Kimmirut Fish Habitat Assessment Project

Final Summary Report

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Executive Summary

A fall fish and fish habitat assessment was conducted at the Kimmirut wetland area between Lake Tuullitsut and Lake Fundo between August 30 and September 4, 2013. The assessment included making hydrologic measurements and surface water quality sampling. The assessment was being conducted due to a request to the Government of Nunavut – Community and Government Services Department from the Nunavut Water Board as part of a Water Licence review process from an application to operate a newly constructed Waste Water Treatment (WWT) system which would drain effluent into the wetland adjacent to Kimmirut.

Eight (8) discharge measurements were obtained in the wetland upstream and downstream of the WWT system. No seasonal discharge data was obtained, nor is it available, though it is assumed that spring snowmelt would result in higher early season flows and hydrologic response to rainfall events would be evident. There is potential for the sewage release to alter the physical conditions of the watercourse at the base of the slope where sewage would enter the channel. In its current condition, sewage released from the lower lagoon would likely saturate the surrounding organic material at the base of the slope prior to entering the channel. Over time, this seasonal contribution would likely become channelized and the transit time from the lower lagoon into the wetland would increase. However, based on the measurements obtained and the observations made within the effect of the WWT System on the hydrology (water level and discharge) of the wetland is likely to be minimal.

Baseline water chemistry in the watercourse in fall 2013 was characterized based on three samples in the watercourse and one sample in Lake Tuullitsut inlet. Water was clear and had high dissolved oxygen concentrations. Nutrients were not detected at measurable concentrations and organic carbon concentrations were low, indicating that the system has very low productivity. Some metals were present in the water in low concentrations, presumably from natural sources. Hydrocarbons were not detected.

The flux of nutrients, organic carbon and other constituents from the lagoon to the watercourse would likely have a measurable effect on water chemistry of the watercourse and Lake Tuullitsut. Input of nutrients and organic carbon into an aquatic ecosystem can result in increased biological productivity and associated changes in fish habitat quality.

Fish and fish habitat assessments of the wetland and inlets and outlets of the adjoining lakes indicate the wetland and lakes provide important habitat for Arctic char. Two forage species of fish were also captured during the assessment, the threespine stickleback and the ninespine stickleback. These forage fish were captured in lower numbers that for Arctic char. A number of year classes were captured within the wetland ranging from juveniles to adults. The release of effluent into the wetland area may degrade the quality of fish habitat for Arctic, especially after multiples years of discharge.

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Abbreviations

BOD	biological oxygen demand
BTEX	benzene, toluene, ethylene and xylene
CCME	Canadian Council of Ministers of the Environment
DELT	deformities, erosion of fins, lesions and tumors
DO	dissolved oxygen
GN-CGS	Government of Nunavut's Community and Government Services
GPS	global positioning system
Nunami	Nunami Stantec Limited
NWB	Nunavut Water Board
RPD	Relative Percent Difference
TDS	total dissolved solid
TOC	total organic carbon
TSS	total suspended solid
UTM	Universal Transverse Mercator
WWT	Waste Water Treatment

1 INTRODUCTION

1.1 Background

Construction of the Waste Water Treatment WWT system was approved by the Nunavut Water Board (NWB) in 2009 and construction was completed in 2011. The Government of Nunavut's Community and Government Services (GN-CGS), on behalf of the Hamlet of Kimmirut, Nunavut is in the renewal application process for a water licence from the NWB to operate their newly constructed WWT system. Currently, the Hamlet does not have an active water licence for their waste water treatment.

The new WWT system is designed to treat Hamlet wastewater through two exfiltrating lagoons, which discharge into a natural tundra wetland area. The wetland area would be the main method of treatment, with the lagoons acting as a primary treatment process. Reviewers of the NWB Water Licence application expressed concerns regarding potential fish populations that may utilize the wetland area. Due to these concerns, the NWB requested the GN-CGS to conduct a fish and fish habitat survey to assess potential harmful effects to fish populations or their habitat in the wetland area and receiving lakes. Nunami Stantec Limited (Nunami) was contracted by GN-CGS to conduct this assessment.

Originally two separate field seasons were proposed, a fall survey and a spring survey. As the fall survey obtained the necessary information to answer the questions asked by the GN-CGS, the spring survey was cancelled.

