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Total Maximum Daily Load (TMDL) for Fecal Coliform in the Waters of Ship Creek in Anchorage, Alaska

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TMDL AT A GLANCE:

Water Quality-limited?	Yes
Hydrologic Unit Code:	19020401
Criteria of Concern:	Fecal coliform
Designated Uses Affected:	Water supply and water recreation
Major Source(s):	Urban runoff
Loading Capacity:	2.39×10^{12} FC/year
Wasteload Allocation:	2.15×10^{12} FC/year (Section 6 includes seasonal allocations)
Load Allocation:	0 FC/year
Margin of Safety:	2.39×10^{11} FC/year
Necessary Load Reductions (to meet WLA):	Annual: 2 percent
	Winter: 43 percent
	Spring: 0 percent
	Summer: 4 percent

Executive Summary

Ship Creek is located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in southcentral Alaska. The state of Alaska included Ship Creek on its 1998 303(d) list as water quality-limited due to fecal coliform, from the mouth to the Glenn Highway, identifying urban runoff as the expected pollutant source. A Total Maximum Daily Load (TMDL) is established in this document to meet the requirements of Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130), which require the establishment of a TMDL for the achievement of water quality standards when a waterbody is water quality-limited. A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. A TMDL represents the amount of a pollutant the waterbody can assimilate while maintaining compliance with applicable water quality standards.

Applicable water quality standards for fecal coliform in Ship Creek 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 is developed for the most stringent of these—the fecal coliform criteria for drinking, culinary, and food processing water supply that 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)).

Fecal coliform data indicate that Ship Creek does not meet the applicable water quality standards. The largest and most frequent exceedances of the water quality criteria occur during summer months, likely due to increased stormwater runoff and source activity (e.g., pets and wildlife). Fecal coliform concentrations are lower during colder winter months that experience less stormwater runoff. Concentrations steadily increase during spring months, with increased surface runoff during spring thaw and breakup. Because of the substantial seasonal variation in fecal coliform levels, the Ship Creek TMDL is developed on a seasonal basis to isolate times of similar weather, runoff and instream conditions.

Because Ship Creek does not have a sufficient record of corresponding flow and water quality data, the TMDL was 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 stream based on instream concentrations representing water quality standards.

The following table summarizes the results of the TMDL analysis. The MOS was included explicitly as 10 percent of the loading capacity. Because stormwater discharges in the MOA are regulated by a National Pollutant Discharge Elimination System (NPDES) stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Ship Creek are addressed through the wasteload allocation component of this TMDL. Therefore, the load allocation for the Ship Creek fecal coliform TMDL is zero. The fecal coliform wasteload allocations for Ship Creek are provided as seasonal allocations for the entire watershed and are equal to the loading capacity minus the MOS.

Season	Loading Capacity (FC/season)	MOS (FC/season)	Wasteload Allocation (FC/season)	Percent Reduction (for Wasteload Allocation)
Winter	3.20E+11	3.20E+10	2.88E+11	43%
Spring	7.58E+11	7.58E+10	6.82E+11	N/A
Summer	1.31E+12	1.31E+11	1.18E+12	4%
Total (FC/yr)	2.39E+12	2.39E+11	2.15E+12	2%

Implementation of the Ship Creek TMDL will be achieved through actions associated with the relevant MS4 permit. EPA recommends that for NPDES-regulated municipal and small construction stormwater discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. The policy recognizes the need for an iterative approach to control pollutants in storm water discharges and anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

Follow-up monitoring will likely be conducted cooperatively by ADEC and MOA to track the progress of TMDL implementation and subsequent water quality response, track BMP effectiveness, and track the water quality of Ship Creek to evaluate future attainment of water quality standards.

1. Overview

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130) require the establishment of a Total Maximum Daily Load (TMDL) for the achievement of state water quality standards when a waterbody is water quality-limited. A TMDL identifies the amount of pollution control needed to maintain compliance with standards and includes an appropriate margin of safety. The focus of the TMDL is reduction of pollutant inputs to a level (or "load") that fully supports the designated uses of a given waterbody. The mechanisms used to address water quality problems after the TMDL is developed can include a combination of best management practices and/or effluent limits and monitoring required through National Pollutant Discharge Elimination System permits.

The state of Alaska included Ship Creek on its 1998 303(d) list as water quality-limited due to fecal coliform. The listed segment (Alaska ID Number 20401-020) was originally listed in 1990 and is included on the 1998 list as a Tier I water[1]. The 303(d) list identifies urban runoff as the expected pollutant source. This document establishes a TMDL to address the fecal coliform impairment in Ship Creek.

The following sections provide general background information on the Ship Creek watershed.

1.1 Location

Ship Creek is located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in southcentral Alaska (Figure 1-1). The Anchorage Bowl is a broad valley bordered by the Chugach Mountain Range on the east and the Turnagain Arm and Knik Arm of Cook Inlet to the southwest and northwest. The 123-mi^2 Ship Creek watershed contains areas of Chugach State Park, Elmendorf Air Force Base and Fort Richardson Army Base. The headwaters of Ship Creek are in the Chugach Mountains and, from the headwater region, the main stream flows toward the northwest and flows to the west as it enters MOA, eventually discharging into Knik Arm of Cook Inlet.

1.2 Population

Population within the Ship Creek watershed was estimated using geographic information systems (GIS) analysis that incorporated 2000 Census block data for the basin. Block level spatial and census data for MOA were clipped to the watershed boundary. Population was then summed for blocks in the watershed. The analysis resulted in an estimated population of 19,729 persons and a total of 7,966 households within the basin.

[1] Tier I: Water quality-limited waterbodies which require water quality assessments to verify the extent of pollution and what controls are in place or needed.

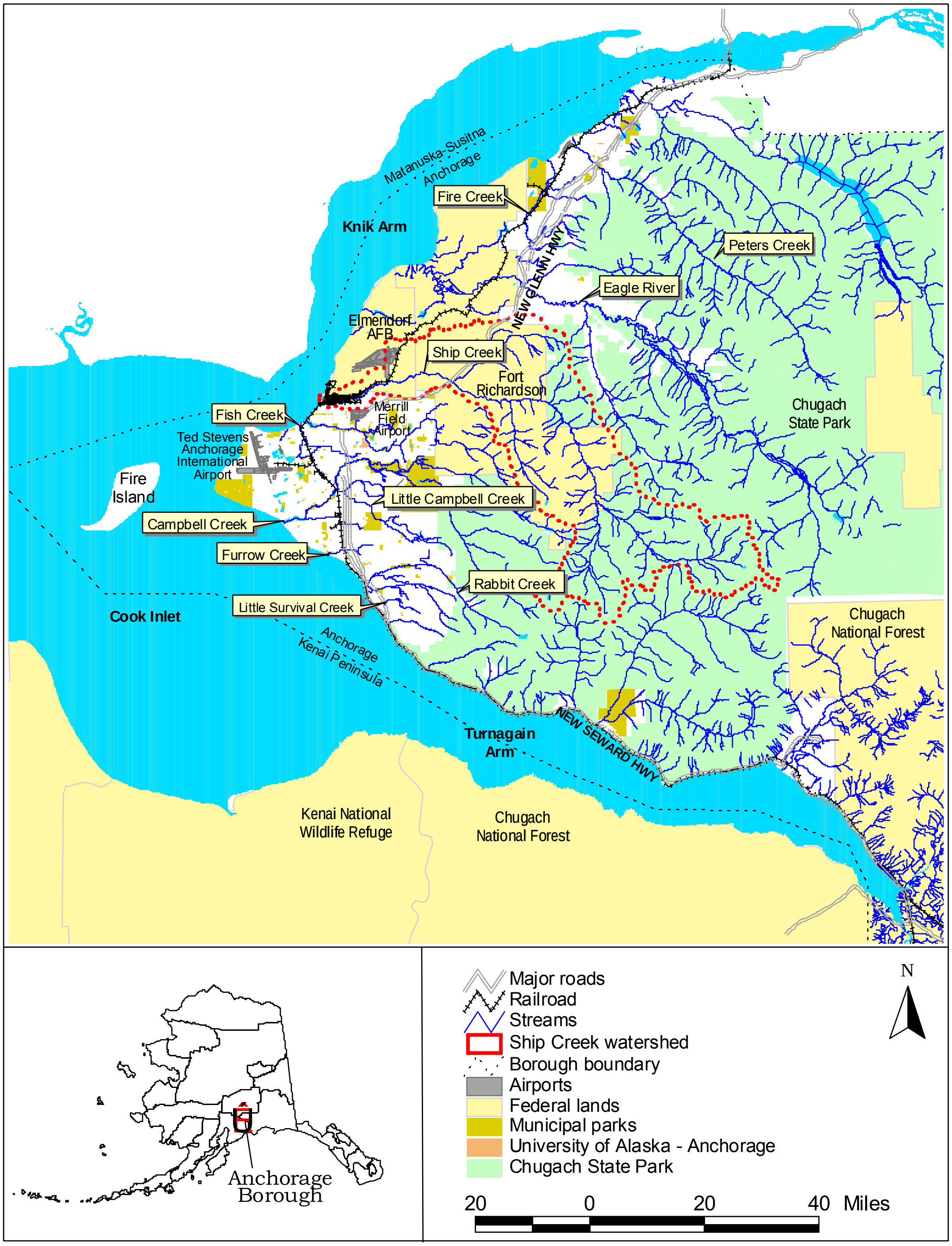


Figure 1-1. Location of Ship Creek watershed

1.3 Topography

Anchorage is a broad valley bounded by the Knik Arm and Turnagain Arm of Cook Inlet. The terrain rises gradually to the east for about 10 miles, with marshes interspersed with glacial moraines, shallow depressions, small streams and knolls (AWSO, 1997). Beyond this valley area, the Chugach Mountains are situated in a north-northeast to south-southwest direction, with average elevations between 4,000 and 5,000 ft and peaks up to 10,000 ft. Elevations in the Ship Creek watershed range from 5,000 feet above sea level along the drainage divide in the Chugach Mountains to zero feet above sea level at the outlet into Cook Inlet. The main channel is approximately 29 miles long, with an average rate of fall of about 93 feet per mile. The rate of fall varies from an average of 931 feet per mile in the eastern mountainous region of the basin to an average of 73 feet per mile in the western portion of the basin. Slope gradients in the extreme western portion of the watershed are very low.

1.4 Landuse

MOA created a complete land cover classification to provide the foundation for mapping inland areas according to their common surface hydrologic and gross pollutant generation potential. The “Storm Water Runoff” grid was derived through analysis of IKONOS satellite imagery and other geographic datasets (especially landuse, streets, drainage, coastland and wetlands data). The dataset was built to provide information for storm water management applications.

The land cover data include five major classes: Impervious, Barren Pervious, Vegetated Pervious, Snow and Ice, and Water. These land cover classes are further subdivided to reflect changes in perviousness due to different land development applications. For example, impervious surfaces are classified as either street surface, directly connected impervious, and indirectly connected impervious and vegetation classes are reclassified as either landscaped or forested. The MOA land cover classifications are described in Table 1-1.

Table1-2 and Figure 1-2 present the land use distribution of the Ship Creek watershed. As shown in Figure 1-2, the MOA land cover does not include information for the entire watershed and covers only about 20 percent of the watershed. Unclassified upper portions of the watershed are located in the Chugach State Park with forested land cover. The remaining portion of the watershed not included in the park or classified in the MOA land coverage was assumed to be forested land. The lower Ship Creek watershed contains larger areas of urban residential and commercial land uses, with the highest concentration of urban land uses near the mouth of the stream. Forest cover accounts for nearly 95 percent of the total land cover in the basin, while urban land covers (landscaped, impervious surfaces, and streets) account for the remaining 5 percent.

Table 1-1. MOA land cover classification system

Land Cover	Land Cover Description
Impervious	Large paved areas, parking lots, rooftops.
Directly Connected Impervious	Impervious features (not including roads) that are immediately adjacent to paved roads and spatially intersect a 60-foot buffer from the edge of pavement. For example, a large parking lot that extends beyond 60 feet from the edge of a paved road will be categorized as directly connected impervious as long as a portion of that feature enters a 60-foot buffer from an adjacent roadway.
Indirectly Connected Impervious	Areas that do not intersect the 60-foot buffer from the edge of pavement. These include impervious areas that are adjacent and/or within the vicinity of dirt or unpaved roads.
Streets	Paved roadways.
Landscaped	Parks, open fields, residential yards, large areas of non-forested and non-wetland vegetation.
Forested	Areas of tree canopy—natural forest.
Barren	Includes areas of zero or little vegetation, exposed soil, non-active land-cover.
Wetland	Moist areas containing vegetation, marshes, bogs.
Lakes/Water	Areas of exposed water bodies, reservoirs.

