Alaska Department of Environmental Conservation
555 Cordova Street
Anchorage, Alaska 99501

Total Maximum Daily Loads (TMDLs) for Metals in the Waters of Pullen Creek in Skagway, Alaska

May 2010

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

JUN 16 2010

OFFICE OF
WATER AND WATERSHEDS

Ms. Lynn J. Tomich Kent, Director
Water Division
Department of Environmental Conservation
555 Cordova Street
Anchorage, Alaska 99501-2617

Re: Approval of the Pullen Creek Metals Total Maximum Daily Loads (TMDLs)

Dear Ms. Kent:

The Alaska Department of Environmental Conservation (ADEC) submitted the Pullen Creek TMDLs for metals to the U.S. Environmental Protection Agency on June 2, 2010. Following our review, EPA is pleased to approve the TMDLs for Pullen Creek [Alaska ID Number 10303-004] in Skagway, Alaska.

Our review indicates that these allocations have been established at a level that, when fully implemented, will lead to the attainment of the water quality standards addressed by these TMDLs. Therefore, ADEC does not need to include Pullen Creek on the next 303(d) list of impaired waters for the pollutants covered by these TMDLs.

We greatly appreciate the opportunity to work with your staff throughout the development of these TMDLs. In particular, we are impressed by the commitment and hard work shown by Laura Eldred in developing these TMDLs.

By EPA's approval, these TMDLs are now incorporated into the State's Water Quality Management Plan under Section 303(e) of the Clean Water Act. We look forward to continuing to work collaboratively on water quality issues in Pullen Creek. If you have any questions, please feel free to call me at (206) 553-4198, or Martha Turvey of my staff at (206) 553-1354.

Sincerely,

Michael A. Bussell, Director
Office of Water and Watersheds

cc: Ms. Laura Eldred, Nonpoint Source Water Pollution Control Section, ADEC
Ms. Cindy Gilder, Manager, Nonpoint Source Water Pollution Control Section, ADEC
Ms. Nancy Sonafrank, Manager, Water Quality Standards Assessment and Restoration Program, ADEC

Contents

Figures

Tables

Total Maximum Daily Load (TMDL) for

Metals in

Pullen Creek, Alaska

TMDL AT A GLANCE:

Water Quality Limited?	Yes
Alaska ID Number:	10303-004
Criteria of Concern:	Metals (cadmium, copper, lead , and zinc)
Designated Uses Affected:	Growth and propagation of fish, shellfish, other aquatic life, and wildlife
Major Source(s):	Historical mining transport and transfer operations

Metal	Loading Capacity (mg/kg)	WLA (mg/kg)	LA (mg/kg)	MOS (mg/kg)	Maximum Observed (mg/kg)	Percent Reduction[a]
Total Cadmium	0.596	N/A	0.5364	0.0596	1.6	63%
Total Copper	35.7	N/A	32.13	3.57	120	70%
Total Lead	35	N/A	31.5	3.5	330	89%
Total Zinc	123.1	N/A	110.79	12.31	480	74%

a. Reductions are calculated based on maximum concentration observed among all stations on Pullen Creek. Section 6 presents targeted reductions by stream segment, based on observed concentrations measured at individual monitoring stations.

Executive Summary

Pullen Creek (lower mile), is located at the northern end of the Lynn Canal by the City of Skagway, Alaska, where it empties into Skagway Harbor. The harbor is located adjacent to the mouth of the Skagway River and is formed by a small peninsula that separates the harbor from where the river empties into the Taiya Inlet, which opens into the Lynn Canal. The only natural drainage directly into Skagway Harbor is Pullen Creek, which runs through the community of the City of Skagway. Pullen Creek is approximately 1.5 miles long, with its headwaters beginning in the rail yard at the northeast end of town before draining into Skagway Harbor. Two spring fed tributaries enter Pullen Creek along its length and for much of the creek flows adjacent to the White Pass and Yukon Railroad, which borders the City of Skagway to the southeast. The Pullen Creek Watershed is almost entirely urbanized and is located entirely within the City of Skagway. The creek provides rearing habitat for coho and Dolly Varden and spawning habitat for coho, pink, and chum salmon (STC 2005).

Pullen Creek (lower mile) and Skagway Harbor were originally jointly listed on Alaska's 1990 section 303(d) list by the Alaska Department of Environmental Conservation (ADEC) due to sediment toxicity potentially from metals. The 303(d) list indicates that high concentrations of lead, zinc, cadmium, copper, and mercury were found in harbor sediments and that sediment lead and zinc concentrations were linked to reduced infauna diversity in benthic communities in the harbor's bottom sediments, prompting the listing for non-attainment of the aquatic life designated use. The original joint listing was made in consideration of metals contamination throughout the harbor and upland areas, though no monitoring had been conducted for Pullen Creek at the time. ADEC first separately listed the lower mile of Pullen Creek on the state's 2006 303(d) list based on monitoring data collected in 2004 and 2005 that showed elevated levels of various metals on stream bottom sediments adjoining streambanks.

The area has a long history of mining activity including the shipping of ore concentrates extracted from the Faro Mine, a galena mining and concentration facility that produced low-grade zinc and lead. Concentrate ores also contained concentrations of arsenic, cadmium, copper, and mercury. High winds are common in Skagway and airborne ore dust resulted from many of the early shipping, storage, and transfer procedures (ADEC 1992). The current metals impairments in Pullen Creek are thought to be due to sediment contamination resulting from historical operations in the harbor and surrounding area related to the transport and transfer of mining ores.

This report documents Total Maximum Daily Loads (TMDLs) for zinc, copper, lead, and cadmium in Pullen Creek. The TMDLs are based on existing sediment contamination levels and are established to meet the requirements of Section 303(d)(1) of the Clean Water Act. A TMDL is composed of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and 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 receive while maintaining compliance with applicable water quality standards.

Because the impairment in Pullen Creek is based on elevated levels of metals in bottom sediments, the TMDL establishes sediment quality targets that represent attainment of water quality standards, including designated uses, and sets the loading capacity equal to those targets. The TMDL target and loading capacity are set equal to the toxicological screening level Threshold Effects Low (TEL), presented in the National Oceanic and Atmospheric Administration (NOAA) *Screening Quick Reference Tables* (Buchman 2008). TELs define chemical sediment concentrations below which toxic effects are rarely observed in sensitive species. A supplemental analysis is included as part of these TMDLs to illustrate that once sediment concentrations meet targets, water column concentrations will also likely decrease and meet applicable water quality criteria.

Because there are no permitted discharges of metals to Pullen Creek, the WLA is not applicable. The LAs are set equal to the respective TEL minus 10 percent for the MOS. The TMDL also establishes an implicit MOS based on the conservative TEL target.

Natural attenuation is recommended as the best course of action to achieve these TMDLs. Implementation should also include practices to maintain stable streambanks and minimize the potential for disturbance, erosion and delivery of contaminated upland and streambank soils. In addition, monitoring should continue to determine whether natural recovery is occurring and concentrations of metal contaminants are decreasing over time due to natural sedimentation processes. Monitoring will allow ADEC to track the progress of changes in water and sediment and determine whether acceptable progress is being made. Monitoring could also include further evaluation of potential stormwater sources and bioassays to determine whether metals impacted sediments are having a deleterious effect on benthic communities.

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 a pollutant that a waterbody can assimilate and maintain compliance with water quality standards. TMDLs include an appropriate margin of safety and identify the level of pollutant control needed to reduce 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 (BMPs) for nonpoint sources and/or effluent limits and monitoring required through National Pollutant Discharge Elimination System (NPDES) permits.

Pullen Creek is located at the northern end of the Lynn Canal by the City of Skagway, Alaska, where it empties into Skagway Harbor. The harbor is located adjacent to the mouth of the Skagway River and is formed by a small peninsula that separates the harbor from where the river empties into the Taiya Inlet, which opens into the Lynn Canal (Figure 1-1). This document summarizes the available monitoring and pollutant source data for Pullen Creek and presents TMDLs to address metals (cadmium, copper, lead, and zinc) impairments. TMDLs are calculated for cadmium, copper, lead and zinc. Identification of metals of concern is discussed further in Section 4.

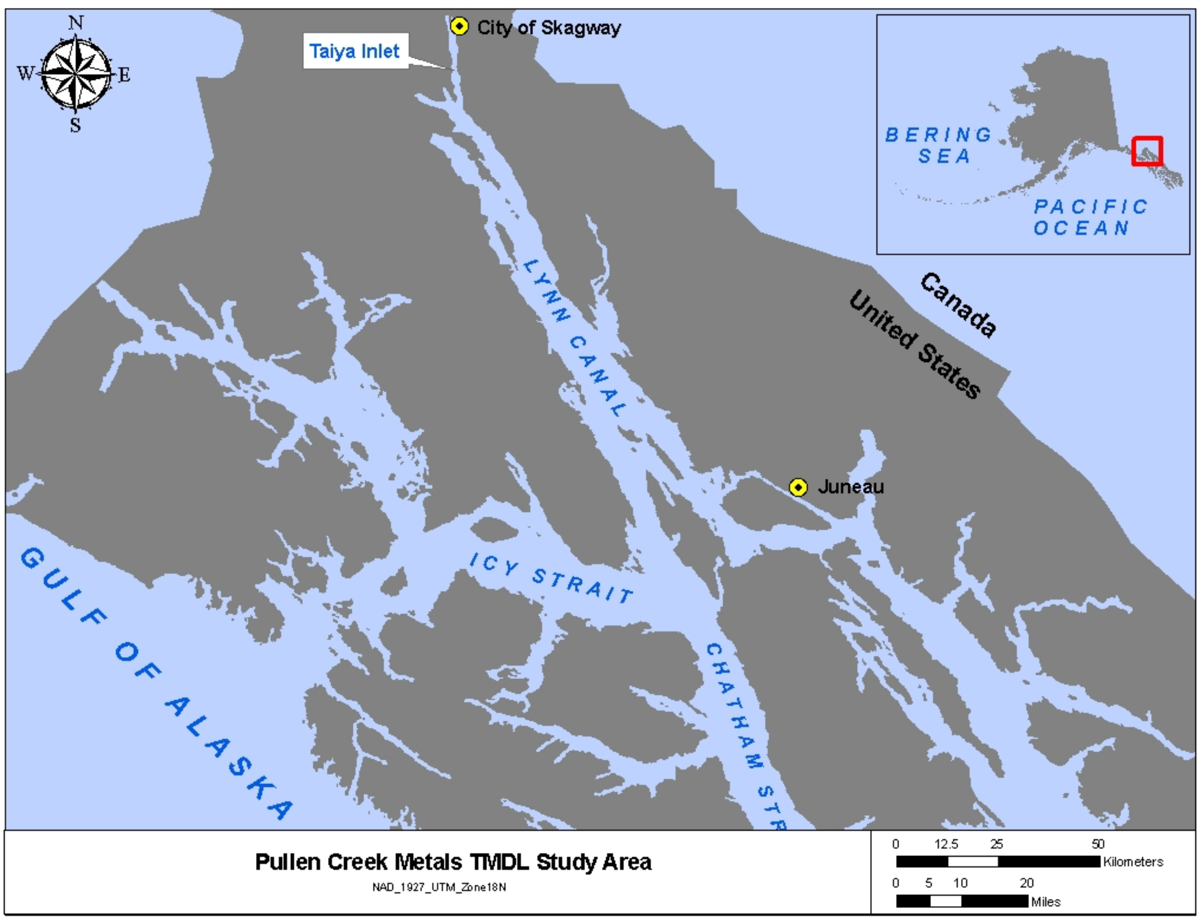


Figure 1-1. Regional location of Pullen Creek

Pullen Creek (lower mile) and Skagway Harbor were originally jointly listed on Alaska's 1990 section 303(d) list by the Alaska Department of Environmental Conservation (ADEC) due to sediment toxicity potentially from metals. High concentrations of lead, zinc, cadmium, copper, and mercury were found in harbor sediments, and reduced infauna diversity was initially correlated with sediment lead and zinc concentrations prompting the listing for non-attainment of the aquatic life designated use. The original joint listing was made in consideration of metals contamination throughout the harbor and upland areas, though no monitoring had been conducted for Pullen Creek at the time. ADEC first separately listed the lower mile of Pullen Creek on the state's 2006 303(d) list. Table 1-1 summarizes the information included in Alaska's approved 2008 303(d) list for Pullen Creek. As discussed in Section 4, monitoring conducted in 2007 and 2008 confirmed metals impairments in Pullen Creek.

Table 1-1. Summary of 303(d) listing information for Pullen Creek from ADEC's 2008 Integrated Report

<table>
<tr><th>Alaska ID Number</th><th>Waterbody</th><th>Area of Concern</th><th>Water Quality Standard</th><th>Pollutant Parameters</th><th>Pollutant Sources</th></tr>
<tr><td>10303-004</td><td>Pullen Creek (Lower Mile)</td><td>Lower mile of Pullen Creek</td><td>Toxic & Other Deleterious Organic and Inorganic Substances</td><td>Metals</td><td>Industrial</td></tr>
<tr><td colspan="6">Pullen Creek has been on the Section 303(d) list since 1990 for non-attainment of the toxic & other deleterious organic and inorganic substances standard for metals. The lower mile of Pullen Creek was previously Section 303(d) listed with the Skagway Harbor listing but was segmented out into its own listing in the 2006 report. A local non-profit group has secured grant funds for performing an environmental assessment on the creek, collecting baseline monitoring data on water quality, flow and sedimentation data, and development of an action strategy for Pullen Creek. Assessment results found no elevated levels of toxics found in water column. Elevated levels of lead, zinc and barium found on stream bottom sediments and adjoining banks. Streambanks are very stable but elevated levels of metals are found near railroad transport areas where ore was transported in the past. Further investigation on the elevated levels needed. There will be a review of data on sediment toxicity and DEC will continue holding discussions with DEC's contaminated sites program and decide how to incorporate them into this project.</td></tr>
</table>

2. Watershed Background

2.1. Location and Physical Setting

Pullen Creek is the only tributary to Skagway Harbor, which serves the City of Skagway in the Skagway River valley, an area approximately two miles long and surrounded by the heavily forested terrain of Tongass National Forest. Vegetation within and surrounding Skagway varies with elevation and soil type, ranging from coastal rainforest to boreal and sub-alpine forests. The city is bordered by the Skagway River to the north, which empties into the Taiya Inlet at the northern end of the Lynn Canal approximately 113 miles northwest of Juneau, Alaska. The Alexander Archipelago, a dense grouping of islands created by the tops of the submerged coastal mountains, separates the City of Skagway from the Gulf of Alaska. The islands of the archipelago are highly mineralized and characterized by irregular steep coasts that create deep channels and fjords (STC 2005).

Skagway Harbor is located adjacent to the mouth of Skagway River. A small peninsula approximately 150 meters in width currently separates the harbor from where the river empties into the Taiya Inlet, which opens into the Lynn Canal. While the harbor served as a shipping hub for regional mining operations, mining ores were transported through the City of Skagway by rail and offloaded onto freighters and barges stationed at the harbor's Ore Dock. The transfer of lead and zinc ores from the Yukon to Skagway by railroad began in the mid-1920s and, except for periods of inactivity between 1982-1986 and 1993-1994, continued until 1997 (STC 2005).

The only drainage feeding directly into Skagway Harbor is Pullen Creek. The entire length (1.5 miles) of Pullen Creek runs along and over the southern boundary of the City of Skagway. Its headwaters begin in the rail yard at the northeast end of town and confluence with Skagway Harbor adjacent to the Broadway Dock. For much of its route it flows adjacent to the White Pass and Yukon Railroad, which borders the City of Skagway to the southeast. Two spring fed tributaries enter Pullen Creek along its length. The first splits from the mainstem approximately 0.51 miles upstream from the mouth. Tributary One is fed by a small spring located near the Jerry Meyers Fish Hatchery, approximately 0.34 miles upstream of its confluence with the mainstem. Tributary Two splits from the mainstem at 18th Street, approximately 1.3 miles from the mouth. This tributary is 0.34 miles long and has a headwater directly under the White Pass and Yukon Route Rail Yard. In addition, below the confluence with Tributary One, Pullen Creek receives inflows from the Alaska Power and Telephone (APT) Dewey Lakes Hydroelectric Plant (STC 2005). Figure 2-1 presents the location and features of Pullen Creek. The spring-fed nature of Pullen Creek makes stream-flow fairly stable with the exception of seasonal and stormwater influence.

Pullen Creek is almost entirely urbanized. It is located entirely within the City of Skagway, has been moved and channelized several times, receives a majority of its runoff is from impervious surfaces, and has 31 culverts along its length. However the Jerry Meyers Fish Hatchery, located on the tributary closest to its mouth, released king and pink salmon fry into the creek until it ceased operation in 2005. The creek also provides over-wintering rearing habitat for coho and Dolly Varden and spawning habitat for coho, pink, and chum salmon (STC 2005).

2.2. Climate

The City of Skagway is within the Alaskan maritime climate zone, which is characterized by cool summers and mild winters. Low-lying fog, overcast skies, rain, and drizzle dominate weather conditions due to air masses over the warmer Pacific Ocean mixing with chilled air over the colder Bering Sea. Average summer air temperatures range between 45 to 67 degrees Fahrenheit (ºF), while average winter temperatures range between 18 to 37ºF. Skagway receives less rain than is typical for Southeast Alaska, with averages of 26 inches of rain per year and 39 inches of snow per year (STC 2005).

