



ASSESSMENT OF FECAL COLIFORM IN LITTLE RABBIT CREEK AND LITTLE SURVIVAL CREEK

FINAL REPORT

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1. Overview

This final report is being prepared under Grant Number ACWA 08-12, Assessment of Fecal Coliform in Little Rabbit Creek and Little Survival Creek. The grant agreement is between the Alaska Department of Environmental Conservation (ADEC) Division of Water (grantor), and the Anchorage Waterways Council (AWC)(grantee).

Little Rabbit and Little Survival Creeks are located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in southcentral Alaska. The state of Alaska included both creeks as Category 4a waters (impaired with a completed Total Maximum Daily Load (TMDL)) in the 2004 Integrated Water Quality Monitoring and Assessment Report (ADEC, 2006a) and the EPA lists both creeks in its 1998 303(d) list as water quality-limited due to non-attainment of the fecal coliform bacteria standard, identifying urban runoff as the pollutant source.

Applicable water quality standards for fecal coliform in Little Rabbit and Little Survival Creeks establish water quality criterion for the protection of designated uses for water supply, water recreation, and growth and propagation of fish, shellfish, other aquatic life, and wildlife. The TMDL was developed for the most stringent of these—the fecal coliform criteria for drinking, culinary, and food processing water supply and states that in a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10% of the samples may exceed 40 FC/100 ml. (18 AAC 70.020(b)(2)(A)(i)) (ADEC, 2006b). Past fecal coliform data has indicated that Little Rabbit and Little Survival Creeks do not meet the applicable water quality standards.

The ADEC initiated this project to collect updated data on both creeks, to determine the current water quality status, and to reassess the listing of these waterbodies.

2. Location and Physical Description of Study Sites

2.1 Geography

Little Rabbit Creek and Little Survival Creek are located in the Anchorage Bowl, the urban center of the Municipality of Anchorage (MOA) in southcentral Alaska (Figure 1). The Anchorage Bowl is a broad valley, bordered to the east by the Chugach Mountain Range, to the northwest by Knik Arm, and to the southeast by Turnagain Arm of Cook Inlet (Figure 1).

Little Rabbit Creek is located in southeast Anchorage and is the main tributary to Rabbit Creek, which is one of several creeks that flow into Potter Marsh. Little Rabbit Creek begins in the Chugach Mountains at an elevation of 4,200 ft and flows through the mountains to the valley where it discharges to Rabbit Creek at an elevation of 100 ft (ADEC, 2004a). Little Survival Creek has an elevation of 2,300 ft in the upper portions of the watershed and varies from 0-100 ft at the mouth (ADEC, 2004b).

2.2 Land Use

The dominant land use in the Little Rabbit Creek watershed is “Vacant/Intertidal” (54%), followed by “Parks and Open Space” (23%) which includes the Chugach State Park, and residential (16%) (ADEC, 2004a). Less than 1% of the watershed falls under “Industrial” and “Commercial” uses (ADEC, 2004a). Two estimates of population in the Little Rabbit Creek watershed were available: 769 and 975 (ADEC, 2004a).

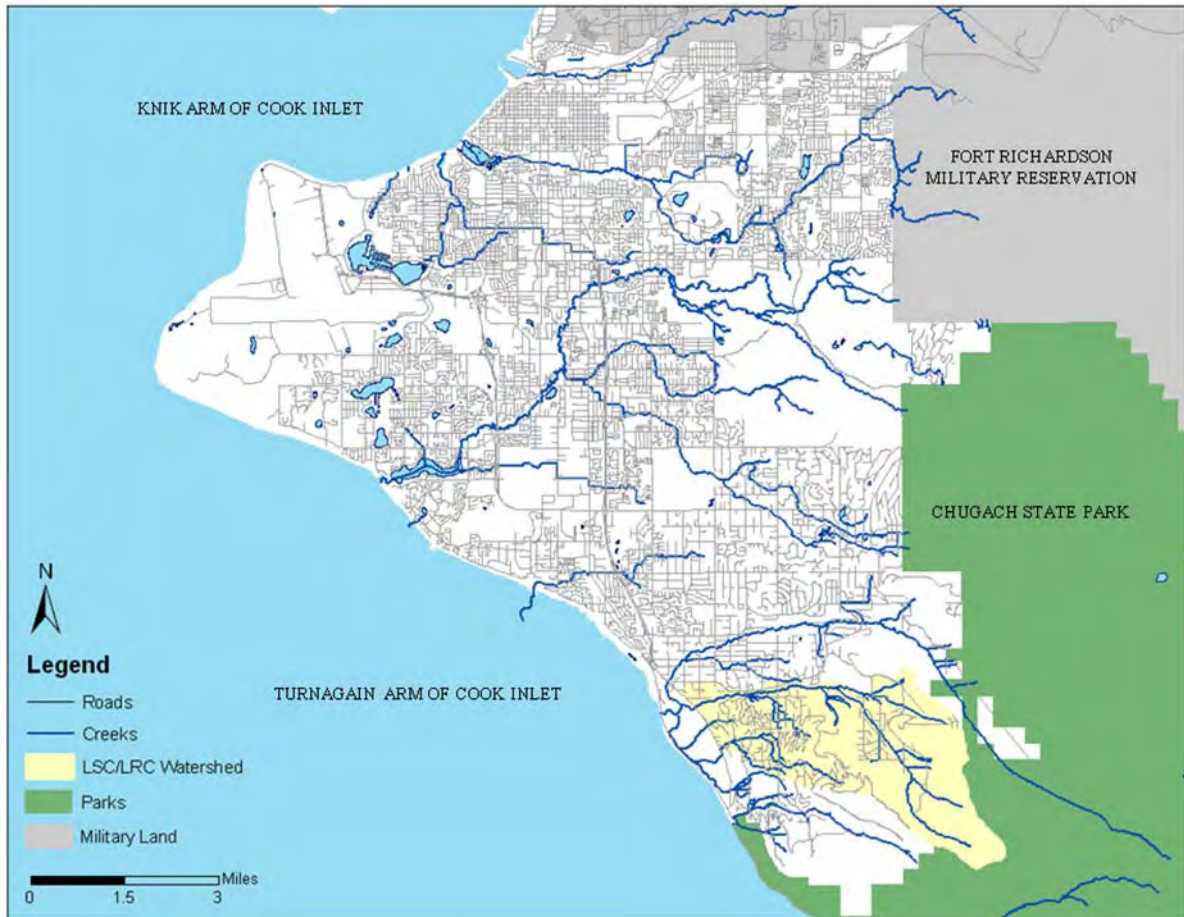


Figure 1. Map of the Municipality of Anchorage (white), showing the study area of Little Rabbit and Little Survival Creeks (yellow).

The dominant land use in the Little Survival Creek watershed is “Vacant/Intertidal” (53%), followed by “Residential” (39%) and “Rights of Way” (8%) (ADEC 2004b). One percent of the watershed is categorized as “Industrial” and 0% as “Commercial” (ADEC, 2004b). Two estimates of population in the Little Survival Creek watershed were available: 50 (based on the 2000 census data) and 460 (ADEC, 2004b).

2.3 Climate

Anchorage is located in a transitional climate zone in Alaska, between maritime and continental zones. The climate is warmer and wetter than the continental, interior climate zone and cooler and drier than the maritime, coastal climate zone (Dilley and Dilley, 2000). Transitional zone temperatures normally range from 0°F–65°F (WWRC, 2002). Temperatures are moderated by the surrounding mountain ranges and Cook Inlet. In Anchorage, the average high temperature is 42.9°F and the average low is 28.9°F based on data from Ted Stevens International Airport from April 1952-December 2000; monthly averages are provided in Figure 2.

The Chugach Mountains serve as a barrier for the warm, moist air from the Gulf of Alaska and the result is often precipitation. Average annual precipitation (rain and snowmelt) is less than 20 inches (Dilley and Dilley, 2000). Average annual snowfall ranges from approximately 70 inches on the west side of

Anchorage and 90 inches on the east side; total snow increases as elevation increases in the Chugach Mountains (AWSO, 1997). Average monthly snowfall data from Anchorage’s official measuring station at Ted Stevens International Airport are shown below (Figure 3).

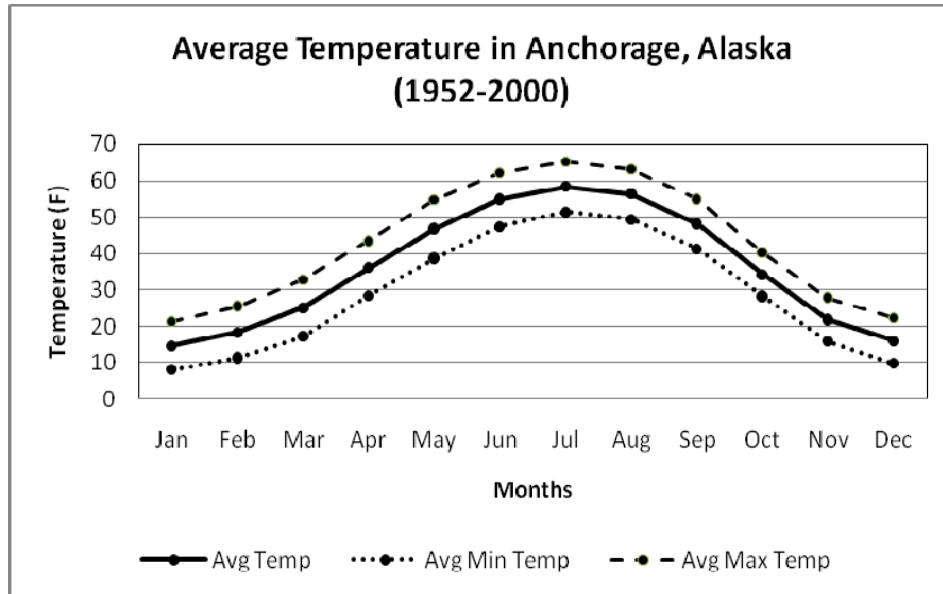


Figure 2. Average temperature in Anchorage, Alaska by month, based on climate data collected at Ted Stevens International Airport from 1952-2000.

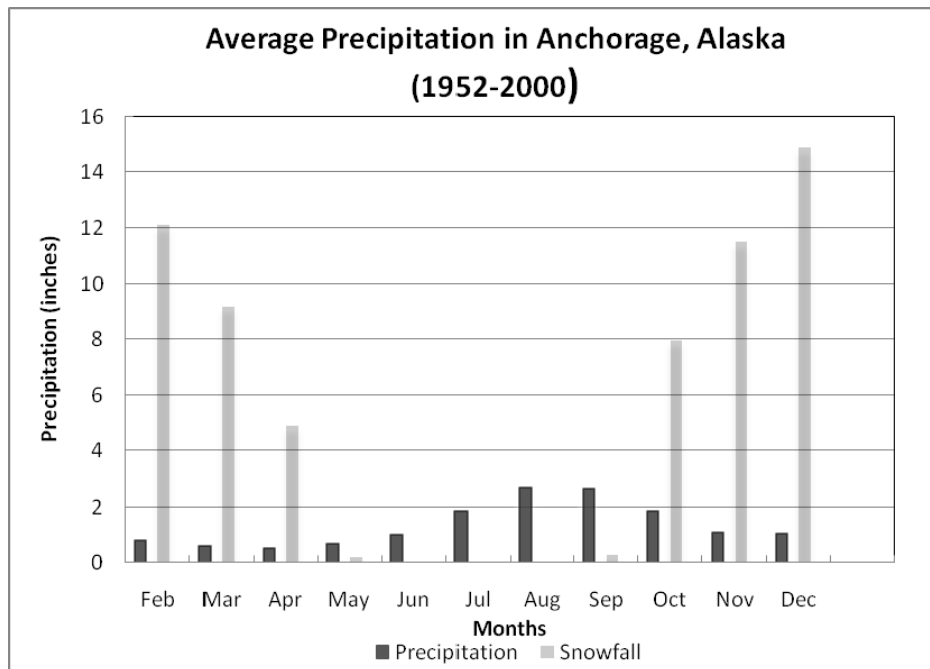


Figure 3. Average precipitation and snowfall in Anchorage, Alaska by month, based on climate data collected at Ted Stevens International Airport from 1952-2000.

