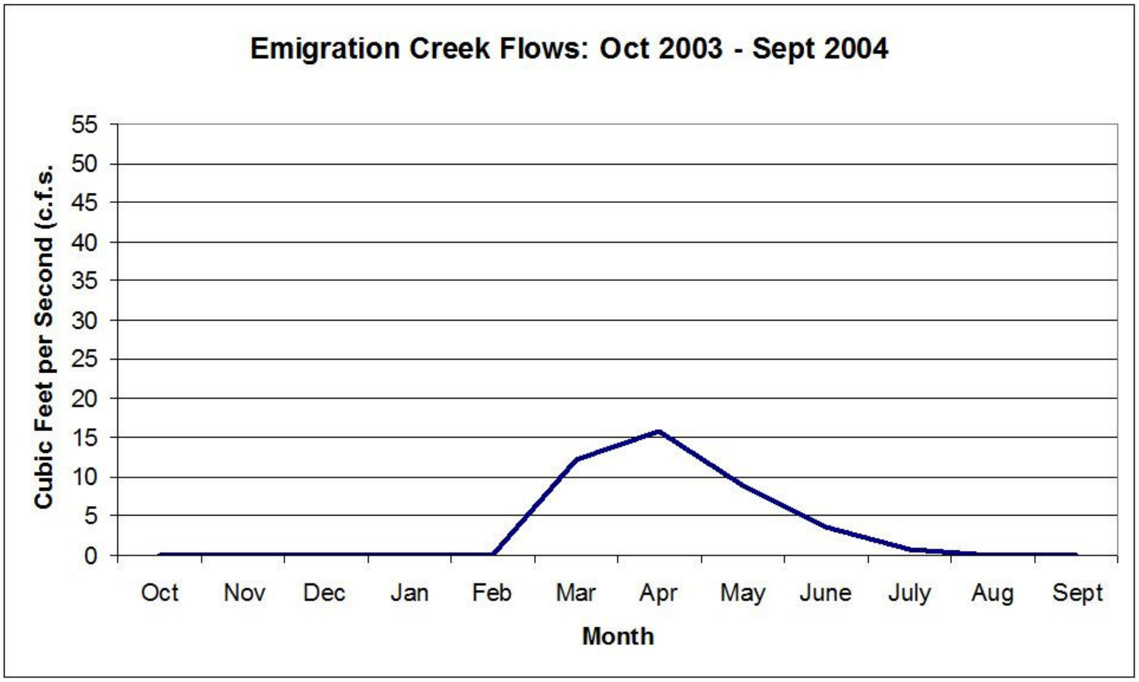

Emigration Creek Flows: Oct 1998 - Sept 1999
Cubic Feet per Second (c.f.s.)
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

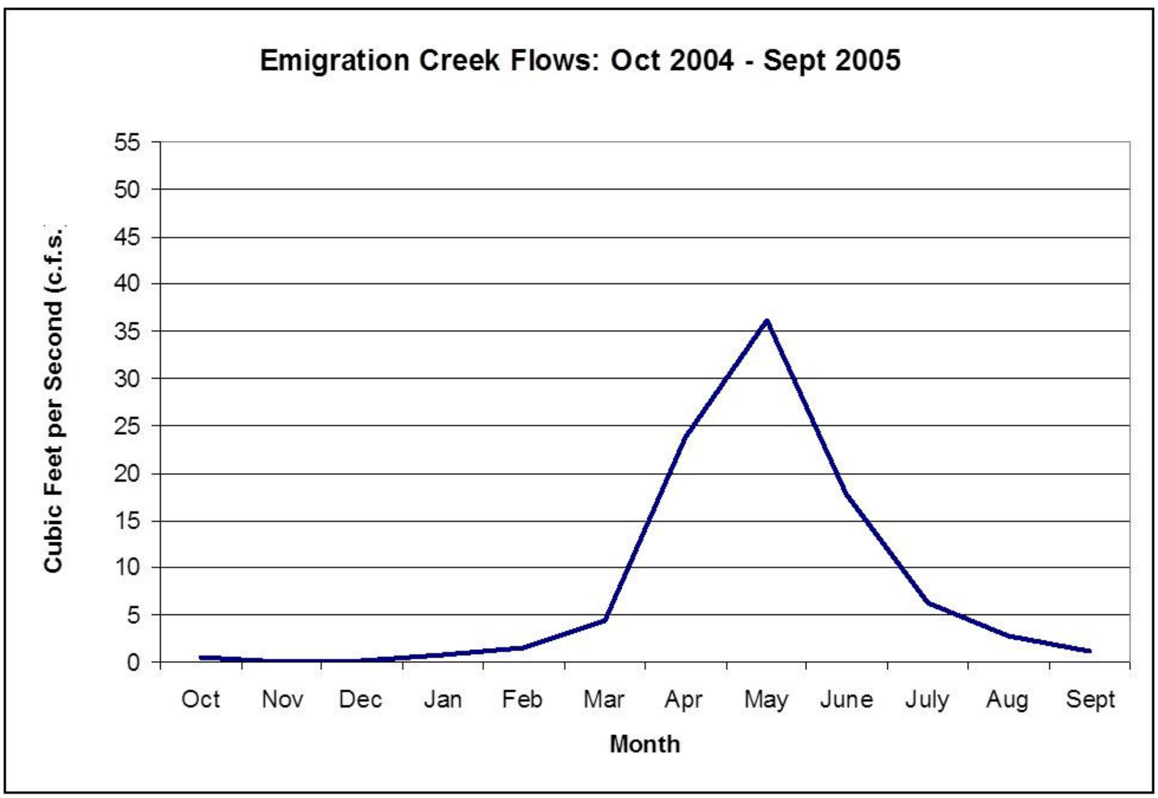

Emigration Creek Flows: Oct 1999 - Sept 2000
55
50
45
40
35
30
25
20
15
10
5
0
Cubic Feet per Second (c.f.s.)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

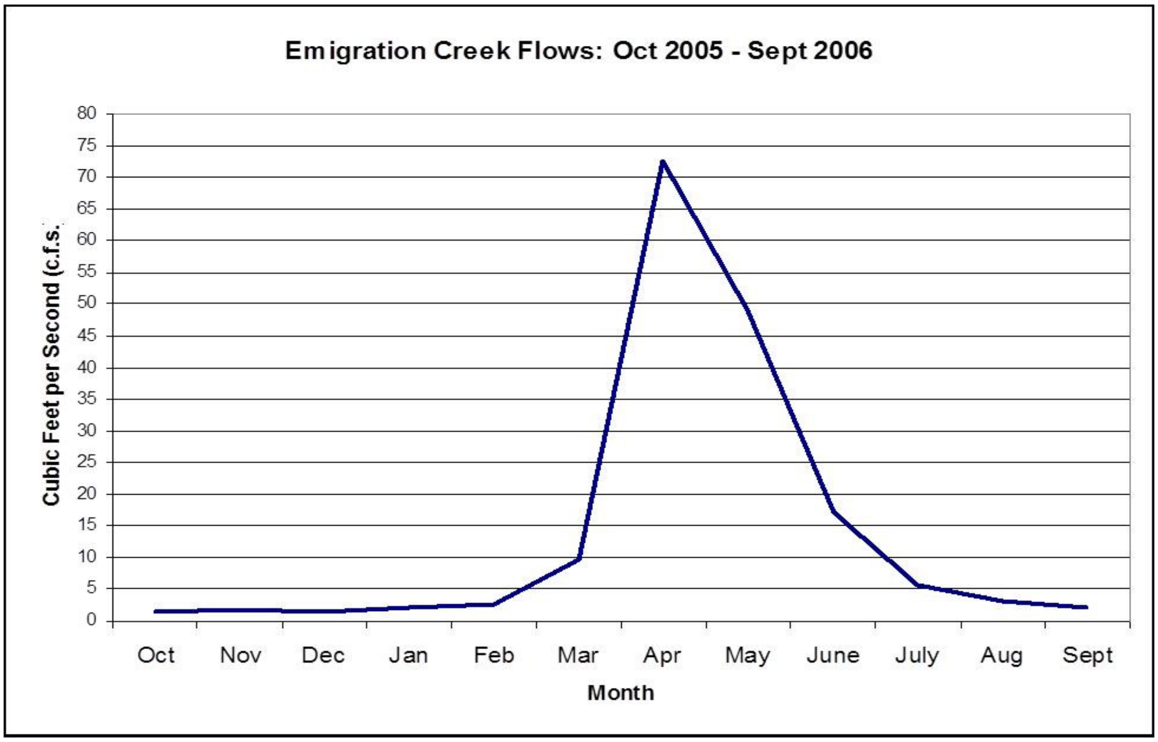

Emigration Creek Flows: Oct 2000 - Sept 2001
55
50
45
40
35
30
25
20
15
10
5
0
Cubic Feet per Second (c.f.s.)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

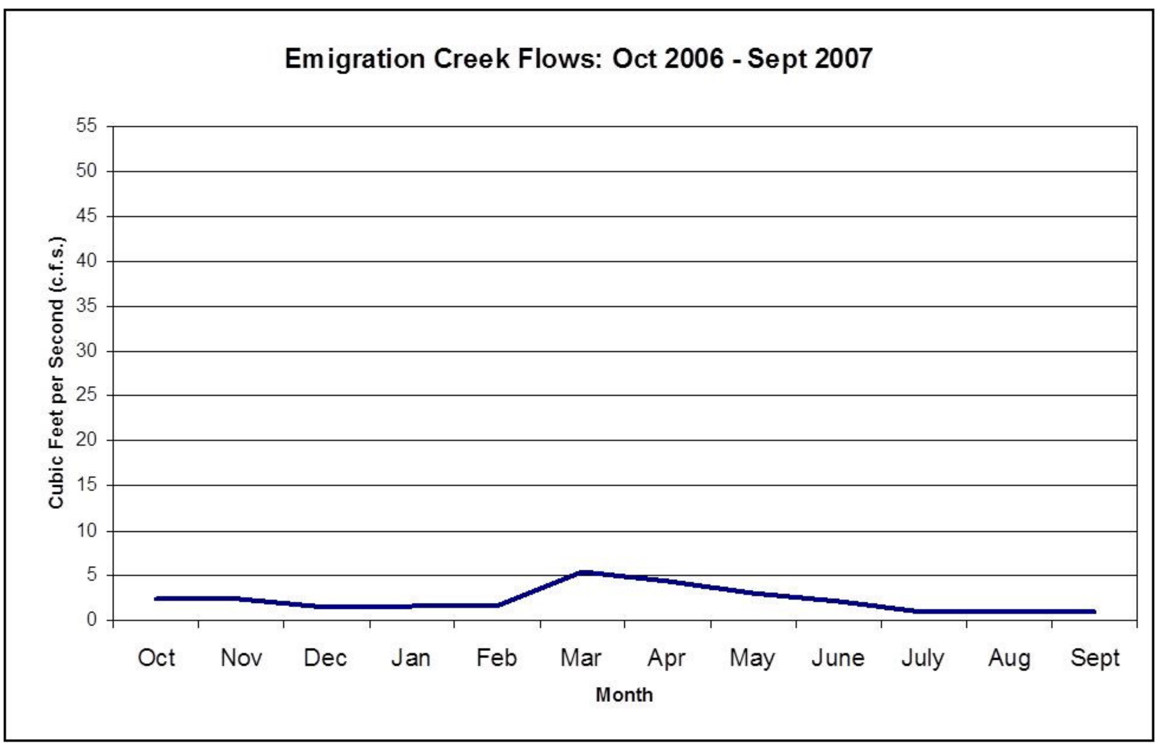

Emigration Creek Flows: Oct 2001 - Sept 2002
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