Table 1-2. Landuse distribution in Ship Creek watershed

Landuse	Area (acres)	Percent of total area
Barren	351	<1%
Indirectly Connected Impervious (ICI)	789	1%
Directly Connected Impervious (DCI)	2,144	3%
Street	596	<1%
Wetland	5	<1%
Landscaped	250	<1%
Forested	74,835	95%
Total	78,970	

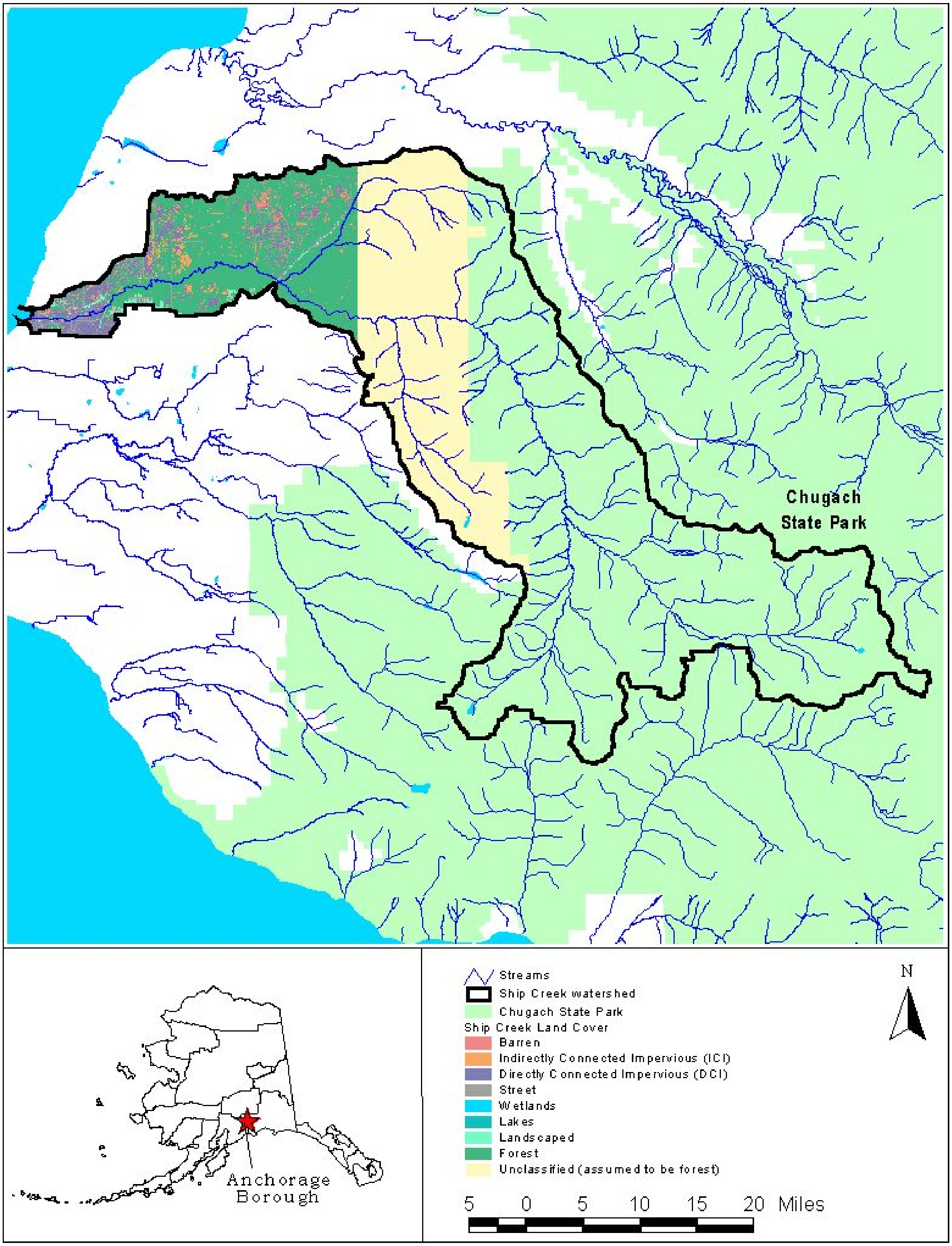
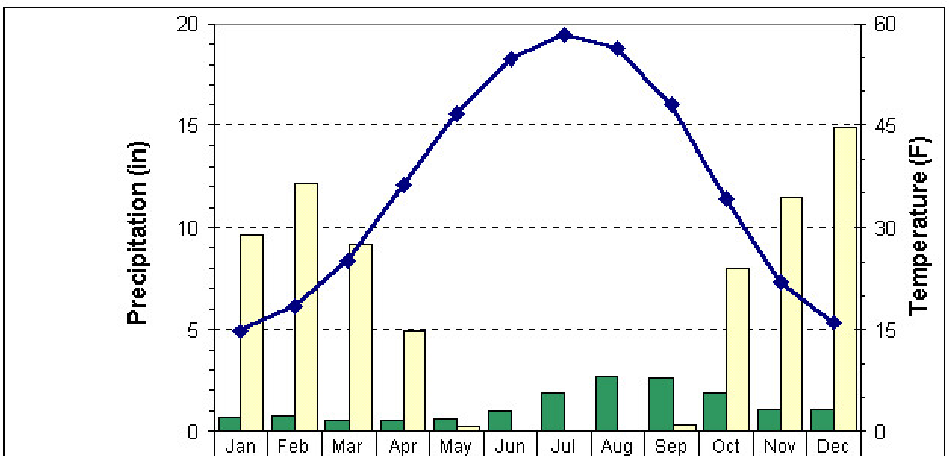


Figure 1-2. Landuse distribution in the Ship Creek watershed

1.5 Climate

The Anchorage area is contained in the "transition" climate zone of Alaska, between the maritime and continental zones. Temperatures in the transition zone typically range between zero and the low 60s degrees Fahrenheit (EF) (WWRC, 2002). The Chugach Mountains act as a barrier to the influx of warm, moist air from the Gulf of Alaska, resulting in annual precipitation amounts equal to 10 to 15 percent of that measured at weather stations located on the Gulf side of the Chugach Range. Annual snowfall varies from approximately 70 inches on the west side of Anchorage to about 90 inches on the east side. Snow totals increase steadily with increasing elevations in the Chugach Mountains where winter arrives a month earlier and stays a month longer at the 1,000 to 2,000 ft elevation (AWSO, 1997).

Summer temperatures average around 60° F. Autumn begins in early September and ends in mid-October with temperatures falling in September and snowfalls increasing in October (AWSO, 1997). Winter lasts from mid-October to early April, with the coldest temperatures typically occurring in January. Spring begins in late April and May with less precipitation and increasing temperatures. Figure 1-3 presents a summary of monthly averages for rainfall, snowfall and temperature at the Anchorage Ted Stevens International Airport (500280), based on the period of record at the station from April 1952 to December 2001.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean precipitation	0.74	0.83	0.61	0.55	0.68	1.02	1.87	2.7	2.63	1.89	1.1	1.08
Mean snowfall	9.6	12.1	9.2	4.9	0.2	0	0	0	0.3	8	11.5	14.9
Mean temperature	14.7	18.4	25.1	36.1	46.8	54.8	58.3	56.3	48.1	34.2	21.9	16

Figure 1-3. Monthly average precipitation and temperatures at Anchorage Ted Stevens International Airport

1.6 Hydrology

Groundwater

Located on the eastern flanks of the Cook Inlet is a deep structural trough filled with thousands of feet of sedimentary deposits and overlain by alluvial and glacial deposits. These alluvial and glacial deposits underlie the western portion of Anchorage and form the aquifer system, known as the Anchorage lowlands aquifers, that supplies the majority of water used by the Municipality of Anchorage (Brabets, et al., 1999). The Elmendorf Moraine, which lies north of Ship Creek on Elmendorf Air Force Base and Fort Richardson, marks the northern boundary of the lowland aquifer system. The moraine extends across Cook Inlet between Mt. McKinley and Wasilla. Municipal groundwater systems north of the Elmendorf Moraine are discontinuous due to poorly defined glacial aquifers.

An extensive confining layer known as the Bootlegger Cover Formation underlies the lowland aquifers that are found south of the moraine (Brabets, et al., 1999). This formation consists of dense clayey silt deposits, and separates the upper unconfined aquifer from an underlying confined aquifer. The unconfined aquifer is hydraulically connected to many of the streams and lakes in Anchorage. Streams originating in the adjacent mountains flow across alluvial fans and lose a significant amount of water to the aquifer. Although stream seepage through the alluvial fans comprises an important zone of recharge, the unconfined aquifer is recharged over wide areas of Anchorage by direct infiltration of precipitation (Brabets, et al., 1999). Water is gained from the aquifer by the creek downstream of the alluvial fans, and baseflow in Ship Creek, measured below the power plant at Elmendorf Air Force Base, is approximately 2.6 cubic feet per second. Within the watershed, at elevations below 200 feet, very high densities of groundwater discharge points occur (Brabets, et al., 1999). Water pumped from the unconfined aquifer removes water that would have discharged to local streams. The removal of this natural water has little effect on regional groundwater drawdown.

Surface Water

Ship Creek originates from the combined flow of smaller tributary streams located in the Chugach Mountains. The creek flows through the city of Anchorage before discharging to the Knik Arm of Cook Inlet. Ice cover can affect the streams for a significant part of the year, with ice typically present in late November to early December and open water reappearing around the beginning of April (Ourso, 2001). The time of ice cover varies according to the elevation of a particular segment of the stream.

USGS has measured streamflows in Ship Creek in various places (Figure 1-4) for different periods (Table 1-3). Only one of the three USGS gaging stations established for continuous-flow measurement remains active today (USGS stream gage #15276000). USGS #15276000 is located below the military/MOA water supply dam at approximately river mile 10 and about 0.2 miles downstream of the point where a large proportion of Ship Creek water is currently removed from the watershed. The gage has a long-term mean annual flow of 166 cubic feet per second (cfs).

Long-term daily average flow for USGS gage 15276000 is presented in Figure 1-5, based on its 55-year period of record. The figure shows that daily mean flows peak in late May and early June due primarily to snowmelt and again in the fall, primarily in response to precipitation input. Low flow occurs during the winter months. The amount of water available in Ship Creek at any given time and location is impacted by a variety of consumptive uses and by the influence of shallow and deep-water aquifers (groundwater systems) through natural processes and disturbances within the streambed. In turn, some water is gained from returns by non-consumptive users and from springs from groundwater systems. In addition, seasonal flow fluctuations make available stream flow highly variable, while most consumptive user demand tends to be more constant, with the exceptions of seasonal uses such as golf course irrigation and watering of lawns and trees.

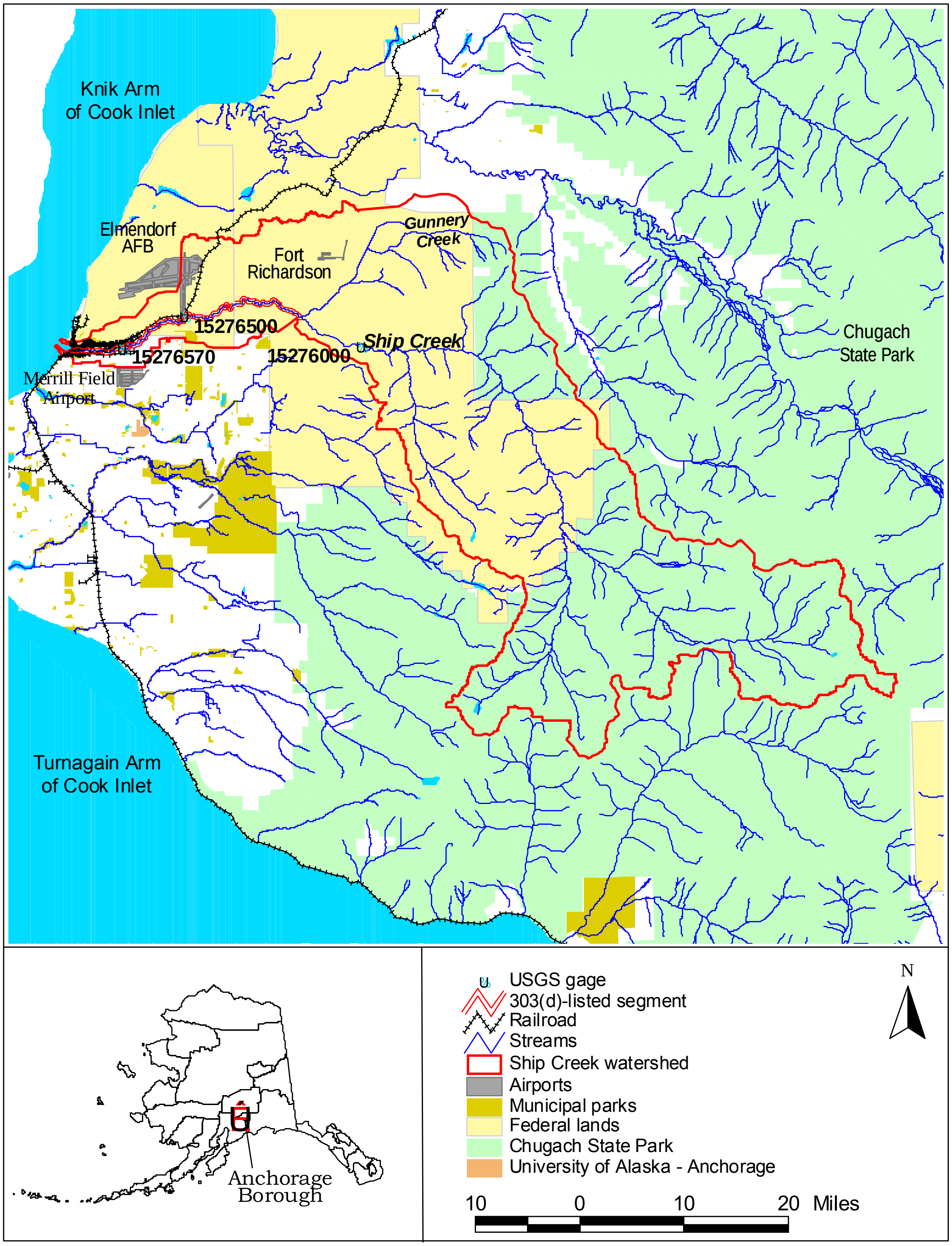


Figure 1-4. Location of USGS gages in the Ship Creek watershed

Table 1-3. Summary of available flow data for Ship Creek

	15276000	15276500	15276570
Start date	10/1/46	5/1/63	10/1/70
End date	9/30/01	9/30/71	1/31/81
Average monthly flows over the period of record			
January	43.1	28.5	40.8
February	76.6	91.4	81.5
March	132.8	128.9	123.8
April	160.5	154.6	163.5
May	193.6	215.7	197.6
June	223.1	215.0	245.8
July	250.2	240.4	267.4
August	287.1	254.8	312.1
September	317.5	285.9	332.7
October	352.2	312.0	346.3
November	368.2	337.6	347.9
December	402.9	382.4	391.1