2.4 Hydrology

Little Rabbit Creek is approximately 7 miles long and watershed estimates range from 3,814 to 4,228-acres (ADEC, 2004a). The headwaters of the creek begin in the Chugach Mountains and flow northwesterly to the confluence with Rabbit Creek in the Potter Marsh area. While there are no known storm drains connected to the creek (ADEC, 2004a), ditches often parallel the roads in the developed parts of the watershed, delivering water and sediments to the creeks during periods of heavy rain or snowmelt.

Little Survival Creek is approximately 4 miles long and watershed estimates range from 700 to 1152-acres (ADEC 2004b). The headwaters of Little Survival Creek also begin near the Chugach Mountains and drains to Potter Marsh near Turnagain Arm. Other than contributions from roadside ditches, there are no piped storm water outfalls to the creek (ADEC, 2004b).

The USGS maintained two continuous streamflow gages in the Little Rabbit Creek watershed in the early 1980's. Data from these gages show increases in flow in the spring, due to snowmelt, and high flows in the summer and fall, due to summer and fall storms (ADEC, 2004a). Low flow occurs during the winter months.

There are no current or historic streamflow gages in the Little Survival Creek watershed.

3. Summary of Pre-existing Water Quality Status

Title 18, Chapter 70 of the Alaska Administrative Code (ACC) establishes water quality standards for the State of Alaska. The ACC also includes designated "uses" that are to be protected and the water quality criteria necessary to ensure protection of those uses. The following uses have been designated and apply to Little Rabbit Creek and Little Survival Creek: 1) water supply, 2) water recreation, and 3) growth and propagation of fish, shellfish, and other aquatic life.

Past data indicate that Little Rabbit and Little Survival Creeks did not meet the applicable water quality standards. The largest and most frequent exceedances of the water quality criteria in both creeks occurred during summer months, likely due to increased stormwater runoff and source activity (i.e., wildlife). Fecal coliform concentrations were lower during colder winter months that experience less stormwater runoff. Concentrations steadily increased during spring months, with increased surface runoff during spring thaw and breakup.

3.1 Non-attainment of Fecal Coliform Bacteria Standard

In 1994 the State of Alaska included Little Rabbit and Little Survival Creeks in the EPA's Section 303(d) impaired waters list for non-attainment of the fecal coliform Bacteria standard (ADEC, 2006a). A Total Maximum Daily Load (TMDL) for fecal coliform was developed and approved by the EPA in 2004, attributing summer spikes in fecal coliform exceedances to increased stormwater runoff and increased source activity (i.e., wildlife) (ADEC, 2004a&b). Both creeks were removed from the Section 303(d) list after the TMDL's were developed and are currently listed as a Category 4a waters in Alaska's 2006 Integrated Water Quality Monitoring and Assessment Report, for non-attainment of the fecal coliform Bacteria standard due to urban runoff (ADEC, 2006a). Class 4a waters are designated as impaired, but not needing a TMDL because one has already been completed. The Alaska Water Quality Standards for fecal coliform are presented in Table 1.

Because Little Rabbit and Little Survival Creeks did not have a record of corresponding flow and water quality data, the TMDL's were developed using a simple approach that uses an empirical equation to

calculate pollutant loading in the absence of flow data. The Simple Method (Schueler, 1987) was used for the TMDL analysis. The Simple Method is a lumped parameter empirical model used to estimate stormwater pollutant loadings under conditions of limited data availability. The approach calculates pollutant loading using drainage area, event mean pollutant concentrations, precipitation and a runoff coefficient based on impervious area in the watershed. The method was used to calculate existing fecal coliform loading based on observed fecal coliform data and the loading capacity for the streams based on instream concentrations representing water quality standards.

Table 1. Alaska water quality standards for fecal coliform bacteria (Source: ADEC, 2006b).

Water Use	Fecal Coliform Bacteria Standard
(A) Water Supply (i) drinking, culinary and food processing	In a 30-day period, the geometric mean may not exceed 20 FC/100 ml, and not more than 10% of the samples may exceed 40 FC/100ml. For groundwater, the FC concentration must be less than 1 FC/100 ml, using the fecal coliform Membrane Filter Technique, or less 3 FC/100 ml, using the fecal coliform most probable number (MPN) technique.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	The geometric mean of samples taken in a 30-day period may not exceed 200 FC/100ml, and not more than 10% of the samples may exceed 400 FC/ml. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for drinking water supply, (1)(A)(i), apply.
(A) Water Supply (iii) aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100ml, and not more than 10% of the samples may exceed 400 FC/100ml. For products not normally cooked, the criteria for drinking water supply (1)(A)(i), apply.
(A) Water Supply (iv) industrial	Where worker contact is present, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml.
(B) Water Recreation (i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml.
(B) Water Recreation (ii) secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 FC/100 ml, and not more than 10% of the total samples may exceed 400 FC/100ml.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Not applicable.

4. Summary of Sampling Methods

The purpose of the work described in the remainder of this report was to monitor fecal coliform levels along with concurrent flow measurements and reassess the non-attainment status of the creeks with respect to the fecal coliform standards, identify possible sources, and determine temporal and spatial fluctuations. Turbidity measurements were also collected to identify any possible correlations between turbidity and fecal coliform bacteria.

4.1 Sample Collection

Fecal coliform bacteria samples, turbidity measurements, and flow data were collected once a week from five sites on Little Rabbit Creek and five sites on Little Survival Creek for a sampling period of 12

months. While a 12 month period was the goal, actual sampling was limited to months when the creek was ice free. A duplicate sample was collected each week for a frequency of 10%.

All samples were collected in accordance with AWC’s ADEC approved Quality Assurance Project Plan. Laboratory samples for fecal coliform, and water samples for turbidity were collected first from each site to minimize the disturbance of stream sediment. Fecal coliform samples were collected in sterile 100 ml containers provided by the SGS Environmental Services. Turbidity samples were collected in the instrument container designed for the LaMotte Model 2020e Portable Turbidity Meter . The hand-held dip sampling procedure for non-isokinetic sampling of surface waters method described in the USGS National Field Manual for the Collection of Water-Quality Data (USGS, 2006) was used.

Stream discharge or flow was measured in cubic feet per second using a Swoffer 3000-13 Current Velocity Meter. Data was recorded at each sampling location after each sample was collected. Sample locations were selected at the downstream end of a straight riffle with a run of at least six feet where possible. A semi-permanent transect was established at each sample location and a minimum of five nodes per transect was established. The Flow Protocols contained in the Standard Operating Procedures for the Quality Assurance Project Plan for the AWC CEMP was used for measurement of streamflow.

4.2 Sampling Locations

Sampling locations were selected in consultation with ADEC staff to represent waters with no urban impact (headwaters), all urban impacts (mouth of creek), and immediately downstream of areas with common land use practices. Sampling locations for Little Rabbit Creek are described in Table 2 and shown on Figure 4. Sampling locations for Little Survival Creek are described in Table 3 and shown on Figure 5.

Table 2. Sampling site descriptions for Little Rabbit Creek.

Site Name	Site Description
LRC1	Upstream of Kings Way Drive, just south of Paine Road; this site is as near the headwaters as access allowed.
LRC2	Approximately 150 yards west of the end (gate) of Jamie Avenue, at wooden bridge.
LRC3	Just upstream of Goldenview Drive.
LRC4	Immediately downstream of Bridgeview Drive, just south of Rabbit Creek Road. This site is just below the confluence of Little Rabbit and a southern branch of the creek which is heavily channelized.
LRC5	Approximately 50 yards upstream from Old Seward Highway, near the AWC’s CEMP site (MaLRab02v).

Table 3. Sampling site descriptions for Little Survival Creek.

Site Name	Site Description
LSC1	Downstream of Mountainside Village Drive.
LSC2	Downstream of Ashland Drive.
LSC3	Upstream of Goldenview Drive.
LSC4	Immediately upstream of Tideview Drive.
LSC5	Just downstream of pump station driveway south of Tideview Drive on the Old Seward Highway.

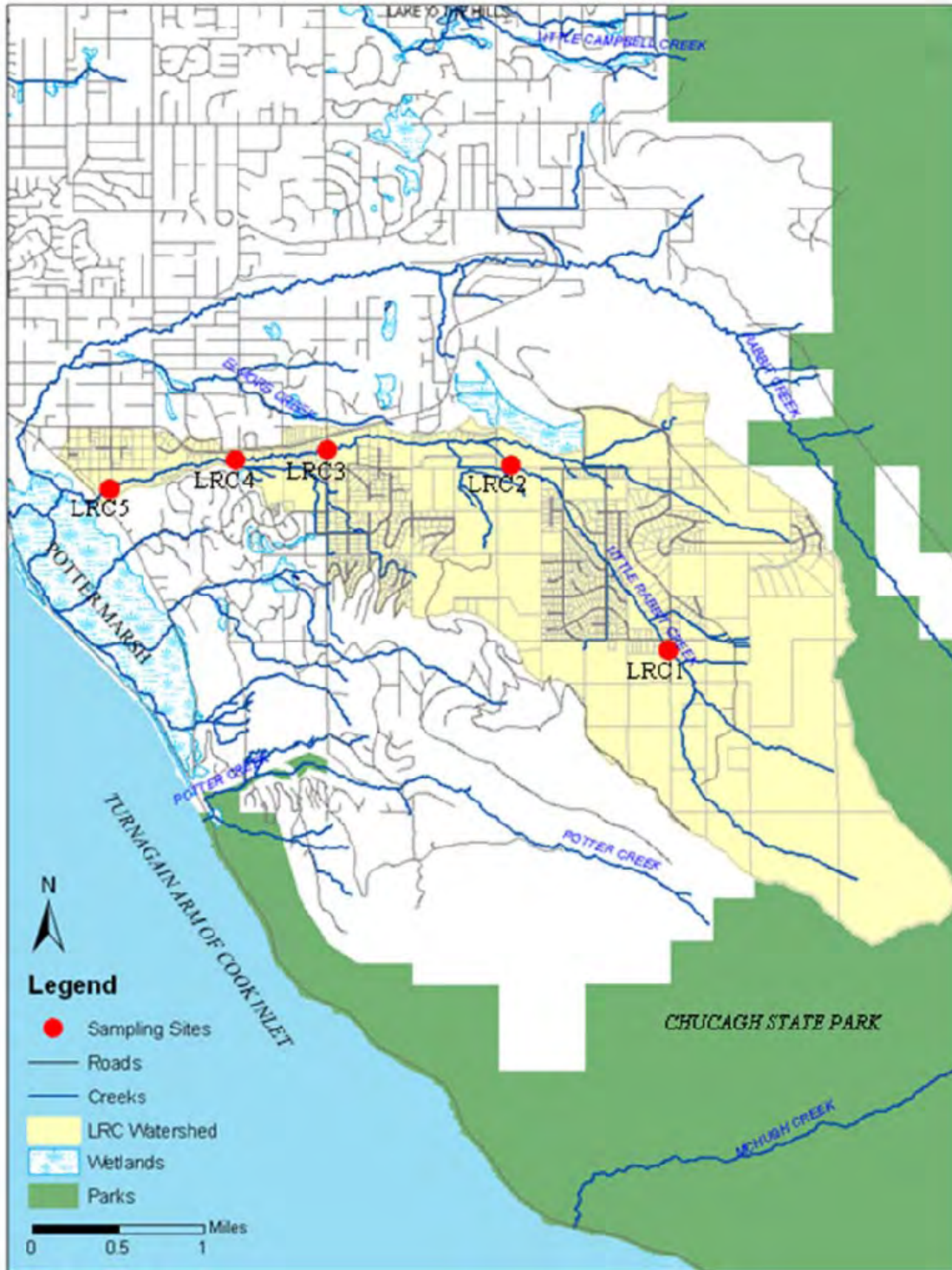


Figure 4. Map showing the five sampling sites located on Little Rabbit Creek, starting near the headwaters at LRC1.