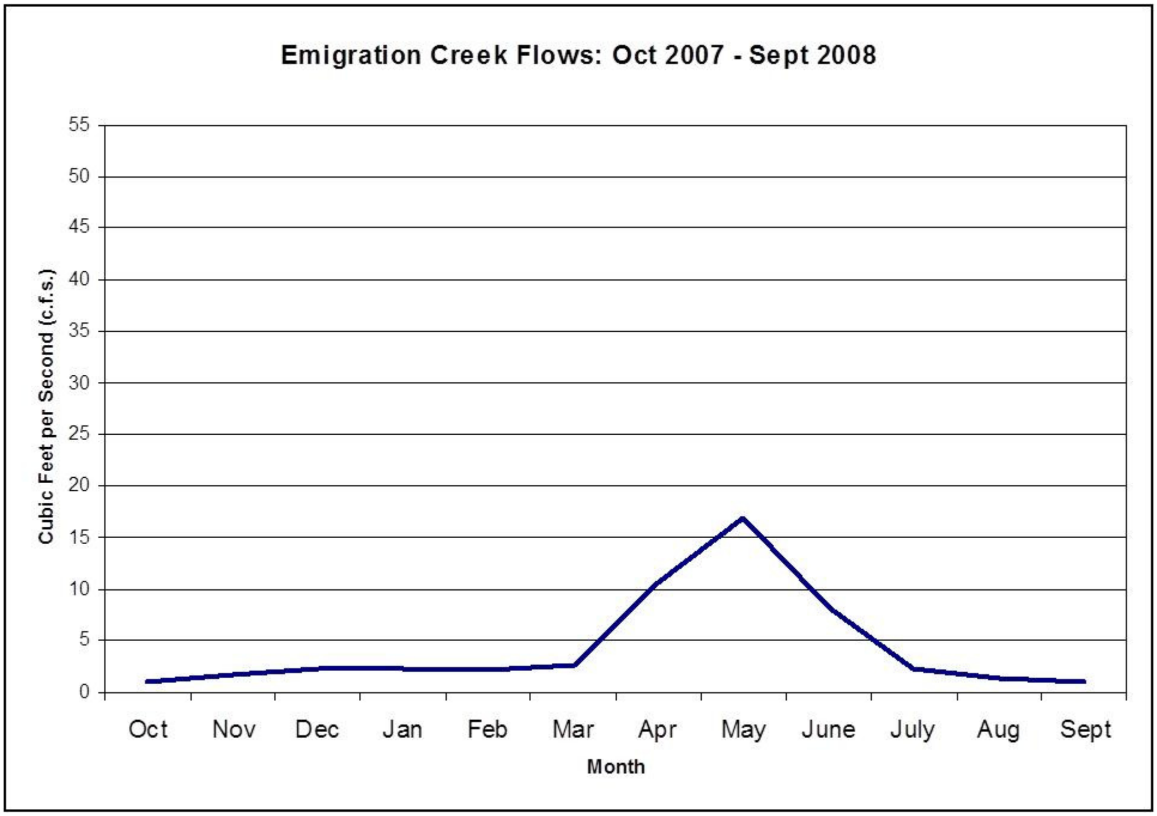

Emigration Creek Flows: Oct 2002 - Sept 2003
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

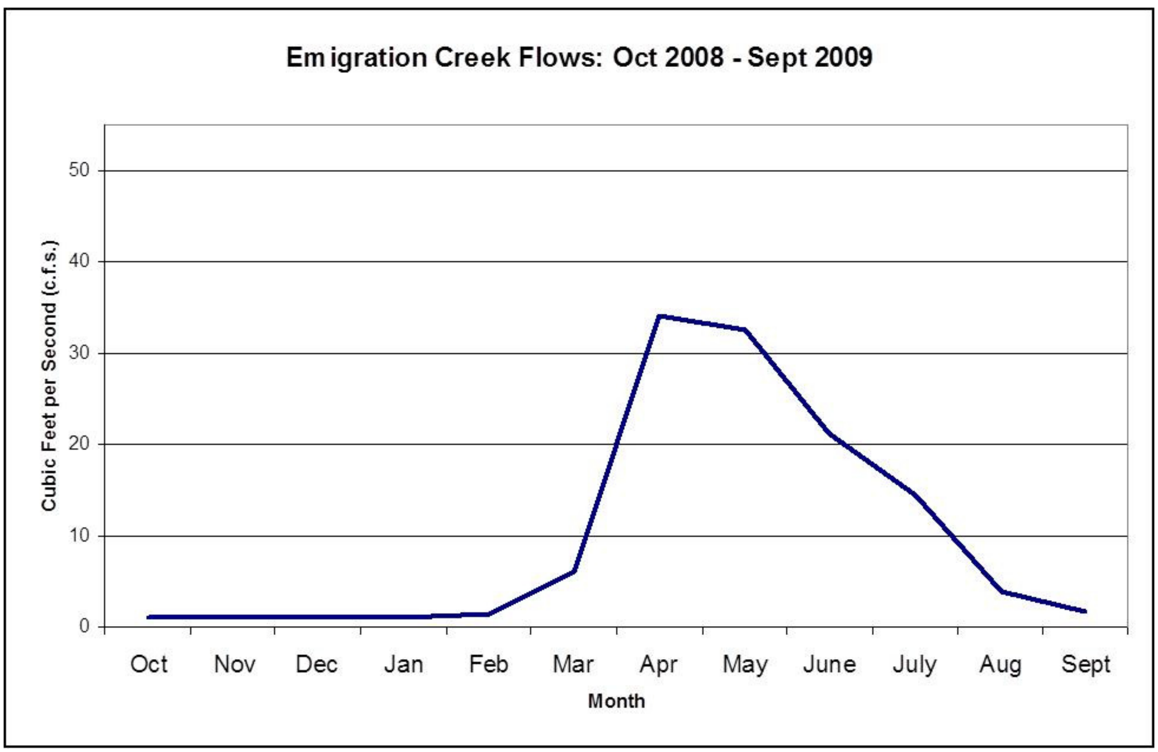

Emigration Creek Flows: Oct 2003 - Sept 2004
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month


Emigration Creek Flows: Oct 2004 - Sept 2005
Cubic Feet per Second (c.f.s.
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

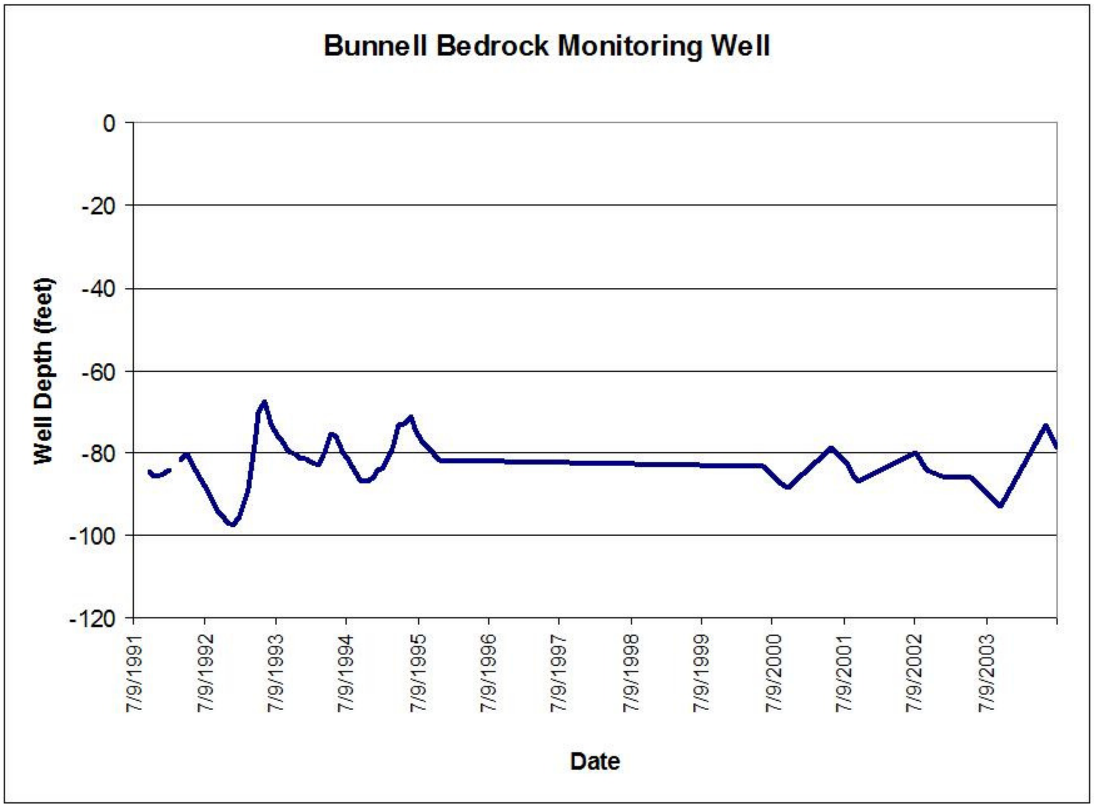

Emigration Creek Flows: Oct 2005 - Sept 2006
Cubic Feet per Second (c.f.s.)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