1.2 Purpose

A fish and fish habitat assessment was conducted in the wetland and surrounding area of the Hamlet of Kimmirut, Baffin Island to assess the risk to fish and fish habitat from the discharge of wastewater effluent from the communities two sewage lagoons into a natural tundra wetland area. The assessment also collected baseline water quality and hydrology information within the wetland system for the potential development of future monitoring activities.

Key questions addressed by the assessment were:

- What is the hydrology of the WWT System and how will the increase in flow affect the flow patterns within the wetland?
- What is the baseline water quality of the wetland?
- Are there fish within the wetland system?
- If there are fish present in the wetland, then what species of fish are they? Are they an endangered species or a species at risk? Are they consumable or non-consumable fish species?
- Will the operation of the wastewater treatment system cause disruption, destruction or harmful alteration to the fish habitat? Are the types of fish in the wetland susceptible to pollutants?

- Do fish travel through the wetland year round or only seasonally? Can the flow of wastewater effluent be diverted away from their migration routes or habitat locations?
- How will the increase in flow affect fish and fish habitat? Will the addition of effluent flow increase the likelihood for fish habitat? Will it negatively affect fish habitat? How will it change the flow patterns within the wetland?

2 METHODOLOGY

The following sections describe the methodologies used for hydrology, surface water chemistry, and the fish and fish habitat assessment.

2.1 Hydrology

A hydrology team member worked with the fish and fish habitat crew to collect field information relevant to the hydrology work scope, including flow data and incidental observations. Existing information from previous studies related to the WWT System and relevant regional studies were reviewed and used to the extent possible.

Discharge was calculated at ten locations using the velocity-area method. The velocity-area method of calculating discharge in open channels consists of measurements of water velocity, water depth, and the distance across the channel between measurement locations. The discharge is calculated as the sum of the product of mean velocity, depth and width between measurement locations or verticals. Water velocity was measured with the OTT MF Pro Electromagnetic velocimeter; the unit was calibrated before use.

2.2 Surface Water Chemistry

Field data collection of surface water samples, quality controlled processes followed, and how these results were related to applicable guidelines is discussed the following sections.

2.2.1 Field Data Collection

Water chemistry data collection methods followed applicable Canadian Council of Ministers of the Environment (CCME) sampling protocols (CCME 2011). Water samples were collected at the four wetland sites:

- midpoint between wetland inlet and Lake Fundo outlet,
- wetland inlet,
- wetland midpoint, and
- wetland outlet.

In-situ water chemistry measurements of turbidity, dissolved oxygen (DO), temperature, specific conductivity and pH were obtained using a hand-held YSI Multimeter and Orbeco Turbidity meter. Both meters were calibrated in the field prior to use.

Water chemistry grab samples were collected in laboratory-provided containers. To extend sample hold times samples for dissolved fractions were collected using a clean 1.0 L collection device and gravitationally filtered through a 0.45 µm filter in the field. The samples were submitted to ALS Canada

Ltd. for chemical analysis. ALS Canada Ltd. is accredited through Canadian Association for Laboratory Accreditation. The following parameters were analyzed:

- **conventional parameters:** total suspended solids, pH, conductivity, total hardness, total alkalinity, major ions (magnesium, calcium, sodium, potassium, sulphate and chloride), and total organic carbon (TOC)
- **nutrients:** nitrate-nitrite, ammonia nitrogen, total Kjeldahl nitrogen, total phosphorus, and dissolved phosphorus
- **metals:** CCME total metal scan, which includes aluminum, silver, arsenic, boron, barium, beryllium, cadmium, cobalt, copper, chromium, iron, mercury, lithium, manganese, molybdenum, nickel, lead, antimony, selenium, tin, titanium, thallium, uranium, vanadium and zinc
- **hydrocarbons:** BTEX (benzene, toluene, ethylene and xylene) and F1-F3 fractions, and total phenols
- biochemical oxygen demand (BOD 5-day test)
- fecal coliforms

2.2.2 Quality Control

Quality control samples were collected to verify the integrity of the grab samples (CCME 2011). One of each of the following types of quality control samples was collected:

- **field duplicate** (also referred to as a replicate sample): two or more samples collected in quick succession from the same location in the water body. Duplicates are used to calculate precision.
- **trip blank:** a sample is prepared in the laboratory and travels with the sample bottles from the laboratory to the sampler, to the sample site, and then back to the laboratory without ever being opened. Trip blanks indicate contamination within the bottle.
- **field blank:** a sample is prepared in the field with filling a sampling bottle with de-ionized water provided by the laboratory, mimicking the sample collection process. Field blanks indicate contamination within the bottle or from the sampling process.