Figure 5. Map showing the five sampling sites located on Little Survival Creek, starting near the headwaters with LSC1.

5. Little Rabbit Creek Data Analysis

5.1 Descriptive Statistics

5.1.1 Turbidity

Turbidity in Little Rabbit Creek for the sampling period ranged from 0.21- 51.00 Nephelometric Turbidity Units (NTU's), with a median of 2.76 and an average of 6.40 NTU's. Turbidity was highest in September 2007 and was lowest in October 2007; turbidity was moderate in the remainder of the sampling period (May-June 2008) (Figure 6). Monthly descriptive statistics are included for Little Rabbit Creek in Table 4.

Turbidity also varied between the five sampling sites located on Little Rabbit Creek. The highest turbidity was recorded at LRC5, the most downstream site, while the lowest turbidity was recorded at LRC1, the site closest to the headwaters of the creek (Table 5, Figure 6). A summary of the data, by site and month is shown in Table 6.

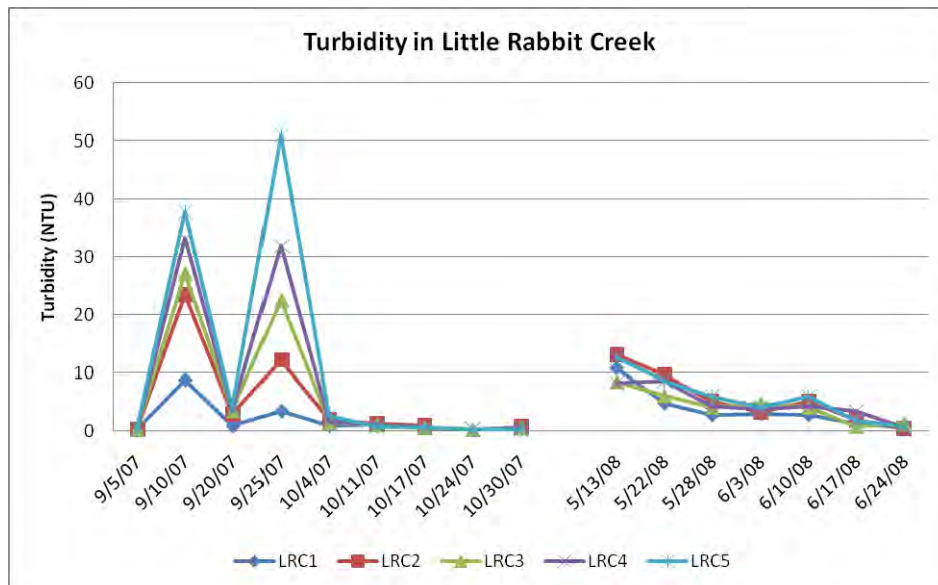


Figure 6. Turbidity in Little Rabbit Creek during the study period.

Table 4. Summary of Little Rabbit Creek turbidity data by month.

Month	No. of samples	Turbidity (NTU)			
		Min	Median	Mean	Max
September 2007	20	0.21	3.87	13.40	51.00
October 2007	23	0.27	3.87	0.93	2.64
May 2008	15	2.76	8.27	7.55	12.60
June 2008	20	0.45	2.85	2.70	6.02

Table 5. Summary of Little Rabbit Creek turbidity data by site.

Sampling Site	No. of Samples	Sampling Period		Turbidity (NTU)			
		Start Date	End Date	Min	Median	Mean	Max
LRC1	16	9/5/2007	6/24/2008	0.21	1.11	2.83	10.76
LRC2	16	9/5/2007	6/24/2008	0.24	2.92	5.49	23.50
LRC3	16	9/5/2007	6/24/2008	0.29	2.48	5.45	27.10
LRC4	16	9/5/2007	6/24/2008	0.30	3.49	6.64	33.20
LRC5	16	9/5/2007	6/24/2008	0.53	3.40	8.64	51.00

Table 6. Summary of Little Rabbit Creek turbidity, summarized by month and site.

Site: LRC1		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.21	2.12	3.29	8.72
October 2007	4	0.63	0.92	0.90	1.11
May 2008	3	2.76	4.79	6.10	10.76
June 2008	4	0.54	1.96	1.85	2.94
Site: LRC2		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.24	7.56	9.72	23.50
October 2007	4	0.82	1.11	1.24	1.92
May 2008	3	0.24	9.63	9.28	23.50
June 2008	4	0.45	3.50	2.69	5.10
Site: LRC3		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.29	13.02	13.31	27.1
October 2007	5	0.27	0.64	0.80	1.42
May 2008	3	4.13	6.08	6.24	8.51
June 2008	4	0.81	2.74	2.77	4.78
Site: LRC4		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.30	17.75	17.25	33.2
October 2007	5	0.28	0.60	0.81	1.59
May 2008	3	4.26	8.27	7.07	8.67
June 2008	4	0.68	3.54	3.00	4.26
Site: LRC5		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.53	20.98	23.37	51.0
October 2007	5	0.29	0.57	0.94	2.64
May 2008	3	6.02	8.62	9.08	12.60
June 2008	4	0.75	3.00	3.19	6.02

5.1.2 Stream flow

Flow in Little Rabbit Creek for the sampling period ranged from 1.03-32.71 cubic feet per second (cfs), with a median of 6.64 and an average of 6.95 cfs. Flow was highest in September 2007, with lower but comparable flows during the remainder of the study period (Figure 7). Monthly descriptive statistics are included for Little Rabbit Creek in Table 7.

Flow also varied between the five sampling sites located on Little Rabbit Creek. The highest flow was observed at LRC5, the most downstream site, while the lowest flow was observed at LRC1, near the headwaters of the creek (Table 8, Figure 7). A summary of the data, by site and month is shown in Table 9.

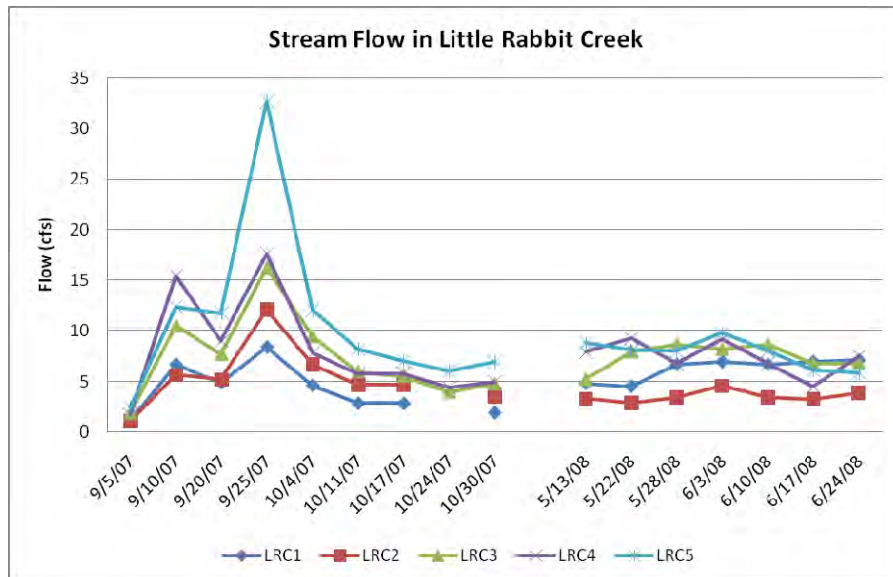


Figure 7. Stream flow in Little Rabbit Creek during the study period.

Table 7. Summary of Little Rabbit Creek stream flow data by month.

Month	No. of samples	Flow (cfs)			
		Min	Median	Mean	Max
September 2007	20	1.03	8.05	9.22	32.71
October 2007	23	1.91	5.57	5.67	12.1
May 2008	15	2.93	6.74	6.42	9.24
June 2008	20	3.25	6.81	6.56	9.81

Table 8. Summary of Little Rabbit Creek stream flow data by site.

Sampling Site	No. of Samples	Sampling Period		Flow (cfs)			
		Start Date	End Date	Min	Median	Mean	Max
LRC1	15	9/5/2007	6/24/2008	1.03	4.78	5.10	8.36
LRC2	15	9/5/2007	6/24/2008	1.09	3.90	4.56	12.09
LRC3	16	9/5/2007	6/24/2008	1.82	7.28	7.41	16.29
LRC4	16	9/5/2007	6/24/2008	1.68	7.12	7.75	17.59
LRC5	16	9/5/2007	6/24/2008	2.44	8.07	9.66	32.71

Table 9. Summary of Little Rabbit Creek stream flow data, summarized by month and site.

Site: LRC1		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	1.03	11.49	5.22	8.36
October 2007	4	1.91	2.82	3.03	4.59
May 2008	3	4.50	4.78	5.31	6.64
June 2008	4	6.64	6.78	6.90	7.10
Site: LRC2		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	1.09	5.43	6.01	12.09
October 2007	4	3.49	4.67	4.87	6.66
May 2008	3	2.93	3.31	3.24	3.47
June 2008	4	3.25	3.69	3.80	4.58
Site: LRC3		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	1.82	9.15	9.10	16.29
October 2007	5	3.96	5.57	5.95	9.49
May 2008	3	5.23	7.95	7.29	8.69
June 2008	4	6.78	7.52	7.63	8.69
Site: LRC4		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	1.68	12.18	10.91	17.59
October 2007	5	4.35	5.76	5.73	7.79
May 2008	3	6.74	7.88	7.95	9.24
June 2008	4	4.51	7.12	6.99	7.50
Site: LRC5		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	2.44	12.11	12.11	32.71
October 2007	5	6.06	7.07	7.07	12.10
May 2008	3	8.04	8.09	8.09	8.83
June 2008	4	5.91	7.09	7.48	9.81

5.1.3 Fecal Coliform Bacteria

Fecal coliform concentrations in Little Rabbit Creek for the sampling period ranged from 0-9500 Fecal Colonies/100ml, with a median concentration of 21 and a mean of 223 FC/100ml. Fecal coliform concentrations were highest in September 2007, and lowest in June 2008 (Figure 8). Monthly descriptive statistics are included for Little Rabbit Creek in Table 10.

Fecal coliform concentrations also varied between the five sampling sites located on Little Rabbit Creek. The highest concentrations were observed at LRC4, the second most downstream site, while the lowest concentrations were observed at LRC1, near the headwaters of the creek (Table 11, Figure 8). A summary of the data, by site and month, is shown in Table 12.