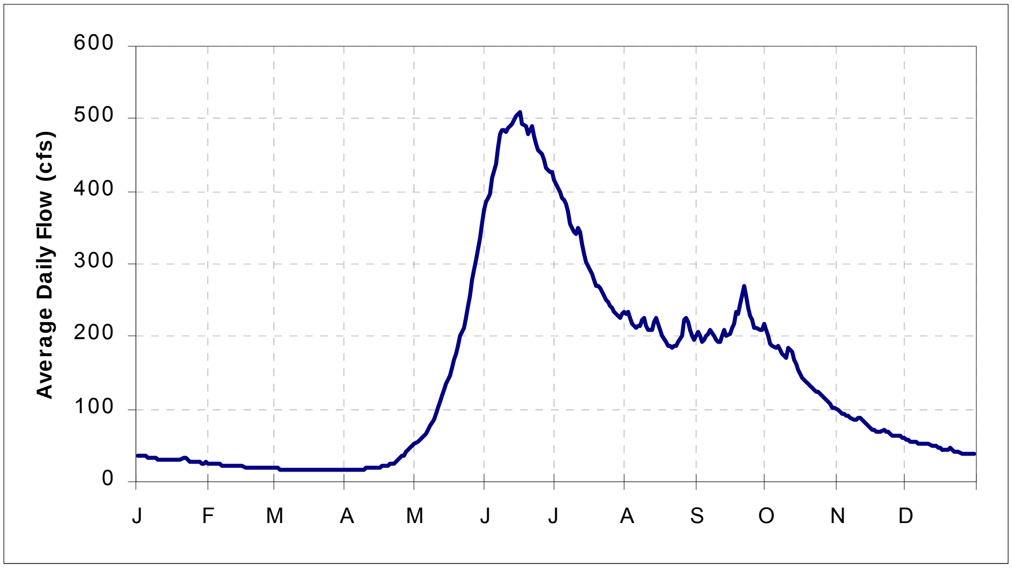


Figure 1-5. Average daily streamflow at USGS gage 15276000, Ship Creek (10/1/46-9/30/01)

2. Water Quality Standards and TMDL Target

Water quality standards designate the "uses" to be protected (e.g., water supply, recreation, aquatic life) and the "criteria" for their protection (e.g., how much of a pollutant can be present in a waterbody without impairing its designated uses). TMDLs are developed to meet applicable water quality standards, which may be expressed as numeric water quality criteria or narrative criteria for the support of designated uses. The TMDL target identifies the numeric goals or endpoints for the TMDL that equate to attainment of the water quality standards. The TMDL target may be equivalent to a numeric water quality standard where one exists, or it may represent a quantitative interpretation of a narrative standard. This section reviews the applicable water quality standards and identifies an appropriate TMDL target for calculation of the fecal coliform TMDL in Ship Creek.

2.1 Applicable Water Quality Standards

Title 18, Chapter 70 of the Alaska Administrative Code (ACC) establishes water quality standards for the waters of Alaska, including the designated uses to be protected and the water quality criteria necessary to protect the uses. Designated uses established in the State of Alaska Water Quality Standards (18 AAC 70.020) for fresh waters of the state include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife, and are applicable to all fresh waters, unless specifically exempted. Fecal coliform water quality standards for each use and applicable to Ship Creek are presented in Table 2-1. The TMDL must be developed to meet all applicable criteria. The most stringent of these is the following criteria for drinking, culinary, and food processing water supply:

> *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))*

2.2 Designated Use Impacts

Designated uses for Alaska's waters are established by regulation and are specified in the State of Alaska Water Quality Standards (18 AAC 70.020). For fresh waters of the state, these designated uses include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife. Ship Creek does not support its designated uses of water supply and water recreation due to elevated instream fecal coliform levels. The presence of fecal coliform indicates an increased risk of pathogen contamination in a waterbody. Consumption of or contact with pathogen-contaminated waters can result in a variety of gastrointestinal, respiratory, eye, ear, nose, throat and skin diseases.

2.3 TMDL Target

The TMDL target is the numeric endpoint used to evaluate the loading capacity and necessary load reductions and represents attainment of applicable water quality standards. Ship Creek has applicable numeric water quality criteria for fecal coliform, and the TMDL will be developed to meet the most stringent of these criteria—criteria for drinking, culinary, and food processing water supply (water supply). The water quality standard of a geometric mean of 20 FC/100 mL in a 30-day period will be used as the basis for this TMDL. The not-to-exceed criterion will not be used directly in the TMDL calculation because the available data does not support the use of an approach to link the frequency of exceedances (e.g., not to exceed in 10 percent of the samples) to fecal coliform loading. Using the geometric mean criterion results in a more stringent loading capacity and it is expected that maintenance of the geometric mean criterion will also result in maintaining the not-to-exceed criterion.

Table 2-1. Alaska water quality standards for fecal coliform

Water Use	Description of 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/100 ml. For groundwater, the FC concentration must be less than 1 FC/100 ml, using the fecal coliform Membrane Filter Technique, or less than 3 FC/100 ml, using the fecal coliform most probable number (MPN) technique.
(ii) agriculture, including irrigation and stock watering	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. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for drinking water supply, (1)(A)(i), apply.
(iii) aquaculture	For products normally cooked, 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. For products not normally cooked, the criteria for drinking water supply, (1)(A)(i), apply.
(iii) 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.
(ii) secondary contact	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/100 ml.
(C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	Not applicable

3. Data Analysis

The compilation and analysis of data and information is an essential step in understanding the general water quality conditions and trends in an impaired water. Several sources of data were reviewed to characterize the water quality of Ship Creek; however, some data were only used for general and background information and were not used directly in the calculation of the TMDL. This section outlines and summarizes all of the data reviewed and includes the following information:

- Data inventory—describes the available data and information used to evaluate water quality conditions
- Data analyses—presents results of various data analyses evaluating trends and relationships in instream data

3.1 Data Inventory

Table 3-1 and the following discussion summarizes the available fecal coliform data for Ship Creek, including data collected by MOA, Anchorage Waterways Council (AWC), and USGS. Figure 3-1 presents the monitoring station locations.

Table 3-1. Summary of available fecal coliform data for Ship Creek

Site	Location Description	No.[1]	Start Date	End Date	Min	Avg	Max	Over 40 FC/100 mL		Note[2]
								No.	%	
MOA stations										
SHP10	Ship at Anchorage Trade Center	304	2/10/89	9/30/94	0	85.3	3,200	123	40%	
SHP15	*Unknown*	2	3/16/89	3/22/89	0	0	0	0	0%	
SHP20	*Unknown*	3	3/9/89	3/22/89	0	0	0	0	0%	
SHP25	*Unknown*	1	3/9/89	3/9/89	0	0	0	0	0%	
SHP40	*Unknown*	1	3/9/89	3/9/89	0	0	0	0	0%	
AWC stations										
MaShi01v	Ship at AWC office	6	8/20/02	12/19/02	28	87.7	160.0	5	83%	
MaShi03v	Ship under Reeve Blvd. Bridge	6	8/20/02	12/19/02	19	59.5	250.0	1	17%	
USGS stations										
15276200	Ship C at Glenn Hwy	2	3/20/00	6/8/00	2	6	10	0	0%	2/100%
15276570	Ship C Bl Power Plant at Elmendorf AFB	2	3/16/00	6/1/00	9	20	31	0	0%	1/50%
611343149494100	Ship C at Reeve Blvd	1	9/4/98	9/4/98	8	8	8	0	0%	1/100%

[1] Number of samples.
[2] Number and percentage of measurements marked as "estimated value."

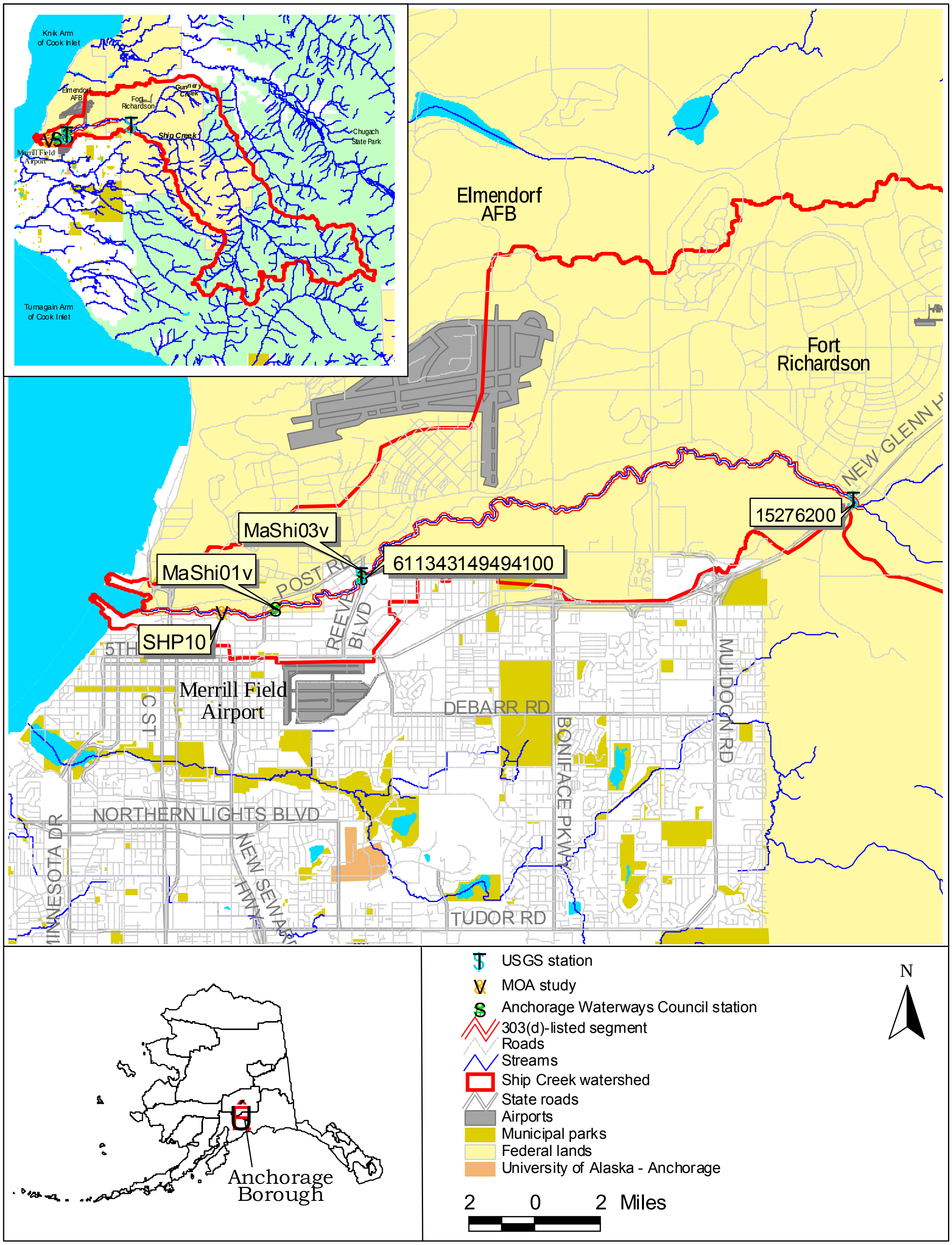


Figure 3-1. Locations of water quality monitoring stations in Ship Creek

3.2 Data Analysis

The following sections discuss data analyses conducted to evaluate any important trends or aspects of the fecal coliform levels in Ship Creek, based on MOA data collected at station SHP10. Several sources of data were reviewed to characterize the water quality of Ship Creek; however, some of the data were used for general and background information rather than specific analyses and calculation of the TMDL. Many of the datasets available for Ship Creek contain limited number of samples, do not capture seasonal differences, are older than other available data, and/or contain estimated (rather than measured) values. The following analyses were based on the MOA data collected in at SHP10 in Ship Creek from 1989 through 1994. The MOA dataset is the most robust dataset available, representing extensive monitoring over an 18-month period, with sufficient data for meaningful analyses.

Impairment Analysis

An impairment analysis compares available instream data with applicable water quality standards to confirm the listed impairment (i.e., nonsupport of fecal coliform water quality standards). The analysis also evaluates the magnitude and frequency of water quality standards exceedances. Fecal coliform data collected by MOA at SHP10 in Ship Creek were compared to the geometric mean and not-to-exceed standards to evaluate impairment and water quality standards exceedances.

For comparison to the geometric mean criterion, geometric means were calculated for every possible 30-day period included in the dataset, based on all individual observations within that 30-day period. Table 3-2 and Figure 3-2 summarize the calculated geometric means and their comparison to the geometric mean criterion of 20 FC/100 mL. Table 3-2 includes the monthly average, median, minimum, maximum and 25th and 75th percentiles of all calculated geometric means. The table also presents a ratio and percentage of the number of 30-day geometric means included in each month that exceed the 20 FC/100 mL criterion ("Exceedances: Count" and "% of Exceedances"). A table listing all of the calculated exceedances of the geometric mean criterion is included in Appendix A with information on the 30-day period (start and end dates), the number of samples included in the calculation, the geometric mean value and exceedance percentage of the geometric mean.