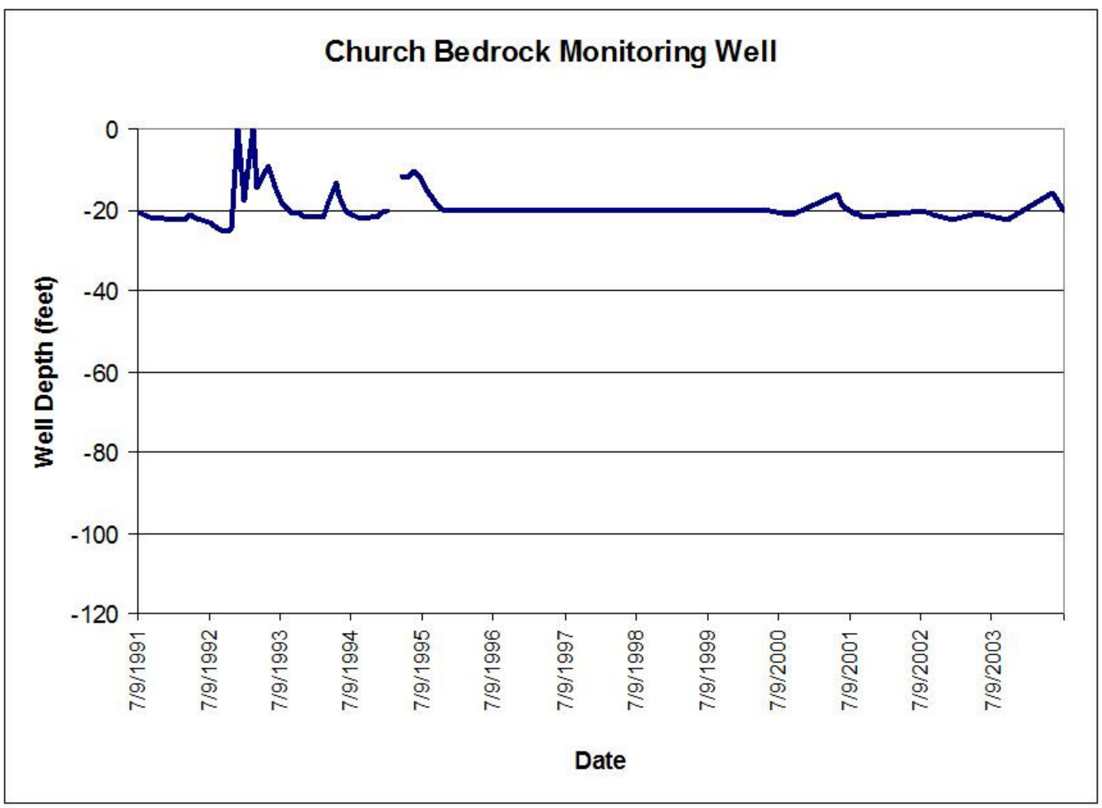

Emigration Creek Flows: Oct 2006 - Sept 2007
Cubic Feet per Second (c.f.s.)
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

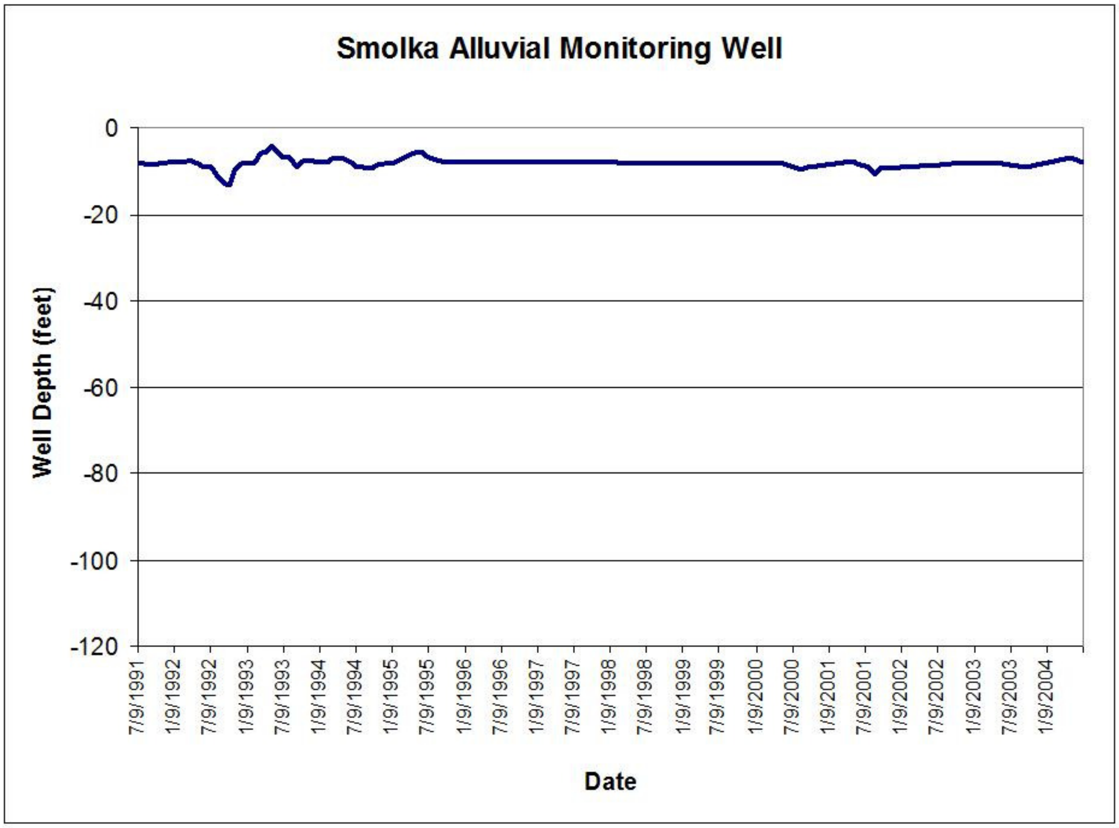

Emigration Creek Flows: Oct 2007 - Sept 2008
Cubic Feet per Second (c.f.s.)
55
50
45
40
35
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

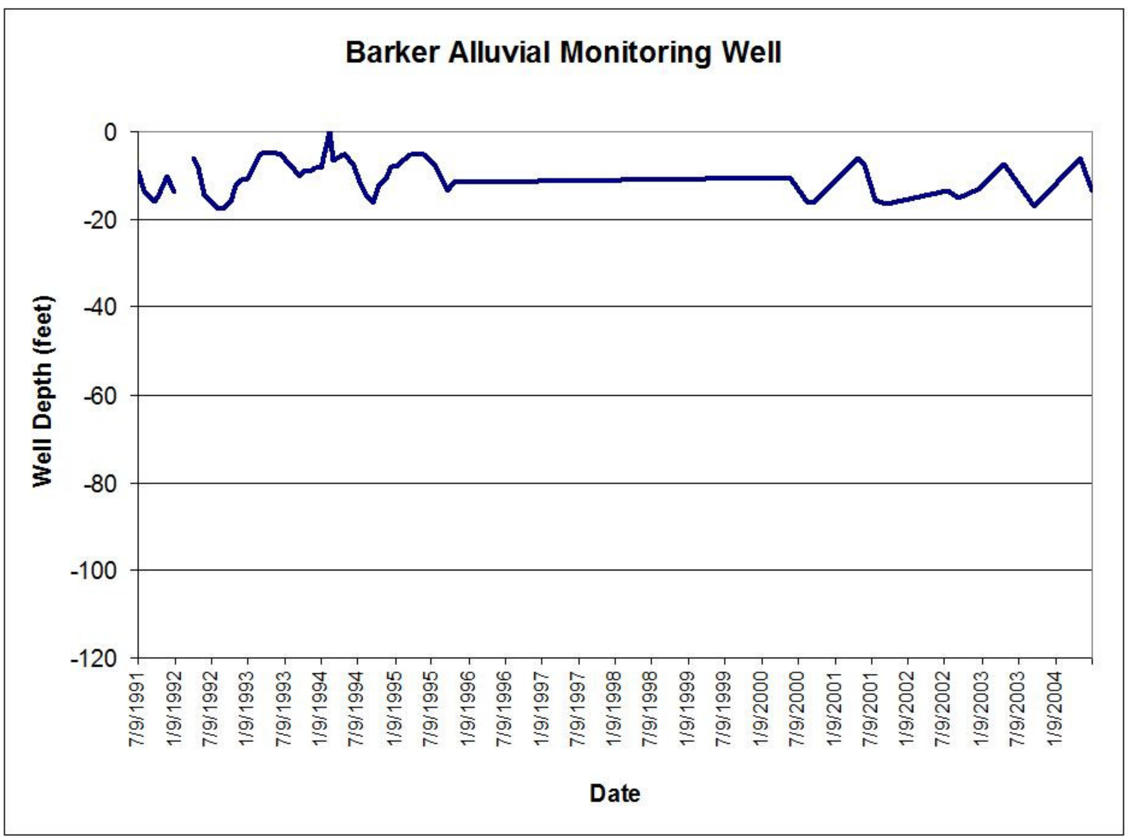

Emigration Creek Flows: Oct 2008 - Sept 2009
Cubic Feet per Second (c.f.s.)
50
40
30
20
10
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Month