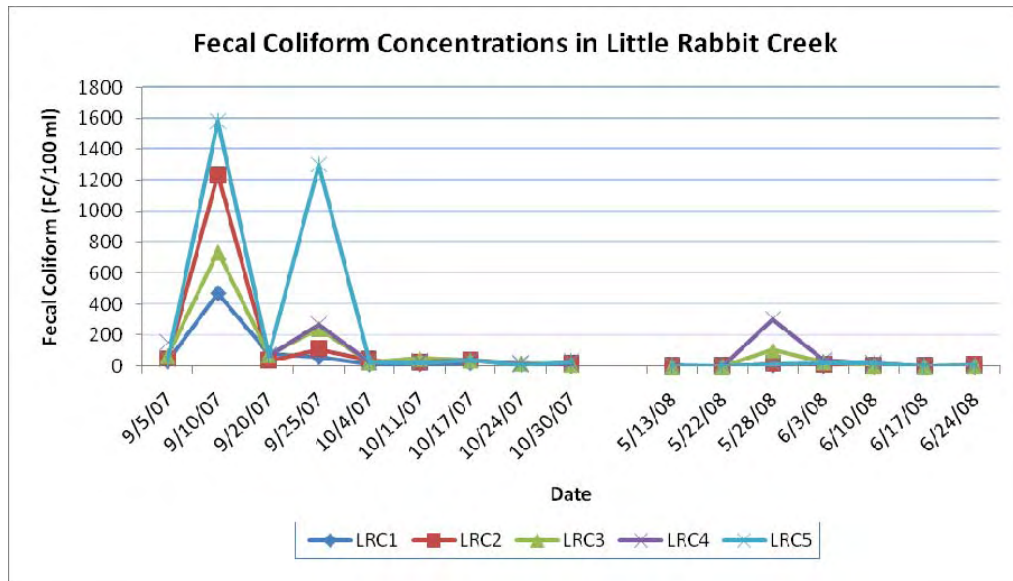


Figure 8. Fecal coliform concentrations in Little Rabbit Creek during the study period.

Table 10. Summary of Little Rabbit Creek fecal coliform data by month.

Month	No. of samples	Fecal Coliform (FC/100ml)			
		Min	Median	Mean	Max
September 2007	20	34	95.5	808.85	9500
October 2007	23	5	23	25.30	51
May 2008	15	0	2	30.6	304
June 2008	20	0	4.5	9.3	41

Table 11. Summary of Little Rabbit Creek fecal coliform data by site.

Sampling Site	No. of Samples	Sampling Period		Fecal Coliform (FC/100ml)			
		Start Date	End Date	Min	Median	Mean	Max
LRC1	15	9/5/07	6/24/08	0	6	48	470
LRC2	15	9/5/07	6/24/08	1	18	106	1236
LRC3	16	9/5/07	6/24/08	0	29	89	736
LRC4	16	9/5/07	6/24/08	1	29	656	9500
LRC5	16	9/5/07	6/24/08	1	24	199	1582

Table 12. Summary of Little Rabbit Creek fecal coliform data by month and site.

Site: LRC1		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	34	70.50	161.25	470
October 2007	4	5	14	14	23
May 2008	3	2	4	4	6
June 2008	4	0	0.50	1.25	4
Site: LRC2		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	37	77	356.75	1236
October 2007	4	18	30	29.75	41
May 2008	3	1	1	6	16
June 2008	4	1	5	5.25	10
Site: LRC3		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	67	158	279.75	736
October 2007	5	12	28	30.2	51
May 2008	3	0	1	35.33	105
June 2008	4	2	6	10.75	29
Site: LRC4		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	71	210.5	2498	9500
October 2007	5	14	29	25.8	42
May 2008	3	1	2	102.33	304
June 2008	4	3	10.5	16.25	41
Site: LRC5		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	44	684	684	1582
October 2007	5	9	26	26	40
May 2008	3	1	2	2	13
June 2008	4	3	12.5	12.5	24

5.2 Correlations

Although correlations do not establish causality among variables, they can help identify potential relationships. Since increases in rainfall or snowmelt increase run-off and stream flow, it is reasonable to expect turbidity to increase with increasing flow. Under the same premise, fecal coliform loading may also increase with increasing flow. Additionally, it has been suggested that fecal coliform has an affinity for sediment particles, suggesting that fecal coliform concentrations may also increase with increases in turbidity.

5.2.1 Turbidity and Flow

Data from Little Rabbit Creek shows a relationship between turbidity and flow. The highest turbidity concentration (51 NTU) occurred during the highest flow (32.71 cfs) (Figure 9).

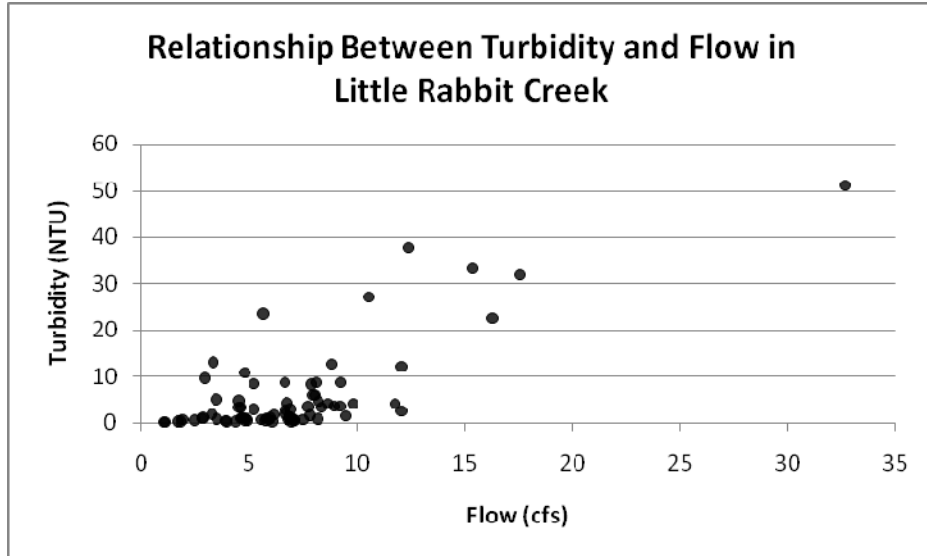


Figure 9. Relationship between turbidity and flow in Little Rabbit Creek during the study period.

5.2.2 Fecal Coliform and Turbidity

In Little Rabbit Creek, fecal coliform concentration appears to increase with increases in turbidity levels (Figure 10).

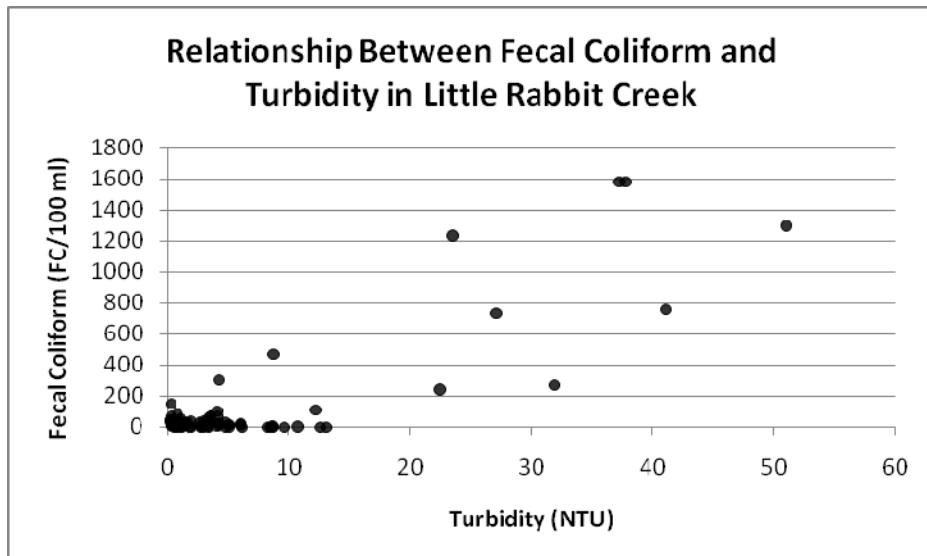


Figure 10. Relationship between fecal coliform and turbidity in Little Rabbit Creek during the study period.

5.2.3 Fecal Coliform and Flow

Fecal coliform concentrations in Little Rabbit Creek appear to be related to flow, particularly at the lower end and higher end of the flow range (Figure 11). When flow is below 5 cfs, bacteria concentrations remain below 200 FC/100ml; when flow is above 15 cfs, bacteria concentrations are always above 200 FC/100ml (Figure 11). During intermediate flows, between 5-15 cfs, a range of fecal coliform concentrations were observed.

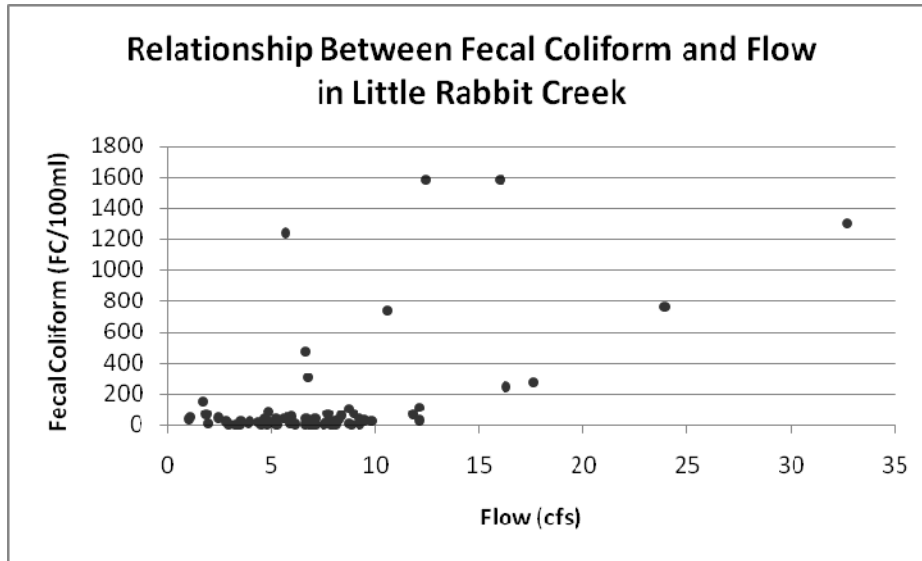


Figure 11. Relationship between fecal coliform and flow in Little Rabbit Creek during the study period.

5.3 Creek-wide Fecal Coliform Exceedances

5.3.1 Geometric Mean

The Alaska State Water Quality Standards require the use of a geometric mean to determine exceedances. The geometric mean is calculated for a 30-day period and requires a minimum of five samples within the 30-days (Tim Stevens, ADEC, pers. comm., March 6, 2008). To calculate the geometric mean, a series of “moving” or “rolling” windows of 30-day periods were defined based on the sample dates throughout the study period. The moving windows are defined in Table 13.

Table 13. Moving 30-day windows used for geometric mean calculations of fecal coliform exceedances in Little Rabbit Creek. Each 30-day window includes 25 samples (5 sample dates x 5 sampling sites).

Year	Month	Moving 30 day Window	1 st and Last Sample Dates	No. of Sample Dates Included
2007	September-October	1 st	9/5/2007-10/4/2007	5
	September-October	2 nd	9/20/2007-10/17/2007	5
	September-October	3 rd	9/25/2007-10/24/2007	5
	October	4 th	10/4/2007-10/30/2007	5
2008	May-June	5 th	5/13/2008-6/10/2008	5
	May-June	6 th	5/22/2008- 6/17/2008	5
	May-June	7 th	5/28/2008-6/24/2008	5

The geometric mean was calculated in Microsoft Excel, using the GEOMEAN formula. Because the formula does not permit zero values, also zeros (non-detects) were replaced with 1's (Tim Stevens, ADEC, pers.com, July 2007).

Table 14 shows the geometric mean results for Little Rabbit Creek. The Alaska State Water Quality Standard for fecal coliform was described in detail in Section 3. The relevant criteria for Little Rabbit Creek is the water supply standard for drinking, culinary and food processing. This stipulates that the geometric mean may not exceed 20 FC/100ml in a 30-day period. The second part of the standard, related to percent of samples is described in the next section (Section 5.3.2). Additionally, the less stringent water recreation standard for contact recreation was also examined in the event that Little Rabbit Creek be considered for a less stringent, and possibly more relevant, water use. The contact recreation standard states that the geometric mean may not exceed 100FC/100ml in a 30-day period.