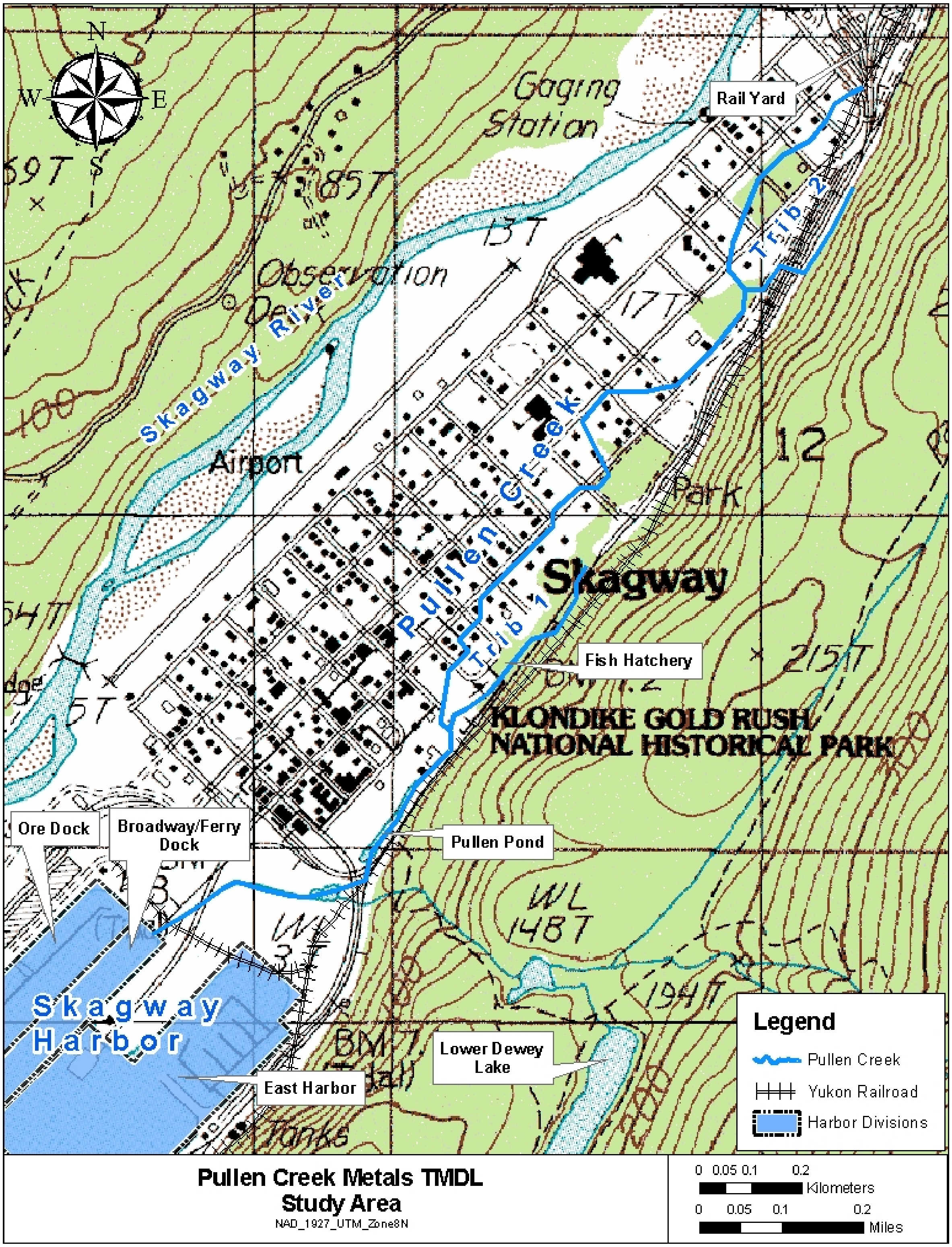


Figure 2-1. Pullen Creek study area location

2.3. Cultural and Economic History

Skagway is located within the traditional territory of the Chilkoot Band of the Tlingit Tribe. Skagway and its surrounding area were important historically as trade routes that ranged from the interior of Alaska and Canada to the tip of California. While what is known as the city of Skagway now was not occupied year-round, the neighboring community of Dyea was a permanent Tlingit village (STC 2005).

In 1896, the discovery of gold brought prospectors to settle in Skagway. Although the Klondike Gold Rush lasted only three years (1896–1899), it drew some 20,000 prospectors traveling through Skagway on their way to either the Chilkoot Pass or White Pass trail. In 1900, Skagway became Alaska's first incorporated city. By then the gold rush years had ended and, as a result, Skagway's economy stabilized around the railroad industry. The town experienced an economic boom during World War II, and Skagway became an important part in Alaska's defense system. A fuel pipeline was built paralleling the railroad from Skagway to Whitehorse in the Yukon Territory of Canada during the war. The pipeline and the railroad were used to haul materials for the war effort and for the construction of the Alaska-Canada Highway (STC 2005).

Another economic boom occurred during the late 1960s through the mid 1970s with the opening of the Cyprus Anvil lead-zinc mine in Faro, Canada. Skagway's freight shipments increased from 132,000 tons annually to 800,000 tons by the mid-1970s. The White Pass and Yukon Route (WP & YR) built an ore terminal and ship basin on city-leased tidelands to handle the increased capacity (currently known as the ore dock). As labor costs continued to increase and the market price for ore decreased after 1975, the mine was forced to close in 1982. The railroad, which was dependent on the mine shipments, was also shut down (STC 2005).

After the initial closure of the mine in 1982, it was bought and sold multiple times. Resumption of ore shipping activities, though on a much smaller scale took place from 1986 until 1997 except for a period of inactivity between 1993-1994. The Klondike Highway, which links Skagway and Whitehorse was completed in 1978 and became open year-round by 1986. At this time tourism began to play a more important role in the city's economy (STC 2005).

Skagway is one of three Southeast Alaskan communities that is connected to the road system, allowing access to the Yukon Territority, northern British Columbia, interior Alaska, and the lower 48 states. This also makes Skagway an important port-of-call for the Alaska Marine Highway — Alaska's ferry system — and serves as the northern terminus of the important and heavily-used Lynn Canal corridor (STC 2005).

Currently the city is a tourist center and serves as an important trade route for Southeast Alaska. It currently hosts freight barges, ferries, cruise ships, water taxis, and fishing boats (STC 2005). As of the 2000 census, the population of the city was 862. However, the population doubles in the summer tourist season to support more than 900,000 visitors. The port of Skagway is a popular stop for cruise ships, and the tourist trade is a big part of the business of Skagway. The White Pass and Yukon Route narrow gauge railroad, part of the area's mining past, is now in operation only for the tourist trade and runs throughout the summer months.

3. 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 include 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 criterion where one exists, or it may represent a quantitative interpretation of a narrative criterion. This section reviews the applicable water quality standards and identifies an appropriate TMDL target for calculation of the metals TMDLs in Pullen Creek. Metals for which TMDLs are calculated are cadmium, copper, lead and zinc. Identification of metals of concern is discussed further in Section 4.

3.1. 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. State water quality criteria are defined for both marine and fresh waterbodies. In the case of Pullen Creek fresh water criteria are applicable.

Designated uses established in the State of Alaska Water Quality Standards (18 AAC 70) for fresh waters include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife. Table 3-1 lists water quality criteria for toxic and other deleterious organic and inorganic substances, on which the 303(d) listing for Pullen Creek is based.

Table 3-1. Fresh water quality criteria for toxic and other deleterious organic and inorganic substances (18 AAC 70.020)

Designated use	Description of criteria
(11) Toxic and other deleterious organic and inorganic substances, for fresh water uses	
(A) Water Supply	
(i) drinking,culinary, and food processing	The concentration of substances in water may not exceed the numeric criteria for drinking water and human health for consumption of water and aquatic organisms shown in the Alaska Water Quality Criteria Manual (see note 5). Substances may not be introduced at concentrations that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(ii) agriculture, including irrigation and stock watering	The concentration of substances in water may not exceed the numeric criteria for drinking water and stockwater and irrigation water shown in the Alaska Water Quality Criteria Manual (see note 5). Substances may not be introduced at concentrations that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(iii) aquaculture	Same as (11)(C).
(iv) industrial	Concentrations of substances that pose hazards to worker contact may not be present.
(B) Water Recreation	
(i) contact recreation	The concentration of substances in water may not exceed the numeric criteria for drinking water shown in the Alaska Water Quality Criteria Manual (see note 5). Substances may not be introduced at concentrations that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(ii) secondary recreation	Concentrations of substances that pose hazards to incidental human contact may not

Designated use	Description of criteria
	be present.
(C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife	The concentration of substances in water may not exceed the numeric criteria for aquatic life for fresh water and human health for consumption of aquatic organisms only shown in the Alaska Water Quality Criteria Manual (see note 5), or any chronic and acute criteria established in this chapter, for a toxic pollutant of concern, to protect sensitive and biologically important life stages of resident species of this state. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects on aquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.

The State of Alaska has adopted EPA's water quality criteria for priority and non-priority pollutants. Alaska's water quality criteria are based on the dissolved (biologically active) fraction of metal concentration in ambient water. Criteria are developed to protect aquatic life and consist of two classifications, Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC). CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect, representing an acute criterion. CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect, representing a chronic criterion. The development of these TMDLs was designed to not only restore sediment quality but to also ensure that waters in Pullen Creek attain both the acute and chronic criteria. Table 3-2 presents the applicable criteria for metals of concern in Pullen Creek.

Table 3-2. Freshwater water quality criteria for metals of concern in Pullen Creek

Metal	Acute criterion (CMC; ug/L)	Chronic criterion (CCC; ug/L)
Cadmium	2	0.25
Copper	13	9
Lead	65	2.5
Zinc	120	120

Note: The freshwater criteria are expressed as a function of hardness (mg/L) in the water column. The values given correspond to a hardness of 100 mg/L.
Criteria are shown only for those metals that are of concern for the sediment impairment.

3.2. Sediment Quality Targets

Pullen Creek is currently listed as impaired due to metals impacting sediment. Monitoring studies for Pullen Creek have indicated high concentrations of several priority pollutant metals including cadmium, copper, lead, and zinc in bottom sediments. To date, ADEC has not adopted numeric sediment quality standards for the evaluation of impacts to aquatic life. However, the ADEC Contaminated Sites Remediation Program has issued the technical memorandum *Sediment Quality Guidelines* (DEC 2004), which recommends using the Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) for evaluating sediment quality. TELs define chemical sediment concentrations below which toxic effects are rarely observed in sensitive species, while PELs define concentrations above which effects are frequently or always observed. Table 3-3 presents the TELs and PELs for metals of concern, as provided in the *NOAA Screening Quick Reference Tables* (Buchman 2008).

Table 3-3. Freshwater sediment screening levels for metals of concern in Pullen Creek

Metal	TEL (mg/kg)	PEL (mg/kg)
Cadmium	0.596	3.53
Copper	35.7	197
Lead	35	91.3
Zinc	123.1	315

Buchman (2008)
Note: Screening levels are included only for those metals shown to be of concern through the data analysis presented in Section 4.

3.3. Impairments

Pullen Creek (lower mile) was originally jointly listed with Skagway Harbor on Alaska's 1990 section 303(d) list by ADEC due to potential sediment toxicity from elevated metals in streambed sediments. Recent monitoring conducted in 2007 and 2008 confirmed metals impairments in Pullen Creek sediments, which are thought to be a result of historical mining activities and ore shipping operations in Skagway Harbor. The entire length of Pullen Creek runs along and over the southern boundary of the City of Skagway, adjacent to the White Pass/Yukon Railroad. During the height of mining operations in the area, approximately 50,000 tons of ore were transported to Skagway Harbor by rail. The transport, storage, and subsequent transfer of ore to ships are thought to be the primary pathways of heavy metals contamination in the surrounding areas. High winds are common in the area and airborne ore dust resulted from many of the early shipping, storage, and transfer procedures (ADEC 1992).

Impairments in the lower mile of Pullen Creek are based on applicable freshwater criteria for toxic and other deleterious organic and inorganic substances, including metals. Regarding concentrations of pollutants in stream sediments, the freshwater criteria state that "…There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects on aquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter." Recent and historical monitoring found metals concentrations in Pullen Creek sediments are greater than the TEL and PEL sediment screening levels recommended by the state for evaluating sediment quality.

3.4. TMDL Target

The TMDL target is the numeric endpoint used to identify the loading capacity and represents attainment of applicable water quality standards. The listed impairments in Pullen Creek are caused by elevated metals concentrations in the stream bottom sediments. Therefore, to address the impairment in Pullen Creek the TMDL establishes targets for acceptable levels of metals in stream bottom sediments to support designated uses. The numeric sediment quality target represents conditions under which Pullen Creek will meet applicable water quality standards.

As discussed in Section 3.2, ADEC recommends using TELs and PELs for evaluating sediment quality. The TEL was chosen as the TMDL target. Because the TEL is the more stringent of the available guidelines, it provides a more conservative target to ensure that resulting sediment and overlying water quality conditions will support water quality standards, including applicable designated uses. The applicable metals TELs are listed in Table 3-3.

While Pullen Creek's listed impairment is based on sediment quality rather than exceedances of water quality criteria for metals in surface waters, limited data show some exceedances of applicable water quality criteria. While sediment targets will be used to calculate the TMDLs, water quality criteria will also be used as supplementary targets to confirm that the TMDL sediment quality targets will support all applicable water quality standards. A supplemental analysis is included as part of these TMDLs to illustrate that once sediment concentrations meet targets, water column concentrations will also likely decrease and meet applicable water quality criteria.

TMDLs are established for those metals shown to exceed the TEL (as shown in Section 4)—cadmium, copper, lead and zinc.

4. Data Review

This section presents the available sediment and water column monitoring data for Pullen Creek. Four monitoring studies included sampling of various media in Pullen Creek focused on metals contamination due to historical mining ore shipping operations in the area. Relevant reports are listed in Table 4-1.

Table 4-1. Summary of Pullen Creek monitoring reports

Report Name	Publisher	Publish Date	Data Type for Pullen Creek
Evaluation of Metals and Petroleum Derivatives in Skagway Harbor and Pullen Creek Sediments and Surface Waters	Tetra Tech Inc. for ADEC	Feb 2009	Water Column
Evaluation of Skagway Harbor and Pullen Creek Sediments and Surface Waters	Tetra Tech Inc. for ADEC	Feb 2008	Sediment
Pullen Creek Assessment	Skagway Traditional Council	July 2005	Soils, Sediment, Water Column
Skagway Harbor Field Investigation	Tetra Tech Inc. for EPA	Feb 1990	Sediment, Water Column

4.1. Sediments

Sediment metals monitoring in Pullen Creek includes a studies conducted in 1990 for EPA, 2004 by the Skagway Traditional Council (STC), and 2007 for ADEC. The locations of monitoring stations from the 2004 and 2007 surveys of Pullen Creek are shown in Figure 4-1. The exact 1990 sampling location is not known, but is in the general area of the creek's headwaters.

Table 4-2 presents sediment metals data collected during the 2004/2005 study, and Table 4-3 presents data collected during the 2007 study. Metals concentrations in Table 4-2 and Table 4-3 are bold if they exceed the TEL screening level and bold and underlined if they exceed the PEL screening level. As discussed in Section 3.4, the TEL was chosen as the TMDL target for each metal of concern in Pullen Creek. TELs define chemical sediment concentrations below which toxic effects are rarely observed in sensitive species, while PELs define concentrations above which effects are frequently or always observed.