Field duplicate precision was deemed to be acceptable when there was <25% relative difference, when the mean of the replicates is ≥ 10 method detection limit (CCME 2011).

The Relative Percent Difference (RPD) was defined as:

$$\text{RPD} = \frac{S2-S1}{\left[\frac{S1+S2}{2}\right]} * 100\%$$

where S1 and S2 are the sample results

2.2.3 Application of Guidelines

The water chemistry results were compared to applicable water quality guidelines. Water quality guidelines are considered to be conservative values such that compliance with them will afford a high degree of ecosystem protection. Guidelines typically represent an upper threshold for potentially toxic constituents such as metals, but may represent an acceptable range or a lower threshold for constituents that are necessary to support aquatic life, such as dissolved oxygen.

The federal CCME Water Quality Guidelines for the Protection of Aquatic Life (CCME 2014) were used for this study. No applicable territorial or municipal water quality guidelines were identified for the study area. Water quality guidelines referred to in Section 3.2 are listed in Appendix A, Table A-1.

2.3 Fish Sampling

Fish and fish habitat data was collected at six sites:

- Lake Fundo outlet
- midpoint between wetland inlet and Lake Fundo outlet
- wetland inlet,
- wetland midpoint,
- wetland outlet, and
- Lake Tuullitsut inlet.

At each site, fish habitat was assessed along a 100 m reach. Five transects were established to collect habitat data; located at 0 m, 25 m, 50 m, 75 m, and 100 m along the reach. The following data was collected along each transect:

- general channel morphology;
- channel width;
- wetted width;
- water depth, velocity, and discharge measurements at 0.25, 0.5 and 0.75 of wetted width;
- substrate composition;
- bank description (i.e., height, slope, and stability);
- functional cover type and abundance; and
- riparian vegetation composition;
- global positioning system (GPS) recordings and photographs

Habitat quality was rated using habitat quality classes based on four habitat types; migration, overwintering, rearing, and spawning (Table 1-1). Based on the criteria outlined in Table 1-1, field personnel rated watercourses for each of the four categories as nil, poor, moderate, or good for each of three fish species categories (Table 1-2). The three species categories assessed were forage fish (small bodied species such as sticklebacks and minnows), coarse fish (such as suckers), and harvested fish (large bodied species characterized by their importance in recreational and subsistent fisheries). This qualitative assessment of a watercourse's effectiveness as fish habitat was used in conjunction with quantitative data collected on site to achieve a comprehensive assessment of fish habitat.

Fish sampling was conducted at each site along the full 100 m reach. Fish were collected using an electrofisher, seine nets, minnow traps, and hoop nets (i.e., fyke nets). Hoop nets a non-destructive method of capturing fish were left overnight to increase sampling effort and the potential for capturing fish. Fish were released live, whenever possible. Fish sampling methods included the collection the following:

- Species ID
- Length
- Weight
- Visual inspection for parasites
- Deformities, erosion of fins, lesions and tumors (DELT)

If a fish had to be sacrificed additional information was obtained including;

- Sex
- Maturity
- Age
- Gonad somatic index

In addition to the site-specific transect-based assessment, continuous habitat mapping was conducted along the entire length of the wetland system to include potential important habitat features which may exist between sampling sites.

3 RESULTS

The following sections summarize the results of the data collected during the fall survey, completed during August 31 to September 3, 2013, for hydrology, surface water chemistry, and fish and fish habitat.

3.1 Hydrology

Hydrometric measurements were obtained for ten (10) locations as part of this assessment (Table 3-1).