Little Rabbit Creek exceeded the water quality standard of 20 FC/100ml in a 30-day period in September-October, during the 1st-3rd moving 30-day windows (Table 14). It also exceeded the less stringent criteria of 100 FC/100ml in the first 30-day period in September-October. The highest exceedance occurred in the beginning of the study period (1st 30-day window) and was 126.16 FC/100 ml, which was more than double the second highest exceedance of 50.80 FC/100 ml (Table 14). No exceedances were observed in the 4th-7th moving windows, which represent October 2007 and May-June 2008.

Table 14. Geometric mean of fecal coliform for all sites in Little Rabbit Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (* denotes exceedance of the water supply standard of 20 FC/100ml; **denotes exceedance of both the water supply and the water recreation standard of 100 FC/100ml).

Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	126.1574456**
	September-October	2 nd	50.80754784*
	September-October	3 rd	30.34020825*
	October	4 th	17.27902665
2008	May-June	5 th	5.648518705
	May-June	6 th	5.998781891
	May-June	7 th	7.181791161

5.3.2 Percent Exceedances

In addition to the geometric mean, the second part of the Alaska Water Quality Standards for water supply stipulates that not more than 10% of the sample may exceed 40FC/100ml. The less stringent standard for water recreation states that not more than 1 sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100ml. Table 15 shows the percent of samples that exceed these values for the 30-day windows defined in Table 13, as well as the exceedance count ratio which is simply the ratio of the number of samples exceeding the defined standard to the total number of samples within the specified 30-day window.

In Little Rabbit Creek, the percent of samples exceeding the 40FC/100ml was higher than 10% in all cases (Table 15). The largest percentage of samples in exceedance was 76% and occurred in the first 30-day period of the study. However, Little Rabbit Creek was close to meeting the standard for much of the study period as October 2007 and May-June 2008 had 12% of the samples in exceedance of 40FC/100ml

(Table 15). In terms of the 200FC/100ml standard, Little Rabbit Creek exceeded this standard in September-October 2007, but did not have exceedances in the remainder of the study period.

Table 15. Percent exceedances of fecal coliform in Little Rabbit Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (*denotes exceedance of the water quality standard).

Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100 ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	76%*	19:25	32%*	8:25
	September-October	2 nd	48%*	12:25	12%*	3:25
	September-October	3 rd	32%*	8:25	12%*	3:25
	October	4 th	12%*	3:25	0%	0:25
2008	May-June	5 th	12%*	3:25	4%	4:25
	May-June	6 th	12%*	3:25	4%	4:25
	May-June	7 th	12%*	3:25	4%	4:25

5.4 Fecal Coliform Exceedances By Site

5.4.1 Geometric Mean

The geometric mean was also calculated for each site on Little Rabbit Creek, using 5 samples per 30-day window (see Table 13). All sites exceeded the fecal coliform standard at some time during the study period. LRC4 had the highest geometric mean of all the sites, at 240.07 FC/100ml (Table 16). Each site on Little Rabbit Creek met the standard in May and June 2008.

5.4.2 Percent Exceedances

Percent exceedances for water supply (10% can't exceed 40FC/100ml) and water recreation (10% can't exceed 200FC/100ml) were calculated for each site on Little Rabbit Creek (Table 17). LRC1, LRC2 and LRC5 had no exceedances of either standard in May-June 2008, whereas LRC3 and LRC4 has exceedances of the water supply standard in every 30-day window (all months). Overall, percent of samples exceeding the water supply standard ranged from 0-80%, and percent exceeding the water recreation standard ranged from 0-40%. LRC1 at the headwaters had the fewest exceedances overall (Table 17).

Table 16. Geometric mean of fecal coliform by site in Little Rabbit Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (* denotes exceedance of the water supply standard of 20 FC/100ml; **denotes exceedance of both the water supply and the water recreations standard of 100 FC/100ml).

LRC1			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	65*
	September-October	2 nd	29*
	September-October	3 rd	12
	October	4 th	7
2008	May-June	5 th	3
	May-June	6 th	2
	May-June	7 th	2
LRC2			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	98*
	September-October	2 nd	42*
	September-October	3 rd	21*
	October	4 th	14
2008	May-June	5 th	3
	May-June	6 th	3
	May-June	7 th	5
LRC3			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	119.62**
	September-October	2 nd	63.26*
	September-October	3 rd	48.83*
	October	4 th	26.76*
2008	May-June	5 th	7.12
	May-June	6 th	8.18
	May-June	7 th	11.70
LRC4			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	240.07**
	September-October	2 nd	58.36*
	September-October	3 rd	42.77*
	October	4 th	23.66*
2008	May-June	5 th	13.50
	May-June	6 th	16.82
	May-June	7 th	18.24
LRC5			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	174.11**
	September-October	2 nd	73.92*
	September-October	3 rd	49.33*
	October	4 th	22.89*
2008	May-June	5 th	6.60
	May-June	6 th	8.22
	May-June	7 th	9.87

Table 17. Percent exceedance of fecal coliform by site in Little Rabbit Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (* denotes exceedance of the water quality standard).

LRC1						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	60%*	3:5	20%*	1:5
	September-October	2 nd	40%*	2:5	0%	0:5
	September-October	3 rd	20%*	1:5	0%	0:5
	October	4 th	0%	0:5	0%	0:5
2008	May-June	5 th	0%	0:5	0%	0:5
	May-June	6 th	0%	0:5	0%	0:5
	May-June	7 th	0%	0:5	0%	0:5
LRC2						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	80%*	4:5	20%*	1:5
	September-October	2 nd	40%*	2:5	0%	0:5
	September-October	3 rd	40%*	2:5	0%	0:5
	October	4 th	20%*	1:5	0%	0:5
2008	May-June	5 th	0%	0:5	0%	0:5
	May-June	6 th	0%	0:5	0%	0:5
	May-June	7 th	0%	0:5	0%	0:5
LRC3						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	80%*	4:5	40%*	2:5
	September-October	2 nd	60%*	3:5	20%*	1:5
	September-October	3 rd	40%*	2:5	20%*	1:5
	October	4 th	20%*	1:5	0%	0:5
2008	May-June	5 th	20%*	1:5	0%	0:5
	May-June	6 th	20%*	1:5	0%	0:5
	May-June	7 th	20%*	1:5	0%	0:5
LRC4						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	80%*	4:5	40%*	2:5

	September-October	2 nd	60%*	3:5	20%*	1:5
	September-October	3 rd	40%*	2:5	20%*	1:5
	October	4 th	20%*	1:5	0%	0:5
2008	May-June	5 th	40%*	2:5	20%*	1:5
	May-June	6 th	40%*	2:5	20%*	1:5
	May-June	7 th	40%*	2:5	20%*	1:5
LRC5						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	80%*	4:5	40%*	2:5
	September-October	2 nd	40%*	2:5	20%*	1:5
	September-October	3 rd	20%*	1:5	20%*	1:5
	October	4 th	0%	0:5	0%	0:5
2008	May-June	5 th	0%	0:5	0%	0:5
	May-June	6 th	0%	0:5	0%	0:5
	May-June	7 th	0%	0:5	0%	0:5

6. Little Survival Creek Data Analysis

6.1 Descriptive Statistics

6.1.1 Turbidity

Turbidity in Little Survival Creek for the study period ranged from 0.06- 80.30 NTUs, with a median of 1.42 and an average of 4.56 NTU's. Turbidity was highest on May 12, 2008 and lowest in October 2007 and June 2008 (Figure 12). Monthly descriptive statistics are included for Little Rabbit Creek in Table 18.

Turbidity also varied between the five sampling sites located on Little Survival Creek. The highest turbidity spikes were recorded at LSC1, the most upstream site, while the lowest turbidity was recorded at LSC3 (Table 19, Figure 12). A summary of the data, by site and month is shown in Table 20.

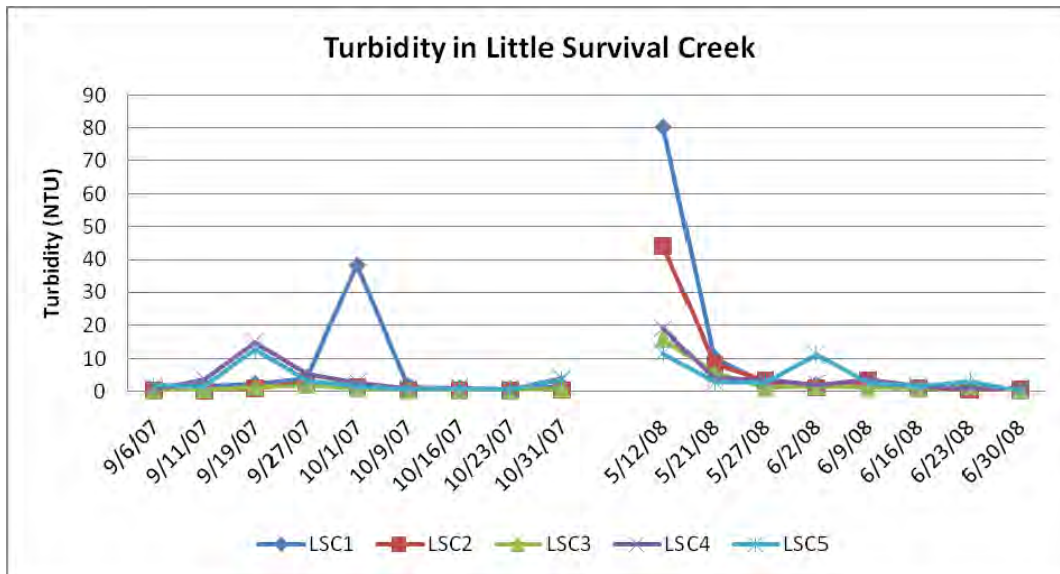


Figure 12. Turbidity in Little Survival Creek during the study period.

Table 18. Summary of Little Survival Creek turbidity data by month.

Month	No. of samples	Turbidity (NTU)			
		Min	Median	Mean	Max
September 2007	20	0.09	1.73	3.06	15.0
October 2007	25	0.06	0.92	2.56	38.2
May 2008	15	0.95	5.49	9.39	80.3
June 2008	25	0.14	1.10	1.86	11.20

Table 19. Summary of Little Survival Creek turbidity data by site.

Sampling Site	No. of Samples	Sampling Period		Turbidity (NTU)			
		Start Date	End Date	Min	Median	Mean	Max
LSC1	17	9/6/07	6/30/08	0.4	1.73	8.96	80.3
LSC2	17	9/6/07	6/30/08	0.11	0.96	4.06	44.2
LSC3	17	9/6/07	6/30/08	0.06	0.92	1.92	16.1
LSC4	17	9/6/07	6/30/08	0.7	2.66	4.17	19.0
LSC5	17	9/6/07	6/30/08	0.14	2.72	3.67	13.0

Table 20. Summary of Little Survival Creek turbidity data, summarized by month and site.

Site: LSRC1		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.4	2.06	2.19	4.25
October 2007	5	0.62	1.6	8.64	38.3
May 2008	3	2.65	10.31	45.31	80.3
June 2008	5	0.4	1.03	1.42	2.65
Site: LSC2		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.23	0.67	1.12	2.9
October 2007	5	0.11	0.39	0.44	1.14
May 2008	3	3.27	8.24	18.57	44.2
June 2008	5	0.56	1.09	1.32	3.27
Site: LSC3		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.41	0.81	0.90	1.91
October 2007	5	0.06	0.22	0.38	0.92
May 2008	3	0.95	5.49	7.51	16.1
June 2008	5	0.14	0.95	0.94	1.42
Site: LSC4		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.7	4.54	6.19	15.0
October 2007	5	0.79	1.13	1.92	3.99
May 2008	3	3.80	4.11	8.97	19.0
June 2008	5	0.92	1.75	1.93	3.8
Site: LSC5		Turbidity (NTU)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	1.56	2.46	4.87	13
October 2007	5	0.47	0.99	1.40	3.58
May 2008	3	2.72	2.98	5.8	11.7
June 2008	5	0.14	2.72	3.70	11.2

6.1.2 Stream flow

Flow in Little Survival Creek for the study period ranged from 0.00-13.98 cubic feet per second (cfs), with a median of 0.74 and an average of 1.51 cfs. Flow was highest in May 2008 and lowest in September and October 2007 (Figure 13). Monthly descriptive statistics are included for Little Survival Creek in Table 21.