The fecal coliform data at SHP10 in Ship Creek were also compared to the not-to-exceed standard (i.e., not to exceed 40 FC/100 mL in more than 10 percent of the samples in a 30-day period), as summarized in Table 3-3 and Figure 3-3. For a summary of the instantaneous concentrations, Table 3-3 includes the average, median, minimum, maximum, and 25th and 75th percentiles of all values within each month. For comparison to the criterion, samples within any possible 30-day period were compared to the not-to-exceed criterion and the calculated exceedances are summarized in Table 3-3 ("Exceedances: Count" and "% of Exceedances"). For example, there are 23 possible 30-day periods that include samples collected in January. In 15 of those 23 periods (or 65 percent), more than 10 percent of the values exceeded 40 FC/100 mL. A table listing all exceedances of the not-to-exceed criterion is included in Appendix A.

Table 3-2. Summary statistics of geometric means calculated using observed fecal coliform data

Data: 2/10/89 to 9/30/94

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	43	26	7	121	17	57	15:24	63%
Feb	55	67	5	93	20	86	15:20	75%
Mar	105	91	1	380	19	149	19:26	73%
Apr	97	52	1	484	16	141	21:29	72%
May	12	11	2	27	5	20	8:27	30%
Jun	11	9	1	25	6	16	5:24	21%
Jul	16	13	2	51	8	22	9:29	31%
Aug	39	38	10	91	27	45	26:30	87%
Sep	25	21	1	83	17	29	16:30	53%
Oct	25	22	12	48	16	33	14:24	58%
Nov	22	21	8	39	10	30	12:21	57%
Dec	35	28	1	116	17	38	13:20	65%
All Data	41	22	1	484	12	41	173:304	57%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

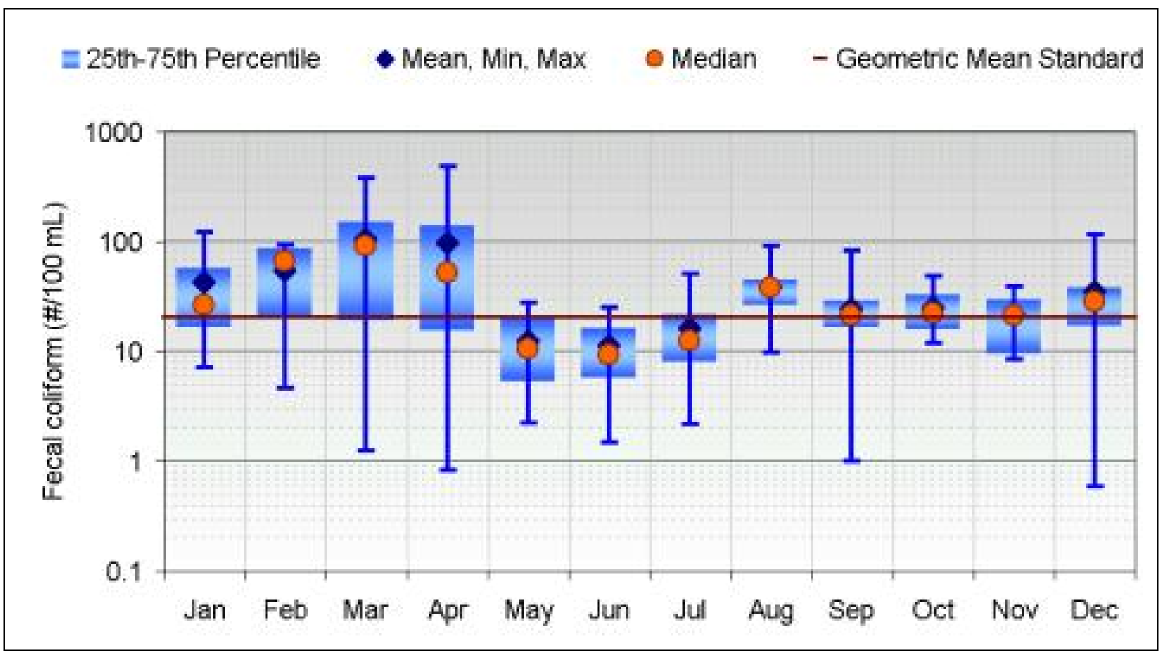


Figure 3-2. Summary of calculated geometric means of fecal coliform in Ship Creek

Table 3-3. Summary statistics for the evaluation of exceedances of the not-to-exceed criterion

Data: 2/10/89 to 9/30/94

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	91	44	0	770	29	80	15:23	65%
Feb	112	84	0	800	46	120	19:25	76%
Mar	266	119	0	1889	40	293	21:28	75%
Apr	59	21	0	590	8	48	7:26	27%
May	21	10	0	154	6	17	4:26	15%
Jun	16	11	0	60	5	18	3:28	11%
Jul	45	22	1	229	11	47	10:28	36%
Aug	54	42	11	300	20	64	14:27	52%
Sep	170	19	0	3200	9	45	8:28	29%
Oct	48	25	3	330	13	40	6:22	27%
Nov	30	15	0	169	7	36	3:21	14%
Dec	85	43	0	400	15	78	13:22	59%
All Data	85	28	0	3200	11	70	123:304	40%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
[2] Ratio of observed fecal coliform values that exceed the water quality criterion to the observed fecal coliform values in the month.
[3] Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

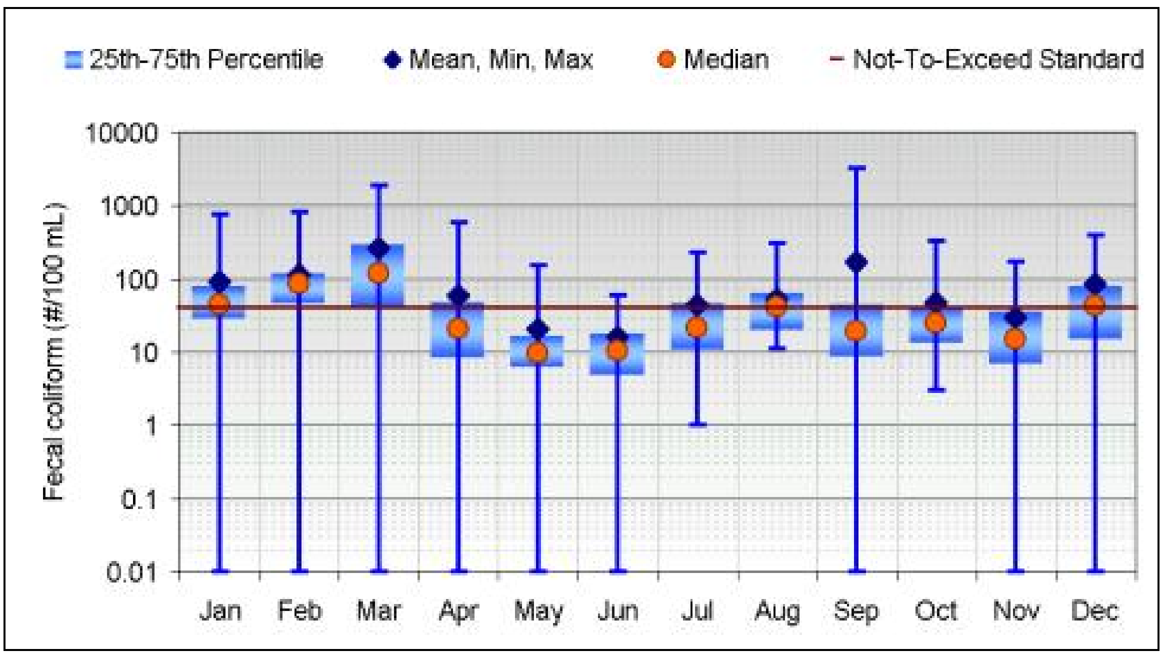


Figure 3-3. Summary of instantaneous fecal coliform levels in Ship Creek

Temporal Variation

Evaluation of temporal patterns can assist in identifying potential sources in the watershed, seasonal variations or declining/improving water quality trends. Flow data are not available with fecal coliform data to evaluate the relationship of seasonal flow differences on fecal coliform levels; however, some assumptions can be made based on fecal coliform distributions and likely flow and source patterns in the watershed. Ship Creek does not experience a drastic seasonal variation in fecal coliform concentrations. As shown in Figure 3-3, increased coliform levels occur during March, likely due to runoff during spring breakup, and decreased levels during the drier months of May and June. Levels increase during July, August and September due to late summer storms. Winter fecal coliform levels in Ship Creek are comparable to late summer levels. Coliform levels in many area streams are typically substantially lower during frozen winter months; however, because Ship Creek receives thermal discharge from the power plant, it does not freeze during the winter season. Because of this, large populations of ducks typically inhabit the area during winter months, likely accounting for the coliform levels comparable to warmer or wetter months.

4. Pollutant Sources

The identification of sources is important to the successful implementation of a TMDL and the control of pollutant loading to a stream. Characterizing watershed sources can provide information on the relative magnitude and influence of each source and its impact on instream water quality conditions. This section discusses the potential sources of fecal coliform to Ship Creek, including point and nonpoint sources.

4.1 Point Sources

Stormwater runoff to Ship Creek is expected to be a primary source of fecal coliform. Stormwater is traditionally considered a nonpoint source, carrying pollutants to receiving waters through surface runoff. However, when stormwater is permitted and carried through conveyances to discrete discharges to streams, it is considered a point source. Unlike most constant point sources (e.g., WWTP discharges), stormwater is precipitation-driven.

4.2 Nonpoint and Natural Sources

The Alaska 303(d) list identifies urban runoff as the primary source of fecal coliform to Ship Creek. Snowmelt and rainfall transport bacteria that is deposited and accumulated on the surface of residential and urban areas. Likely sources of the accumulated bacteria are waterfowl, domestic animals (e.g., cats and dogs) and native animals (e.g., moose, bear, etc.). Animals can deposit fecal matter directly into the watershed streams or on the land surface where it is available for overland transport in surface runoff. MOA (1990) concludes that pet and waterfowl feces appear to the major sources of fecal coliform for runoff in the Anchorage area. Additionally, because Ship Creek does not freeze during the winter season due to thermal discharges from the power plant, large populations of ducks inhabit the area during winter months.

Wildlife may be a considerable source of fecal coliform to Ship Creek, both through direct deposition and deposition on watershed surfaces; however, it is difficult to estimate fecal coliform contributions from wildlife in the Anchorage area. It is not feasible to isolate wildlife populations for area watersheds due to the mobility and large ranges of the wildlife throughout the area. Additionally, while fecal coliform production of many agricultural animals has been researched, there is little or no information on the bacteria production rates of wildlife species native to the Anchorage area.

Although the information is not available to quantify the direct loading from wildlife sources in the watershed, Alaska Department of Fish and Game (ADF&G) provided qualitative estimates of wildlife populations in the Anchorage area that are used to provide general background on the types of animals that may be contributing to the fecal coliform impairments in the area. The following summarizes the information provided by ADF&G (Rick Sinnott, personal communication, 1/30/03):

- Approximately 200-300 moose live in the Anchorage Bowl, not including moose that live solely in Fort Richardson or Chugach State Park, and as many as 1,000 moose are in the Anchorage Bowl in winter.

- About 2,000 Canada geese inhabit the Anchorage Bowl. Most of these geese are located west of Lake Otis Boulevard and north of Tudor Road (i.e., Fish Creek area) in grassy parks, school grounds, and athletic fields in April and July-October and in bogs, ponds, and lakes in May-July. Thousands more Canada and other geese fly through the area in spring and fall, primarily in the Anchorage Coastal Wildlife Refuge (located on the Turnagain Arm and including Potter Marsh).

- Anchorage may contain 2,000 or more mallards in the winter, with most located in open creeks (Ship Creek and Chester Creek).

- Anchorage also has several thousand pigeons, primarily downtown and midtown.

- At most, there are 100-150 beavers in the Anchorage Bowl.

- Latest counts showed no more than 6 brown bears and 30-40 black bears in the Anchorage Bowl.

Another potential source of fecal coliforms is failing septic systems. Septic systems have the potential to contribute fecal coliform to receiving waters through surface breakouts and subsurface malfunctions. Failing septic systems located in close proximity to receiving waterbodies are more likely to impact instream conditions. The majority of septic systems in the Anchorage area are located more than 100 feet away from any streams. Additionally, the majority of the houses (more than 95 percent) in the Ship Creek watershed are connected to city sewer and do not use onsite septic systems and 99-100 percent of those built close to the stream are connected to city sewer (Kevin Kleweno, ADEC, Division of Environmental Health, Drinking Water & Wastewater Program, personal communication to Timothy Stevens, ADEC, January 31, 2003). Therefore, it is unlikely that septic systems are a source of fecal coliform impacting Ship Creek.

5. Analytical Approach

Developing TMDLs requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. In identifying the technical approach for development of the fecal coliform TMDL for Ship Creek, the following core set of principles was identified and applied:

- ***The TMDLs must be based on scientific analysis and reasonable and acceptable assumptions.*** All major assumptions have been made based on available data and in consultation with appropriate agency staff.

- ***The TMDLs must use the best available data.*** All available data in the watershed were reviewed and were used in the analysis where possible or appropriate.

- ***Methods should be clear and as simple as possible to facilitate explanation to stakeholders.*** All methods and major assumptions used in the analysis are described. The TMDL document has been presented in a format accessible by a wide range of audiences, including the public and interested stakeholders.

The analytical approach used to estimate the loading capacity, existing loads, and allocations presented below relies on these principles and provides a TMDL calculation that uses the best available information to represent watershed and instream processes.