Table 3-1 Hydrometric Station Locations and Discharges

Location/Name		Coordinates	Discharge		Measurement Date
			m^3/s	m^3/day	
Q1	Lake Tuullitsut Inlet	19 V 453595 6967277	0.132	11407	August 30, 2013
Q2	NA	19 V 453710 6967457	0.100	8644	August 30, 2013
Q3	Wetland Midpoint	19 V 453754 6967811	0.105	9111	August 30, 2013
Q4	Below Wetland Inlet	19 V 453874 6968074	0.108	9335	August 30, 2013
Q5	East Lake Discharge	19 V 453967 6968375	0.073	6340	August 30, 2013
Q6	Above Wetland Inlet	19 V 453977 6968411	0.033	2854	August 30, 2013
Fundo Lake Outlet to Wetland		19 V 454212 6968574	0.010	885	September 3, 2013
Fundo Lake Outlet to unnamed lake		19 V 454246 6968552	0.016	1400	September 3, 2013
Seep 1		19 V 453755 6968363	3.2E-06	0.275	September 4, 2013
Seep 3		19 V 453739 6968440	7.1E-04	61.37	September 4, 2013

3.1.1 WWT System to Wetland

At the base of the lower lagoon, a seep (Seep 3) was observed and measured (7.1E-04 m^3/s). The seep continued as overland flow for nearly 70 m south. A second measurement was obtained below Seep 3 at location Seep 1. Seep 1 discharge here orders of magnitude lower (3.2 E-06 m^3/s). Perceived sub-surface flow headed approximately 90 m to the east until it discharged at the base of the slope entering the wetland at approximately UTM 453897 6968407 above W4.

3.1.2 Fundo Lake – Above Wetland

Fundo Lake has two outlets; the first discharges southwest by way of a wide, shallow channel while the second outlet discharges to the south into an unnamed lake. Measured on September 3, 2013 discharge to the south channel and the unnamed lake was 0.010 m^3/s and 0.016 m^3/s respectively.

South of Fundo Lake, two channels combine to form the primary channel of the wetland. One channel, measured at location W6, originates from Fundo Lake. The second channel, measured at location Q5, originates from the unnamed lake. Discharge measured on August 30, 2013 at location Q5 and Q6 was

0.073 m^3/s and 0.033 m^3/s, respectively. The combined discharge represents measured surface water contributions upstream of where the WWT system discharge would enter the wetland.

3.1.3 Wetland below WWT System

Discharge, measured on August 30, 2013 at location Q4 was 0.108 m^3/s. This location represents current discharge in the wetland below any WWT System releases.

Trow Associates Inc. describes the theoretical operation of the WWT System (Trow 2008). In this, they predict the following release rates for the Upper and Lower Lagoon. Discharge from the Lower Lagoon (Table 3-2) would enter the wetland upstream of location W4.

Table 3-2 Prediction of Release Rates for the Upper and Lower Lagoons.

From	To	# of Days	Sewage Released	Release Rate
May 16	Jun 15	31	-	-
June 16	Jul 15	30	29,273 m^3	975 m^3/day
July 16	Aug 31	47	37,407 m^3	795 m^3/day
Sep 1	Sep 30	30	14,621 m^3	487 m^3/day
SOURCE Trow Associates Inc. (2008)				

Discharge, measured on August 30, 2013 at location Q4 was 0.108 m^3/s or 9935 m^3/day. The maximum estimate release rate from the Lower Lagoon (975 m3/day) equates to approximately 10% of the daily flow at this location. At Q4, mean water depth was 0.26 m. For perspective, increasing mean water depth at W4 by 0.03 m without increasing velocity would result in approximately a 10% increase in discharge, or the equivalent of one day of sewage release. Had discharge measurements been obtained in June and July, it is likely discharge in the wetland would have been greater. As such, the overall effect of the sewage release on the empirical properties of the wetland (level and discharge) would be even less evident. The estimated August and September sewage release rates are approximately 8% and 5% of the daily discharge measured at W4, respectively.

3.1.4 Wetland Mid-point

Discharge, measured on August 30, 2013 at location Q3 was 0.105 m^3/s.

3.1.5 Wetland Outlet

Two locations were selected and measured to quantify the contribution from the wetland into Lake Tuullitist. Discharge at Q1, measured on August 30, 2013 was 0.132 m^3/s and located immediately upstream of Lake Tuullitsit. Q2 was located further upstream but downstream of an unnamed lake within the wetland. Discharge at Q2, measured on August 30, 2013 was 0.100 m^3/s.