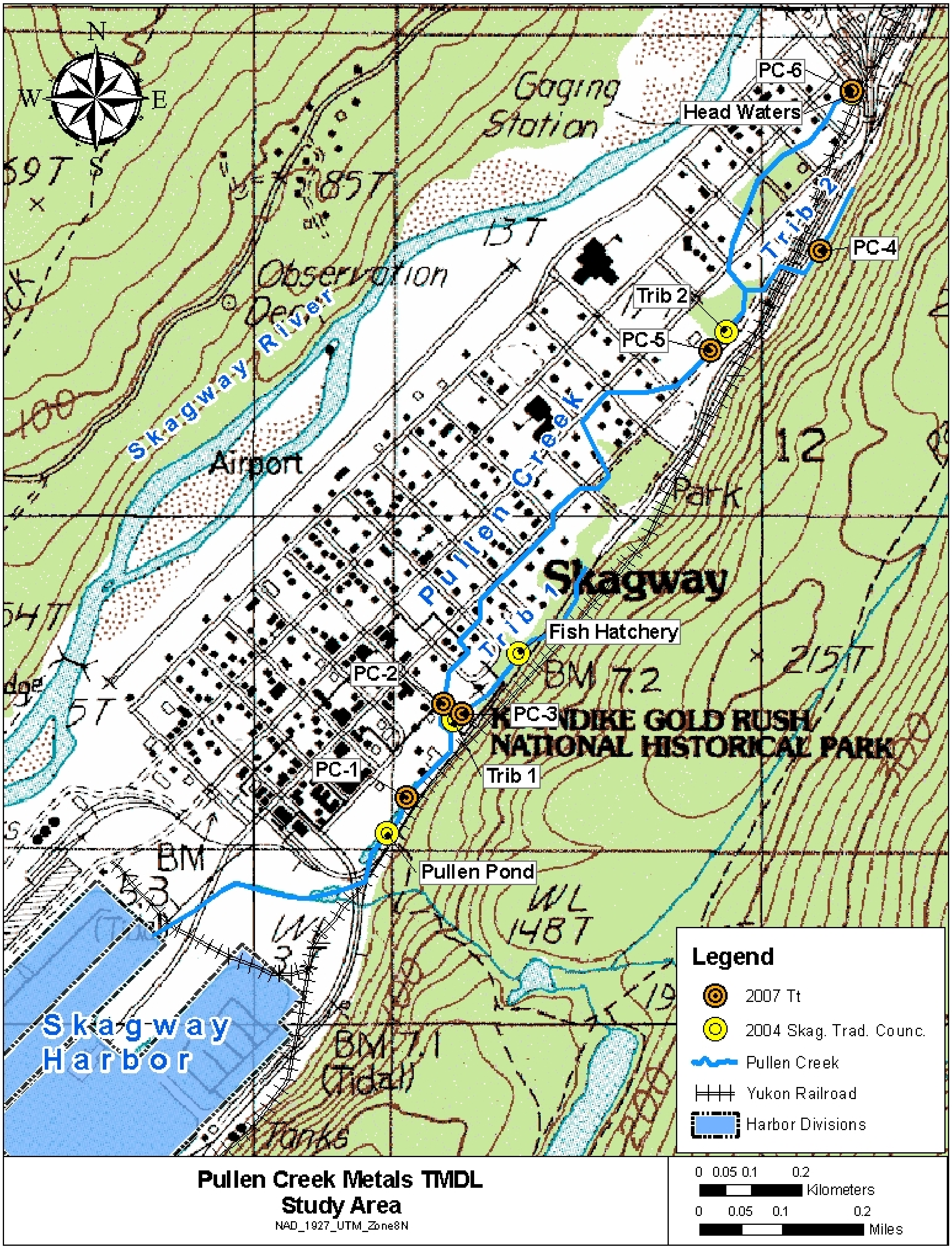


Figure 4-1. Pullen Creek historical monitoring locations

Table 4-2. Sediment metals concentrations measured at stations in Pullen Creek in 2004/2005

Date	Arsenic (mg/kg)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
TEL	5.9	N/A	0.596	37.3	35.7	35	0.174	N/A	N/A	123
PEL	17	N/A	3.53	90	197	91.3	0.486	N/A	N/A	315
Headwaters (rail yard)										
Feb '04	**<u>17.5</u>**	1,840	**1.6**	30.6	N/A	**<u>633</u>**	ND	ND	2.4	**<u>557</u>**
May '04	1.2	170	ND	6.9	N/A	**<u>130</u>**	ND	ND	ND	**160**
Aug '04	**7.8**	397	**0.6**	14	N/A	**<u>159</u>**	ND	ND	0.8	**145**
Nov '04	4.2	159	**2.3**	12	32	**<u>123</u>**	0.1	ND	ND	**139**
Mar '05	ND	187	**2**	16.9	**47.3**	**<u>215</u>**	**0.2**	ND	ND	**200**
Fish Hatchery										
Feb '04	**<u>19.2</u>**	1,340	**1.7**	**43.5**	N/A	**<u>207</u>**	ND	ND	0.7	**<u>835</u>**
May '04	3.4	180	ND	14	N/A	**<u>98</u>**	ND	ND	0.6	**<u>770</u>**
Aug '04	4.8	180	ND	7.1	N/A	**64.4**	ND	ND	ND	**218**
Nov '04	4.5	172	**2.5**	11.2	14.3	**70**	0.1	ND	ND	**170**
Mar '05	ND	196	ND	8.7	17.3	**50.3**	0.1	ND	ND	**134**
Tributary 2, 18th and State										
Feb '04	**15**	1,070	**2**	32	N/A	**<u>373</u>**	ND	ND	0.9	**<u>913</u>**
May '04	1.6	200	ND	5.6	N/A	**66**	ND	ND	ND	**200**
Aug '04	**8.6**	248	**1**	14	N/A	**<u>232</u>**	ND	ND	0.8	**<u>565</u>**
Nov '04	4	136	**3.1**	4.3	9.7	**53**	0	ND	ND	91
Mar '05	ND	198	**2**	11.7	20.7	**<u>107</u>**	0.1	ND	ND	**271**
Tributary 1										
Feb '04	**7.1**	1,080	**0.7**	12	N/A	**<u>263</u>**	ND	ND	ND	**<u>551</u>**
May '04	1.2	190	ND	5.5	N/A	**75**	ND	ND	ND	**240**
Aug '04	2.3	99.7	ND	2.7	N/A	**60.7**	ND	ND	ND	**179**
Nov '04	5.5	172	**3.1**	12	29	**<u>108</u>**	0.1	ND	ND	**<u>353</u>**
Mar '05	ND	191	**2.4**	11.4	**36.8**	**<u>116</u>**	0.1	ND	ND	**<u>452</u>**
Pullen Pond										
Feb '04	**13**	1,290	ND	20	N/A	**<u>422</u>**	ND	ND	1.2	**293**
May '04	0.8	250	ND	5.5	N/A	**80**	ND	ND	ND	110
Aug '04	2.9	394	ND	3.6	N/A	**52.8**	ND	ND	ND	**137**
Nov '04	2.4	168	**2.1**	7.3	34	**<u>113</u>**	0.1	ND	ND	**174**
Mar '05	ND	132	**1.3**	4.2	9.7	33.4	0.1	ND	ND	90.6

Note: Concentrations exceeding TEL screening levels are bold and exceeding PEL screening levels screening levels are bold and underlined.

Table 4-3. Sediment metals concentrations measured at stations in Pullen Creek in 2007

	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)
TEL	0.596	35.7	35	18	123
PEL	3.53	197	91.3	36	315
Stations					
PC-1	0.17	7.7	**87**	2.5	**130**
PC-2	0.18	7.3	**44**	4.1	**170**
PC-3	0.12	8.3	**44**	3.7	120
PC-4	**1.6**	**120**	**<u>330</u>**	8.9	**<u>340</u>**
PC-5	**1.3**	**40**	**<u>180</u>**	6.4	**<u>480</u>**
PC-6	**1.1**	7.6	28	4.3	61

Note: Concentrations exceeding TEL screening levels are bold and exceeding PEL screening levels screening levels are bold and underlined.

Monitoring in 1990 included a single sediment sample collected at the headwaters of Pullen Creek. Sample results showed metal concentrations (lead and zinc) in sediment to be below the TEL screening levels (35 mg/kg for lead and 123.1 mg/kg for zinc).

Monitoring conducted by the STC in 2004/2005 included sediment samples collected at five locations along Pullen Creek on five dates between February 2004 and March 2005 (Table 4-2). Sampling results showed high sediment metals concentrations at all locations. Zinc and cadmium concentrations exceeded the TEL screening level at all locations, with zinc exceeding the PEL at four locations (Headwaters, Confluence with Tributary 1, Confluence with Tributary 2 at 18th and State St., and Fish Hatchery). Lead sediment concentrations exceeded the PEL at all locations, and copper concentrations exceeded the TEL at the Confluence with Tributary 1 station and the Headwaters station located just downstream of the rail yard. Mercury, selenium and silver were below detection limits in the majority of samples. One sample (Fish Hatchery station in February 2004) exceeded the TEL for chromium, while the remaining 24 samples were well below the chromium TEL. All samples collected during the initial sampling date in February 2004 exceeded the TEL for arsenic. However, samples collected during subsequent events had arsenic concentrations below the TEL, with the exception of two samples collected in August 2004 (Rail Yard and Tributary 2) that exceeded the TEL but were below the PEL. Because arsenic concentrations in sediment samples were below the TEL during later sampling events, including the final event in February 2005 having concentrations below detection limits, it is assumed that arsenic is not a metal of concern for Pullen Creek. Based on the 2004/2005 dataset, metals consistently exceeding screening levels and requiring TMDLs include cadmium, copper, lead and zinc. This conclusion is supported by results of the 2007 monitoring.

The 2007 Tetra Tech study included sediment sampling at six locations in Pullen Creek and indicated that the headwater sites generally exceeded TEL values for cadmium, copper, lead, and zinc and in some cases exceeded PEL values for lead and zinc (Table 4-3). Metal concentrations were generally lower than those measured in 2004, however. Only one station (PC-5 at 18th and State St.) had higher metals concentrations in 2007 than in 2004. Though generally lower than concentrations measured in 2004, TEL limits were exceeded at three stations for cadmium (PC-4, PC-5, and PC-6), two stations for copper (PC-4 and PC-5), five stations for lead (PC-1 through PC-5), and four stations for zinc (PC-1, PC-2, PC-4, and PC-5). In addition, two stations (PC-4 and PC-5) exceeded the PEL level for lead and zinc. Sites further downstream were generally below all thresholds examined, with the exception of lead and zinc, which exceeded the TEL. Therefore, lead and zinc TELs are exceeded throughout Pullen Creek, cadmium and copper TELs are exceeded in the headwaters, and nickel sediment screening levels are not exceeded at all.

Sediment results for the Pullen Creek monitoring studies are presented in Figure 4-2 through Figure 4-5 for cadmium, copper, lead and zinc, respectively. Data for 2004 are presented as averages of the five samples collected at the respective location, along with the range of sample concentrations from minimum to maximum.

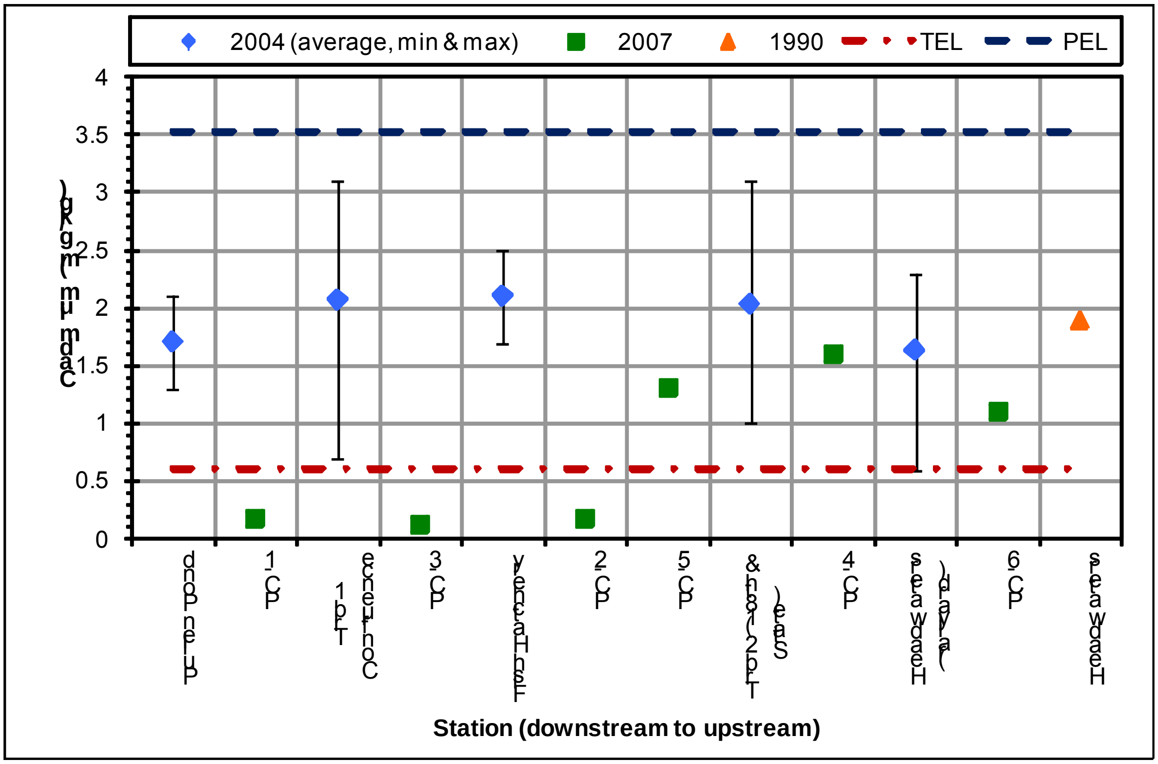


Figure 4-2. Sediment cadmium concentrations measured throughout Pullen Creek (1990, 2004 and 2007)

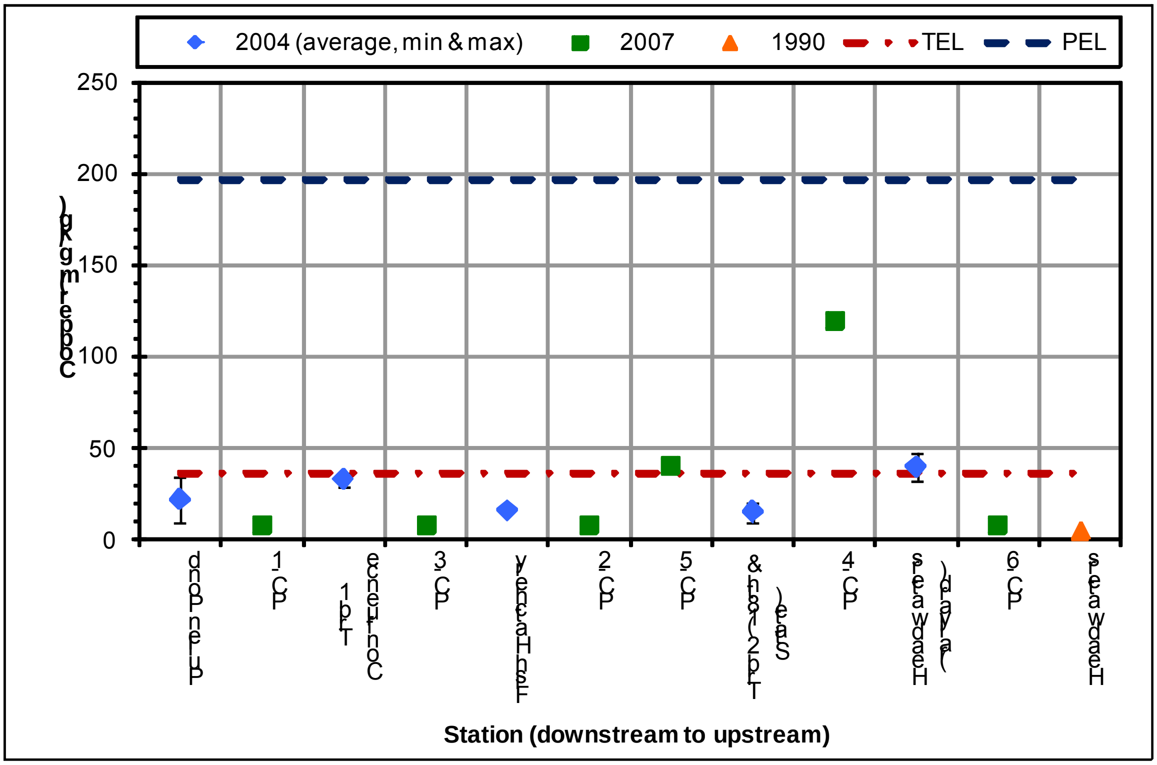


Figure 4-3. Sediment copper concentrations measured throughout Pullen Creek (1990, 2004 and 2007)

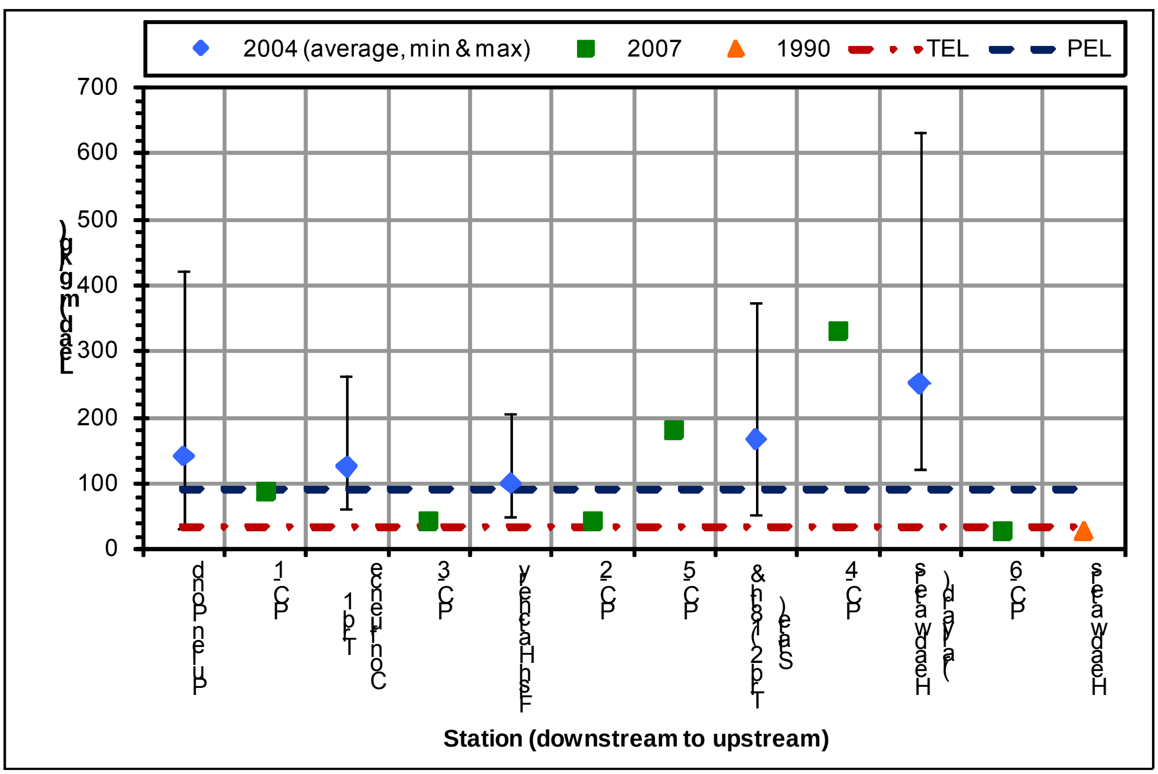


Figure 4-4. Sediment lead concentrations measured throughout Pullen Creek (1990, 2004 and 2007)