Flow also varied between the five sampling sites located on Little Survival Creek. The highest flow was observed at LSC4, the second most downstream site, while the lowest median and mean flow was observed at LSC1, the most upstream site (Table 22, Figure 13). A summary of the data, by site and month, is shown in Table 23.

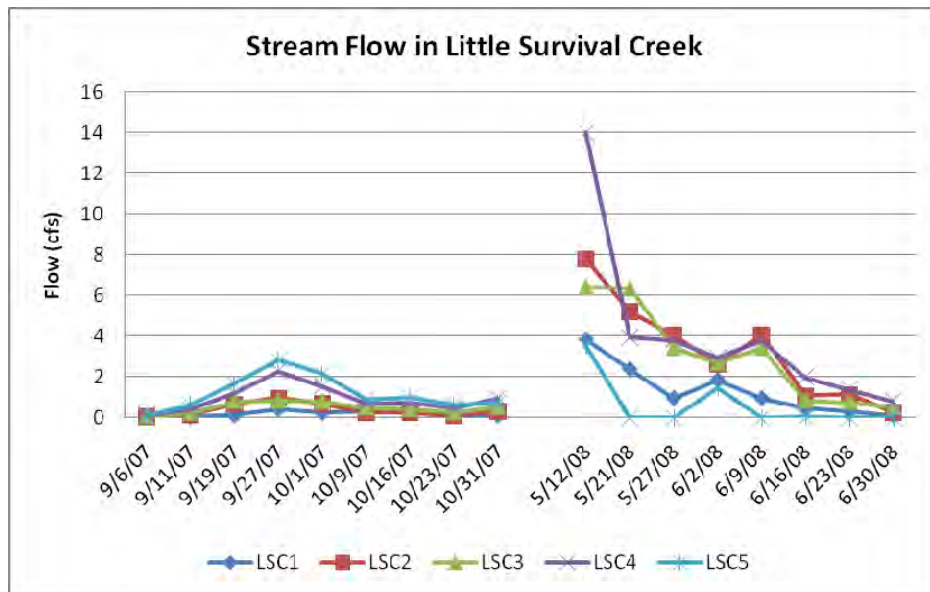


Figure 13. Stream flow in Little Survival Creek during the study period.

Table 21. Summary of Little Survival Creek stream flow data by month.

Month	No. of samples	Flow (cfs)			
		Min	Median	Mean	Max
September 2007	20	0.50	0.43	0.69	2.81
October 2007	25	0.10	0.50	0.60	2.14
May 2008	15	0.00	3.85	4.38	13.98
June 2008	25	0.00	0.97	1.34	4.07

Table 22. Summary of Little Survival Creek stream flow data by site.

Sampling Site	No. of Samples	Sampling Period		Flow (cfs)			
		Start Date	End Date	Min	Median	Mean	Max
LSC1	17	9/6/07	6/6/08	0.05	0.29	0.75	3.85
LSC2	17	9/6/07	6/6/08	0.05	0.70	1.75	7.78
LSC3	17	9/6/07	6/6/08	0.07	0.80	1.78	6.42
LSC4	17	9/6/07	6/6/08	0.12	1.39	2.41	13.98
LSC5	17	9/6/07	6/6/08	0.0	0.63	0.92	3.51

Table 23. Summary of Little Survival Creek stream flow data, by month and site.

Site: LSC1		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.05	0.11	0.18	0.44
October 2007	5	0.1	0.26	0.212	0.3
May 2008	3	0.97	2.39	3.12	3.85
June 2008	5	0.4	1.03	1.42	2.65
Site: LSC2		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.05	0.42	0.47	0.98
October 2007	5	0.11	0.26	0.33	0.7
May 2008	3	4.07	5.2	5.68	7.78
June 2008	5	0.27	1.14	1.84	4.07
Site: LSC3		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.07	0.53	0.49	0.84
October 2007	5	0.27	0.5	0.5	0.79
May 2008	3	3.44	6.35	5.40	6.42
June 2008	5	0.53	0.86	1.66	3.44
Site: LSC4		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.12	0.81	1.01	2.29
October 2007	5	0.47	0.74	0.88	1.54
May 2008	3	3.8	3.93	7.24	13.98
June 2008	5	0.81	1.97	2.18	3.8
Site: LSC5		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0.12	0.99	1.31	2.81
October 2007	5	0.62	0.88	1.07	2.14
May 2008	3	0	0	1.17	3.51
June 2008	5	0	0	0.30	1.48

6.1.3 Fecal Coliform Bacteria

Fecal coliform concentrations in Little Survival Creek for the study period ranged from 0-270 FC/100ml, with a median concentration of 16 and a mean of 38 FC/100ml. Fecal coliform concentrations were highest in September 2007, and lowest in June 2008 (Figure 14). Monthly descriptive statistics are included for Little Survival Creek in Table 24.

Fecal coliform concentrations also varied between the five sampling sites located on Little Survival Creek. The highest fecal coliform was observed at LSC1, the most upstream site, while the lowest concentrations were observed at LSC2 and LSC3 (Table 25, Figure 14). A summary of the data, by site and month is shown in Table 26.

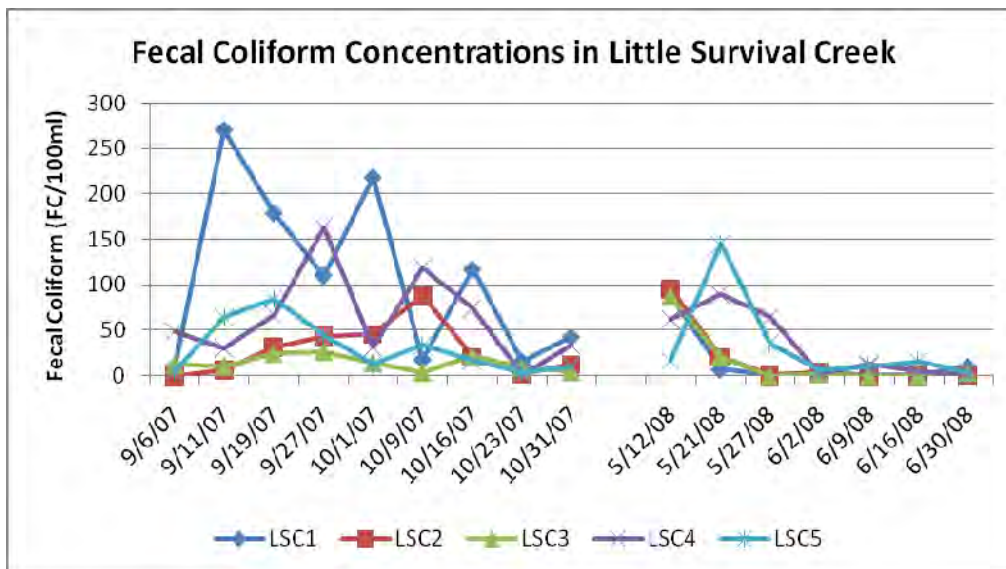


Figure 14. Fecal coliform concentrations in Little Survival Creek during the study period.

Table 24. Summary of Little Survival Creek fecal coliform data by month.

Month	No. of samples	Fecal Coliform (FC/100ml)			
		Min	Median	Mean	Max
September 2007	20	0	38	61.75	270
October 2007	25	1	18	38.88	218
May 2008	15	0	35	49	145
June 2008	25	0	3	4	15

Table 25. Summary of Little Survival Creek fecal coliform data by site.

Sampling Site	No. of Samples	Sampling Period		Fecal Coliform (FC/100ml)			
		Start Date	End Date	Min	Median	Mean	Max
LSC1	16	9/6/2007	6/30/2008	1	17	68	270
LSC2	16	9/6/2007	6/30/2008	0	10	24	96
LSC3	16	9/6/2007	6/30/2008	0	11	16	87
LSC4	16	9/6/2007	6/30/2008	0	42	51	163
LSC5	16	9/6/2007	6/30/2008	3	16	31	145

Table 26. Summary of Little Survival Creek fecal coliform data by month and site.

Site: LSC1		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	10	145	142	270
October 2007	5	16	43	82	218
May 2008	3	1	48	48	88
June 2008	5	1	2	4	10
Site: LSC2		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	0	20	21	44
October 2007	5	3	21	34	88
May 2008	3	1	21	39	96
June 2008	5	0	0	1	4
Site: LSC3		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	11	19	19	27
October 2007	5	4	9	11	22
May 2008	3	0	21	36	87
June 2008	5	0	2	2	4
Site: LSC4		Flow (cfs)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	31	59	78	163
October 2007	5	1	34	52	119
May 2008	3	62	65	72	90
June 2008	5	0	4	5	13
Site: LSC5		Fecal Coliform (FC/100ml)			
Month	No. of samples	Min	Median	Mean	Max
September 2007	4	4	54	49	84
October 2007	5	3	12	15	33
May 2008	3	16	35	65	145
June 2008	5	3	8	8	15

6.2 Correlations

Although correlations do not establish causality among variables, they can help identify potential relationships. Since increases in rainfall or snowmelt increase run-off and stream flow, it is reasonable to expect turbidity to increase with increasing flow. Under the same premise, fecal coliform loading may also increase with increasing flow. Additionally, it has been suggested that fecal coliform has an affinity for sediment particles, suggesting that fecal coliform concentrations may also increase with increases in turbidity.

6.2.1 Turbidity and Flow

The available data from Little Survival Creek do not show a relationship between turbidity and flow. The highest turbidity concentration (80.3 NTU) occurred at 3.85 cfs (Figure 15).

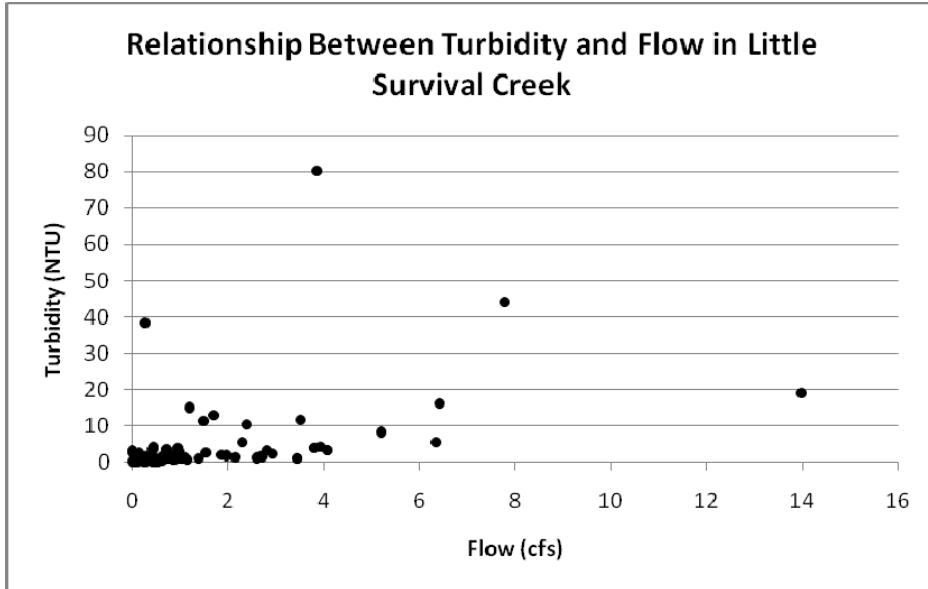


Figure 15. Relationship between turbidity and flow in Little Survival Creek during the study period.