3.2 Surface Water Chemistry

3.2.1 Baseline Water Chemistry

Water chemistry samples were collected at four locations in fall 2013, see Table 3-3 and Appendix B. Baseline water chemistry data of the watercourse at three locations and Lake Tuullitsut inlet are provided in Appendix A, Tables A-2 and A-3.

Table 3-3 Water Chemistry Sampling Locations

Site Description	Site ID	Zone	Easting	Northing	Date	Time
Lake Tuullitsut Inlet	W1	19V	453506	6967222	01-Sep-2013	12:45
Watercourse Outlet	W2	19V	453588	6967277	01-Sep-2013	12:45
Watercourse Midpoint	W3	19V	453729	6967819	01-Sep-2013	13:30
Watercourse Inlet	W4	19V	453859	6968209	01-Sep-2013	14:15

Water temperature ranged between 3.58 and 7.01°C, with a decreasing temperature trend from the watercourse inlet towards Lake Tuullitsut. Major ion concentrations were similar at the four sampling locations, with calcium as the dominant cation and bicarbonate and sulphate as the dominant anions, see Figure 3-1. Total dissolved solid (TDS) concentrations and electrical conductivity were moderately low (i.e., less than 200 mg/L TDS and 330 µS/cm). Water was moderately soft based on hardness (less than 120 mg/L). The median pH concentration was 7.98, indicating slightly alkaline water (pH over 7.0). Total suspended solid (TSS) concentrations were below the detection limit of 4 mg/L. Dissolved oxygen concentrations were high.

Nutrient concentrations, including nitrate, nitrite, ammonia, total Kjeldahl nitrogen, and total and dissolved phosphorus, were all below detection limits. Based on the lack of measurable nutrients, the watercourse can be classified as ultra-oligotrophic or very nutrient-poor. Total organic carbon concentration was low (less than 5 mg/L). Biological oxygen demand (BOD) was less than analytical detection limit of 2 mg/L at all sites. Fecal coliform bacteria were detected at sites W1 and W2 at very low counts.

Metals occur naturally in surface waters in small quantities. Total metal concentrations of aluminum, arsenic, barium, cobalt (only at Site W1), copper, iron, magnesium, molybdenum, nickel, silver, uranium, and vanadium were above laboratory detection limits. Aluminum concentrations exceeded the CCME water quality guideline of 0.005 mg/L at sites W1, W2 and W4. Aluminum concentrations often exceed the CCME water quality guideline in surface waters due to naturally occurring aluminum concentrations. See also Section 3.2.2 for discussion on nickel concentrations.

Hydrocarbons and organic compounds were undetected, with the exception of phenols at Site W4 (see also Section 3.2.2 for additional discussion).