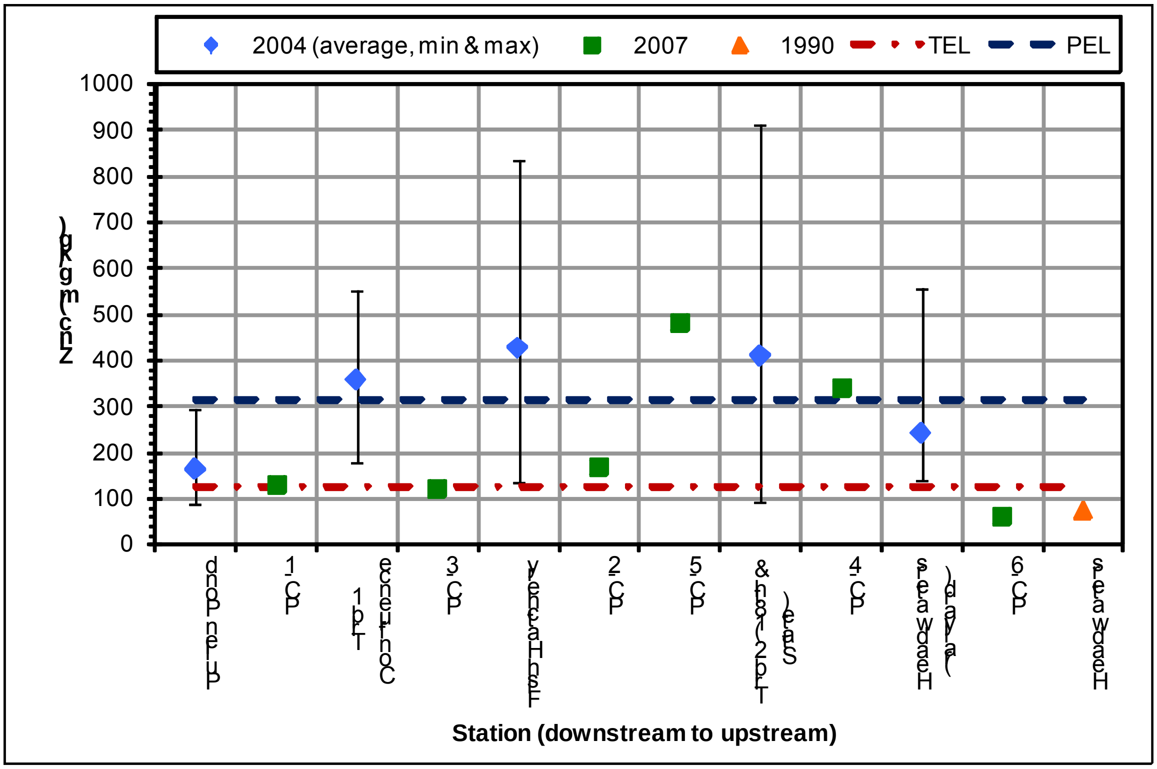


Figure 4-5. Sediment zinc concentrations measured throughout Pullen Creek (1990, 2004 and 2007)

As shown in Figure 4-2 through Figure 4-5 metals concentrations in the creek sediments generally seem to be lower in the 2007 samples. While this could suggest that metals are being buried by cleaner sediment or flushed out of the system, the data are not sufficient enough to draw any conclusions. In addition, contaminant concentrations in streambed sediment samples can greatly vary, even within a single stream site or cross-section.

The 2004 monitoring is the only study to include sediment sampling on multiple dates, as shown in Figure 4-6, providing the opportunity to evaluate changes in concentrations over time as well as throughout the creek. The data show cadmium and copper being higher at all locations during the November 2004 and March 2005 sampling events and lead and zinc being highest during the February 2004 event. While data do not show one location exhibiting consistently higher concentrations than other stations, the headwaters site near the rail yard includes sample concentrations that are higher than most of the other stations for copper and lead. While the data do show both spatial and temporal variations in concentrations, after reviewing weather and flow data and other factors, the STC concluded the differences were not due to seasonal fluctuations but simply reflect mixing variability in the soil and sediment. Soil data were also collected during the STC 2004 study, obtained outside the stream channel but within a few feet of the creek's high-water line and 3-5 feet below the surface. These data showed consistently higher levels of metals around the headwaters/rail yard and fish hatchery sites.

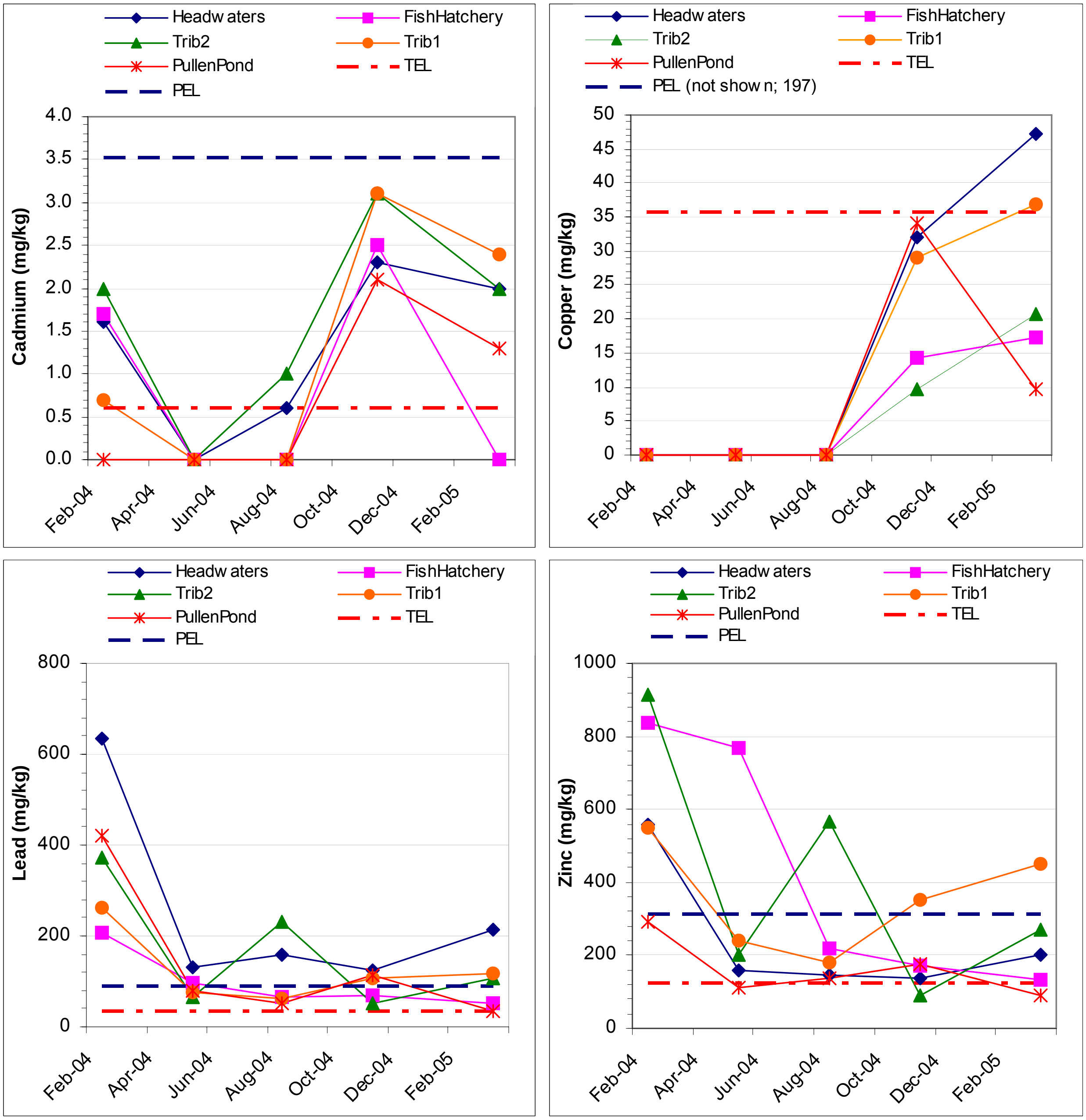


Figure 4-6. 2004/2005 sediment monitoring results in Pullen Creek

4.2. Surface Water

Monitoring of surface waters for metals in Pullen Creek was conducted as part of three studies, including the 1990 study by Tetra Tech for EPA, the 2004 STC study and a recent 2008 monitoring study conducted for ADEC by Tetra Tech. The 2004 monitoring locations are the same as those identified in the sediment monitoring section and presented in Figure 4-1. The exact 1990 monitoring location is not known, but is in the vicinity of the creek headwaters. Study data from 1990 and 2004 were not particularly useful in characterizing water quality conditions of Pullen Creek because of the lack of monitoring locations in 1990 and analytical results that consistently showed metals concentrations to be below detectable levels in 2004. These studies are discussed briefly below.

1990 and 2004 Surface Water Quality Monitoring

A single sample was collected in 1990 in the vicinity of the headwaters of Pullen Creek and analyzed for lead and zinc concentrations. The reported concentrations of lead and zinc were 156 µg/L and 529 µg/L, respectively, both well above the applicable acute water quality criteria (65 µg/L for lead and 120 µg/L for zinc).

Surface water monitoring in 2004 included samples collected in concert with sediment samples. Water samples were analyzed for arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc concentrations. Only two stations, Pullen Pond and Headwaters, reported concentrations above detection levels. Monitoring results for these stations are presented in Table 4-4. Detectable concentrations were well below applicable water quality criteria.

Table 4-4. 2004 surface water monitoring results for stations with detectable concentrations in Pullen Creek

Metal	Headwaters (µg/L)					Pullen Pond (µg/L)					Acute criterion (µg/L)	Chronic criterion (µg/L)
	Feb ‘04	May ‘04	Aug ‘04	Nov ‘04	Mar ‘05	Feb ‘04	May ‘04	Aug ‘04	Nov ‘04	Mar ‘05		
Arsenic	ND	ND	ND	0.0002	ND	ND	ND	ND	ND	ND	340	15
Barium	84	ND	130	0.052	0.052	77	ND	1200	0.046	0.052	NA	NA
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	0.25
Chromium	0.63	ND	0.7	ND	ND	1.6	ND	1.6	ND	ND	16	11
Copper	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	13	9
Lead	ND	ND	ND	0.001	0.001	ND	ND	ND	ND	ND	65	2.5
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4	0.77
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	5
Silver	ND	0.5	ND	ND	ND	1.01	0.6	ND	ND	ND	3.2	NA
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	0.003	0.007	120	120

2008 Surface Water Quality Monitoring

As a follow up to the 2007 sediment monitoring, sampling was conducted in Pullen Creek in September 2008 with the overall objective to characterize surface water quality under both baseflow and stormflow conditions. The 2007 study of sediments in Pullen Creek showed significant concentrations of metals, however, surface waters were not examined to determine if sediment metals are being mobilized and moved downstream. Specific project objectives for the 2008 sampling included:

- Sampling of Pullen Creek surface waters under baseflow and stormflow conditions to determine if Pullen Creek is a significant source of metals to Skagway Harbor and if metals observed in the sediments of upper Pullen Creek are mobilized under storm conditions.
- Sampling a reference location in a comparable watershed in terms of size, drainage, and flow as Pullen Creek to establish potential background concentrations that will be used in the evaluation of Pullen Creek to aid in the determination of whether pollutant levels are from natural or anthropogenic sources.

Pullen Creek monitoring locations included ones that had been sampled previously in 2007 and new sampling locations at stormwater outfalls, below the APT Dewey Lakes Hydroelectric Plant, and a reference location. Table 4-5 provides a summary of the Pullen Creek 2008 monitoring locations.

Table 4-5. 2008 monitoring study sampling locations

Location description	Site	Station type	Stormwater metals (Cd, Cu, Pb, Ni, Zn)	Baseflow metals (Cd, Cu, Pb, Ni, Zn)
Pullen Creek	PC-1	Surface water	X	X
	PC-2	Surface water	X	X
	PC-3	Surface water		
	PC-4	Surface water		
	PC-5	Surface water	X	X
	PC-6	Surface water		
	PC-7	Stormwater outfall	X	
	PC-8	Stormwater outfall	X	
	PC-9	Stormwater outfall	X	
	REF-PC	Surface water	X	X
Hydro-Electric Plant	EP-1	Facility discharge	X	

Monitoring Locations

The 2007 evaluation of Pullen Creek sediments indicated that metals may be impairing the upper watershed, but was unable to determine if metals are mobilized downstream. To determine if increased loads of metals are carried during periods of high flows, stormflows were characterized as part of the 2008 monitoring study. Surface water at four sites, including a reference location (REF-PC) and sites previously sampled in 2007 (PC-1, PC-2, and PC-5), were sampled under baseflow and stormflow conditions to evaluate the potential movement of metals downstream.

Monitoring under baseflow conditions was conducted in September 2008, while stormwater sampling was done in October 2008. Also, during the October 2008 storm event, sites PC-7, PC-8, PC-9 and EP-1 were sampled. Sample sites PC-7, PC-8, and PC-9 are stormwater outfalls that are located upstream of sites PC-1, PC-2, and PC-5, respectively, and site EP-1 represents discharge from the APT Dewey Lakes Hydroelectric Plant, which makes up a large portion of Pullen Creek’s flow. Figure 4-7 shows the locations of the 2008 monitoring sites, excluding the reference site. Station REF-PC was collected on a tributary to the Skagway River approximately 1 mile north of the city of Skagway.

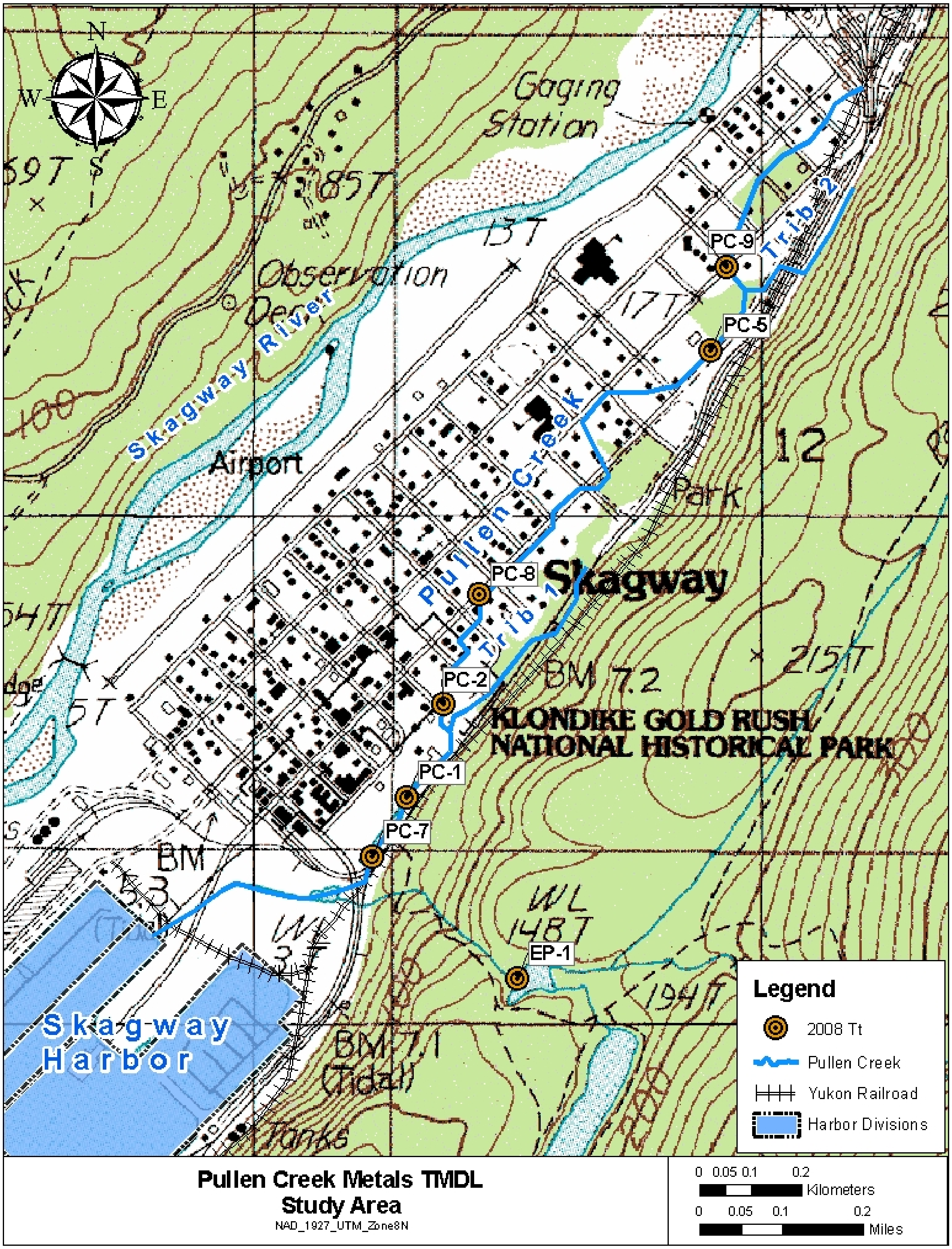


Figure 4-7. Pullen Creek 2008 surface water and outfall monitoring locations

Monitoring Results

A summary of the baseflow and stormwater monitoring results is provided in Table 4-6 and Figure 4-8. In Table 4-6 concentrations exceeding the chronic criterion (CCC) are bold and concentrations exceeding the acute criterion (CMC) are bold and underlined.