5.1 Analysis Background

When developing a TMDL based on instream observed data, existing loads can typically be estimated using corresponding observed flow and water quality data. Similarly, allowable loads can be calculated using observed flows and an appropriate TMDL target concentration. For example, a loading capacity curve can be developed by multiplying observed flow values by the water quality standard and graphing the resulting loads. An existing load curve can be developed by multiplying the observed flow values by the observed water quality data. Existing loads that plot above the TMDL curve therefore represent deviations from the water quality standard and those plotting below the curve represent compliance with standards. The area beneath the TMDL curve represents the loading capacity of the stream.

To conduct a load duration curve analysis it is necessary to have a continuous flow record or a dataset of flows covering a broad range of flow conditions during times of water quality sampling in the impaired stream. Although Ship Creek has a consistent record of fecal coliform data from the 1989-90 MOA study, it does not have flow data corresponding to the time and location of available fecal coliform data. Therefore, the TMDL development approach must be done using a simpler approach that uses an empirical equation to calculate pollutant loading in the absence of flow data.

The Simple Method (Schueler, 1987) was used to calculate existing fecal coliform loading based on watershed characteristics and observed fecal coliform data. The method was also used to calculate loading capacity for the stream, based on instream concentrations representing water quality standards.

Because Ship Creek experiences considerable seasonal variation in instream fecal coliform levels, the TMDL analysis calculates loads and reductions on a seasonal basis to isolate times of similar instream, weather, and flow conditions. The analysis is conducted for the three major seasons in the watershed—winter (October 1 - March 31), spring (April 1 - May 31), and summer (June 1 - September 30). During winter months, precipitation falls primarily as snow, resulting in little to no surface runoff. Snow and ice accumulated during winter melts with the increasing temperatures during spring, creating increased surface runoff and steadily increasing instream flows. Summer experiences warmer temperatures and summer storms that produce peaks of high instream flows.

The following sections discuss the TMDL analysis in more detail, including the data inputs and results.

5.2 Evaluation of Existing Loads

The Simple Method (Schueler,1987) was used to calculate fecal coliform loading in Ship Creek. The Simple Method is a lumped parameter empirical model to estimate stormwater pollutant loadings under conditions of limited data availability. The approach calculates pollutant loading using drainage area, pollutant concentrations, a runoff coefficient and precipitation. In the Simple Method, the amount of rainfall runoff is assumed to be a function of the imperviousness of the contributing drainage area. More densely developed areas have more impervious surfaces, such as rooftops and pavement, causing more stormwater to runoff rather than be absorbed into the soil. The Simple Method equation is:

$$L = CF \cdot P \cdot Pj \cdot Rv \cdot C \cdot A$$

where:

- L = Pollutant load (fecal coliform counts per time interval)
- CF = Conversion factor (1,028,270 mL/in-acre)
- P = Precipitation depth (inches) over desired time interval
- Pj = Fraction of rainfall that produces runoff (assumed to be 0.9 [Schueler, 1987])
- Rv = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff
- C = Pollutant concentration (FC/100 mL)
- A = Area of the watershed (acres)

The following sections discuss the identification of the parameters for calculation of fecal coliform loading in Ship Creek using the Simple Method.

Precipitation (P)

Seasonal precipitation totals for use in the Simple Method were determined based on historical records at Ted Stevens International Airport, National Climatic Data Center Station 500280 (Figure 5-1). Precipitation totals measured at the NCDC station represent water-equivalent totals of rain, snow, and other forms of precipitation. Precipitation falling as snow during the winter months accumulates and does not result in surface runoff as rainfall would. Therefore, if precipitation totals from winter months are used in the Simple Method, the calculations result in unrealistic surface runoff and loading to the stream. To account for this, precipitation totals were modified to more realistically reflect runoff patterns in the area.

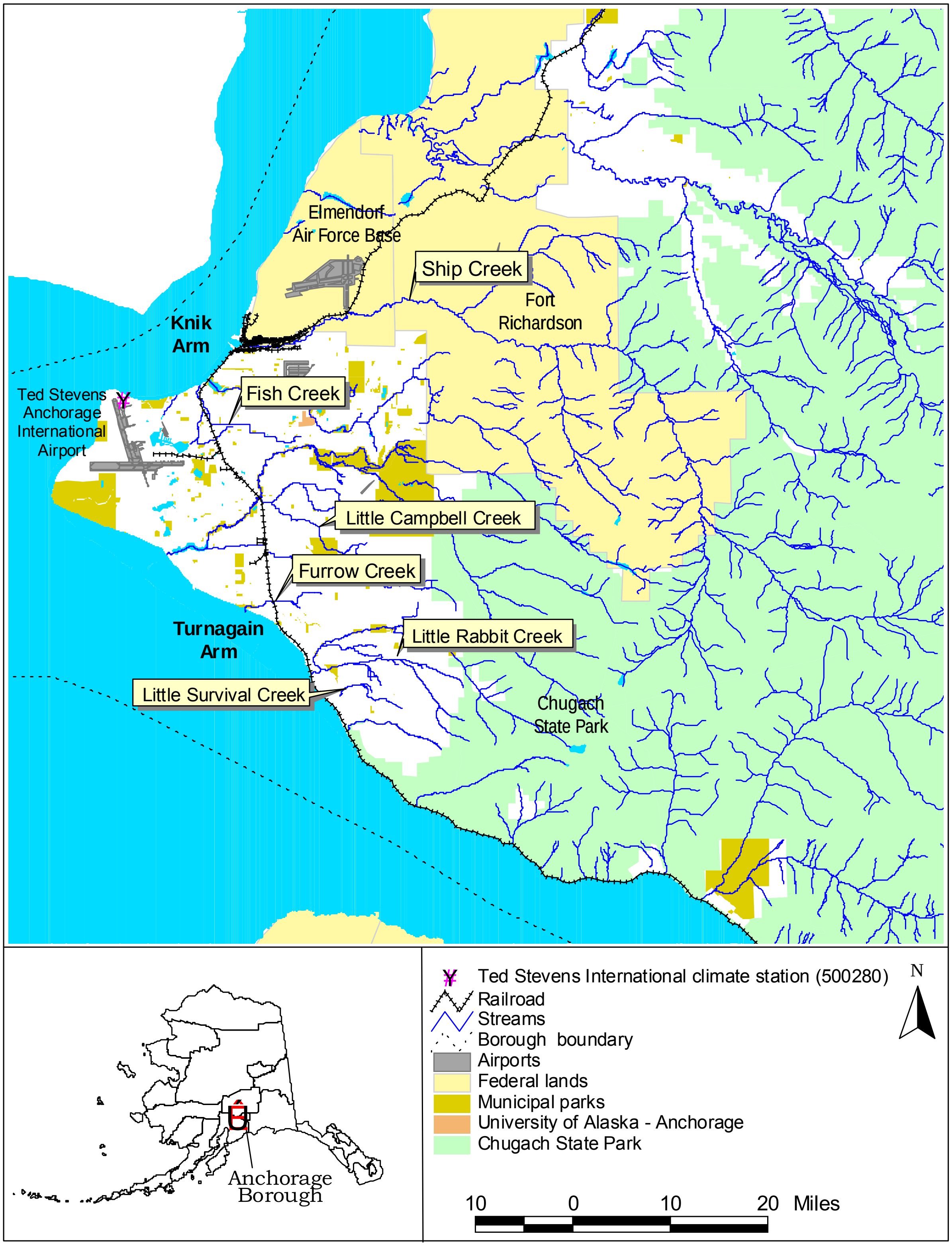


Figure 5-1. Location of Ted Stevens International Airport climate station (500280)

Precipitation during the winter months was divided into snow and rainfall to isolate the portion of measured precipitation that would result in runoff (i.e., rainfall) and that portion that would remain frozen on the watershed surface (i.e., snow). The snow portion was then added to the spring precipitation totals to reflect the time period that the accumulated snow would melt and contribute to surface runoff. To divide the precipitation into rainfall and snowfall portions, monthly snowfall totals from the airport were converted to water-equivalent precipitation and subtracted from the monthly precipitation totals also recorded at the airport.

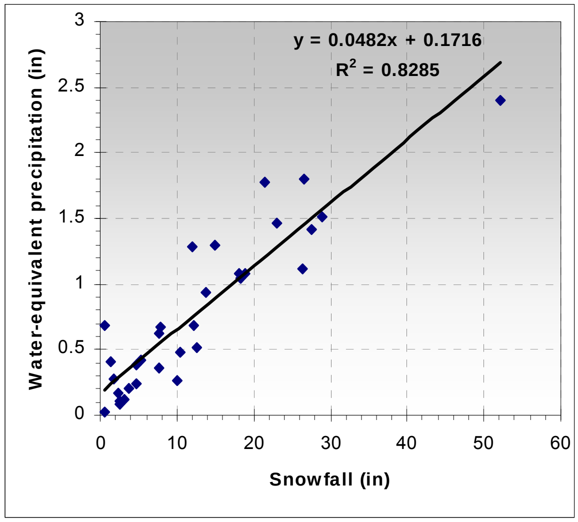


Figure 5-2. Relationship between snowfall and water-equivalent precipitation

To convert the snow to water-equivalent precipitation it was necessary to identify a conversion factor relating snow depth to water-equivalent depth. Monthly snowfall and total precipitation depths recorded at the Ted Stevens climate station for January, February and December of every year from 1980 through 1987were evaluated to establish a relationship between the two measures. (Data from 1998 through 2002 were discarded due to periods of data gaps [e.g., missing days].) Monthly totals measured during months with average temperatures below 20° F were used to establish a correlation between snowfall and water-equivalent precipitation, as shown in Figure 5-2. The regression equation representing the relationship between the two parameters (also shown in Figure 5-2) was used to convert recorded winter snowfalls to water-equivalent precipitation.

Monthly average snowfall and rainfall precipitation values were then calculated for the period of record used in the TMDL analysis—February 1989 through September 1994, corresponding to available fecal coliform data. The monthly averages were summed to calculate the corresponding seasonal totals. Additionally, the average monthly snowfall totals for winter were summed and added to the spring totals to account for the effect of runoff during spring melt. Table 5-1 summarizes the seasonal precipitation totals and corrections for snowfall.

Table 5-1. Seasonal precipitation totals

Season	Total Measured Precip (in)	Snowfall correction (in)	Corrected Precip (in)
Winter	6.99	-4.56	2.43
Spring	1.19	4.56	5.75
Summer	9.91	0.00	9.91

Runoff Coefficient (Rv)

Because site-specific runoff coefficients were not available for the Anchorage area, a relationship between watershed imperviousness and the storm runoff coefficient (Rv) developed by Schueler (1987) was used to determine the runoff coefficient (Rv) for Ship Creek watershed. Schueler (1987) used nationwide data collected for the National Urban Runoff Program study (USEPA, 1983) with additional data collected from Washington, DC, area watersheds to establish the relationship, represented by the following equation:

$$Rv = 0.05 + 0.9(I)$$

where:

I = Impervious fraction of the drainage area

An overall runoff coefficient for Ship Creek watershed was determined based on impervious areas throughout the watershed using land cover data provided by the MOA. As discussed in Section 1.4, the land cover data include classes to reflect changes in perviousness due to different land development applications. For example, impervious surfaces are classified as either street surface, directly connected impervious, and indirectly connected impervious. Vegetation classes were reclassified as either landscaped or forested. Wetlands were derived from features mapped by MOA and superimposed on the land cover data. Any category classified as impervious is assumed to be 100 percent impervious, while all other classes are 0 percent impervious. The total impervious area in the watershed was divided by the total watershed area to determine the overall impervious fraction of the watershed. This value (I) was used with the Schueler (1987) equation to determine the runoff coefficient (Rv) for Ship Creek watershed. Table 5-2 presents the total watershed area, total impervious area and the resulting I and Rv values.

Table 5-2. Information used in calculation of runoff coefficient for Ship Creek watershed

Total Area (acres)	Total Impervious Area (acres)	Overall Percent Imperviousness	Runoff Coefficient (Rv)
78,970	3,526	4%	0.09

Pollutant Concentration (C)

Observed fecal coliform data by MOA between 1989 and 1994 were used to calculate the C value for use in the Simple Method. The C value represents the average pollutant concentration, preferably the event mean concentration (EMC), which is a flow-weighted average concentration. Because concentrations of pollutants can widely vary throughout a storm event and between events, a flow-weighted average can account for variability and result in a more representative “average” concentration. Unfortunately, flow data are not available with available fecal coliform data, prohibiting the calculation of EMCs. To minimize the impact of variability of concentrations in the stream during and between storm events (and to be consistent with water quality standards), the geometric mean of observed fecal coliform samples is used as the C value. The seasonal C values were calculated as geometric means based on the MOA data and were calculated using all observations within a season. For example, the representative geometric mean of 12 FC/100 mL for spring was calculated using all samples collected in April and May during the period of record (i.e., 1989-1994). The resulting seasonal C values for Ship Creek are included in Table 5-3.

Calculation of Existing Load

The Simple Method was also used to calculate seasonal loading capacities. The parameters representing watershed characteristics (e.g., precipitation, runoff coefficients and area) remain the same for the loading capacity calculation; however, the pollutant concentration (C) is changed to reflect TMDL conditions—conditions meeting water quality standards. Therefore, the C value for calculation of loading capacities is equal to the geometric mean water quality criterion of 20 FC/100 mL. The calculated loading capacities are summarized in Table 5-3, along with the existing loadings and resulting load reductions.