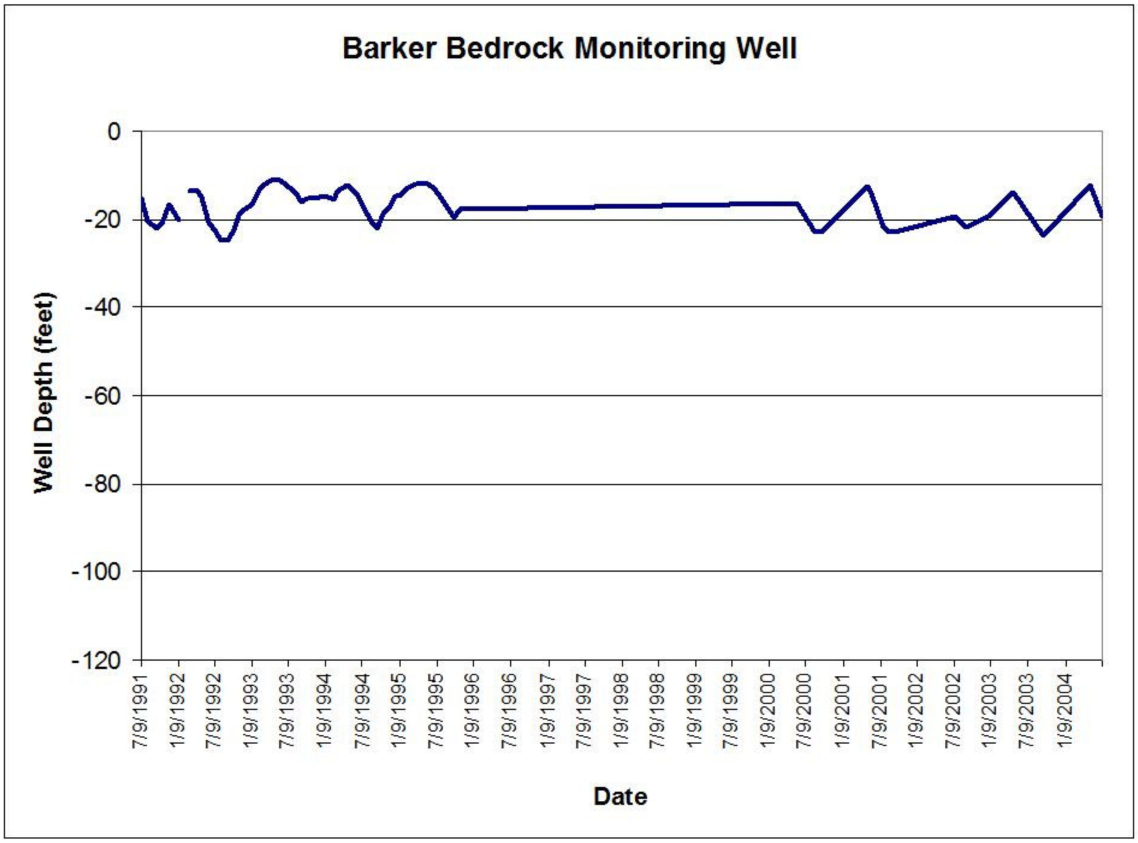
APPENDIX C WELL DEPTH INFORMATION (EID)





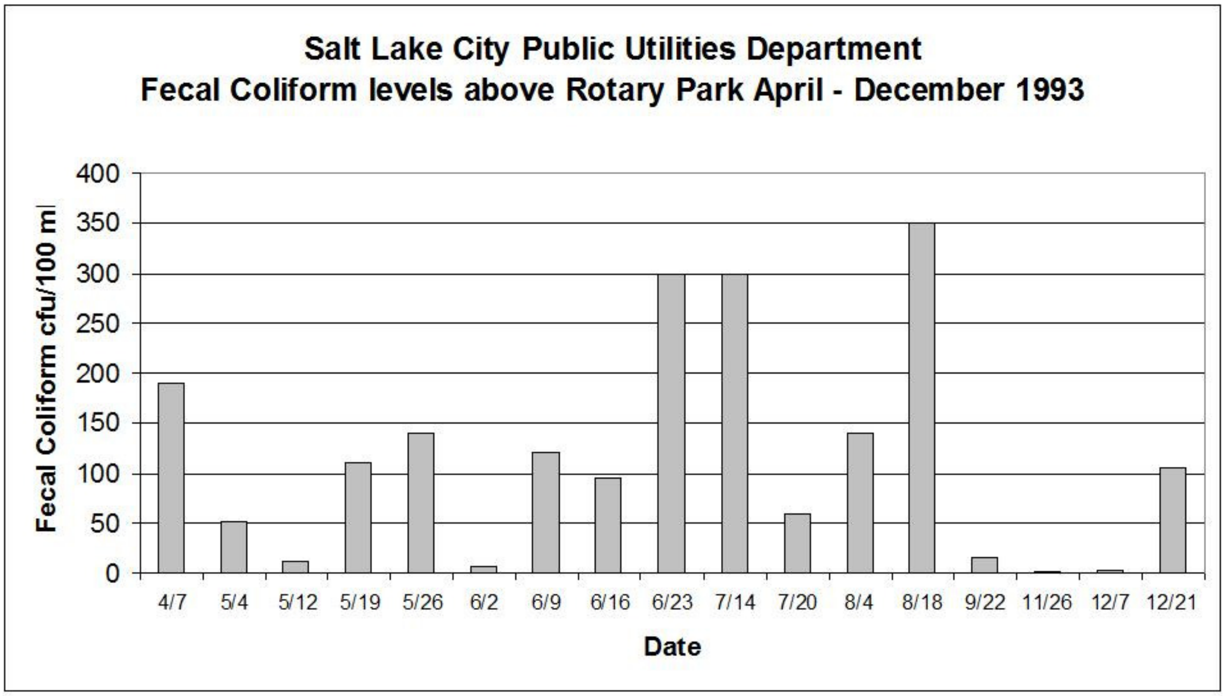

Smolka Alluvial Monitoring Well
Well Depth (feet)
0
-20
-40
-60
-80
-100
-120
7/9/1991
1/9/1992
7/9/1992
1/9/1993
7/9/1993
1/9/1994
7/9/1994
1/9/1995
7/9/1995
1/9/1996
7/9/1996
1/9/1997
7/9/1997
1/9/1998
7/9/1998
1/9/1999
7/9/1999
1/9/2000
7/9/2000
1/9/2001
7/9/2001
1/9/2002
7/9/2002
1/9/2003
7/9/2003
1/9/2004
Date

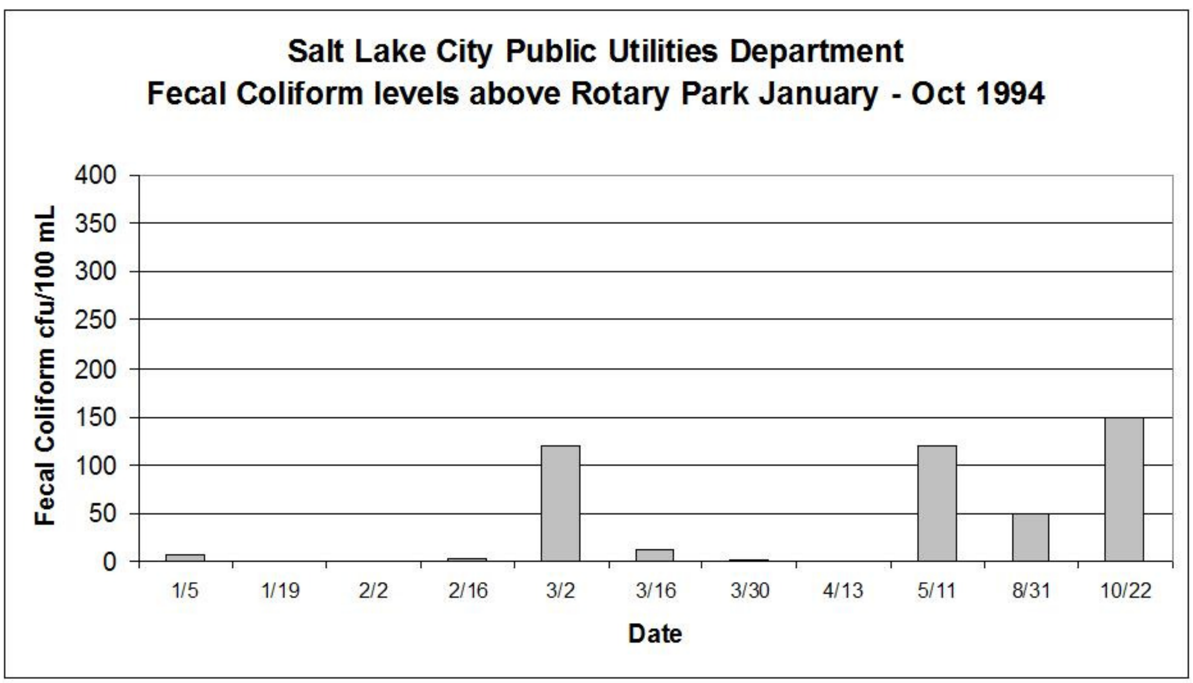

Barker Alluvial Monitoring Well
Well Depth (feet)
0
-20
-40
-60
-80
-100
-120
7/9/1991
1/9/1992
7/9/1992
1/9/1993
7/9/1993
1/9/1994
7/9/1994
1/9/1995
7/9/1995
1/9/1996
7/9/1996
1/9/1997
7/9/1997
1/9/1998
7/9/1998
1/9/1999
7/9/1999
1/9/2000
7/9/2000
1/9/2001
7/9/2001
1/9/2002
7/9/2002
1/9/2003
7/9/2003
1/9/2004
Date

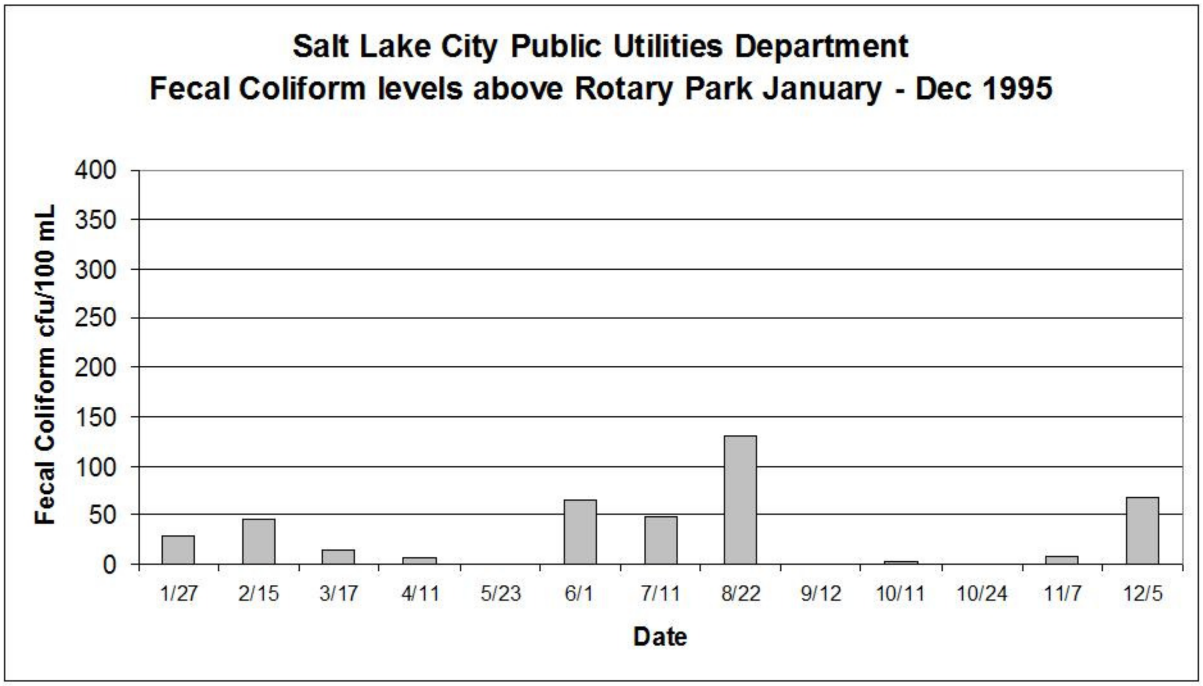

Barker Bedrock Monitoring Well
Well Depth (feet)
0
-20
-40
-60
-80
-100
-120
7/9/1991
1/9/1992
7/9/1992
1/9/1993
7/9/1993
1/9/1994
7/9/1994
1/9/1995
7/9/1995
1/9/1996
7/9/1996
1/9/1997
7/9/1997
1/9/1998
7/9/1998
1/9/1999
7/9/1999
1/9/2000
7/9/2000
1/9/2001
7/9/2001
1/9/2002
7/9/2002
1/9/2003
7/9/2003
1/9/2004
Date