Concentrations of dissolved cadmium were not detected in the surface water of Pullen Creek with the exception of sites PC-1 SW (1.9 µg/L), PC-5 (1.4 µg/L), and PC-8 (0.53 µg/L). It should be noted that all three of these samples had total cadmium concentrations below the detection limit (0.47 µg/L). In addition, the dissolved cadmium detection limit was greater than the applicable chronic criteria (0.25 µg/L). No site recorded dissolved cadmium concentrations above the acute criteria (2.0 µg/L). Sites PC-7 and PC-8 were the only sites to have detectable concentrations of total cadmium, which were 1.8 and 0.50 µg/L, respectively.

Concentrations of dissolved copper were identified in the baseflow sample from site PC-5 (4.3 µg/L) and stormwater outfall samples from PC-7 and PC-8 (3.5 and 28.1 µg/L, respectively). All other Pullen Creek sample sites had no measured levels of dissolved copper (detection limit = 2.6 µg/L). Total copper concentrations detected ranged from 2.8 (PC-2 SW) to 26.8 (PC-1 SW) µg/L. Total copper was not detected at sample sites PC-1, PC-2, PC-5, PC-5 SW, PC-REF, PC-REF SW, and EP-1

Concentrations of dissolved lead values ranged from 1.8 (site PC-2 SW) to 11.7 (site PC-2) µg/L, well below the applicable acute water quality criterion (65 µg/L). Eight of twelve samples collected exceeded the chronic criterion (2.5 µg/L) for dissolved lead. Concentrations of total lead detected ranged from 0.44 (PC-1) to 12.8 (PC-8) µg/L. Total lead was not detected at site PC-5.

Concentrations of dissolved zinc were detected at all sample sites and ranged from 9.7 (PC-1 SW) to 148 µg/L (PC-8). Only five of the twelve samples recorded concentrations greater than 30 µg/L—PC-1 (71.4 µg/L), PC-2 (45.5 µg/L), PC-5 (38.3 µg/L), EP-1 (70.6 µg/L), and PC-8 (148 µg/L)—and PC-8 was the only sample with a concentration that exceed the acute and chronic criteria (120 µg/L). Total Zinc was not detected at sites PC-5, EP-1, and PC-REF SW. Concentrations of total zinc ranged from 11.9 (PC-REF) to 163 (PC-8) µg/L.

Table 4-6 and Figure 4-8 compare the data to applicable water quality criteria for the metals of concern. Because these data represent instantaneous concentrations during a single sampling event, it is most appropriate to compare the data to the applicable acute criterion to evaluate exceedances of water quality standards. No in-stream samples exceeded the acute criterion for any of the metals of concern. Two in-stream samples exceeded the chronic criterion for cadmium, and eight of the nine samples exceeded the chronic criterion for lead. However, without additional data, it is unknown whether these concentrations represent persistent conditions that would result in violation of the chronic criteria, rather than infrequently elevated concentrations. Therefore, the available data do not indicate that water quality conditions are violating water quality criteria. However, as discussed further in Section 6, a supplemental analysis is performed as part of these TMDLs to evaluate reduction in water column metals concentrations that would result from reductions in sediment concentrations to ensure attainment of water quality criteria in the overlying water column.

Table 4-6. Pullen Creek 2008 surface water monitoring results

Sample Type	Site Name	Total Cadmium (µg/L)	Dissolved Cadmium (µg/L)	Total Copper (µg/L)	Dissolved Copper (µg/L)	Total Lead (µg/L)	Dissolved Lead (µg/L)	Total Zinc (µg/L)	Dissolved Zinc (µg/L)
Surface Water – Baseflow	PC-1	ND	ND	ND	ND	0.44	**5.6**	21.9	71.4
	PC-2	ND	ND	ND	ND	2.8	**11.7**	64.1	45.5
	PC-5	ND	**1.4**	ND	4.3	ND	**11.2**	ND	38.3
	PC-REF	ND	ND	ND	ND	2	**7.1**	11.9	29.3
Surface Water – Stormflow	PC-1	ND	**1.9**	26.8	ND	4.8	**3.0**	12.3	9.7
	PC-2	ND	ND	2.8	ND	2.4	1.8	15.4	14.1
	PC-5	ND	ND	ND	ND	2.4	**2.9**	14.4	17.8
	PC-REF	ND	ND	ND	ND	1.1	**2.8**	ND	13.6
Outfall Runoff	PC-7	1.8	ND	10.6	3.5	11	1.9	63.7	25.2
	PC-8	0.5	**0.53**	19.5	**28.1**	12.8	**3.9**	163	**148**
	PC-9	ND	ND	4.8	ND	7	1.9	46	24.5
	EP-1	ND	ND	ND	ND	1.3	2.1	ND	70.6

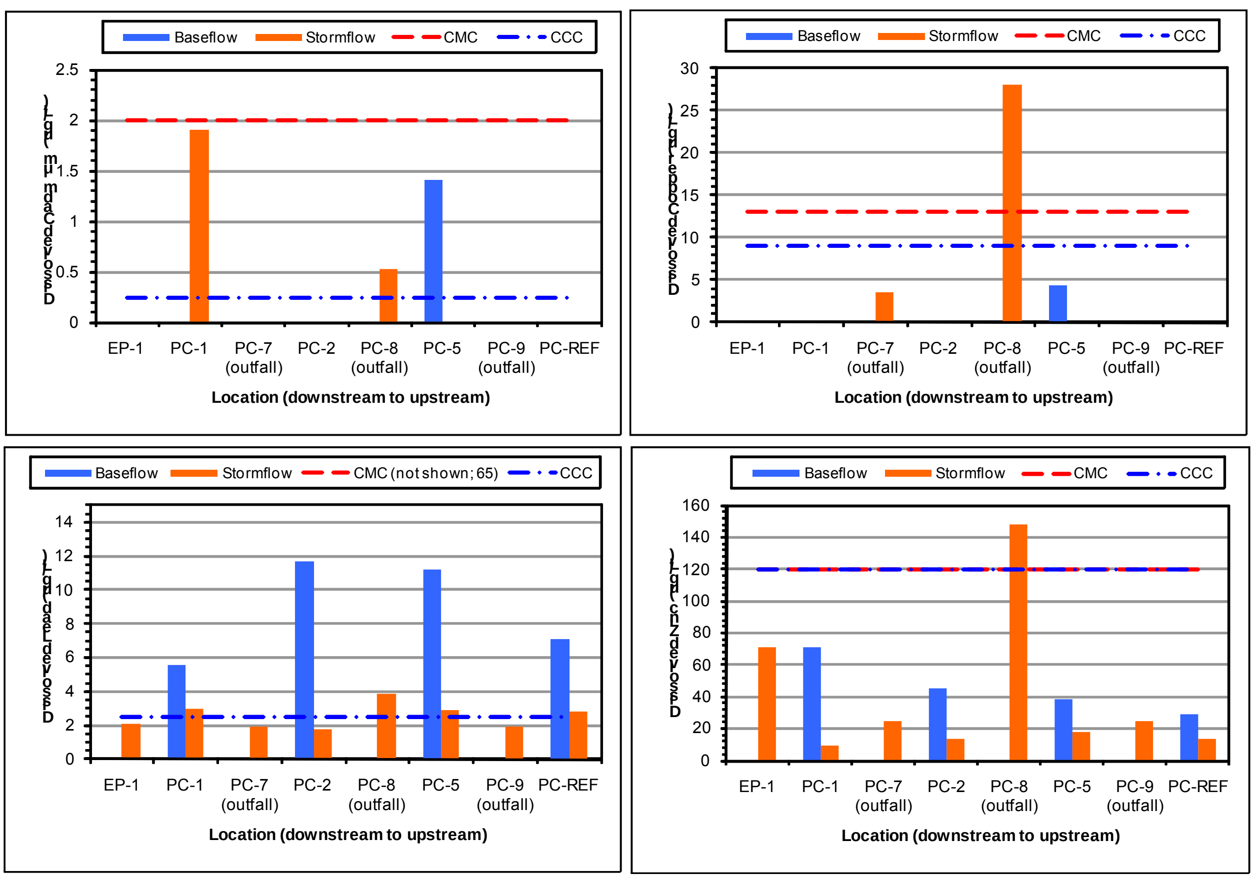


Figure 4-8. Pullen Creek 2008 surface water monitoring results for dissolved metals

Monitoring results of the 2008 Pullen Creek sampling study indicate that the concentrations of metals (cadmium, copper, lead and zinc) present during stormflow conditions are, in most cases, slightly lower than at baseflow conditions. In addition, the reference site, as well as two of the stormwater outfall sites sampled, PC-7 and PC-9, showed similar levels of metals as the Pullen Creek sites (PC-1, PC-2, and PC-5) for all parameters. Surface water samples met applicable water quality criteria for copper and zinc, but exceeded chronic criteria (but not acute criteria) for cadmium and lead. The stormwater runoff sample at outfall site PC-8 showed concentrations of dissolved zinc and dissolved copper that exceeded the fresh water acute criteria and were considerably higher than concentrations found at all other sites. However, because flow was not measured for the outfall discharge, the corresponding metals loads being discharged to Pullen Creek at this outfall is unknown. As shown in Figure 4-8, the stormwater does not seem to impact the in-stream conditions, illustrated by lower concentrations at the station downstream (PC-2) of the outfall when compared to the station upstream (PC-5) of the outfall. In addition, the in-stream samples collected during stormflow conditions have lower metals concentrations than samples collected during baseflow conditions at the same station. While the data are not sufficient to draw conclusions regarding the impact of stormwater inputs, this could indicate that stormwater inputs provide dilution to the creek rather than acting as a source of metals.

The total and dissolved fractions of the metals were comparable for the metals at several stations, indicating that the majority of the metals in the water column are dissolved with a smaller portion as particulate. In addition, 2004 monitoring included analysis of total suspended solids (TSS) in water samples, and all samples were below the detection limit of 4 mg/L. This further suggests that metals in the surface water are likely in the dissolved phase rather than particulate.

The fact that the reference site showed concentrations of metals similar to the concentrations found in the Pullen Creek samples suggests that current metal concentrations might be attributed to natural background conditions for the area. However, data were not sufficient to use ADEC's natural condition background tool to calculate background concentrations of metals.

4.3. Summary

A review of the available sediment and surface water quality monitoring data in Pullen Creek suggest that:

- Sediment lead and zinc concentrations are elevated throughout the length of Pullen Creek, particularly in the creek headwaters.
- Sediment copper and cadmium concentrations are elevated in the Pullen Creek headwaters, but not in the lower reaches, suggesting a depositional area downstream of Tributary 2.
- Surface water concentrations of lead are elevated throughout the length of Pullen Creek, but do not exceed the acute criterion.
- Concentrations of dissolved copper and dissolved zinc exceeded the fresh water acute criteria in the stormwater outfall sample from PC-8. However, in-stream concentrations met acute criteria at all sites, indicating the elevated concentrations from this outfall are not affecting in-stream concentrations.
- Baseflow metals concentrations are slightly higher than those observed during stormflow conditions. The lower concentrations of metals during stormflow conditions could be due to the dilution that occurs during rain events, and are not necessarily an indication that the total metal load is greater during baseflow conditions.

- The similarity between baseflow and stormflow metals concentrations suggests that external sources are not significantly impacting the stream. Rather, concentrations are greatest during baseflow conditions, which could indicate impacts are due to a more constant source of metals to the stream, likely historically contaminated sediments.
- Data on total versus dissolved metals and TSS indicate that the majority of the metals in the water column are present as dissolved metals, not particulate. This supports the assumption that the metals in the creek sediments are the result of historically accumulated metals, and that there is not currently an active input of sediment-attached metals to further accumulate on the creek bottom.
- Detectable concentrations of various metals were found in the surface water samples from every Pullen Creek site, including the reference site. The concentrations of metals found in the reference site suggest that detectable levels of metals are naturally occurring in the area.

5. Potential Sources of Metals Pollution

Based on available data and information, it is believed that the current metal impairments in Pullen Creek are primarily the result of loadings from historically contaminated sediments that have accumulated in the creek. As discussed previously, ore concentrates extracted from the Faro Mine, a galena mining and concentration facility that produced low-grade zinc and lead, were shipped through the area. Concentrate ores also contained concentrations of cadmium, copper, and mercury.

During its periods of operation, the Nahku ore storage and transfer facility in nearby Skagway Harbor processed approximately 50,000 tons of ore per month. The transport of ores to the facility by rail and the storage and subsequent transfer of ore to ships are thought to be the primary pathways of heavy metals contamination in the City of Skagway and Pullen Creek. High winds are common in Skagway and airborne ore dust resulted from many of the early shipping, storage, and transfer procedures (ADEC 1992). While historically accumulated metals in sediments are the expected primary source of metals to the creek, other possible sources of metals to Pullen Creek could include:

- Upland nonpoint sources / unregulated stormwater runoff
- Contaminated sites
- Regulated stormwater
- NPDES permitted facilities

The following sections summarize the available information for these potential sources of metals to Pullen Creek. Other than historically contaminated sediments, the available data for each of the potential sources does not suggest they are affecting the creek and therefore do not justify representing them as inputs to the creek and establishing a direct link between their inputs and the Pullen Creek impairments. Rather they are discussed in the following sections to identify other sources that, although not expected to be contributing to the existing impairment, were considered and evaluated based on available information as potential sources.

5.1. Upland Nonpoint Sources

The 2004 study of the concentrations of heavy metals in various environmental media in and around the City of Skagway found high levels of metals, particularly lead and zinc, in upland and streambank soils surrounding Pullen Creek, concentrated near areas of past ore transport activities at the rail yard. Accumulated metals are likely the result of the historic mining-related operations in the area. However, information from the STC and in the Pullen Creek 303(d) listing indicate that streambanks are stable, decreasing the possibility for contaminated soils to be eroded and delivered to the creek. In addition, as discussed in Section 4, recent monitoring supports the assumption that stormwater sources do not seem to be a significant contributor of heavy metals to Pullen Creek (Tetra Tech 2009).

5.2. Contaminated Sites

The White Pass & Yukon Railroad yard located near the headwaters of Pullen Creek is a known contaminated site impacted by heavy metals contamination. ADEC's Division of Spill Prevention and Response, Contaminated Sites Program is responsible for managing clean-up operations at contaminated sites in the state. This program uses two databases to track contaminated sites: Contaminated Sites (CS) and Leaking Underground Storage Tanks (LUST). A review of the CS and LUST databases identified the railroad yard site as an open case that could potentially affect metals contamination in Pullen Creek.

Table 5-1 presents a description of the site's contamination status. Based on information included in the CS database, past monitoring and clean-up efforts at the site have focused on the contamination by organic compounds and petroleum spills. While it is unknown whether this site is acting as a source of metals-contaminated sediment to Pullen Creek, information mentioned in Section 5.1 indicates that streambanks and surrounding soils are stable, decreasing the possibility for contaminated soils to be eroded and delivered to the creek.

Table 5-1. Open contaminated sites in the proximity of Pullen Creek

Site name	Location	File ID	Summary of contamination
White Pass & Yukon Railroad Yard	NE of 23rd Avenue Bridge at Terminus of State St.	1526.38.005	Known surficial soil contamination by chlorinated organic compounds and heavy metals. Potential contamination of groundwater (city water supply). Possible sources of contamination include degreasers, solvents, waste scrap metal, waste batteries and metal ores. Dates of release and extent of contamination unknown. Lead detected up to 4,500 ppm and zinc up to 4,700 ppm. Depth to aquifer 51 feet. City well 2300 feet from site.