Table 5-3. Simple Method values and resulting fecal coliform loads for Ship Creek

Season	P (in)	Pj	Rv	C (FC/100 mL)	A (acres)	Existing Loading (FC/season)
Winter	2.43	0.90	0.09	31.57	78,970.00	5.05E+11
Spring	5.75	0.90	0.09	12.11	78,970.00	4.59E+11
Summer	9.91	0.90	0.09	18.68	78,970.00	1.22E+12
Total (FC/yr)						2.18E+12

5.3 Evaluation of Loading Capacity

Once the existing fecal coliform loadings and the necessary reductions were calculated, they were used to determine monthly loading capacities for Ship Creek, as summarized in Table 5-4.

Table 5-4. Seasonal fecal coliform loading capacities for Ship Creek

Season	Existing Loading (FC/season)	Loading Capacity (FC/season)	Percent Reduction
Winter	5.05E+11	3.20E+11	37%
Spring	4.59E+11	7.58E+11	N/A
Summer	1.22E+12	1.31E+12	N/A
Total (FC/yr)	2.18E+12	2.39E+12	N/A

6. TMDL

A TMDL represents the total amount of a pollutant that can be assimilated by a receiving water while still achieving water quality standards. A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must include a margin of safety (MOS), either 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

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

Table 6-1 summarizes the overall fecal coliform TMDL for Ship Creek.

This TMDL will be implemented using adaptive management and will be revised, as necessary, based on future information on sources and instream conditions. Adaptive management is an approach where monitoring and source controls are used to provide more information for future review and revision of a TMDL. This process recognizes that water quality monitoring data and knowledge of watershed dynamics may be insufficient at the time a TMDL is developed, but that the TMDL uses the best information available during its development. An adaptive management strategy seeks to collect additional monitoring data to understand better how systems react to BMPs and reduced pollutant loading into a system. Information from an adaptive management process can then be used to refine a future TMDL, so that the future TMDL and allocations best represent how to improve water quality in a specific watershed.

Table 6-1. Summary of the Ship Creek fecal coliform TMDL

Source	Annual Existing Fecal Coliform Load	Percent Reduction	Annual Allocated Fecal Coliform Load
Nonpoint Sources:			
N/A (watershed covered by MS4 permit)	0 FC/yr	0%	0 FC/yr
Point Sources:			
Ship Creek watershed	2.81E+12 FC/yr	2%	2.15E+12 FC/yr
Total Existing Load	**2.81E+13 FC/yr**	**Load Allocation**	**0 FC/yr**
		Wasteload Allocation	**2.15E+12 FC/yr**
		Margin of Safety[1]	**2.39E+11 FC/yr**
		TMDL = Loading Capacity =	**2.39E+12 FC/yr**

[1]MOS was included explicitly as 10 percent of the loading capacity.

6.1 Margin of Safety

The MOS accounts for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be implicit (e.g., incorporated into the TMDL analysis through conservative assumptions) or explicit (e.g., expressed in the TMDL as a portion of the loading) or a combination of both. For the Ship Creek TMDL, the MOS was included explicitly as 10 percent of the loading capacity.

6.2 Load Allocation

Nonpoint sources are typically represented by loads carried to receiving waters through surface runoff resulting from precipitation events. However, because stormwater discharges in the MOA are regulated by a NPDES stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Ship Creek are addressed through the wasteload allocation component of this TMDL. Therefore, the load allocation for the Ship Creek fecal coliform TMDL is zero. If data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.

6.3 Wasteload Allocation

The only permitted source of fecal coliform in the watershed of the impaired segment of Ship Creek is stormwater runoff. The MOA is subject to an MS4 permit that regulates stormwater discharges and EPA policy and regulation indicate that stormwater runoff regulated by the NPDES program through an MS4 permit must be addressed through wasteload allocations in a TMDL (USEPA, 2002). Therefore, the Ship Creek TMDL establishes wasteload allocations for watershed loads of fecal coliform.

The fecal coliform wasteload allocations for Ship Creek are provided as monthly allocations for the entire watershed. Because the load allocation is zero, the wasteload allocations are equal to the loading capacity minus the MOS, as summarized in Table 6-2 and Figure 6-1. Allocations are not established for future loads because ADEC does not anticipate any future permits for the discharge of fecal coliform to Ship Creek. Additionally, if data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.

Table 6-2. Fecal coliform wasteload allocations for Ship Creek

Season	Loading Capacity (FC/season)	MOS (FC/season)	Wasteload Allocation (FC/season)	Percent Reduction (for Wasteload Allocation)
Winter	3.20E+11	3.20E+10	2.88E+11	43%
Spring	7.58E+11	7.58E+10	6.82E+11	N/A
Summer	1.31E+12	1.31E+11	1.18E+12	4%
Total (FC/yr)	2.39E+12	2.39E+11	2.15E+12	2%

6.4 Seasonal Variation

Fecal coliform concentrations and loading in Ship Creek vary seasonally, likely due to variations in weather and source activity. To account for this seasonality, this TMDL establishes seasonal allocations. Seasonal allocations represent loads allocated to time periods of similar weather, runoff, and instream conditions and can help to identify times of greatest impairment and focus TMDL implementation efforts by identifying times needing greater load reductions, as illustrated in Figure 6-2.

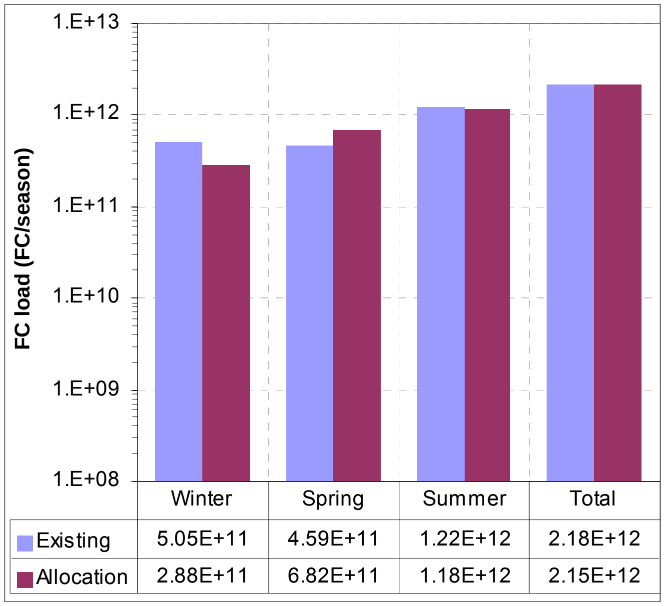


Figure 6-1. Summary of existing and allocated fecal coliform loads

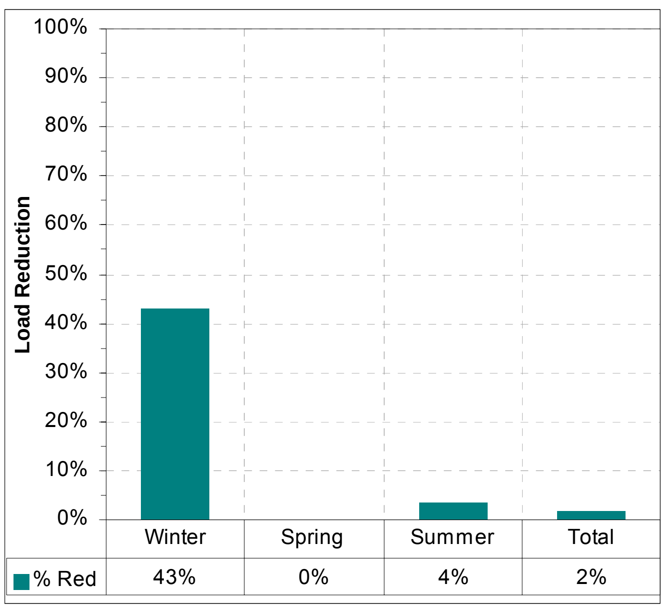


Figure 6-2. Seasonal variation in necessary load reductions

7. Implementation

According to EPA policy on addressing regulated stormwater in TMDLs (USEPA, 2002), wasteload allocations can be translated to effluent limitations in the applicable permit through the use of best management practices (BMPs). The following discussion summarizes information contained in USEPA (2002).

NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the relevant approved TMDL. Typically, those effluent limitations to control the discharge of pollutants are expressed in numerical form. However, because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, EPA's policy recognizes that only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. Therefore, EPA recommends that for NPDES-regulated municipal and small construction stormwater discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits. The policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

Appropriate BMPs will be identified for implementation in the Ship Creek watershed in the municipality's NPDES MS4 permit. Information on the applicability of the BMPs for removal of fecal coliform and on the feasibility of implementation in the Ship Creek watershed will be taken into account when identifying BMPs.

The National Stormwater Best Management Practices database (http://www.bmpdatabase.org/) provides access to BMP performance data in a standardized format for over 190 BMP studies conducted over the past fifteen years. The database was developed by the Urban Water Resources Research Council (UWRRC) of American Society of Civil Engineers (ASCE) under a cooperative agreement with the U.S. Environmental Protection Agency.

Some studies on BMP effectiveness have evaluated the ability of certain BMPs to remove fecal coliform and other bacteria. The Center for Watershed Protection has compiled a stormwater treatment database containing information from studies conducted from 1990 to the present. Schueler (2000) provides a summary of the information in the database. The included studies do not provide sufficient fecal coliform data to statistically evaluate the effectiveness of BMPs in removing bacteria from urban runoff, but Schueler (2000) indicates that mean fecal coliform removal rates typically range from 65 to 75 percent from ponds and wetlands and 55 percent for filters. Schueler (2000) and SMRC (2000) also reports that water quality swales (including biofilters and wet and dry swales) consistently exported bacteria. Although it is possible that the bacteria thrive in the warm swale soils, the studies do not account for potential sources of bacteria directly to the swales, such as wildlife and domestic pets. Table 7-1 provides examples of BMP removal efficiencies for bacteria. Because information on BMP efficiency for fecal coliform is limited, information in Table 7-1 should be applied with consideration of local knowledge of the environmental conditions and BMP performance in the Anchorage area.

CWP (1997) discusses the use and effectiveness of BMPs in cold climates. Due to the characteristics such as freezing temperatures and snowmelt events, some BMPs are not appropriate or require modifications for use in cold climates. Table 7-2 provides a summary of the applicability of BMPs to colder climates.

Table 7-1. Fecal coliform removal for various BMPs

BMP Type	Fecal Coliform Bacteria Removal (%)
Detention and Dry Extended Detention Ponds	78
Wet Ponds	70
Shallow Marsh Wetland	76
Submerged Gravel Wetland	78
Filters (excluding vertical sand filters)	37
Infiltration Basins	90
Water Quality Swales	-25
Ditches	5

Adapted from Schueler (2000) and SMRC (2000)

Table 7-2. Applicability of BMPs to cold climate conditions (CWP, 1997)

Type	BMP	Classification	Notes
Ponds	Wet Pond	◗	Can be effective, but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity in the permanent pool during ice cover.
	Wet ED Pond	●	Some modifications to conveyance structures needed. Extended detention storage provides treatment during the winter season.
	Dry ED Pond	◗	Few modifications needed. Although this practice is easily adapted to cold climates, it is not highly recommended overall because of its relatively poor warm season performance.
Wetlands	Shallow Marsh	❍	In climates where significant ice formation occurs, shallow marshes are not effective winter BMPs. Most of the treatment storage is taken up by ice, and the system is bypassed.
	Pond/Wetland System	◗	Pond/Wetland systems can be effective, especially if some ED storage is provided. Modifications for both pond and wetland systems apply to these BMPs. This includes changes in wetland plant selection and planting.
	ED Wetland	●	See Wet ED Pond. Also needs modifications to wetland plant species.
Infiltration	Porous Pavement	❍	This practice is restricted in cold climates. It cannot be used on any pavement that is sanded, because the pavement will clog.
	Infiltration Trench	◗	Can be effective, but may be restricted by groundwater quality concerns related to infiltrating chlorides. Also, frozen ground conditions may inhibit the infiltration capacity of the ground.
	Infiltration Basin	◗	See infiltration trench.

Type	BMP	Classification	Notes
Filtering Systems	Surface Sand Filter	❍	Frozen ground considerations, combined with frost heave concerns, make this type of system relatively ineffective during the winter season.
	Underground Sand Filter	●	When placed below the frost line, these systems can function effectively in cold climates.
	Perimeter Sand Filter	❍	See Surface Sand Filter.
	Bioretention	◗	Problems functioning during the winter season because of reduced infiltration. It has some value for snow storage on parking lots, however.
	Submerged Gravel Wetlands	◗	Some concerns of bypass during winter flows. Has been used in relatively cold regions with success., but not tested in a wide range of conditions.
Open Channel Systems	Grassed Channel	◗	Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Valuable for snow storage.
	Dry Swale	◗	Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Very valuable for snow storage and meltwater infiltration.
	Wet Swale	◗	Reduced effectiveness in the winter season because of dormant vegetation. Can be valuable for snow storage.
	Vegetated Filter Strip	◗	See Dry Swale.

ED: Extended Detention
● Easily applied to cold climates; can be effective during the winter season.
◗ Can be used in cold climates with significant modifications; moderately effective during the winter season.
❍ Very difficult to use in cold climates. Generally not recommended.

8. Monitoring

Follow-up monitoring for a TMDL is important in tracking the progress of TMDL implementation and subsequent water quality response as well as in evaluating any assumptions made during TMDL development. Monitoring results can be used to support any necessary future TMDL revisions and to track BMP effectiveness. Most importantly, monitoring will track the water quality of Ship Creek to evaluate future attainment of water quality standards.

USEPA (2002) outlines EPA regulatory requirements for and provides guidance on establishing WLAs for stormwater in TMDLs. The memorandum also provides information on the implementation of effluent limitations through NPDES permits consistent with the TMDL WLAs. The policy outlined affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address stormwater discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality.