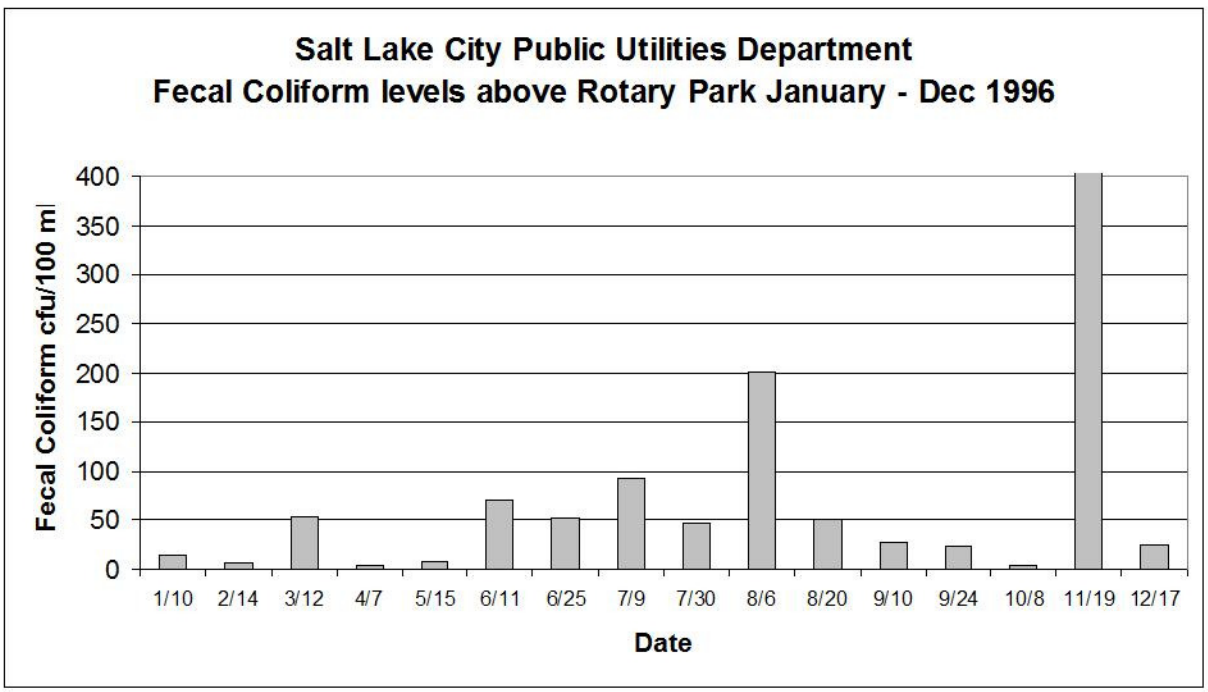
APPENDIX D SALT LAKE CITY WATER QUALITY DATA

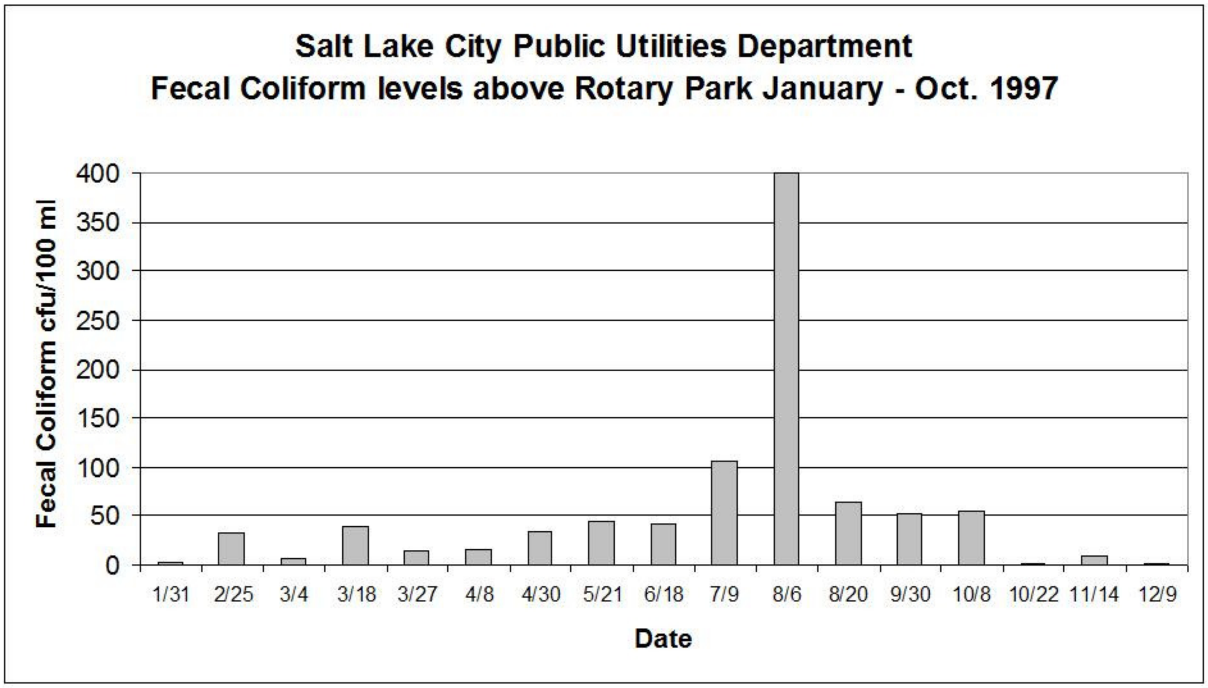
Data collected above Rotary Park.