6.2.2 Fecal Coliform Concentrations and Turbidity

In Little Survival Creek, fecal coliform concentrations do not appear to be related to turbidity levels (Figure 16). The highest bacteria concentrations of 270 FC/100ml occurred at low turbidity (1.73 NTU), while the highest turbidity observed (80.3 NTU) was associated with bacteria concentrations of 88 FC/100ml (Figure 16).

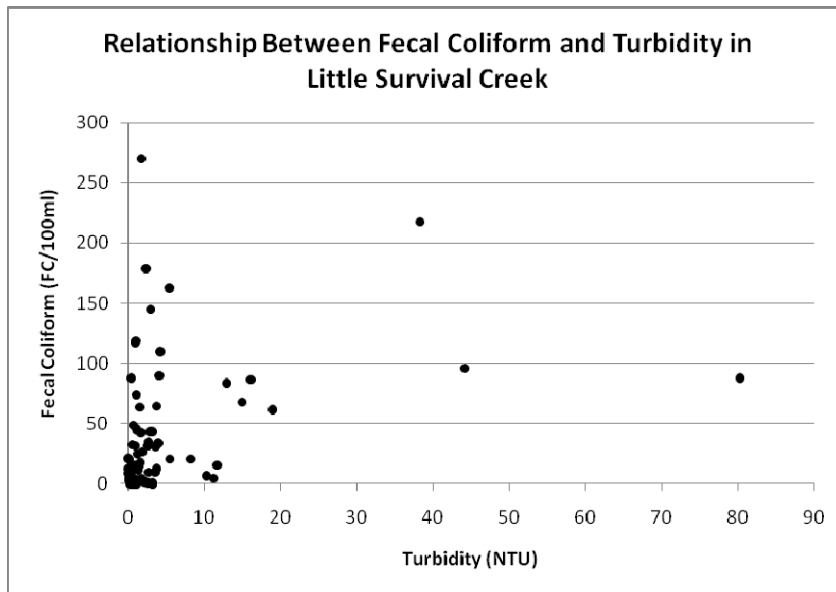


Figure 16. Relationship between fecal coliform and turbidity in Little Survival Creek during the study period.

6.2.3 Fecal Coliform Concentrations and Stream Flow

Fecal coliform concentrations in Little Survival Creek do not appear to be related to flow (Figure 17). The highest bacterial concentrations of 270 FC/100 ml occurred when flow was only 0.07 cfs and bacterial concentration was only 62 FC/100ml at the highest observed flow of 13.98 cfs (Figure 17).

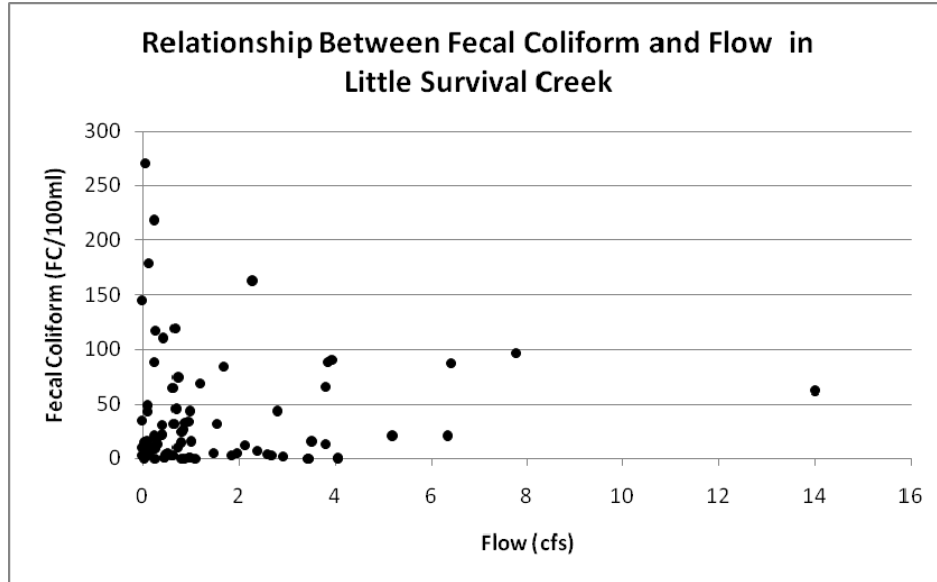


Figure 17. Relationship between fecal coliform and stream flow in Little Survival Creek during the study period.

6.3 Creek-wide Fecal Coliform Exceedances

6.3.1 Geometric Mean

The Alaska State Water Quality Standards require the use of a geometric mean to determine exceedances. The geometric mean is calculated for a 30-day period and requires a minimum of five samples within the 30-days (Tim Stevens, ADEC, pers. comm., April 2008). To calculate the geometric mean, a series of moving windows of 30-day periods were defined based on the sample dates throughout the study period. The moving windows are defined in Table 27.

Table 27. Moving 30-day windows used for geometric mean calculations of fecal coliform exceedances in Little Survival Creek. Each 30-day window includes 25 samples (5 sampling dates x 5 sampling sites).

Year	Month	Moving 30 day Window	1 st and Last Sample Dates	No. of Sample Dates Included
2007	September-October	1 st	9/6/2007-10/1/2007	5
	September-October	2 nd	9/11/2007-10/9/2007	5
	September-October	3 rd	9/19/2007-10/16/2007	5
	September-October	4 th	9/27/2007-10/23/2007	5
	October	5 th	10/1/2007-10/31/2007	5
2008	May-June	6 th	5/12/2008-6/9/2008	5
	June	7 th	6/2/2008- 6/30/2008	4

The geometric mean was calculated in Microsoft Excel, using the GEOMEAN formula. Because the formula does not permit zero values, also zeros (non-detects) were replaced with 1's (Tim Stevens, ADEC, pers.com, July 2007).

Table 28 shows the geometric mean results for Little Survival Creek. The Alaska State Water Quality Standard for fecal coliform was described in detail in Section 3. The relevant criteria for Little Survival Creek is the water supply standard for drinking, culinary and food processing. This stipulates that the geometric mean may not exceed 20 FC/100ml in a 30-day period. The second part of the standard, related to percent of samples is described in the next section (Section 6.3.2). Additionally, the water recreation standard for contact recreation was also examined in the event that Little Survival Creek should be considered for a less stringent and potentially more relevant water use in the future. The contact recreation standard states that the geometric mean may not exceed 100FC/100ml in a 30-day period.

Little Survival Creek exceeded the water quality standard of 20 FC/100ml in a 30-day period in September-October, during the 1st-4th moving 30-day windows (Table 28). However, the less stringent criteria of 100 FC/100ml was never exceeded during the study period and no exceedances, of either standard, occurred in May-June 2008

Table 28. Geometric mean of fecal coliform for all sites in Little Survival Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (* denotes exceedance of the water supply standard of 20 FC/100ml; **denotes exceedance of both the water supply and the water recreations standard of 100 FC/100ml).

Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	32.12*
	September-October	2 nd	42.30*
	September-October	3 rd	43.05*
	September-October	4 th	25.23*
	October	5 th	19.15
2008	May-June	6 th	8.70
	June	7 th	2.70

6.3.2 Percent Exceedance

In addition to the geometric mean, the second part of the Alaska Water Quality Standards for water supply stipulates that not more than 10% of the sample may exceed 40FC/100ml. The less stringent standard for water recreation states that not more than 1 sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100ml. Table 29 shows the percent of samples that exceed these values for the 30-day windows defined in Table 27, as well as the exceedance count ratio which is simply the ratio of the number of samples exceeding the defined standard to the total number of samples within the specified 30-day window.

In Little Survival Creek, the percent of samples exceeding the 40FC/100ml was higher than 10% in 6 out of 7 cases; the 30-day moving window that occurred in June 2008 met the water quality standard (Table 29). The largest percentage of samples in exceedance was 52% and occurred in the 2nd and 3rd 30-day windows in September-October 2008. In reference to the 200FC/100ml standard, Little Survival Creek met this standard throughout the entire study period, with exceedances ranging from 0-5% (Table 29).

Table 29. Percent exceedances of fecal coliform in Little Survival Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (*denotes exceedance of the water quality standard).

Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100 ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	48%*	12:25	8%	2:25
	September-October	2 nd	52%*	13:25	8%	2:25
	September-October	3 rd	52%*	13:25	4%	1:25
	September-October	4 th	40%*	10:25	4%	1:25
	October	5 th	28%*	7:25	4%	1:25
2008	May-June	6 th	24%*	6:25	0%	0:25
	June	7 th	0%	0:20	0%	0:25

6.4 Fecal Coliform Exceedances By Site

6.4.1 Geometric Mean

The geometric mean was also calculated for each site on Little Survival Creek using 5 samples per 30-day window (see Table 27). All sites exceeded the fecal coliform Standard at some time during the study period, with the exception of LSC3 (Table 30). LSC1, the headwaters site, had the highest geometric mean of all the sites, at 115.84 FC/100ml and was the only site to exceed the water recreation standard of 100 FC/100ml (Table 30).

6.4.2 Percent Exceedances

Percent exceedances for water supply (10% can't exceed 40FC/100ml) and water recreation (10% can't exceed 200FC/100ml) were calculated by site. LSC3 was the only site that never exceeded the water supply standard; LSC1 was the only site to exceed the water recreation standard (Table 31).

Overall, percent of samples exceeding the water supply standard ranged from 0-80%, and the percent exceeding the water contact standard ranged from 0-40%. LSC3 did not exceed either of the water quality standards at any time during the study period (Table 31).

Table 30. Geometric mean of fecal coliform by site in Little Survival Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (* denotes exceedance of the water supply standard of 20 FC/100ml; **denotes exceedance of both the water supply and the water recreations standard of 100 FC/100ml).

LSC1			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	102.99**
	September-October	2 nd	115.84**
	September-October	3 rd	98.00*
	September-October	4 th	60.46*
	October	5 th	50.11*
2008	May-June	6 th	4.50
	June	7 th	2.34
LSC2			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	13.53
	September-October	2 nd	33.13*
	September-October	3 rd	41.27*
	September-October	4 th	25.70*
	October	5 th	20.14*
2008	May-June	6 th	6.04
	June	7 th	1.41
LSC3			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	17.07
	September-October	2 nd	13.48
	September-October	3 rd	15.49
	September-October	4 th	12.63
	October	5 th	9.01
2008	May-June	6 th	2.29
	June	7 th	1.86
LSC4			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	55.75*
	September-October	2 nd	66.58*
	September-October	3 rd	79.24*
	September-October	4 th	34.07*
	October	5 th	24.90*
2008	May-June	6 th	24.83*
	June		3.38
LSC5			
Year	Month	30-day Window	Geometric Mean
2007	September-October	1 st	25.77*
	September-October	2 nd	39.29*
	September-October	3 rd	29.78*
	September-October	4 th	15.29
	October	5 th	11.37
2008	May-June	6 th	20.98*
	June	7 th	6.89

Table 31. Percent exceedances of fecal coliform by site in Little Survival Creek, relative to the Alaska State Water Quality Standards for water supply and water recreation (*denotes exceedance of the water quality standard).