USEPA (2002) indicates that where BMPs are used to implement the WLAs, the NPDES permit should require the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data), although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. EPA recommends that such permits require collecting data on the performance of the BMPs. The monitoring data can provide a basis for revised management measures and indicate any necessary adjustments to the BMPs. Any monitoring for stormwater required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

9. Public Comments

EPA regulations [40 CFR §130.7(c)(1)(ii)] require public review consistent with the ADEC continuing planning process and public participation requirements. EPA TMDL guidance calls for a description of the public participation process, including a summary of significant comments and the responses to those comments (i.e. a responsiveness summary).

The following summarizes the comments and responses received on the public review draft of the six Anchorage Streams Total Maximum Daily Load (TMDL) documents developed by the Alaska Department of Environmental Conservation (ADEC).

A public notice for all six TMDLs was published in the Anchorage Daily News newspaper on Sunday, February 8, 2004, and included the meeting time and place, a description of issues to be discussed, the availability of the draft TMDLs and the schedule for comments. ADEC also published the notice and the draft TMDLs on their website *www.state.ak.us/dec/water/wnpspc/anchorage_streams_tmdl.htm* and the public notice appeared on the State of Alaska's public notice page at *www.state.ak.us/dec/public_notices.htm.* The notice was placed and appeared in "Whats up", a free e-mail newsletter published biweekly and widely subscribed to by government agencies, industry, environmental and education groups. Individual email invitations were also sent to key stakeholders and others who expressed interest.

The public comment period ran from February 8 through March 8, 2004. A public meeting was held in Anchorage on February 24, 2004, at the Alaska Department of Environmental Conservation Anchorage office to present the draft TMDLs. ADEC also made a presentation on the TMDLs at The Alaska Forum for the Environment on February 10, 2004.

No written comments were received during the 30-day public review period. Oral comments were received during the public meeting. Those comments and ADEC's responses are summarized in the attachment entitled **Six Anchorage Streams TMDLs Public Responsiveness**. In addition to the comments received at the public meeting, ADEC received numerous comments during the pre-public review of the February 28, 2003, TMDL draft from the Municipality of Anchorage. On March 4, 2003, the ADEC conducted a pre-public review of the draft TMDL with key stakeholders (Anchorage Municipality, USGS, Anchorage Waterways Council, and the University of Alaska, Anchorage, Environmental and Natural Resources Institute). ADEC received comments from the MOA based on discussions at the March 04, 2003, meeting. ADEC addressed all the comments received and incorporated many of them into the public review draft. Stakeholder comments, ADEC and Tetratech's responses, and how comments were incorporated into the TMDL can be found in the attachment entitled **Anchorage FC TMDLs - Comments on Initial drafts - DEC Response.**

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Appendix A: Water Quality Standards Exceedances

Exceedances of Geometric Mean Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
1	2/10/89 to 3/9/89 (6 samples)	152	20	132	760%
2	2/16/89 to 3/16/89 (7 samples)	122	20	102	612%
3	2/21/89 to 3/22/89 (8 samples)	77	20	57	383%
4	2/27/89 to 3/29/89 (8 samples)	55	20	35	276%
5	3/7/89 to 4/3/89 (8 samples)	56	20	36	282%
6	3/9/89 to 4/3/89 (7 samples)	48	20	28	239%
7	3/14/89 to 4/13/89 (8 samples)	29	20	9	144%
8	3/16/89 to 4/13/89 (7 samples)	27	20	7	136%
9	6/26/89 to 7/26/89 (6 samples)	22	20	2	109%
10	6/30/89 to 7/26/89 (5 samples)	35	20	15	176%
11	7/7/89 to 7/31/89 (5 samples)	37	20	17	187%
12	7/12/89 to 8/8/89 (5 samples)	39	20	19	194%
13	7/20/89 to 8/16/89 (5 samples)	46	20	26	230%
14	7/26/89 to 8/24/89 (5 samples)	38	20	18	189%
15	7/31/89 to 8/30/89 (6 samples)	44	20	24	219%
16	8/8/89 to 8/31/89 (6 samples)	43	20	23	217%
17	8/16/89 to 9/13/89 (7 samples)	38	20	18	190%
18	8/24/89 to 9/22/89 (8 samples)	29	20	9	147%
19	8/28/89 to 9/22/89 (7 samples)	27	20	7	135%
20	10/4/89 to 11/3/89 (6 samples)	26	20	6	129%
21	10/10/89 to 11/6/89 (6 samples)	20	20	0	101%
22	10/19/89 to 11/14/89 (6 samples)	30	20	10	150%
23	10/24/89 to 11/21/89 (6 samples)	34	20	14	169%
24	10/30/89 to 11/29/89 (6 samples)	35	20	15	174%
25	11/3/89 to 11/29/89 (5 samples)	37	20	17	186%
26	11/6/89 to 12/6/89 (5 samples)	33	20	13	166%
27	11/14/89 to 12/12/89 (5 samples)	52	20	32	260%
28	11/21/89 to 12/21/89 (6 samples)	99	20	79	496%
29	11/29/89 to 12/28/89 (6 samples)	116	20	96	578%
30	12/6/89 to 1/4/90 (6 samples)	121	20	101	607%
31	12/12/89 to 1/9/90 (6 samples)	120	20	100	602%
32	12/15/89 to 1/9/90 (5 samples)	108	20	88	539%
33	12/21/89 to 1/17/90 (5 samples)	72	20	52	359%
34	12/28/89 to 1/24/90 (5 samples)	57	20	37	283%
35	1/4/90 to 1/29/90 (5 samples)	87	20	67	434%

Exceedances of Geometric Mean Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
36	1/9/90 to 2/6/90 (5 samples)	79	20	59	396%
37	1/17/90 to 2/15/90 (5 samples)	92	20	72	461%
38	1/24/90 to 2/22/90 (6 samples)	20	20	0	102%
39	1/29/90 to 2/28/90 (6 samples)	24	20	4	121%
40	2/15/90 to 3/13/90 (6 samples)	25	20	5	125%
41	2/20/90 to 3/22/90 (7 samples)	41	20	21	205%
42	2/22/90 to 3/22/90 (6 samples)	40	20	20	201%
43	2/28/90 to 3/29/90 (6 samples)	176	20	156	880%
44	3/7/90 to 4/4/90 (6 samples)	148	20	128	740%
45	3/13/90 to 4/11/90 (6 samples)	141	20	121	704%
46	3/19/90 to 4/11/90 (5 samples)	124	20	104	619%
47	3/22/90 to 4/20/90 (6 samples)	47	20	27	237%
48	3/29/90 to 4/24/90 (6 samples)	37	20	17	185%
49	4/4/90 to 5/3/90 (6 samples)	26	20	6	129%
50	4/11/90 to 5/8/90 (6 samples)	22	20	2	109%
51	4/19/90 to 5/17/90 (6 samples)	20	20	0	102%
52	4/20/90 to 5/17/90 (5 samples)	25	20	5	126%
53	4/24/90 to 5/17/90 (4 samples)	27	20	7	137%
54	6/20/90 to 7/19/90 (6 samples)	20	20	0	101%
55	6/25/90 to 7/25/90 (6 samples)	32	20	12	158%
56	7/5/90 to 8/1/90 (6 samples)	31	20	11	154%
57	7/12/90 to 8/9/90 (6 samples)	32	20	12	158%
58	7/16/90 to 8/15/90 (6 samples)	49	20	29	247%
59	7/19/90 to 8/15/90 (5 samples)	41	20	21	206%
60	7/25/90 to 8/22/90 (5 samples)	26	20	6	132%
61	8/1/90 to 8/27/90 (5 samples)	25	20	5	124%
62	8/22/90 to 9/18/90 (5 samples)	26	20	6	131%
63	8/27/90 to 9/25/90 (5 samples)	33	20	13	167%
64	9/7/90 to 10/3/90 (6 samples)	20	20	0	102%
65	9/13/90 to 10/11/90 (6 samples)	34	20	14	170%
66	9/18/90 to 10/11/90 (5 samples)	32	20	12	160%
67	10/3/90 to 10/30/90 (5 samples)	41	20	21	206%
68	10/11/90 to 11/9/90 (6 samples)	39	20	19	196%
69	10/19/90 to 11/14/90 (6 samples)	33	20	13	165%
70	10/24/90 to 11/21/90 (6 samples)	26	20	6	128%
71	10/30/90 to 11/29/90 (6 samples)	21	20	1	107%
72	11/21/90 to 12/21/90 (6 samples)	25	20	5	125%

Exceedances of Geometric Mean Criterion at SHP10 (Data: 2/10/89 to 9/30/94)					
Num	**Exceedance Description**	**Value**	**Criterion**	**Exceedance Amount**	**% Exceedance**
73	11/29/90 to 12/26/90 (6 samples)	25	20	5	127%
74	12/6/90 to 1/3/91 (6 samples)	31	20	11	153%
75	12/13/90 to 1/8/91 (6 samples)	28	20	8	140%
76	12/18/90 to 1/15/91 (6 samples)	24	20	4	122%
77	12/21/90 to 1/15/91 (5 samples)	22	20	2	110%
78	12/26/90 to 1/24/91 (5 samples)	22	20	2	110%
79	1/3/91 to 1/29/91 (5 samples)	44	20	24	220%
80	1/8/91 to 2/5/91 (5 samples)	60	20	40	301%
81	1/15/91 to 2/13/91 (5 samples)	73	20	53	365%
82	1/24/91 to 2/20/91 (6 samples)	93	20	73	464%
83	1/29/91 to 2/27/91 (6 samples)	82	20	62	412%
84	2/5/91 to 3/7/91 (6 samples)	106	20	86	531%
85	2/13/91 to 3/13/91 (6 samples)	127	20	107	634%
86	2/19/91 to 3/21/91 (6 samples)	141	20	121	707%
87	2/20/91 to 3/21/91 (5 samples)	157	20	137	785%
88	2/27/91 to 3/28/91 (6 samples)	174	20	154	870%
89	3/7/91 to 4/2/91 (6 samples)	306	20	286	1529%
90	3/13/91 to 4/10/91 (6 samples)	164	20	144	822%
91	3/21/91 to 4/10/91 (5 samples)	147	20	127	734%
92	3/26/91 to 4/25/91 (5 samples)	97	20	77	487%
93	3/28/91 to 4/25/91 (4 samples)	77	20	57	384%
94	4/2/91 to 4/29/91 (4 samples)	41	20	21	203%
95	4/10/91 to 5/7/91 (5 samples)	20	20	0	100%
96	4/25/91 to 5/20/91 (6 samples)	26	20	6	129%
97	5/3/91 to 5/29/91 (5 samples)	21	20	1	103%
98	6/19/91 to 7/17/91 (5 samples)	31	20	11	153%
99	6/27/91 to 7/25/91 (5 samples)	33	20	13	167%
100	7/2/91 to 7/29/91 (5 samples)	51	20	31	255%
101	7/9/91 to 8/2/91 (5 samples)	51	20	31	254%
102	7/17/91 to 8/15/91 (6 samples)	80	20	60	401%
103	7/25/91 to 8/15/91 (5 samples)	65	20	45	325%
104	7/29/91 to 8/15/91 (4 samples)	91	20	71	454%
105	8/2/91 to 8/15/91 (3 samples)	80	20	60	399%
106	8/9/91 to 9/4/91 (3 samples)	68	20	48	339%
107	8/15/91 to 9/11/91 (3 samples)	83	20	63	417%
108	9/4/91 to 10/2/91 (5 samples)	48	20	28	242%
109	9/11/91 to 10/10/91 (6 samples)	33	20	13	164%

Exceedances of Geometric Mean Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
110	9/18/91 to 10/16/91 (6 samples)	22	20	2	111%
111	11/13/91 to 12/12/91 (4 samples)	21	20	1	104%
112	11/19/91 to 12/18/91 (4 samples)	31	20	11	154%
113	11/25/91 to 12/18/91 (3 samples)	33	20	13	163%
114	1/8/92 to 2/7/92 (7 samples)	23	20	3	117%
115	1/16/92 to 2/13/92 (7 samples)	89	20	69	446%
116	1/22/92 to 2/19/92 (7 samples)	93	20	73	464%
117	1/24/92 to 2/19/92 (6 samples)	85	20	65	426%
118	1/30/92 to 2/25/92 (6 samples)	79	20	59	394%
119	2/3/92 to 3/3/92 (6 samples)	114	20	94	572%
120	2/7/92 to 3/3/92 (5 samples)	126	20	106	630%
121	2/13/92 to 3/13/92 (6 samples)	279	20	259	1394%
122	2/19/92 to 3/19/92 (6 samples)	341	20	321	1704%
123	2/25/92 to 3/26/92 (6 samples)	380	20	360	1898%
124	3/3/92 to 4/1/92 (6 samples)	484	20	464	2422%
125	3/9/92 to 4/8/92 (6 samples)	309	20	289	1547%
126	3/13/92 to 4/8/92 (5 samples)	216	20	196	1078%
127	3/19/92 to 4/16/92 (6 samples)	127	20	107	634%
128	3/26/92 to 4/22/92 (6 samples)	79	20	59	394%
129	4/1/92 to 4/28/92 (6 samples)	52	20	32	262%
130	7/27/92 to 8/26/92 (6 samples)	26	20	6	131%
131	8/4/92 to 8/26/92 (5 samples)	38	20	18	190%
132	8/20/92 to 9/17/92 (4 samples)	20	20	0	100%
133	9/17/92 to 10/14/92 (5 samples)	43	20	23	216%
134	9/29/92 to 10/28/92 (6 samples)	25	20	5	127%
135	10/9/92 to 10/28/92 (5 samples)	42	20	22	211%
136	10/14/92 to 11/10/92 (5 samples)	30	20	10	148%
137	10/28/92 to 11/24/92 (4 samples)	24	20	4	120%
138	11/10/92 to 12/10/92 (5 samples)	32	20	12	159%
139	11/17/92 to 12/14/92 (5 samples)	33	20	13	166%
140	11/24/92 to 12/21/92 (5 samples)	80	20	60	398%
141	11/30/92 to 12/29/92 (5 samples)	66	20	46	331%
142	12/10/92 to 1/8/93 (5 samples)	56	20	36	281%
143	12/14/92 to 1/13/93 (5 samples)	57	20	37	286%
144	12/21/92 to 1/19/93 (5 samples)	58	20	38	288%
145	5/10/93 to 6/7/93 (6 samples)	21	20	1	105%
146	5/17/93 to 6/7/93 (5 samples)	25	20	5	127%