5.3. Regulated Stormwater

EPA's NPDES Stormwater Program regulates stormwater discharges from municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. The City of Skagway is not an MS4 community requiring coverage under the stormwater program. However, individual construction and industrial facilities in the area could be covered under the Construction General Permit (CGP) or Multi-Sector General Permit (MSGP) for stormwater. To identify facilities covered under the general permits, EPA maintains the Electronic Notice of Intent (e-NOI) database for construction sites and industrial facilities that have applied for coverage under EPA's CGP or MSGP. A review of e-NOI identified an active construction permit discharging to Pullen Creek (Table 5-2).

Stormwater from construction facilities are short-term, temporary discharges and are assumed to be an insignificant source of metals. In addition, sites covered under the *NPDES General Permit for Stormwater Discharges from Construction Activities* are required to implement control measures to "prevent litter, construction debris, and construction chemicals that could be exposed to stormwater from becoming a pollutant source in stormwater discharges."

Table 5-2. Study area facilities operating under general stormwater permits

Permit Tracking Number	Application Type	Status	Organization Name	Project Name	City	Area (acre)	Receiving Water
AKR10C586	Construction	Active	Dawson Construction Inc.	E. A. and Jenny Rasmuson Community Health Center	Skagway-Yakutat-Angoon		Pullen Creek

Currently no other facilities have been issued or applied for permit coverage under the MSGP. Any future industrial stormwater sources would be required to meet the minimum measures and requirements of the stormwater permit, including monitoring for any relevant benchmarks for metals. In addition, the final 2008 MSGP (USEPA 2009) discusses the requirements for new discharges to impaired waters in Section 1.1.4.7, stating the following:

If you are a new discharger you are not eligible for coverage under this permit to discharge to an "impaired water", as defined in Appendix A unless you:

a. prevent all exposure to stormwater of the pollutant(s) for which the waterbody is impaired, and retain documentation of procedures taken to prevent exposure onsite with your SWPPP [stormwater pollution prevention plan]; or
b. document that the pollutant(s) for which the waterbody is impaired is not present at your site, and retain documentation of this finding with your SWPPP; or
c. in advance of submitting your NOI [notice of intent], provide to the appropriate EPA Regional Office data to support a showing that the discharge is not expected to cause or contribute to an exceedance of a water quality standard, and retain such data onsite with your SWPPP. To do this, you must provide data and other technical information to the Regional Office sufficient to demonstrate:
   i. For discharges to waters without an EPA approved or established TMDL, that the discharge of the pollutant for which the water is impaired will meet in-stream water quality criteria at the point of discharge to the waterbody; or
   ii. For discharges to waters with an EPA approved or established TMDL, that there are sufficient remaining wasteload allocations in an EPA approved or established TMDL to allow your discharge and that existing dischargers to the waterbody are subject to compliance schedules designed to bring the waterbody into attainment with water quality standards.

5.4. APDES/NPDES Permitted Facilities

A search of EPA's PCS database found no permitted facilities discharging metals to Pullen Creek.

6. TMDL Allocation Analysis

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 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

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$ [1]

The analytical approach used to estimate the loading capacity, existing loads, and allocations for Pullen Creek are based on the best available information to represent the impairment and expected sources.

6.1. Loading Capacity

The loading capacity for a given pollutant is the greatest amount of pollutant that a waterbody can receive without violating applicable water quality standards, as reflected by the water quality target. If the target is a numeric water quality criterion and discharge sources are present, the loading capacity can be calculated as the highest pollutant load that will not cause the criterion to be exceeded.

Metals impairments for Pullen Creek are likely the result of historical contamination causing toxicity in sediments. Sediment contamination is thought to be the result of historic releases from the transport and transfer of mining ores. Because the contamination is thought to be predominantly the result of historical activities and sources, the calculation of loading capacity focuses on existing sediment quality and the reductions necessary to meet the sediment quality TMDL target discussed in Section 3.

The TMDLs for Pullen Creek sediments are concentration-based (mg/kg), consistent with both Alaska's narrative water quality criterion (18 AAC 70.020) and the sediment numeric targets established for this TMDL. The loading capacities for metals in Pullen Creek are equal to the numeric targets identified in Section 3.2 and Table 3-3. The following formula was applied to calculate the percent reductions required to meet the loading capacity:

$$\text{Percent Reduction} = \frac{(\text{Maximum Measured Concentration} - \text{TMDL Target})}{(\text{Maximum Measured Concentration})} \times 100$$

The TMDL approach establishes concentration-based allocations, representing the sediment quality for each metal of concern. A TMDL is established for each individual metal that has been shown to exceed the TEL—cadmium, copper, lead and zinc. The loading capacity (or TMDL) for each metal of concern is set equal to the numeric sediment quality target.

Pullen Creek was divided into eight segments based on the location of monitoring stations used in the TMDL calculations. Data at the individual stations were used to compare the most recent observed concentrations with the loading capacity and identify percent reductions needed by segment. A percent

[1] When TMDL allocations are expressed as loads, the loading capacity is divided into allocations to individual sources (and margin of safety, if explicit); therefore, the sum of the allocations is equal to the loading capacity. However, when a TMDL is expressed as a concentration or other measure, this equation might not apply. If expressed as concentrations, the allocations are typically equal to a concentration target that represents the loading capacity; therefore all allocations are equivalent to, rather than a portion of, the loading capacity.

reduction was not calculated for those segments where the observed sediment concentrations were already less than the numeric sediment target. Figure 6-1 presents a schematic of the Pullen Creek segments.

The loading capacity and allocations for metals in Pullen Creek summarized in Table 6-1 through Table 6-4, for cadmium, copper, lead, and zinc, respectively.

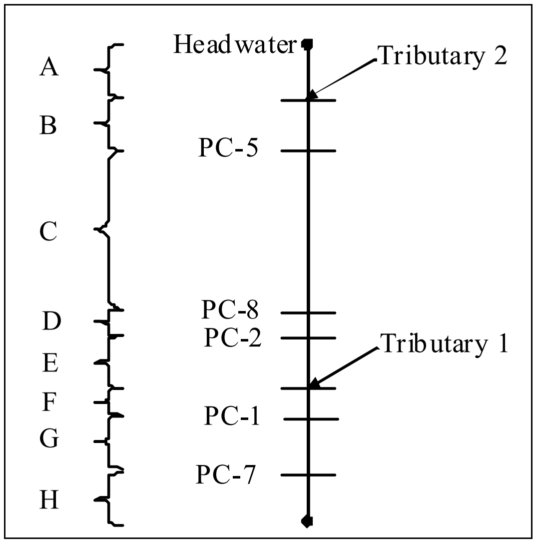


Figure 6-1. Schematic of Pullen Creek segments

Table 6-1. TMDL load allocations for cadmium in Pullen Creek

Location	Segment	Total Cadmium (mg/kg)					Percent Reduction
		Loading Capacity	WLA	LA	MOS	2007 Observed	
Rail Yard Headwater (State St.)	A	0.596	–	0.5364	0.0596	1.1	45.8%
Tributary 2 -Fork at 18th & State	B	0.596	–	0.5364	0.0596	1.6	62.8%
PC-5	C	0.596	–	0.5364	0.0596	1.3	54.2%
PC-8	D	0.596	–	0.5364	0.0596	0.18	NA
PC-2	E	0.596	–	0.5364	0.0596	0.18	NA
Tributary 1	F	0.596	–	0.5364	0.0596	0.12	NA
PC-1	G	0.596	–	0.5364	0.0596	0.17	NA
PC-7	H	0.596	–	0.5364	0.0596	0.17	NA

Table 6-2. TMDL load allocations for copper in Pullen Creek

Location	Segment	Total Copper (mg/kg)					Percent Reduction
		Loading Capacity	WLA	LA	MOS	2007 Observed	
Rail Yard Headwater (State St.)	A	35.7	–	32.13	3.57	7.6	NA
Tributary 2 -Fork at 18th & State	B	35.7	–	32.13	3.57	120	70.3%
PC-5	C	35.7	–	32.13	3.57	40	10.8%
PC-8	D	35.7	–	32.13	3.57	7.3	NA
PC-2	E	35.7	–	32.13	3.57	7.3	NA
Tributary 1	F	35.7	–	32.13	3.57	8.3	NA
PC-1	G	35.7	–	32.13	3.57	7.7	NA
PC-7	H	35.7	–	32.13	3.57	7.7	NA

Table 6-3. TMDL load allocations for lead in Pullen Creek

Location	Segment	Total Lead (mg/kg)					Percent Reduction
		Loading Capacity	WLA	LA	MOS	2007 Observed	
Rail Yard Headwater (State St.)	A	35	–	31.5	3.5	35	NA
Tributary 2 -Fork at 18th & State	B	35	–	31.5	3.5	330	89.4%
PC-5	C	35	–	31.5	3.5	180	80.6%
PC-8	D	35	–	31.5	3.5	44	20.5%
PC-2	E	35	–	31.5	3.5	44	20.5%
Tributary 1	F	35	–	31.5	3.5	187	81.3%
PC-1	G	35	–	31.5	3.5	87	59.8%
PC-7	H	35	–	31.5	3.5	35	NA

Table 6-4. TMDL load allocations for zinc in Pullen Creek

Location	Segment	Total Zinc (mg/kg)					Percent Reduction
		Loading Capacity	WLA	LA	MOS	2007 Observed	
Rail Yard Headwater (State St.)	A	123.1	–	110.79	12.31	61	NA
Tributary 2 -Fork at 18th & State	B	123.1	–	110.79	12.31	480	74.4%
PC-5	C	123.1	–	110.79	12.31	480	74.4%
PC-8	D	123.1	–	110.79	12.31	170	27.6%
PC-2	E	123.1	–	110.79	12.31	170	27.6%
Tributary 1	F	123.1	–	110.79	12.31	150	17.9%
PC-1	G	123.1	–	110.79	12.31	130	5.3%
PC-7	H	123.1	–	110.79	12.31	130	5.3%

6.2. Waste Load Allocation

There are currently no known active permitted discharges of metals to Pullen Creek. Therefore, WLAs for these TMDLs are not applicable, and the available loading capacities are allocated as gross allotments to the load allocations, minus a margin of safety, as summarized in Table 6-1 through Table 6-4 If future activity is proposed within the Pullen Creek watershed that will entail regulated discharge of metals, the TMDL may be revised to include modified WLAs. Possible revision of the WLA in this TMDL will depend on analysis of relevant factors at that time.

6.3. Load Allocation

The impairment conditions in Pullen Creek are thought to be the result of historical contamination due to previous mining operations in the study area. There are no confirmed active nonpoint sources of metals affecting the impaired areas other than accumulated metals concentrations in the in-place sediments.

The load allocations for metals in Pullen Creek are equal to the loading capacity, minus the margin of safety. The load allocations are summarized in Table 6-1 through Table 6-4, for cadmium, copper, lead, and zinc, respectively. Because data are not available to calculate the contribution of individual sources to impairment or establish a predictive link between the various inputs and the resulting sediment concentration, the load allocation can be considered a gross allocation to all sources.

As shown in the tables the majority of the reductions for all metals are required at the upstream locations near the headwater, tributary 2 and location PC-5. Reductions are required throughout the length of Pullen Creek for lead and zinc, whereas for copper and cadmium reductions are required only near the upstream locations with the downstream locations being below the sediment quality guideline concentrations.

6.4. Margin of Safety

A margin of safety must be included in a TMDL to account for any uncertainty or lack of knowledge regarding the pollutant loads and the response of the receiving water. The margin of safety can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. As shown in Table 6-1 through Table 6-4, the margin of safety for the metals TMDLs is explicit as 10 percent of the loading capacity reserved to account for uncertainties in the TMDL. The margin of safety also includes an implicit component derived from the conservative TEL target for the TMDL. TELs define chemical sediment concentrations below which toxic effects are rarely observed in sensitive species.

6.5. Seasonal Variation and Critical Conditions

TMDLs must be developed with consideration of seasonal variation and critical conditions. Seasonal variation and critical conditions associated with pollutant loadings, waterbody response, and impairment conditions can affect the development and expression of a TMDL. A TMDL should include WLAs and LAs that ensure the waterbody will maintain water quality standards under all expected conditions.

The impairment from metals in bottom sediments of Pullen Creek is not thought to be associated with a particular season or environmental condition. The impairment is a result of historical contamination from nearby mining related activities. The TMDL loading capacity is based on the target TEL for cadmium, copper, lead and zinc in sediment. TELs define chemical sediment concentrations below which toxic effects are rarely observed in sensitive species and are considered protective during all conditions.

In addition, the supplemental evaluation of resulting water quality, discussed in the Appendix, is based on analysis of water column concentrations under critical conditions. Based on the 2008 monitoring data, the potential water quality impairments in Pullen Creek are thought to be associated with low-flow conditions that concentrate available loadings from contaminated sediments. The mass balance model developed to represent loadings to the creek is based on low-flow conditions to represent the critical condition.

6.6. Future Growth

Current impairments in Pullen Creek are thought to be the result of historical contamination of sediments caused by mining operations that used Skagway Harbor as a shipping hub. After the closure of the Gelena mine in 1997, shipping activities in Skagway Harbor became dominated by the tourist and travel industries. It currently hosts freight barges, ferries, cruise ships, water taxis, and fishing boats (STC 2005). The port of Skagway is a popular stop for cruise ships, and the tourist trade is a big part of the business of Skagway. Even the White Pass and Yukon Route narrow gauge railroad, part of the area's mining past, is now in operation purely for the tourist trade.

Without further inputs of contaminated sediments, metals contamination in the study area is expected to decrease over time through natural attenuation. While future sources are not anticipated to affect impairment in Pullen Creek, it is possible that future sources, such as facilities that will apply for coverage under the NPDES MSGP, will have the potential to deliver metals to the creek. To address this, the TMDLs establish allocations for future sources equivalent to the following respective LAs to ensure that any future sources also meet established sediment quality targets:

- Total Cadmium: 0.5364 mg/kg
- Total Copper: 32.13 mg/kg
- Total Lead: 31.5 mg/kg
- Total Zinc: 110.79 mg/kg

6.7. Daily Load

The TMDLs for Pullen Creek are presented as allowable maximum concentrations of metals (cadmium, copper, lead and zinc) in streambed sediment. The allowable concentrations are applicable at all times and can therefore be applied on a daily basis. This is consistent with the requirement to express TMDLs on a daily time increment.

7. Implementation

As discussed in the previous sections, the elevated concentrations of metals in the sediments of Pullen Creek is believed to be the result of historically accumulated metals and contaminated sediments from nearby mining-related ore transport operations. There are no known active sources contributing metals to the creek sediments. Therefore, the main options for restoration include allowing the metals to naturally attenuate over time through burial by “clean” sediments or being flushed out of the system during periods of high stream flow or to physically remove the contaminated sediments. However, the benefits or necessity of dredging would require careful consideration because of the potential for damaging habitat and aquatic organisms. Dredging can damage the habitat of benthic macroinvertebrates and may directly kill some organisms including salmon fry and eggs. The process of stirring up suspended sediments during dredging can also damage the gills and/or sensory organs of benthic macroinvertebrates and fish. Suspended sediments can also affect the prey gathering ability of sight-feeding fish. In addition, the resuspension of contaminated sediments provides organisms with additional exposure to metals. Therefore, allowing the metals in Pullen Creek to naturally attenuate while minimizing the potential for future inputs through source control and restoration efforts is the recommended option.

After their 2004–2005 sampling of Pullen Creek found heavy metals present in sediment and nearby soils, the STC developed a Waterbody Recovery Plan under an Alaska Clean Water Action (ACWA) grant (STC 2005, 2006). The Skagway Traditional Council was awarded grant funds for FY06 and developed a statement of work for the proposed plan. The Recovery Plan for Pullen Creek focuses on the cumulative effects of current and future construction projects along or near the stream, recognizing the importance of maintaining stable streambanks and riparian areas for the creek to continue to inhibit erosion and delivery of soils with elevated metals that could further accumulate in the creek. Available monitoring has shown streambank soils to have metals concentrations comparable to those found in streambed sediments. As a result, large-scale disturbance of native vegetation and earth moving projects have the potential to introduce these contaminated soils into the creek exacerbating existing sediment contamination. Specific elements of the Recovery Plan include (STC 2006):

- **Water quality monitoring:** Additional monitoring of the soil, sediment, and water in Pullen Creek would be conducted to gather more data to quantify the extent of existing contamination. Studies should be designed to document seasonal affects on metals re-suspension, the impacts of precipitation events, and to determine if metals concentrations are decreasing over time. Monitoring should also be conducted prior to and after construction projects to evaluate whether these projects are impacting water quality.
- **Streambank erosion:** Soils adjacent to Pullen Creek are easily eroded in some areas, particularly due to foot traffic associated with tourism. Therefore, the STC has made stabilization of the adjacent streambank soils a priority and has proposed the following actions:
  - Revegetation of eroded streambanks, including planting indigenous species of willow and herbaceous plants.
  - Constructing viewing platforms for seasonal tourism groups observing salmon spawning within the creek.
  - Stakeholder efforts to actively pursue the adoption and implementation of city ordinances for building setbacks along Pullen Creek. There are currently no city ordinances addressing this issue.
- **Construction practices:** There are currently no city ordinances regulating construction projects adjacent to waterbodies. The STC recommends that the City of Skagway initiate city ordinances

for development setbacks and requirements for silt fences, soil removal, and contaminated soil care for all construction projects.