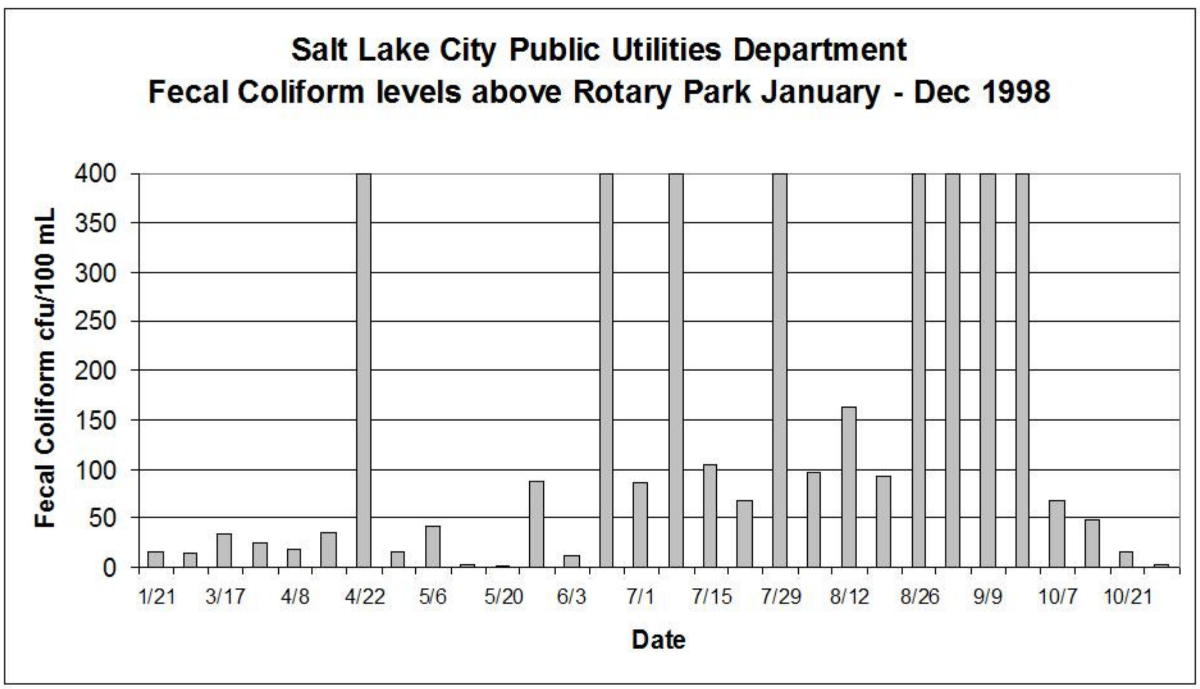


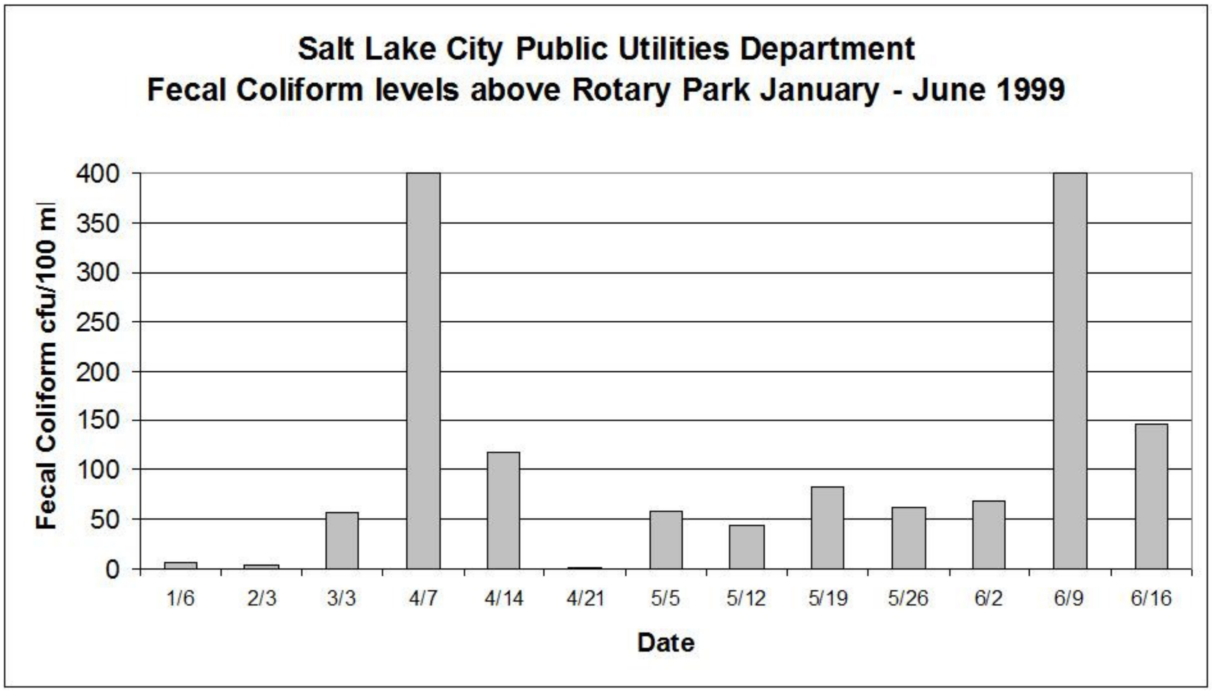


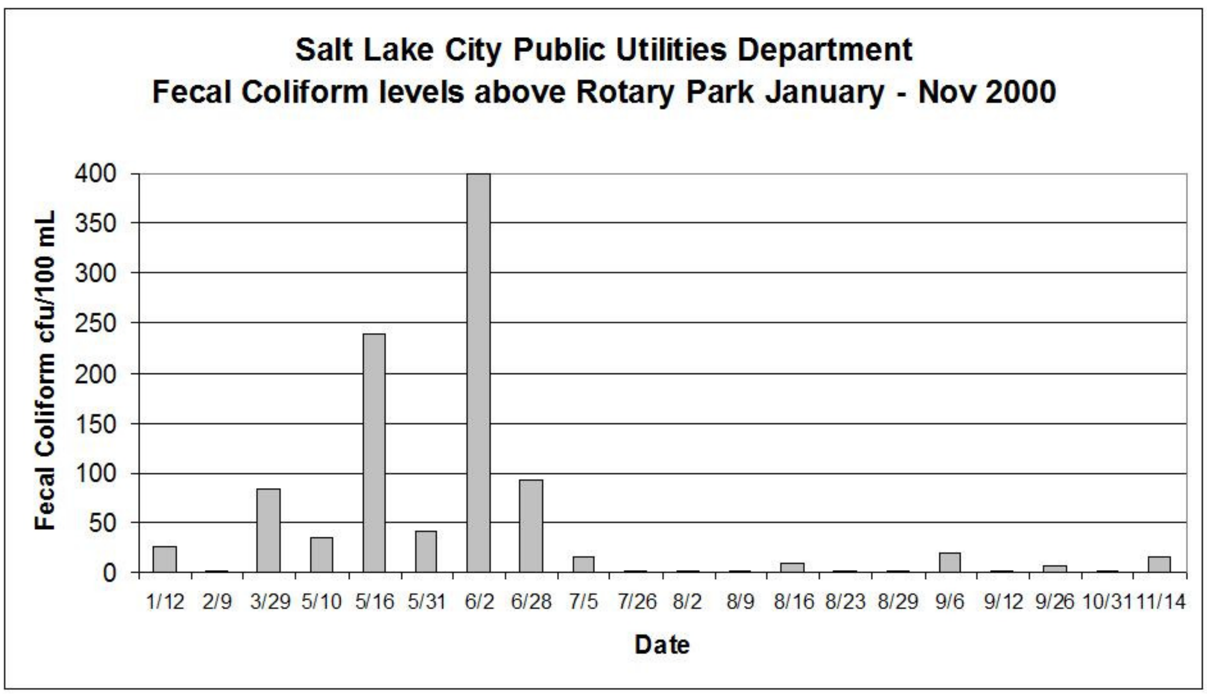

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Dec 1995
Fecal Coliform cfu/100 mL
400
350
300
250
200
150
100
50
0
1/27
2/15
3/17
4/11
5/23
6/1
7/11
8/22
9/12
10/11
10/24
11/7
12/5
Date

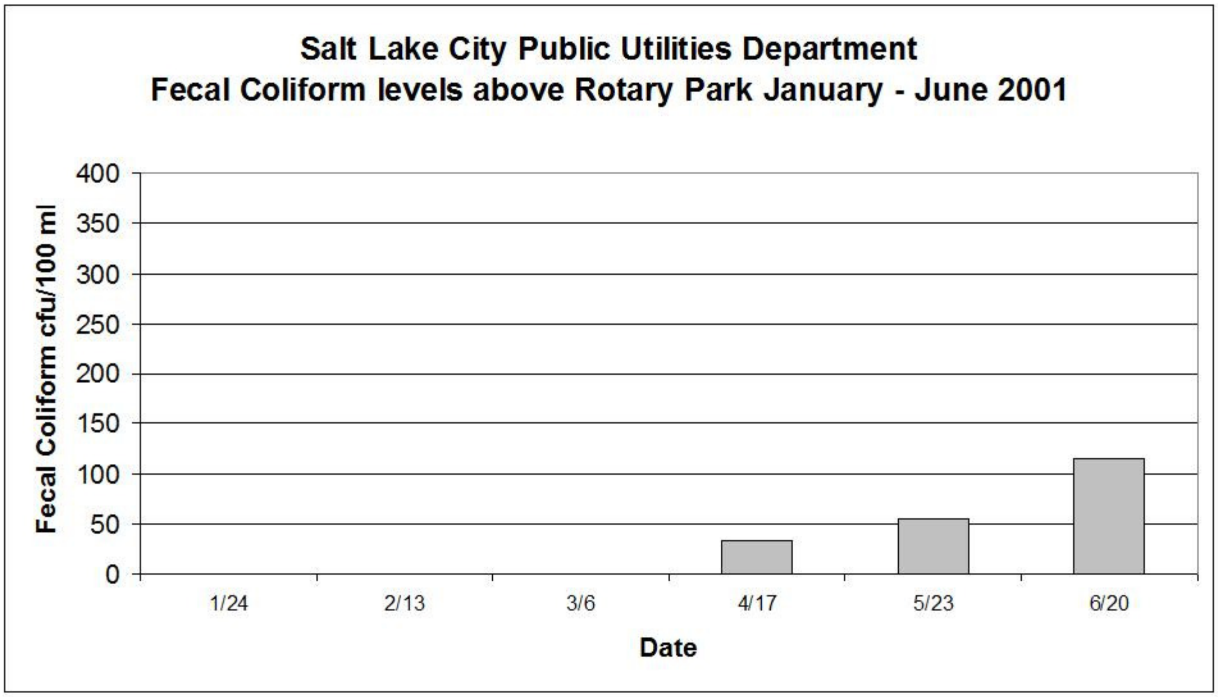

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Dec 1996
Fecal Coliform cfu/100 ml
400
350
300
250
200
150
100
50
0
1/10
2/14
3/12
4/7
5/15
6/11
6/25
7/9
7/30
8/6
8/20
9/10
9/24
10/8
11/19
12/17
Date

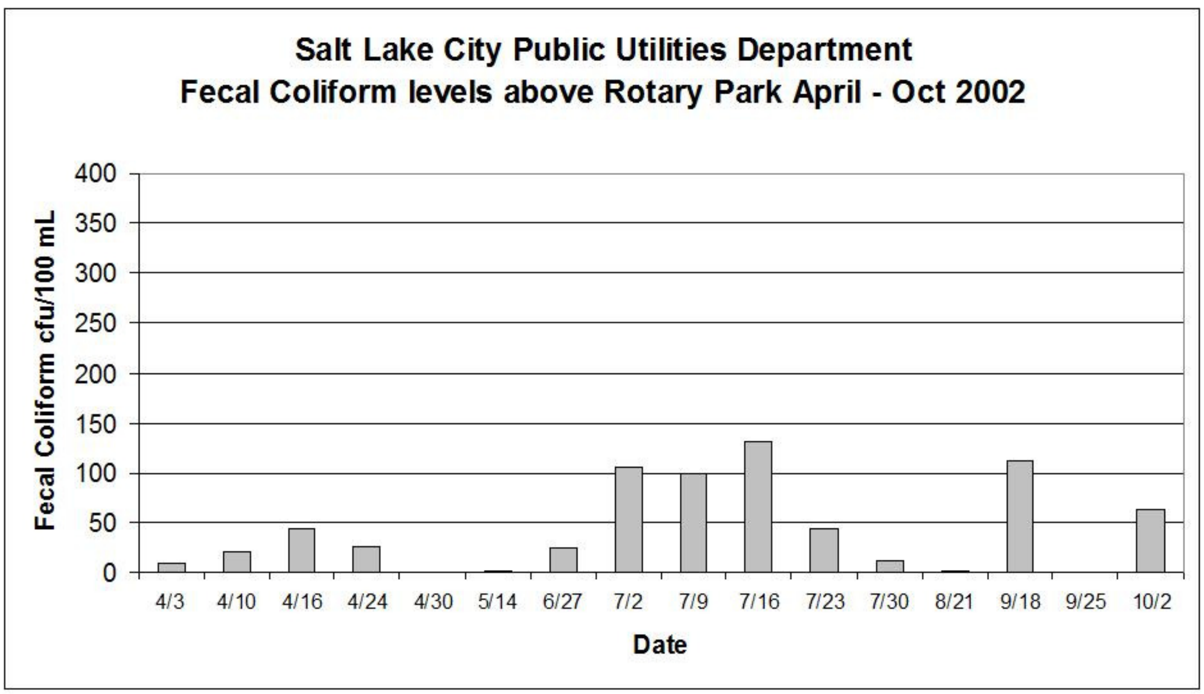

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Oct. 1997
Fecal Coliform cfu/100 ml
400
350
300
250
200
150
100
50
0
1/31
2/25
3/4
3/18
3/27
4/8
4/30
5/21
6/18
7/9
8/6
8/20
9/30
10/8
10/22
11/14
12/9
Date