Exceedances of Geometric Mean Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
147	5/19/93 to 6/18/93 (5 samples)	24	20	4	122%
148	5/27/93 to 6/22/93 (5 samples)	22	20	2	108%
149	6/2/93 to 6/30/93 (5 samples)	21	20	1	105%
150	6/30/93 to 7/26/93 (5 samples)	23	20	3	113%
151	7/12/93 to 8/10/93 (6 samples)	36	20	16	179%
152	7/14/93 to 8/10/93 (5 samples)	40	20	20	200%
153	7/22/93 to 8/19/93 (5 samples)	39	20	19	197%
154	7/26/93 to 8/19/93 (4 samples)	49	20	29	247%
155	8/3/93 to 9/2/93 (5 samples)	39	20	19	196%
156	8/10/93 to 9/9/93 (5 samples)	32	20	12	161%
157	8/19/93 to 9/15/93 (5 samples)	22	20	2	110%
158	8/26/93 to 9/21/93 (5 samples)	27	20	7	137%
159	9/2/93 to 9/28/93 (5 samples)	26	20	6	130%
160	9/9/93 to 9/28/93 (4 samples)	25	20	5	127%
161	9/15/93 to 10/14/93 (4 samples)	24	20	4	120%
162	9/21/93 to 10/14/93 (3 samples)	33	20	13	166%
163	9/28/93 to 10/14/93 (2 samples)	22	20	2	109%
164	10/14/93 to 10/14/93 (1 sample)	25	20	5	125%
165	1/20/94 to 2/18/94 (2 samples)	48	20	28	242%
166	2/18/94 to 2/18/94 (1 sample)	90	20	70	450%
167	3/22/94 to 3/22/94 (1 sample)	66	20	46	330%
168	7/14/94 to 8/12/94 (6 samples)	22	20	2	111%
169	7/21/94 to 8/19/94 (6 samples)	27	20	7	137%
170	7/26/94 to 8/19/94 (5 samples)	31	20	11	157%
171	8/1/94 to 8/19/94 (4 samples)	28	20	8	141%
172	8/5/94 to 9/1/94 (4 samples)	32	20	12	158%
173	8/12/94 to 9/6/94 (4 samples)	22	20	2	109%

Exceedances of Not-to-exceed Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
1	2/10/89 > 10% Limit in 1 30-day set	68	40	28	170%
2	2/16/89 > 10% Limit in 2 30-day sets	146	40	106	365%
3	2/21/89 > 10% Limit in 3 30-day sets	800	40	760	2000%
4	2/27/89 > 10% Limit in 4 30-day sets	64	40	24	160%
5	3/7/89 > 10% Limit in 5 30-day sets	178	40	138	445%
6	3/9/89 > 10% Limit in 6 30-day sets	136	40	96	340%

Exceedances of Not-to-exceed Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
7	3/14/89 > 10% Limit in 6 30-day sets	42	40	2	105%
8	3/16/89 > 10% Limit in 7 30-day sets	54	40	14	135%
9	3/29/89 > 10% Limit in 8 30-day sets	58	40	18	145%
10	4/3/89 > 10% Limit in 8 30-day sets	76	40	36	190%
11	5/4/89 > 10% Limit in 5 30-day sets	66	40	26	165%
12	7/20/89 > 10% Limit in 6 30-day sets	150	40	110	375%
13	7/31/89 > 10% Limit in 5 30-day sets	44	40	4	110%
14	8/16/89 > 10% Limit in 5 30-day sets	54	40	14	135%
15	8/24/89 > 10% Limit in 5 30-day sets	56	40	16	140%
16	8/28/89 > 10% Limit in 5 30-day sets	117	40	77	293%
17	8/31/89 > 10% Limit in 6 30-day sets	42	40	2	105%
18	9/13/89 > 10% Limit in 7 30-day sets	44	40	4	110%
19	10/4/89 > 10% Limit in 6 30-day sets	94	40	54	235%
20	11/3/89 > 10% Limit in 6 30-day sets	78	40	38	195%
21	12/6/89 > 10% Limit in 5 30-day sets	44	40	4	110%
22	12/12/89 > 10% Limit in 5 30-day sets	210	40	170	525%
23	12/15/89 > 10% Limit in 5 30-day sets	320	40	280	800%
24	12/21/89 > 10% Limit in 6 30-day sets	250	40	210	625%
25	12/28/89 > 10% Limit in 6 30-day sets	90	40	50	225%
26	1/4/90 > 10% Limit in 6 30-day sets	48	40	8	120%
27	1/9/90 > 10% Limit in 6 30-day sets	42	40	2	105%
28	1/17/90 > 10% Limit in 5 30-day sets	42	40	2	105%
29	1/24/90 > 10% Limit in 5 30-day sets	76	40	36	190%
30	1/29/90 > 10% Limit in 5 30-day sets	770	40	730	1925%
31	2/15/90 > 10% Limit in 5 30-day sets	90	40	50	225%
32	2/20/90 > 10% Limit in 5 30-day sets	46	40	6	115%
33	2/28/90 > 10% Limit in 6 30-day sets	210	40	170	525%
34	3/7/90 > 10% Limit in 6 30-day sets	102	40	62	255%
35	3/13/90 > 10% Limit in 6 30-day sets	270	40	230	675%
36	3/19/90 > 10% Limit in 6 30-day sets	320	40	280	800%
37	3/22/90 > 10% Limit in 7 30-day sets	230	40	190	575%
38	3/29/90 > 10% Limit in 6 30-day sets	70	40	30	175%
39	4/4/90 > 10% Limit in 6 30-day sets	74	40	34	185%
40	4/11/90 > 10% Limit in 6 30-day sets	76	40	36	190%
41	4/24/90 > 10% Limit in 6 30-day sets	52	40	12	130%
42	5/17/90 > 10% Limit in 6 30-day sets	50	40	10	125%
43	7/5/90 > 10% Limit in 5 30-day sets	46	40	6	115%

Exceedances of Not-to-exceed Criterion at SHP10 (Data: 2/10/89 to 9/30/94)					
Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
44	7/16/90 > 10% Limit in 5 30-day sets	123	40	83	308%
45	7/19/90 > 10% Limit in 6 30-day sets	110	40	70	275%
46	8/9/90 > 10% Limit in 6 30-day sets	54	40	14	135%
47	8/15/90 > 10% Limit in 6 30-day sets	44	40	4	110%
48	9/13/90 > 10% Limit in 5 30-day sets	46	40	6	115%
49	9/18/90 > 10% Limit in 5 30-day sets	510	40	470	1275%
50	10/11/90 > 10% Limit in 6 30-day sets	42	40	2	105%
51	10/30/90 > 10% Limit in 5 30-day sets	330	40	290	825%
52	12/6/90 > 10% Limit in 6 30-day sets	52	40	12	130%
53	12/13/90 > 10% Limit in 5 30-day sets	56	40	16	140%
54	12/21/90 > 10% Limit in 6 30-day sets	42	40	2	105%
55	1/24/91 > 10% Limit in 5 30-day sets	41	40	1	103%
56	1/29/91 > 10% Limit in 5 30-day sets	260	40	220	650%
57	2/5/91 > 10% Limit in 5 30-day sets	100	40	60	250%
58	2/13/91 > 10% Limit in 5 30-day sets	81	40	41	203%
59	2/19/91 > 10% Limit in 5 30-day sets	84	40	44	210%
60	2/20/91 > 10% Limit in 6 30-day sets	88	40	48	220%
61	3/7/91 > 10% Limit in 6 30-day sets	1200	40	1160	3000%
62	3/13/91 > 10% Limit in 6 30-day sets	290	40	250	725%
63	3/21/91 > 10% Limit in 6 30-day sets	156	40	116	390%
64	3/26/91 > 10% Limit in 5 30-day sets	250	40	210	625%
65	3/28/91 > 10% Limit in 6 30-day sets	102	40	62	255%
66	4/2/91 > 10% Limit in 6 30-day sets	590	40	550	1475%
67	5/3/91 > 10% Limit in 4 30-day sets	70	40	30	175%
68	5/20/91 > 10% Limit in 6 30-day sets	154	40	114	385%
69	7/2/91 > 10% Limit in 6 30-day sets	66	40	26	165%
70	7/17/91 > 10% Limit in 5 30-day sets	229	40	189	573%
71	7/29/91 > 10% Limit in 5 30-day sets	134	40	94	335%
72	8/2/91 > 10% Limit in 5 30-day sets	65	40	25	163%
73	8/9/91 > 10% Limit in 5 30-day sets	79	40	39	198%
74	8/15/91 > 10% Limit in 6 30-day sets	99	40	59	248%
75	9/11/91 > 10% Limit in 3 30-day sets	146	40	106	365%
76	9/18/91 > 10% Limit in 3 30-day sets	51	40	11	128%
77	10/2/91 > 10% Limit in 5 30-day sets	47	40	7	118%
78	12/12/91 > 10% Limit in 4 30-day sets	400	40	360	1000%
79	1/3/92 > 10% Limit in 4 30-day sets	94	40	54	235%
80	1/16/92 > 10% Limit in 5 30-day sets	118	40	78	295%

Exceedances of Not-to-exceed Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
81	1/22/92 > 10% Limit in 5 30-day sets	157	40	117	393%
82	1/24/92 > 10% Limit in 6 30-day sets	60	40	20	150%
83	1/30/92 > 10% Limit in 6 30-day sets	54	40	14	135%
84	2/3/92 > 10% Limit in 6 30-day sets	70	40	30	175%
85	2/7/92 > 10% Limit in 7 30-day sets	89	40	49	223%
86	2/13/92 > 10% Limit in 7 30-day sets	120	40	80	300%
87	2/19/92 > 10% Limit in 7 30-day sets	157	40	117	393%
88	3/3/92 > 10% Limit in 6 30-day sets	500	40	460	1250%
89	3/9/92 > 10% Limit in 5 30-day sets	1889	40	1849	4723%
90	3/13/92 > 10% Limit in 6 30-day sets	695	40	655	1738%
91	3/19/92 > 10% Limit in 6 30-day sets	400	40	360	1000%
92	3/26/92 > 10% Limit in 6 30-day sets	300	40	260	750%
93	4/1/92 > 10% Limit in 6 30-day sets	164	40	124	410%
94	4/16/92 > 10% Limit in 6 30-day sets	221	40	181	553%
95	6/12/92 > 10% Limit in 6 30-day sets	55	40	15	138%
96	8/4/92 > 10% Limit in 5 30-day sets	102	40	62	255%
97	8/26/92 > 10% Limit in 6 30-day sets	300	40	260	750%
98	9/17/92 > 10% Limit in 4 30-day sets	3200	40	3160	8000%
99	10/9/92 > 10% Limit in 4 30-day sets	199	40	159	498%
100	10/28/92 > 10% Limit in 6 30-day sets	58	40	18	145%
101	11/24/92 > 10% Limit in 4 30-day sets	169	40	129	423%
102	11/30/92 > 10% Limit in 4 30-day sets	75	40	35	188%
103	12/10/92 > 10% Limit in 5 30-day sets	76	40	36	190%
104	12/14/92 > 10% Limit in 5 30-day sets	42	40	2	105%
105	12/21/92 > 10% Limit in 5 30-day sets	79	40	39	198%
106	12/29/92 > 10% Limit in 5 30-day sets	67	40	27	168%
107	1/13/93 > 10% Limit in 5 30-day sets	83	40	43	208%
108	1/19/93 > 10% Limit in 5 30-day sets	44	40	4	110%
109	1/29/93 > 10% Limit in 5 30-day sets	54	40	14	135%
110	2/3/93 > 10% Limit in 6 30-day sets	76	40	36	190%
111	2/9/93 > 10% Limit in 6 30-day sets	188	40	148	470%
112	2/18/93 > 10% Limit in 6 30-day sets	123	40	83	308%
113	6/2/93 > 10% Limit in 6 30-day sets	60	40	20	150%
114	6/7/93 > 10% Limit in 6 30-day sets	55	40	15	138%
115	7/26/93 > 10% Limit in 5 30-day sets	45	40	5	113%
116	8/3/93 > 10% Limit in 5 30-day sets	86	40	46	215%
117	8/10/93 > 10% Limit in 6 30-day sets	62	40	22	155%

Exceedances of Not-to-exceed Criterion at SHP10 (Data: 2/10/89 to 9/30/94)

Num	Exceedance Description	Value	Criterion	Exceedance Amount	% Exceedance
118	9/21/93 > 10% Limit in 5 30-day sets	77	40	37	193%
119	2/18/94 > 10% Limit in 2 30-day sets	90	40	50	225%
120	3/22/94 > 10% Limit in 1 30-day set	66	40	26	165%
121	7/26/94 > 10% Limit in 5 30-day sets	48	40	8	120%
122	8/5/94 > 10% Limit in 6 30-day sets	44	40	4	110%
123	9/26/94 > 10% Limit in 4 30-day sets	399	40	359	998%