LSC1						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	80%	4:5	40%	2:5
	September-October	2 nd	80%	4:5	40%	2:5
	September-October	3 rd	60%	4:5	20%	1:5
	September-October	4 th	60%	3:5	20%	1:5
	October	5 th	20%	3:5	20%	1:5
2008	May-June	6 th	0%	1:5	0%	0:5
	June	7 th	0%	0:4	0%	0:4
LSC2						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	40%	2:5	0%	0:5
	September-October	2 nd	60%	3:5	0%	0:5
	September-October	3 rd	60%	3:5	0%	0:5
	September-October	4 th	60%	3:5	0%	0:5
	October	5 th	40%	2:5	0%	0:5
2008	May-June	6 th	20%	1:5	0%	0:5
	June	7 th	0%	0:4	0%	0:4
LSC3						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	0%	0:5	0%	0:5
	September-October	2 nd	0%	0:5	0%	0:5
	September-October	3 rd	0%	0:5	0%	0:5
	September-October	4 th	0%	0:5	0%	0:5
	October	5 th	0%	0:5	0%	0:5
2008	May-June	6 th	0%	0:5	0%	0:5
	June	7 th	0%	0:4	0%	0:4
LSC4						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio

2007	September-October	1 st	60%	3:5	0%	0:5
	September-October	2 nd	60%	3:5	0%	0:5
	September-October	3 rd	80%	4:5	0%	0:5
	September-October	4 th	60%	3:5	0%	0:5
	October	5 th	40%	2:5	0%	0:5
	2008	May-June	6 th	60%	3:5	0%
	June	7 th	0%	0:4	0%	0:4
LSC5						
Year	Month	30-Day Moving Window	Percent Exceedance 40 FC/100ml	Exceedance Count Ratio	Percent Exceedance 200 FC/100ml	Exceedance Count Ratio
2007	September-October	1 st	60%	3:5	0%	0:5
	September-October	2 nd	60%	3:5	0%	0:5
	September-October	3 rd	40%	2:5	0%	0:5
	September-October	4 th	20%	1:5	0%	0:5
	October	5 th	0%	0:5	0%	0:5
	2008	May-June	6 th	20%	1:5	0%
	June	7 th	0%	0:4	0%	0:4

7. Summary of Current Water Quality Status and Recommendations

7.1 Water Quality and State Standards

Little Rabbit Creek data showed anticipated relationships. Turbidity and flow were positively correlated and were lowest at the headwaters (LRC1) and highest downstream (LRC5). Fecal coliform was positively correlated with turbidity, but only seemed related to flow at low and high flows. Fecal coliform did not appear to be related to flow at intermediate flows levels. Fecal coliform was lowest at the headwaters (LRC1) and highest at the second most downstream site (LRC4). It was expected to be highest at LRC5, the most downstream site. This suggests that the fecal coliform is settling out somewhere between LRC4 and LRC5.

Creek-wide Little Rabbit Creek exceeded the state water quality standard for non-attainment of the fecal coliform. There are two components to the standard, one which calculates the geometric mean, and another which looks at percent exceedances. Based on the geometric mean, Little Rabbit Creek exceeded the standard for water supply, which is 20FC/100ml, in September-October 2007. Geometric mean exceedances ranged from 30.34-126.15 FC/100ml. There was also an exceedance of the water recreation standard, which is 100 FC/100ml. However, there were no exceedances of either standard in May-June 2008, based on creek-wide data. Based on percent exceedances, Little Rabbit Creek exceeded the water supply standard (i.e., not more than 10% of samples can be higher than 40FC/100ml) throughout the study period, with percentages ranging from 12-76%. Also based on percent exceedances, the water recreation standard (i.e., not more than 10% of samples can be higher than 200 FC/100ml) was exceeded in Little Rabbit Creek in September-October 2007, but met the standard in May-June 2008.

Exceedances of the fecal coliform standard were also analyzed by site in effort to isolate potential sources and hot spots of fecal coliform loading in Little Rabbit Creek. Individually, based on the geometric mean calculations, no site on Little Rabbit Creek exceeded the water supply or water recreation standard in May-June 2008. LRC1, the headwaters site, had the fewest exceedances in September-October 2007. This is to be expected as the headwater site is receiving less flow and turbidity inputs, and is less impacted by run-off from residences which may contain pet waste. Based on the percentage of samples, all sites exceeded the water supply standard for all or most of September-October 2007. Only LRC4, the second most downstream site exceeded the water supply standard in May-June 2008. LRC1 and LRC2 exceeded the water recreation standard in September-October, but less often than the other sites. All sites on Little Rabbit Creek met the water recreation standard in May-June 2008.

Overall, September 2007 was the worst month in terms of fecal coliform concentrations in Little Rabbit Creek.

Little Survival Creek did not display the same relationships between turbidity, flow and fecal coliform as were observed in Little Rabbit Creek. Little Survival Creek has a much smaller watershed and this may have contributed to the differences observed. Turbidity was highest in early May 2007, which corresponded to peaks in flow. However, fecal coliform concentrations were not highest at this time. Fecal coliform was highest in September 2007 when turbidity and flow in the creek were at low to moderate levels. Also, the highest turbidity level (80.3 NTU) occurred in the headwaters site (LSC1), and the second highest turbidity level (44.2NTU) occurred at the LSC2, which is the next site below the headwaters site. Based on sediment loads from increased flow, it was expected that turbidity would be

highest downstream. This suggests that the source of turbidity entered the creek near the headwaters (LSC1) and was diluted or settled out on its way downstream.

Creek-wide, Little Survival Creek exceeded the state water quality standard for non-attainment of the fecal coliform. There are two components to the standard, one which calculates the geometric mean, and another which looks at percent exceedances. Based on the geometric mean, Little Survival Creek exceeded the standard for water supply, which is 20FC/100ml, in September-October 2007. Geometric mean exceedances ranged from 25.23-32.12 FC/100ml. Little Survival Creek did not exceed the water recreation standard, which is 100 FC/100ml. Based on percent exceedances, Little Survival Creek exceeded the water supply standard (i.e., not more than 10% of samples can be higher than 40FC/100ml) throughout the study period, with percentages ranging from 0-52%. However, based on percent exceedances, the water recreation standard (i.e., not more than 10% of samples higher than 200 FC/100ml) was not exceeded in Little Survival Creek during the study period; Percentages ranged from 0-8%.

Exceedances of the fecal coliform standard were also analyzed by site in effort to isolate potential sources and hot spots of fecal coliform loading Little Survival Creek. Individually, based on the geometric mean calculations, all sites on Little Survival Creek exceeded the water supply standard, with the exception of LSC3. Additionally, LSC1 and LSC2 did not exceed the water supply standard in May-June 2008. LSC1, nearest the headwaters, was the only site to exceed the water recreation standard; the exceedance occurred in September-October 2007. LSC3 was the only site that never exceeded either standard.

Over all, September 2007 had the highest fecal concentrations, followed by October 2007.

7.2. Potential Sources of Fecal Coliform

The identification of sources of fecal coliform pollution is an important step in improving water quality conditions in waterbodies that are not meeting state water quality standards. The Alaska 303d list identifies urban runoff as the source of fecal coliform pollution in both Little Rabbit and Little Survival Creeks (ADEC, 2006a). Bacteria is deposited by domestic animals (e.g., cats and dogs), and wildlife (e.g., moose, bear, etc.) and accumulates on the land surface or is directly deposited in the streams. Rainfall and snowmelt transport bacteria deposited on land into the creeks. Estimating the amount of fecal coliform and locations where it is deposited is difficult due to the mobility and large range of animals throughout the MOA. While fecal coliform production of agricultural animals has been studied, little or no information on bacterial production in wildlife native to the Anchorage area is available (MOA, 2003).

However, basic qualitative estimates of wildlife populations were provided by the Alaska Department of Fish and Game (Rick Sinnott, ADF&G, pers. comm., July 2008 and MOA, 2003):

- Approximately 200-300 moose live in Anchorage Bowl in summer and up to 1,000 in winter.
- About 1,000 Canada geese inhabit the Anchorage Bowl
- Anchorage may contain 2,000 or more mallards in the winter
- Anchorage also has several thousand pigeons
- There are an estimated 100-150 beavers in the Anchorage bowl
- More than 35 brown bears and 60 black bears are estimated to inhabit the Anchorage Bowl each summer and fall.
- A dozen wolves, approximately 15 lynx, and an unknown but stable population of fox and coyote inhabit the Anchorage Bowl

- Thousands of snowshoe hares, hundreds of feral rabbits and an unknown population of porcupines inhabit the Anchorage Bowl
- An abundance of smaller animals such as squirrels, meadow voles, shrews , bats, muskrat, mink, marten and otter also live in the area.

While these population estimates do not provide estimates of fecal coliform loading, they do represent a significant source of fecal contamination to Anchorage streams.

7.3 Recommendations for Future Efforts

Based on the data and results obtained during this study, several recommendations can be made for future sampling in Little Rabbit and Little Survival Creeks.

- 1) Continuity in Available Data: Because the ADEC grant period begins on July 1st of a given year, and ends June 30th, data for a continuous summer-fall period has not been collected. It is difficult to determine seasonal variations in fecal coliform, turbidity and flow for this reason. A two year study from July 1st, 2010 through June 30, 2012 would ensure data was collected for a full year, including an intact summer period (the entire summer of 2011). This would help determine if fall (September-October) is consistently the worst time of year for fecal coliform or if fall 2007 was a particularly bad exception. More data may show that the creeks only exceed the water quality standards in the fall and meet the standards the remainder of the year.
- 2) Source Determination: To determine sources, more intensive sampling is needed around sites that had poor water quality compared to the other sites. For Little Rabbit Creek this would be the tributaries that enter the creek around LRC3, LRC4 and LRC5. For Little Survival Creek, the worst water quality was found near the headwaters, which is contrary to what is expected based on less urbanization near the headwaters. Sampling further upstream, if possible, may provide information on the source of fecal coliform at that location.
- 3) Residential Site Assessments: To determine the impact of local residences and development, it would be helpful to assess several factors in landuse surrounding Little Rabbit and Little Survival Creeks. Site assessment of septic systems in the residential areas would be helpful to determine that they are functioning properly. Assessment of road conditions and possible road side improvement projects to reduce run-off containing sediment and fecal coliform from directly entering the creek may also be beneficial. Fecal coliform is known to adhere to sediment and improvements to roads and road side ditches could be made to increase infiltration and reduce runoff. A survey of homeowners to obtain estimates of fecal coliform loading from domestic animals within the watershed would provide information on how much pet waste may be reaching the creeks.
- 4) Consideration of the Designated Water Use : Currently, both Little Rabbit and Little Survival Creeks are required to meet the Alaska State Water Quality Standards for the most stringent standard which is for water supply- drinking, culinary and food processing. Consideration could be given as to whether, based on actual use of these waterbodies, the water recreation standard for contact recreation would be a more appropriate standard based on the use of these waterbodies.

8. References

ADEC, 2006a. Alaska's Final 2006 Integrated Water Quality Monitoring and Assessment Report. Alaska Department of Environmental Conservation, Anchorage, AK. 129 p.

ADEC, 2006b. Water Quality Standards. Alaska Department of Environmental Conservation. Anchorage, AK. 52p.

ADEC , 2004a. Total Maximum Daily Load (TMDL) for Fecal Coliform in the Waters of Little Rabbit Creek in Anchorage, Alaska. Alaska Department of Environmental Conservation. Anchorage, Alaska. 41p.

ADEC , 2004b. Total Maximum Daily Load (TMDL) for Fecal Coliform in the Waters of Little Survival Creek in Anchorage, Alaska. Alaska Department of Environmental Conservation. Anchorage, Alaska. 39p.

Dilley, L.M. and T.E. Dilley. 2000. Guidebook to the Geology of Anchorage, Alaska. Publication Consultants. Anchorage, AK. 256p.

MOA, 2003. Fecal Coliform in Anchorage Streams: Sources and Transport Processes. Document No. APg03001. Municipality of Anchorage, Watershed Management Services. 54p.

USGS. 2006. Chapter A4 (Version 2.0, 9/2006) Collection of Water Samples, 4.1.3.B . National Field Manual for the Collection of Water-Quality Data.
<http://water.usgs.gov/owq/FieldManual/chapter4/html/Ch4_contents.html>. Accessed 2007 July 10.