- **Other potential sources of pollution including snow storage, debris, and stormwater sources:** The piling of snow by Pullen Creek during the winter months has the potential to introduce associated pollutants to the creek when snows melts; therefore the STC recommends that snow be stored at locations away from the stream.
- **Public education:** Visitors and residents of Skagway should be provided with educational materials that detail how their activities in the watershed might be contributing to the contamination problem. Examples of education materials could include interpretive signs, volunteer clean-up days, and public meetings.

As part of the development of the Recovery Plan, the STC has met with various stakeholders to discuss the priorities and content of the plan. These parties include the Taiya Inlet Watershed Council (TIWC), ADEC, the City of Skagway, APT, the National Park Service, the Alaska Department of Fish and Game, the Natural Resources Conservation Service, and the U.S. Fish and Wildlife Service. In conjunction with the STC Recovery Plan, the TIWC has developed an Action Plan for Pullen Creek (TIWC 2007). The TIWC Action Plan for Pullen Creek was designed to identify areas for future restoration efforts. The plan divides the creek into six reaches. General restoration opportunities identified for the Pullen Creek reaches include:

- Streambank plantings to revegetate areas of bare soil and establish riparian areas
- Working with the White Pass & Yukon Railroad to establish and maintain native riparian vegetation
- Working with private land owners to re-meander sites where the creek has been channelized, explore the possibility of relocating the creek where urbanization has irreversibly impacted the stream hydrology and habitat, and organize clean-up to remove litter and debris
- Implementing pedestrian control measures
- Improving fish passage along the creek by removing and replacing old culverts and other structures
- Creating wetlands in suitable areas to treat stormwater from urban land uses

In addition to the restoration, education and source control activities recommended in the STC and TIWC plans, any future sources in the watershed should minimize the potential for contributing metals to Pullen Creek. If future facilities apply for coverage under the MSGP, their stormwater management program should include activities and practices to minimize erosion and delivery of potentially contaminated soils to Pullen Creek.

Mining related shipping operations in Skagway Harbor resumed in late 2007 after the Skagway Ore Terminal was reactivated by Alaska Industrial Development and Export Authority (AIDEA). According to AIDEA's web site they are continuing active discussions with mining companies for potential use of the Skagway Ore Terminal. Any future operations at the ore terminal should implement practices to minimize the release of airborne ore dust that could potentially accumulate in Pullen Creek and other nearby waterbodies and surrounding soils. BMPs and controls can minimize fugitive dust from sources such as haul truck activities and ore and concentrate storage, handling, and loading. Examples of recommended practices include:

- During transport and unloading activities, haul trucks should be covered with a hard cover reducing potential for fugitive dust generation from the payload.
- Onsite ore storage should be in an enclosed storage area with four walls and a roof to protect the ore piles from exposure to precipitation and reduce the impact of wind.
- Ore transfer by loading equipment or conveyor should be performed within enclosed buildings.
- Floor and vehicle cleaning plans should be implemented to minimize the transfer of ore dust from controlled, enclosed buildings to outside areas exposed to wind and precipitation.

8. Public Comments

This proposed TMDL was open for public comment from April 20th to May 21st. A proposed TMDL announcement was posted in the Skagway and Juneau newspapers on April 20th. A public meeting for the proposed TMDL took place in Skagway on May 5th. The public meeting was attended by three members of the community. No written comments on the Draft TMDL were received.

Appendix: Supplemental Analysis of Water Quality

Elevated levels of metals in the sediments of Pullen Creek are expected to be the result of historical activities at the rail yard (e.g., ore transport). As discussed in Sections 4 and 5, recent monitoring supports the assumption that there are no active sources of metals to the creek. It is expected that in-place sediments have experienced historical accumulation of metals and there are no significant active inputs of metals to the creek. For this reason, the TMDL approach establishes a concentration-based allocation, representing a level of sediment quality that will support designated uses. As discussed in Section 6, TMDLs were established for each individual metal that has been shown to exceed the TEL—cadmium, copper, lead, and zinc. The corresponding TMDL targets and allocations were set equivalent to the TEL for the respective metal.

In addition, surface water monitoring data show limited exceedance of applicable water quality criteria. Data available from 1990 and 2004 do not exhibit exceedances; however, 2008 data show exceedances of the chronic water quality criteria (CCC) for lead and cadmium. While these data are limited and not sufficient to make an impairment determination, they represent a potential impairment in Pullen Creek surface waters. To address the potential impairment in the water column, a supplemental analysis was conducted to evaluate the interaction of sediment and water quality in Pullen Creek. A model was developed to represent a simplified mass balance for the system to simulate input and transfer of metals in the creek. The "TMDL" condition represents the simulated water column concentrations that result from sediment concentrations equal to the sediment quality target. This supplemental analysis is included to illustrate that once sediment concentrations meet targets, water column concentrations will also likely decrease and meet applicable water quality criteria.

This section outlines the approach used to evaluate the relationship between sediment quality and overlying water quality for metals in Pullen Creek. The approach utilizes available information on the hydrology of the river system, metals data from sampling events, and information on the fate and transport of the metals in the waterbody.

A.1. Model Development

To represent the linkage between metals input and in-stream response for Pullen Creek, an analytical model was developed. The model represents a simplified mass balance for the system, i.e. simulates input and transfer of metals in the creek.

The predictive model represents Pullen Creek as a series of plug-flow reactors. This type of representation is suitable for flowing waters in which advection dominates, such as the Pullen Creek. A "plug" of a conservative pollutant, introduced at one end will remain intact as it passes through the reactor. Pollutants (metals) are discharged out of the reactor in the same sequence that they enter the reactor. Pullen Creek was segmented into a series of reactors along the length of the impaired segment (Figure A-1) to simulate the distribution of metals along the system and to account for the water balance between each segment and the impact of tributaries on the mainstem of the creek. The model represents the segmented system in one dimension (longitudinal) under a steady-state condition. The steady-state low-flow condition represented the "critical condition." Recent baseflow and stormwater monitoring in the water column showed a general decrease in concentration in the water column during stormflow conditions, likely due to dilution, supporting the use of low flow as the critical period.

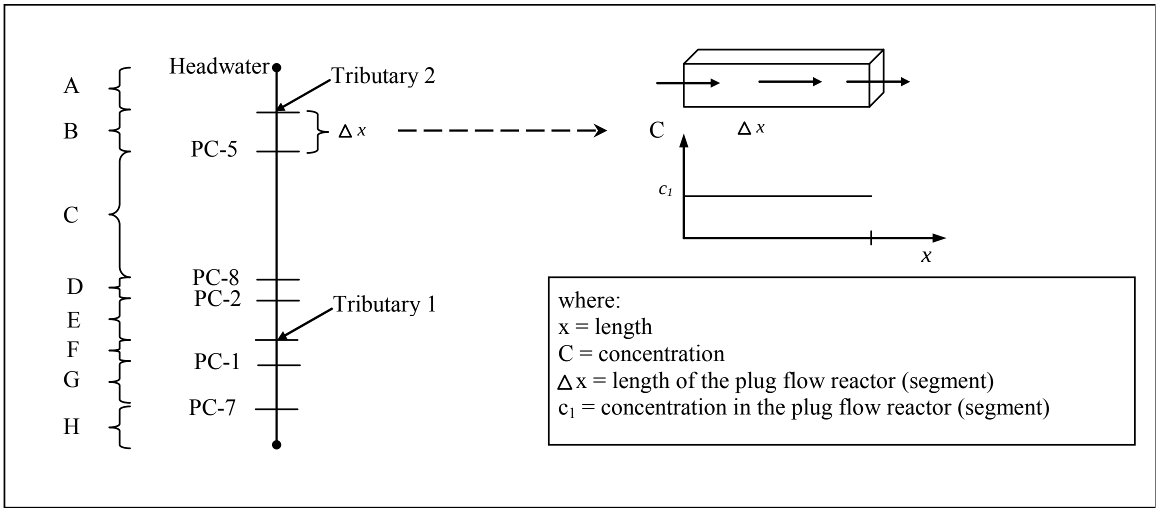
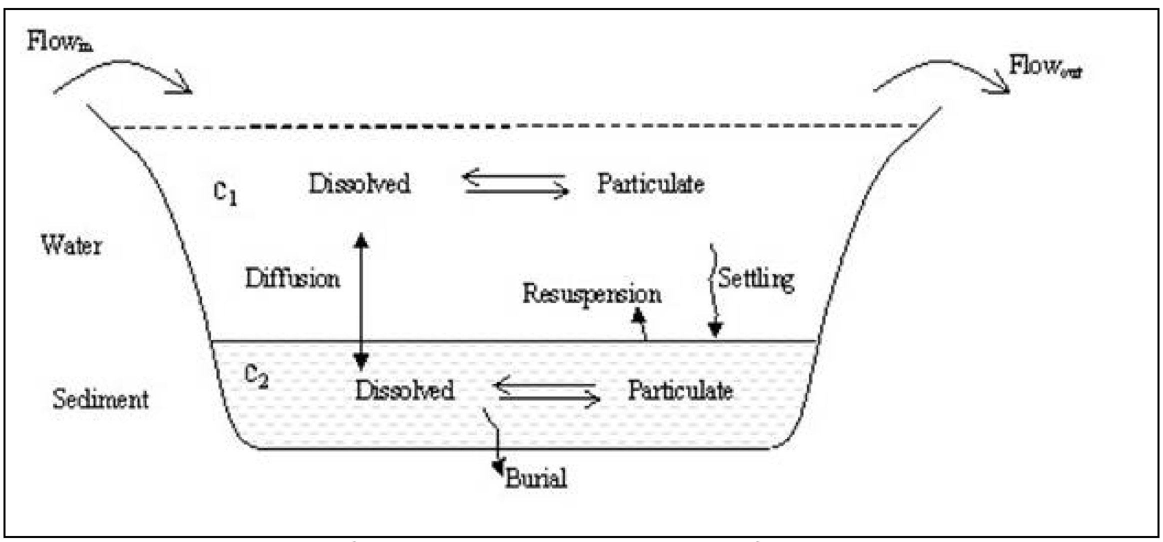


Figure A-1. Plug-flow reactor representation of Pullen Creek

Each of the plug-flow reactors defines a mass balance for metals distributed between sediment and water (Figure A-2). Metals were partitioned into dissolved and particulate fractions in both the water and sediment layers. Mechanisms such as burial and resuspension act on both components, while diffusion acts selectively on the dissolved fraction. The metals in the water column were computed as concentration profiles with respect to distance. Upstream boundary conditions at the headwater, tributaries entering the mainstem of Pullen Creek, and the sediment metals concentration were used to calculate the water column concentration of metals. At each confluence where there is a tributary input, a mass balance of the load just upstream and the load from the tributary was calculated to determine the change in concentration. This concentration was then used as the initial concentration for the next segment. Governing equations representing the plug-flow reactor model are discussed in the following section.



(Note: subscript 1 refers to the water column and subscript 2 refers to the sediment layer).

Figure A-2. Conceptual interactions between water column and sediment layers

Contaminant Budget

A mass balance of metals can be developed for the stream segments assuming that the metals partition into the dissolved and particulate forms and considering the various interactions between the sediment layer and the water column (Figure A-2).

A steady-state contaminant budget can be written for a plug-flow system with constant hydro-geometric characteristics with respect to the water column as (Thomman and Mueller 1987, EPA 1984 and Chapra 1997):

$$U\frac{dC_1}{dx} = \frac{v_s}{H_1}F_{p1}C_1 + \frac{v_d}{H_1}(F_{d2}C_2 - F_{d1}C_1) + \frac{v_r}{H_1}C_2 \qquad (1)$$

where:
U = stream velocity [L/T]
H_1 = depth of water column [L]
C_1 = metal concentration in the water column [M/L^3]
C_2 = metal concentration in the sediment layer [M/L^3]
K_{d1} = metal partitioning coefficient in water column [L^3/M]
K_{d2} = metal partitioning coefficient in sediment layer [L^3/M]

The water column partition coefficient (K_{d1}) for metals ranges from 10^2 to 10^5 L/kg (Thomman and Mueller 1987) and suggests that the sediment partition coefficient (K_{d2}) may be lower than the water column partition coefficient. The sediment-water partition coefficients used for the different metals in the study are shown in Table A-1.

Table A-1. Partition coefficients used in Pullen Creek mass balance model

Metal Property	Lead	Cadmium
Molecular Weight	207.2	112.4
Range Sediment/Water Partition Coefficient in Literature [logKd1] (L/kg)[a]	2.0–7.0	0.5–7.3
Partition Coefficient [logKd1] (L/kg)	3.7	3.6
Sediment/Water Partition Coefficient Kd1 (L/kg) used in Model	5.01E+03	3.98E+03

a. Source: Allison et al., 2005 - Partition Coefficients for Metals in Surface Water, Soil, and Waste

m_1 = suspended solids in the water column [M/L^3]
F_{p1} = fraction of the metal that is in water

$$F_{p1} = \frac{K_{d1}m_1}{1 + K_{d1}m_1} \qquad (2)$$

F_{d1} = fraction of metal dissolved in water

$$F_{d1} = \frac{1}{1 + K_{d1}m_1} \text{ or } (1-F_{p1}) \qquad (3)$$

F_{d2} = fraction of metal dissolved in sediment

$$F_{d2} = \frac{1}{\phi + K_{d2}(1-\phi)\rho} \tag{4}$$

v_d = diffusive mixing velocity [L/T]

$$v_d = 69.35\phi M^{-2/3} \quad \text{(Chapra 1997)} \tag{5}$$

ϕ = sediment porosity (taken as 0.8)

ρ = sediment density [M/L^3]

M = mean metal molecular weight velocity [L/T] (see Table 1-1)

v_s = settling velocity [L/T] (a value of 0.25 m/day was used (literature range is from 0.05-2.5 m/day, Chapra 1997)

v_r = re-suspension velocity

$$v_r = v_s \frac{m_1}{(1-\phi)\rho} - v_b \tag{6}$$

v_b refers to the burial velocity [L/T] (assumed to be negligible or zero for free flowing streams)

The mass balance given in equation 1 can be further rearranged to give:

$$U\frac{dC_1}{dx} = -C_1\left(\frac{v_s}{H_1}F_{p1} + \frac{v_d}{H_1}F_{d1}\right) + C_2\left(\frac{v_d}{H_1}F_{d2} + \frac{v_r}{H_1}\right) \tag{7}$$

Or

$$U\frac{dC_1}{dx} = -C_1 L_1 + C_2 L_2 \tag{7a}$$

where:

$$L_1 = \left(\frac{v_s}{H_1}F_{p1} + \frac{v_d}{H_1}F_{d1}\right) \tag{8}$$

and

$$L_2 = \left(\frac{v_d}{H_1}F_{d2} + \frac{v_r}{H_1}\right) \tag{9}$$

Then for spatially constant sediment layer, equations 7 or 7a have the following solution:

$$C_1 = C_1(0)\cdot\exp\left(-\frac{L_1}{U}x\right) + C_2\frac{L_2}{L_1}\left(1-\exp\left(-\frac{L_1}{U}x\right)\right) \tag{10}$$

The above analytical solution (equation 10) was used to estimate the water column concentration. It can be seen that for the riverine portion the water column concentration C_1 is a function of the travel time downstream (i.e., (x/U), for a distance equal to x and velocity equal to U) , the settling velocity (v_s), the net diffusion and the amount of re-suspension (v_r). Also note that the stream segment takes into account observed sediment data (C_2) as a source to compute the water column concentrations.

Analytical Assumptions

Considerations and assumptions used in the modeling effort to support analysis of water and sediment quality include:

- The waterbody is assumed to be completely advective, and there is no mixing or dispersion.
- The critical conditions were represented by a steady-state low-flow condition within Pullen Creek.
- Direct discharges of metals were assumed constant during the critical condition.
- Hydrogeometric (i.e., depth, width, velocity) characteristics were assumed constant within each segment.
- Sediments do not move horizontally (no advection).
- Atmospheric deposition of metals was not explicitly modeled.
- The burial rate was also assumed to be negligible due to the free flowing nature of the creek.
- The diffusion rate was calculated using the molecular weight of the particular metal.
- The fraction of particulate concentration changes with distance, incorporating observed median TSS results. There are no suspended solids data available. Suspended solids monitoring in 2005 resulted in samples with no detection of suspended solids above the method detection limit of 4 mg/L (STC 2005). In the model a TSS value of 4 mg/L was assumed.
- The plug-flow model applies analytical solutions to estimate the metals concentration profile in Pullen Creek. Observed sediment metals data were used as input to the model and the plug-flow model used in the TMDL development does not provide a complete representation of sediment transport and dynamics in the stream. Insufficient data are available to fully characterize and simulate sediment dynamics with most of the data being historic.

Source Representation

Pullen Creek is approximately 1.5 miles long and is mainly spring fed. It has tributaries feeding it at two separate locations. Flow data in Pullen Creek were limited, and no coincident flow and water quality data were available. Flow data were only available from the base-flow monitoring conducted in 2004 (STC 2005) when flow was measured on three separate days (11/20/2003, 2/23/2003 and 5/17/2004). Mean flow values for Tributary 1, Tributary 2 and Headwaters were estimated and used in the model (2.15 cfs, 1.54 cfs, and 0.032 cfs, respectively). In addition mean velocities and depth were also estimated from this data and input into the model (0.16 ft/sec and 0.2 feet).