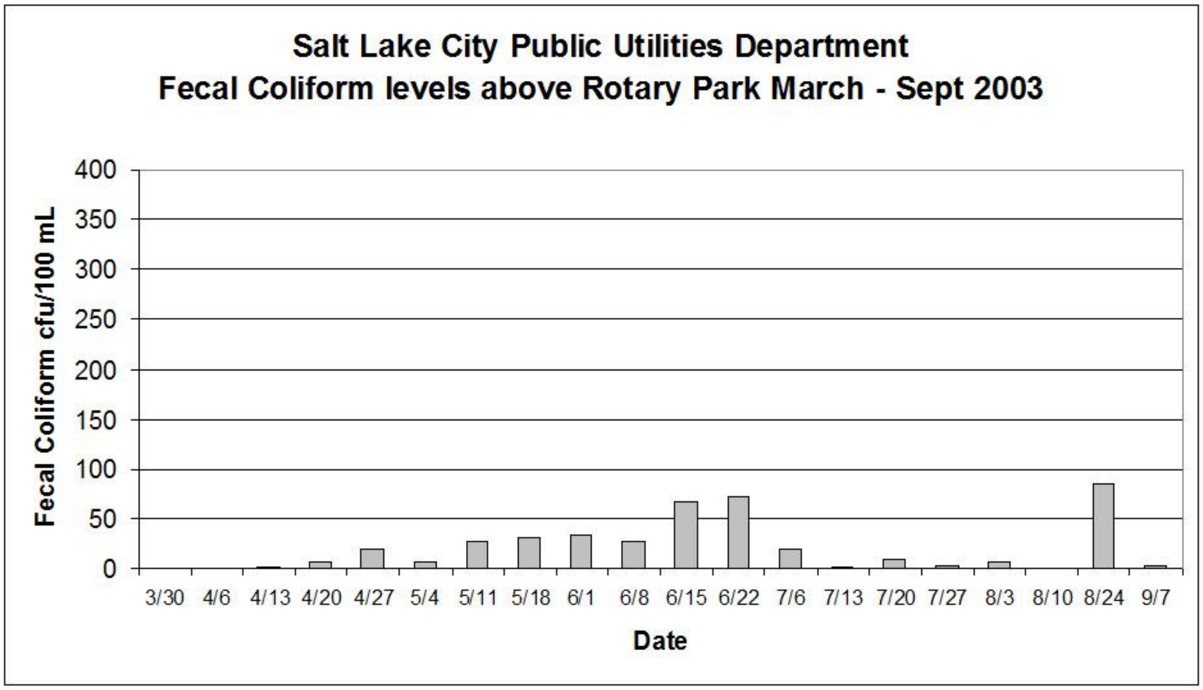

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Dec 1998
Fecal Coliform cfu/100 mL
400
350
300
250
200
150
100
50
0
1/21
3/17
4/8
4/22
5/6
5/20
6/3
7/1
7/15
7/29
8/12
8/26
9/9
10/7
10/21
Date

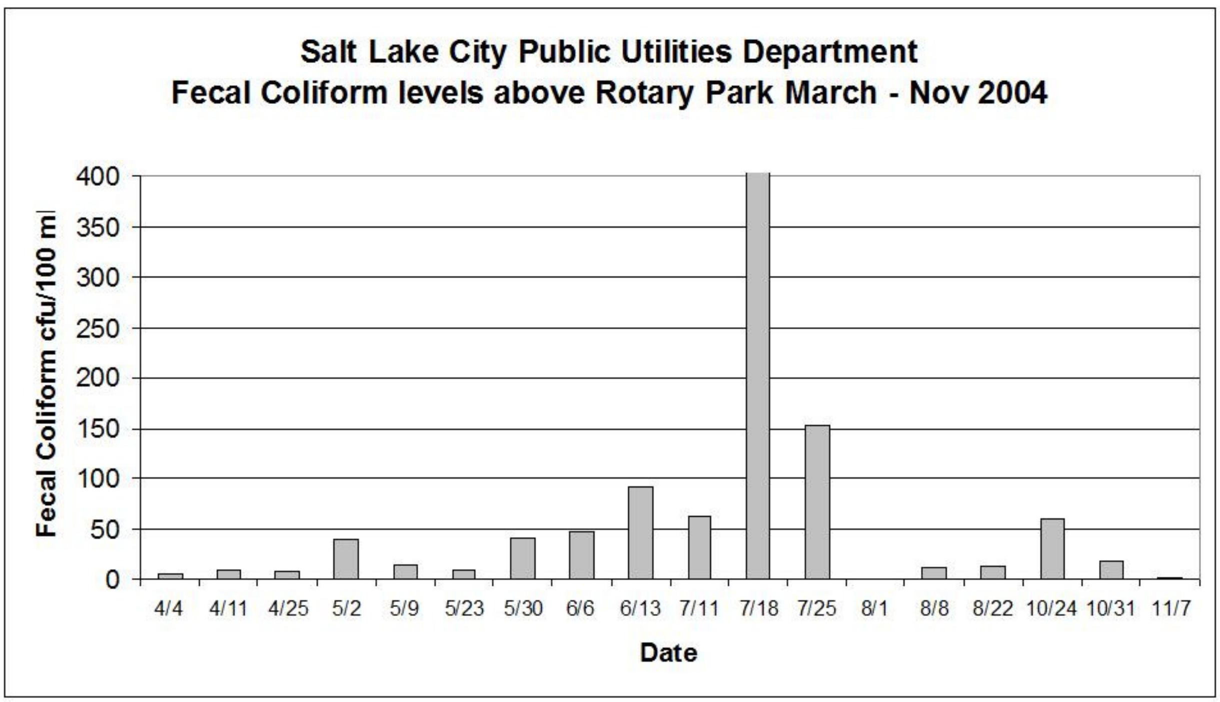

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - June 1999
Fecal Coliform cfu/100 ml
400
350
300
250
200
150
100
50
0
1/6
2/3
3/3
4/7
4/14
4/21
5/5
5/12
5/19
5/26
6/2
6/9
6/16
Date

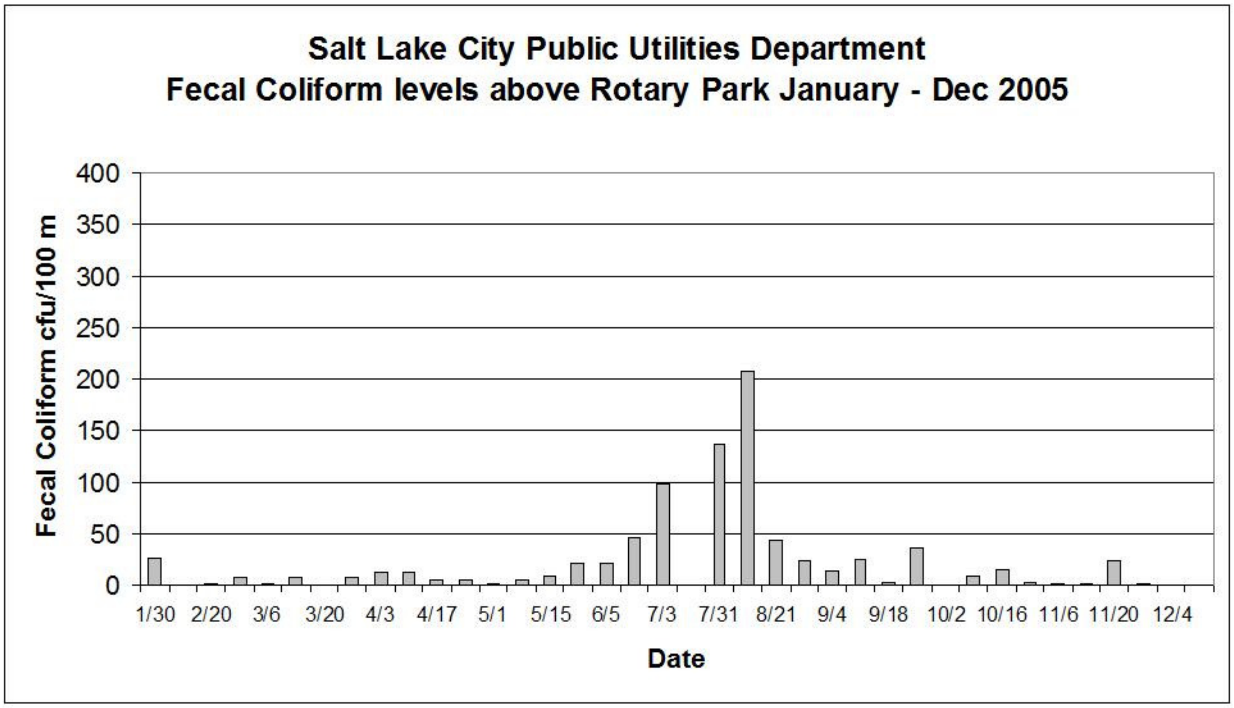

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Nov 2000
Fecal Coliform cfu/100 mL
400
350
300
250
200
150
100
50
0
1/12
2/9
3/29
5/10
5/16
5/31
6/2
6/28
7/5
7/26
8/2
8/9
8/16
8/23
8/29
9/6
9/12
9/26
10/31
11/14
Date

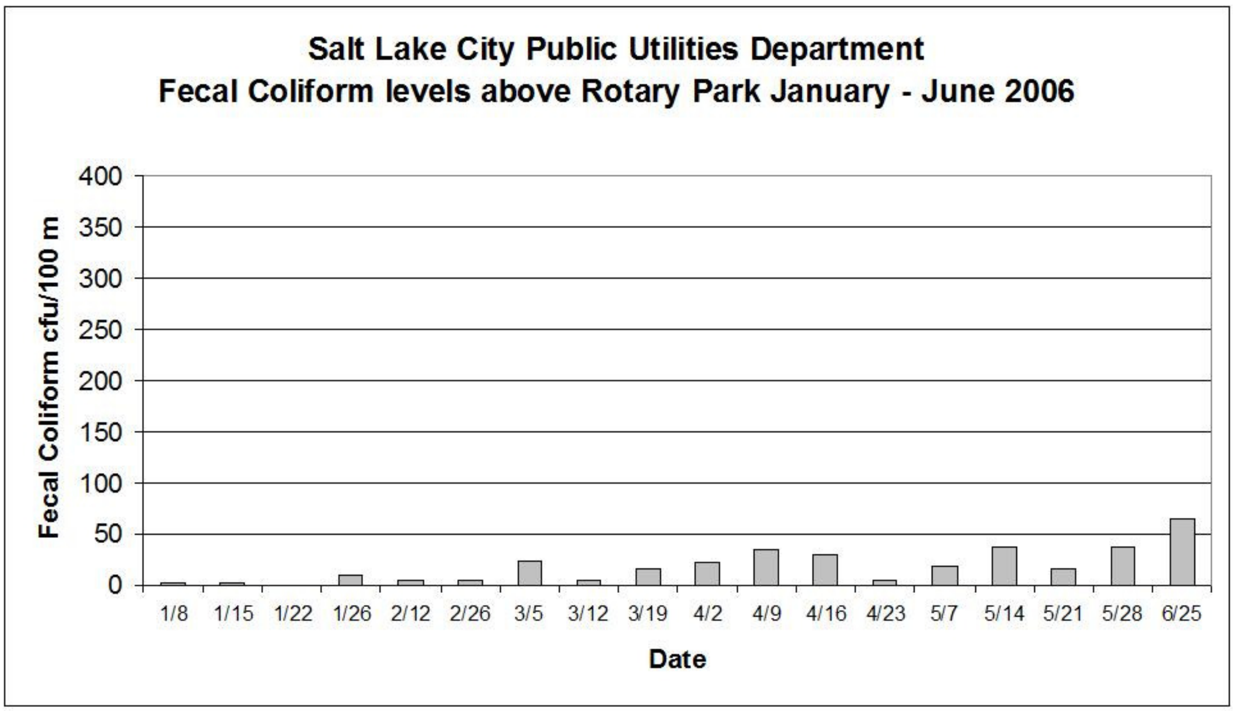

Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - June 2001
Fecal Coliform cfu/100 ml
400
350
300
250
200
150
100
50
0
1/24
2/13
3/6
4/17
5/23
6/20
Date


Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park April - Oct 2002
Fecal Coliform cfu/100 mL
400
350
300
250
200
150
100
50
0
4/3
4/10
4/16
4/24
4/30
5/14
6/27
7/2
7/9
7/16
7/23
7/30
8/21
9/18
9/25
10/2
Date


Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park March - Sept 2003
Fecal Coliform cfu/100 mL
400
350
300
250
200
150
100
50
0
3/30 4/6 4/13 4/20 4/27 5/4 5/11 5/18 6/1 6/8 6/15 6/22 7/6 7/13 7/20 7/27 8/3 8/10 8/24 9/7
Date


Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park March - Nov 2004
Fecal Coliform cfu/100 ml
400
350
300
250
200
150
100
50
0
4/4 4/11 4/25 5/2 5/9 5/23 5/30 6/6 6/13 7/11 7/18 7/25 8/1 8/8 8/22 10/24 10/31 11/7
Date


Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - Dec 2005
Fecal Coliform cfu/100 m
400
350
300
250
200
150
100
50
0
1/30
2/20
3/6
3/20
4/3
4/17
5/1
5/15
6/5
7/3
7/31
8/21
9/4
9/18
10/2
10/16
11/6
11/20
12/4
Date


Salt Lake City Public Utilities Department
Fecal Coliform levels above Rotary Park January - June 2006
Fecal Coliform cfu/100 m
400
350
300
250
200
150
100
50
0
1/8
1/15
1/22
1/26
2/12
2/26
3/5
3/12
3/19
4/2
4/9
4/16
4/23
5/7
5/14
5/21
5/28
6/25
Date

APPENDIX E UDWQ FLOW AND *E. COLI* DATA FOR TMDL

Burr Fork 4992162

Date	Flow (cfs)	E coli (MPN/100ml)
1/24/2007	0.97	13.1
2/12/2007	1.20	17.9
3/15/2007	2.86	7.0
4/5/2007	3.32	7.9
4/25/2007	2.64	4.9
5/15/2007	2.64	9.8
6/19/2007	1.32	72.6
6/28/2007	18.10	222.4
7/3/2007	17.66	66.3
7/9/2007	17.66	39.1
7/25/2007	15.97	96.0
8/2/2007	15.50	38.9
8/8/2007	14.73	76.9
9/21/2007	0.97	13.5
10/30/2007	0.25	9.6
11/21/2007	0.21	6.3
12/27/2007	0.35	2,419.6
1/25/2008	0.36	3.7
2/26/2008	0.26	1.0
4/17/2008	0.96	2.3
5/22/2008	13.15	2.0
6/24/2008	5.39	9.2
9/24/2008	1.20	1.0
12/16/2008	NA	3.7
1/26/2009	0.75	21.4
3/16/2009	1.73	7.5
4/21/2009	11.44	25.5
5/26/2009	6.86	23.8
6/16/2009	3.89	13.2
4/15/2010	5.83	10.6
5/6/2010	9.19	5.3
6/10/2010	8.37	58.4
7/20/2010	1.75	75.4
8/10/2010	1.09	72.3
9/7/2010	0.88	8.0

Emigration Creek at Maple Lane 4992158

Date	Flow (cfs)	E coli (MPN/100ml)
1/24/2007	0.65	1.9
2/12/2007	0.82	30.7
3/15/2007	5.20	6.2
4/5/2007	3.90	9.7
4/25/2007	2.14	2.5
5/15/2007	0.26	42.8
6/19/2007	0.98	25.4
6/28/2007	0.89	96.0
7/3/2007	0.41	166.4
7/9/2007	NA	69.3
7/25/2007	0.40	260.3
8/2/2007	NA	131.4
8/8/2007	0.27	170.4
9/21/2007	0.10	36.4
10/30/2007	0.25	4.0
11/21/2007	0.25	37.7
12/27/2007	0.70	5.1
1/25/2008	0.40	3.8
2/26/2008	0.65	4.0
4/17/2008	8.03	38.0
5/22/2008	11.37	5.1
6/24/2008	3.20	31.9
9/24/2008	0.26	42.8
12/16/2008	NA	1.3
1/26/2009	1.20	9.8
3/16/2009	2.06	3.4
4/21/2009	26.10	21.7
5/26/2009	11.10	8.9
6/16/2009	7.41	14.0

Emigration Creek at Maryfield 4992153

Date	Flow (cfs)	E coli (MPN/100ml)
1/24/2007	0.74	4.7
2/12/2007	1.54	27.8
3/15/2007	5.71	13.4
4/5/2007	3.57	7.8
4/25/2007	2.97	26.7
5/15/2007	0.30	9.9
6/19/2007	1.35	78.6
6/28/2007	1.80	90.8
7/3/2007	0.58	74.9
7/9/2007	NA	26.6
7/25/2007	0.60	387.3
8/2/2007	NA	146.7
8/8/2007	0.40	107.4
9/21/2007	0.10	9.7
10/30/2007	0.58	2.8
11/21/2007	0.40	3.2
12/27/2007	1.00	76.9
1/25/2008	0.50	93.2
2/26/2008	1.05	48.8
4/17/2008	12.43	92.8
5/22/2008	11.14	13.5
6/24/2008	3.60	189.1
9/24/2008	0.30	36.4
12/16/2008	NA	1.6
3/16/2009	2.70	868.1
4/21/2009	27.10	24.4
5/26/2009	9.25	378.0
6/16/2009	4.12	398.7
4/13/2010	NA	40.6
5/6/2010	NA	17.0
6/10/2010	NA	76.7
8/10/2010	NA	516.6
9/7/2010	1.03	94.2

Emigration Creek at Sunnydale 4992150

Date	Flow (cfs)	E coli (MPN/100ml)
1/24/2007	0.41	9.3
2/12/2007	2.44	80.6
3/15/2007	4.45	12.3
4/5/2007	2.27	8.1
4/25/2007	2.10	1.8
5/15/2007	0.10	1505.1
6/19/2007	0.87	108.2
6/28/2007	NA	235.9
7/3/2007	NA	191.8
7/9/2007	NA	435.2
4/17/2008	5.77	130.1
5/22/2008	8.17	30.2
6/24/2008	1.75	235.8
9/24/2008	0.10	1505.1
12/16/2008	NA	2.2
1/26/2009	NA	17.1
3/16/2009	1.97	19.4
4/21/2009	28.60	34.4
5/26/2009	9.91	1748.5
6/16/2009	6.84	507.9

Emigration Creek Above Rotary Park 4992145

Date	Flow (cfs)	E coli (MPN/100ml)
9/24/2008	NA	1.0
12/16/2008	NA	1.0
1/26/2009	0.41	1.3
3/16/2009	3.31	16.6
4/21/2009	NA	38.9
5/26/2009	NA	361.7
6/16/2009	3.84	25.9
9/23/2009	NA	557.9
9/30/2009	NA	297.5
10/28/2009	NA	1.0
11/23/2009	NA	1.0
1/25/2010	NA	2.9
2/17/2010	NA	2.1
3/15/2010	NA	1.3
4/12/2010	NA	14.6
5/10/2010	NA	38.5
6/7/2010	NA	194.0
7/6/2010	5	911.4
7/12/2010	3.9	195.0
7/19/2010	3.4	157.0
7/26/2010	2.9	1286.6
8/2/2010	1.8	108.8
8/9/2010	1.9	124.7
8/15/2010	2.6	104.9
8/23/2010	0.96	55.2

Emigration Creek Below Rotary Park 4992140

Date	Flow (cfs)	E coli (MPN/100ml)
1/24/2007	1.40	1.0
2/12/2007	3.20	113.0
3/15/2007	6.60	11.9
4/5/2007	4.50	4.1
4/25/2007	3.70	32.9
5/15/2007	3.70	90.2
6/19/2007	1.80	222.9
6/28/2007	1.70	95.8
7/3/2007	1.00	52.9
7/9/2007	1.00	93.4
7/25/2007	1.00	290.9
8/2/2007	1.00	261.3
8/8/2007	1.00	151.3
9/21/2007	1.00	90.9
10/30/2007	1.00	12.5
11/21/2007	2.00	5.5
12/27/2007	2.40	1.3
1/25/2008	2.20	1.0
2/26/2008	2.00	4.4
4/17/2008	12.00	149.8
5/22/2008	14.00	108.0
6/24/2008	5.90	250.3
9/24/2008	1.00	145.9
12/16/2008	0.80	12.1
1/26/2009	1.00	15.8
3/16/2009	4.3	13.8
4/21/2009	50.5	47.4
5/26/2009	21	47.0
6/16/2009	15.7	24.5
9/23/2009	1.7	536.2
9/30/2009	2.6	547.3
10/28/2009	2.3	6.9
11/23/2009	2.4	17.5
1/25/2010	2.4	1.0
2/17/2010	2.4	19.4
3/15/2010	2.4	1.0
4/12/2010	5.9	23.6
4/13/2010	8.1	13.0
5/6/2010	18.1	25.7
5/10/2010	18.1	54.4
6/7/2010	15.7	358.5
7/6/2010	3.1	490.9

7/12/2010	2.3	1954.3
7/19/2010	2.3	326.0
7/26/2010	2.4	2419.6
8/2/2010	2.6	460.3
8/9/2010	2.6	394.7
8/10/2010	2.6	141.2
8/15/2010	1.6	1532.8
8/23/2010	2.6	286.3
9/7/2010	1.7	1009.2