All potential sources of metal contamination to Pullen Creek such as tributaries and metals in the sediment were represented as explicit input in the model. The model was segmented at several locations other than the tributaries based on the sediment monitoring conducted at stations PC-5, PC-8, PC-2 and PC-1 and PC-7 along the system. This allowed for representation of the spatial resolution along the system. Table A-2 shows the sediment metals data assigned to each segment in the model. The sediment metals data were assigned using the most recent monitoring conducted in 2007 (Tetra Tech 2008).

Water column data for the headwater and two tributaries was assigned based on the 2008 observed water column data (Tetra Tech 2009), with the assumed concentration set at 1.0 µg/L for lead and 0.47 µg/L for cadmium.

Table A-2. Existing sediment metals concentration assignment along Pullen Creek

Location	Segment	Lead (mg/kg)[a]	Cadmium (mg/kg)[b]
Rail Yard Headwater (State St.)	A	35	1.1
Tributary 2 -Fork at 18th & State	B	330	1.6
PC-5	C	180	1.3
PC-8	D	44	0.18
PC-2	E	44	0.18
Tributary 1	F	187	0.12
PC-1	G	87	0.17
PC-7	H	35	0.17

a. TEL = 35 mg/kg; PEL = 91.3
b. TEL = 0.596 mg/kg; PEL = 3.53 mg/kg

Baseline Conditions

Pullen Creek was segmented into a series of plug-flow reactors to simulate the steady-state distribution of metals. Each segment was assigned an existing sediment metals concentration based on observed data. This allows spatial representation of the sediment concentration and also evaluates the impact of the tributaries along the mainstem of the Pullen Creek. Each of the plug-flow reactors defines a mass balance for metals for the sediment-water system. A separate model was developed for each metal—lead and cadmium.

There are no known active sources of metals in the vicinity of Pullen Creek. However a background concentration of metals based on observed data was assigned at the headwaters of the Pullen Creek. This upstream boundary condition at the headwaters was set based on the observed water column concentration estimated from the 2008 sampling. This metals concentration incorporates historical spills, atmospheric deposition, and unknown contributing sources of metals from area vicinity. Using this upstream boundary condition of $C_1 = C_1(0)$ the water column concentration of metals was calculated using equation 10. At each confluence with a tributary a mass balance of the load just upstream and the load from the tributary was calculated to determine the change in concentration (equation 11). The concentration calculated using equation 11 was then used as the initial concentration in equation 10 for the next segment.

$$C_1(0) = \frac{Q_r C_{1r} + Q_w C_{1w}}{Q_r + Q_w} \qquad (11)$$

where Q_r and C_{1r} refer to the flow and concentration of the receiving river and Q_w and C_{1w} refers to the flow and concentration from the tributary. Note that the tributary concentration was also assumed to be background (similar to the headwater concentration) and was assigned based on the 2008 monitoring. Figure A-3 and Figure A-4 show the predicted existing metals concentration compared to the observed water column data. As shown in the figures, data include exceedances of the chronic water quality criteria for lead and cadmium at all stations. Table A-3 shows the fresh water column acute and chronic criteria for the different metals of concern.

Table A-3. Summary of fresh water water column criteria

Metal	CAS number	Freshwater Acute criterion (CMC; µg/L)	Freshwater Chronic criterion (CCC; µg/L)
Cadmium	7440439	20	0.25
Lead	7439921	65	2.5

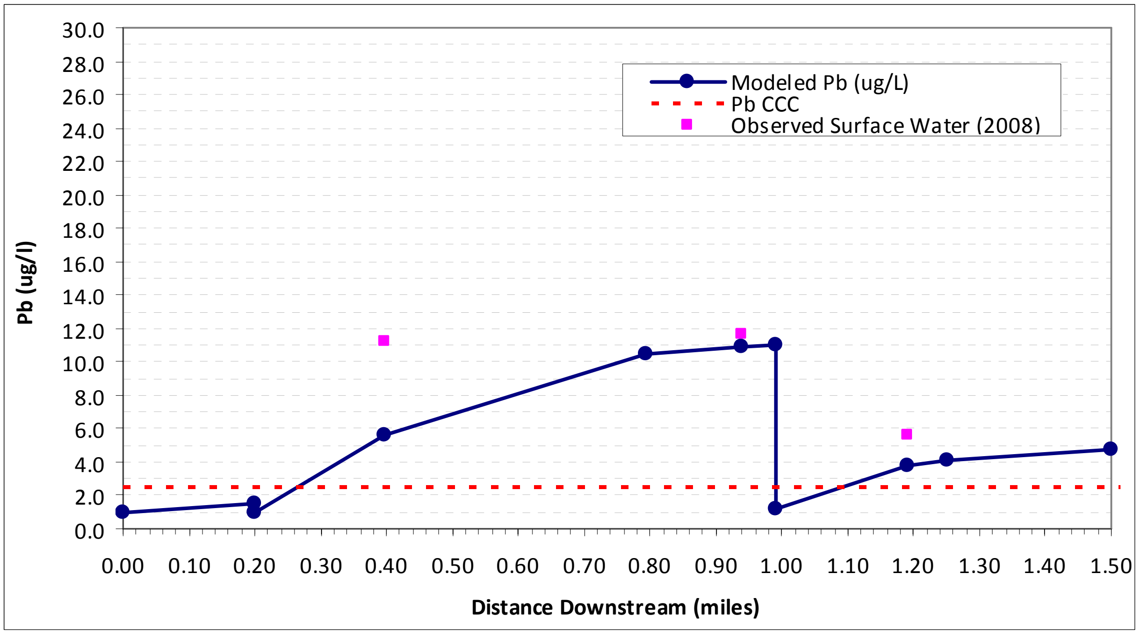


Figure A-3. Existing modeled lead concentration profile along Pullen Creek (note the fresh water acute criteria (CMC) for lead is 65 µg/L)

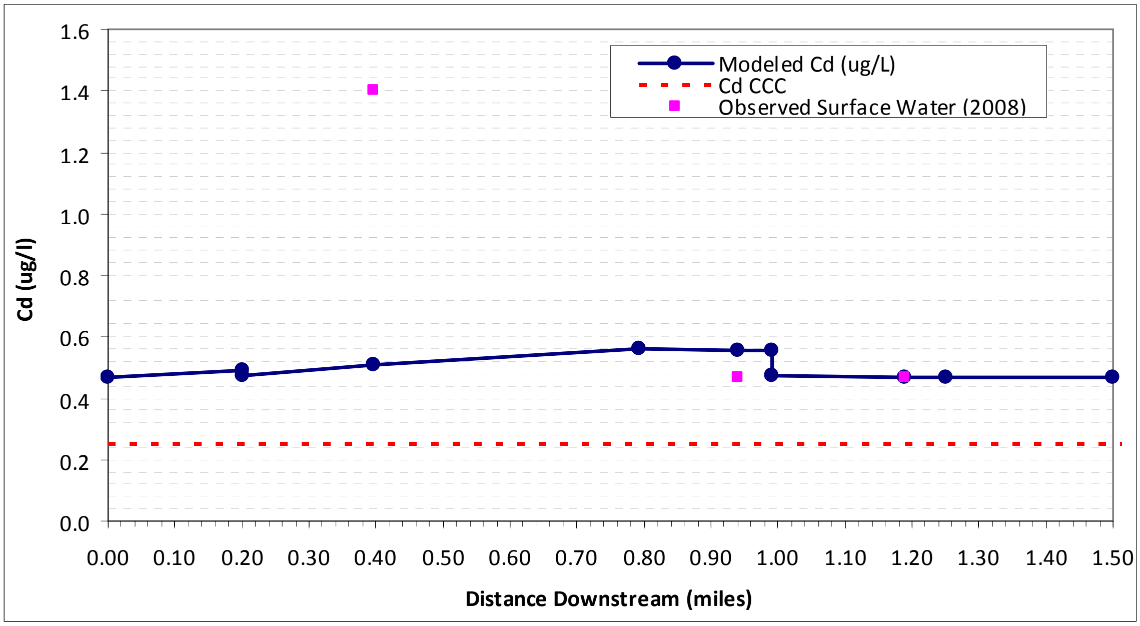


Figure A-4. Existing modeled cadmium concentration profile along Pullen Creek (note the fresh water acute criteria (CMC) for cadmium is 20 µg/L)

A.2. Results

After the sediment source inputs were set to the target sediment concentration, the resulting in-stream water column metals concentration were checked to ensure that the metal water column criteria (both chronic and acute, see Table 3-3) are also achieved.

The headwater and two tributary metals concentrations were assumed to be at background/baseline condition levels. Currently there are no known active sources that are contaminating the headwater or two tributaries. Based on the 2008 monitoring conducted the observed water column concentrations were similar to those observed at the reference monitoring locations indicating that the metals concentrations might be coming in at background. However, setting the sediment cadmium concentration to the TEL target of 0.596 mg/kg did not result in a water column cadmium concentration less than 0.25 mg/L (CCC). To meet the chronic criterion in all segments, the cadmium inputs at the headwaters and the two tributaries were reduced until the water column concentration for cadmium was met. The cadmium concentrations were reduced from 0.47 µg/L to 0.2 µg/L for the headwater and the two tributary inputs to meet the chronic criterion of 0.25 mg/L. This indicates that should cadmium concentrations result in impairment in Pullen Creek, reductions to external inputs might be needed in addition to attainment of sediment quality targets. However, the cadmium concentrations exceeded the chronic criterion, but not the acute criterion. Because the in-stream concentration is based on a single sample, it is unknown if it represents an occasional elevated concentration or a persistent concentration that would result in violation of the chronic criterion.

Figure A-5 and Figure A-6 present the model results for lead and cadmium.

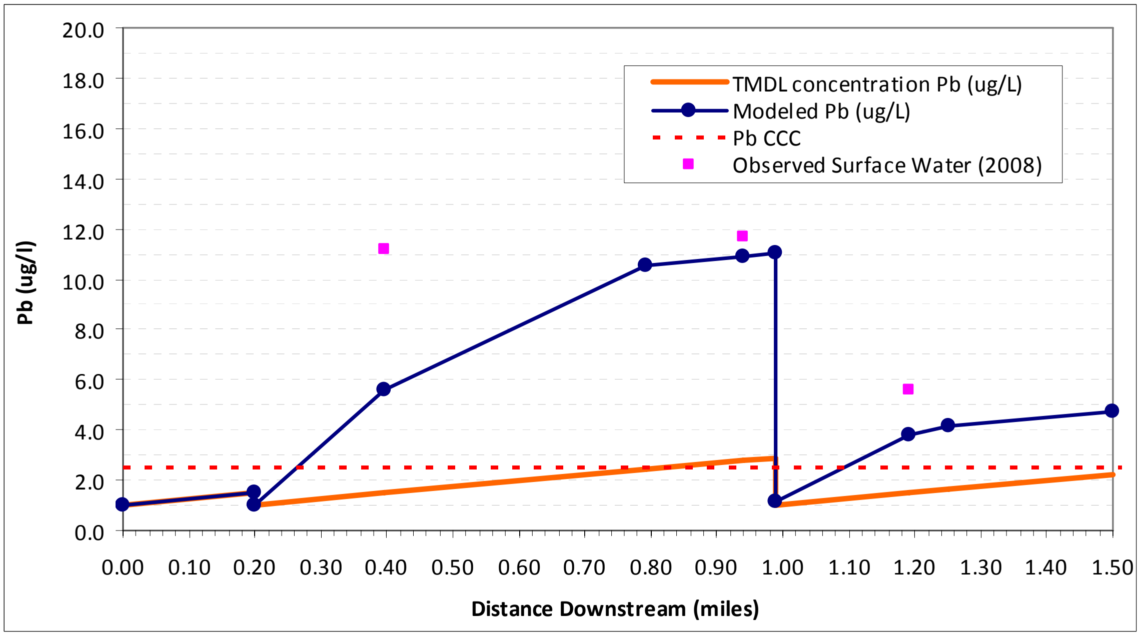


Figure A-5. Modeled TMDL lead concentration profile along Pullen Creek (note the fresh water acute criteria (CMC) for lead is 65 µg/L)

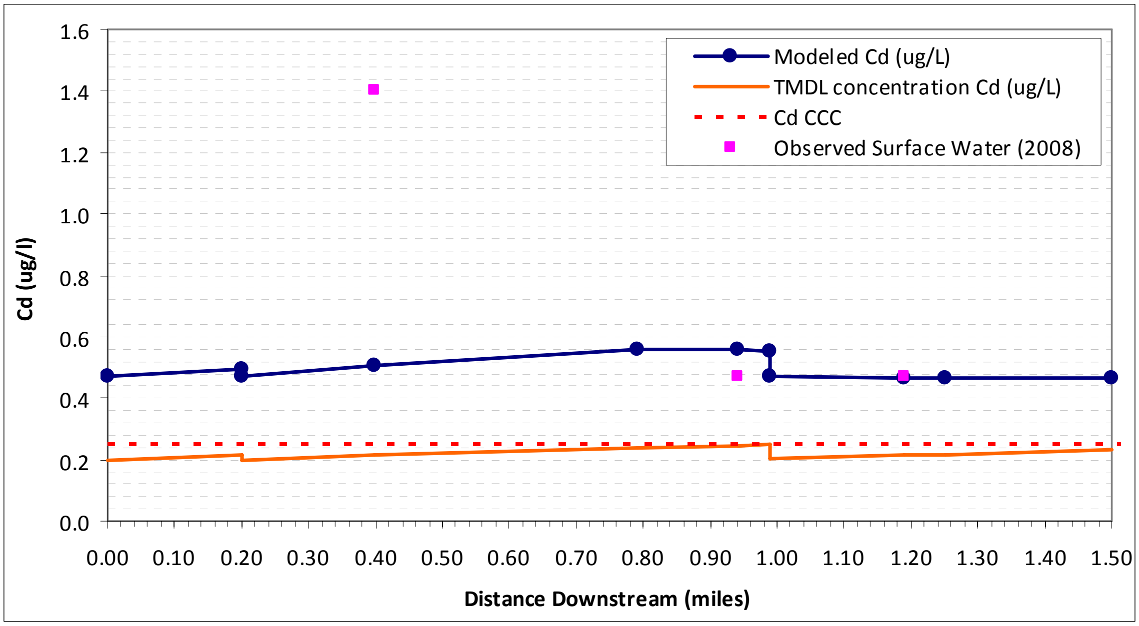


Figure A-6. Modeled TMDL cadmium concentration profile along Pullen Creek (note the fresh water acute criteria (CMC) for cadmium is 20 µg/L)

References

ADEC (Alaska Department of Environmental Conservation). 1992. Site Inspection Report for Nahku Ore Facility Skagway, Alaska. Alaska Department of Environmental Conservation. Juneau, Alaska. June 1992.

Allison, J. D. and T.L. Allison. 2005. *Partition Coefficients For Metals In Surface Water, Soil, And Waste*. For U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/R-05/074 - June 2005.

Buchman, M.F. 2008. *NOAA Screening Quick Reference Tables*. NOAA OR&R Report 08-1. National Oceanic and Atmospheric Administration, Office of Response and Restoration Division, Seattle, WA.

Chapra, S. C., 1997, *Surface Water-Quality Modeling.* McGraw-Hill Series in Water Resources and Environmental Engineering, McGraw-Hill, New York, 844 p.

STC (Skagway Traditional Council). 2005. *Pullen Creek Assessment*. Prepared for the Alaska Department of Environmental Conservations Alaska Clean Water Action Program.

STC (Skagway Traditional Council). 2006. *Pullen Creek Waterbody Recovery Plan Best Management Practices*. Prepared for the Alaska Department of Environmental Conservations Alaska Clean Water Action Program. August 2006.

TIWC (Taiya Inlet Watershed Council). 2007. *Taiya Inlet Stream Condition Assessment*. Taiya Inlet Watershed Council, Skagway, Alaska. August 2007.

Tetra Tech. 1990. Skagway Harbor Field Investigation. Prepared for U.S. Environmental Protection Agency Region 10. February 1990.

Tetra Tech. 2008. *Evaluation of Skagway Harbor and Pullen Creek Sediments and Surface Waters*. Prepared for Alaska Department of Environmental Conservation, Juneau, AK, and U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Tetra Tech. 2009. *Evaluation of Metals and Petroleum Derivatives in Skagway Harbor and Pullen Creek Sediments and Surface Waters*. Prepared for Alaska Alaska Department of Environmental Conservation, Juneau, AK, and U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Thomann, R. V. and J.A. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control.* Harper & Row, New York.

USEPA (U.S. Environmental Protection Agency). 1984. *Technical Guidance Manual for Performing Waste Load Allocations: Book II Streams and Rivers - Chapter 3 – Toxic Substances Impact*. U.S. Environmental Protection Agency, Office of Water, Regulations and Standards, Monitoring and Data Support Division, Washington, DC. June 1984.

USEPA (U.S. Environmental Protection Agency). 2009. Multi-Sector General Permit for Stormwater Discharges Associated with Industrial Activity. U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC. http://www.epa.gov/npdes/pubs/msgp2008_finalpermit.pdf