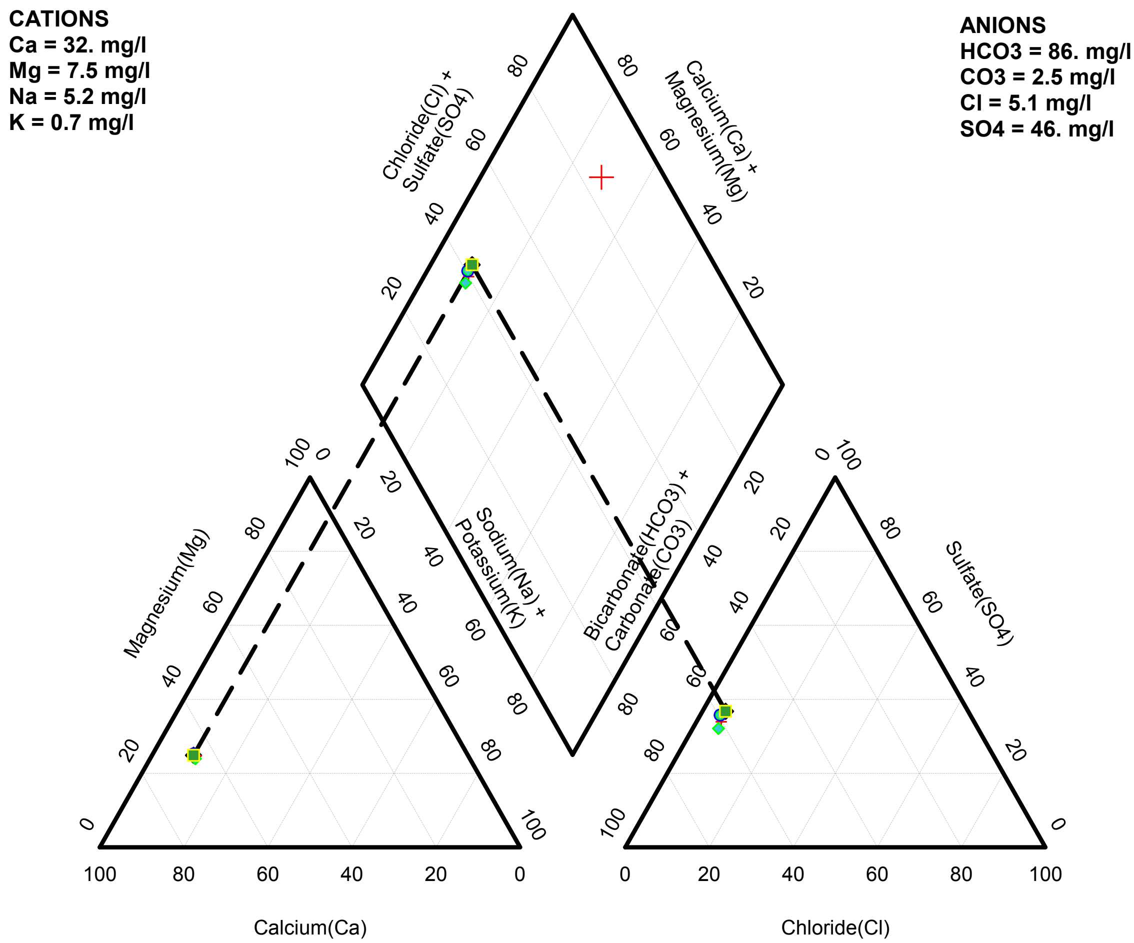

Figure 3-1 Major Ion Concentrations in the Watercourse

3.2.2 Water Chemistry Quality Control Results

For water chemistry quality control results, see Appendix A, Tables A-4 and A-5. Sample hold times were exceeded for nitrate and nitrite analysis (48 h) because of sample shipment time. Based on professional experience, it is not anticipated that the nitrate and nitrite analytical results were affected by the hold time exceedance.

Field duplicate relative percent difference for analytes, for which the mean of the duplicates was ≥ 10 method detection limit, ranged from 0 to 3%. Sampling precision was therefore acceptable, i.e., the relative percent difference was <25%.

Trip blank sample did not have any of the measured analytes above detection limit. The field blank sample had two analytes, phenols and nickel, above detection limit, indicating sample contamination from either the bottles or the sampling process. These analytical results were confirmed by the laboratory through repeat analysis. Phenol concentrations were below detection limit in all samples, except for Site W4. It is possible that the phenol concentration at Site W4 is the result of sample contamination, and should be interpreted with caution. Nickel concentrations were detected at all sites at concentrations higher than detected in the field blank, while below the CCME water quality guideline. It is possible that a part of the nickel concentrations in the sample was a result of sample contamination.

3.3 Fish and Fish Habitat

The assessment focused on determining the presence or absence of fish species in the Tuullitsut River wetland, the proposed receiving body of the Kimmirut sewage lagoon. Fish were collected in 6 locations, Fundo Lake upstream of the proposed discharge site, Tuullitsut River upstream of the wetland, the upstream end of the area known as the wetland, the mid-point of the wetland, downstream of the wetland, and one at the inlet to Tuullitsut Lake (Appendix B). The following summarize the results of the fish and fish habitat assessment.

3.3.1 Fish Habitat

Habitat was assessed at six sites within the wetland valley, two in lake shallows and four in the main channel through the wetland. Below are the results of the fish habitat assessment.

3.3.1.1 Fundo Lake and Outlet (62.844824° -69.898460°)

There are two outlets of Fundo Lake into the watercourse connecting Fundo Lake to Tuullitsut Lake. The western outlet flows to the location where the proposed wastewater treatment lagoon discharge would enter the wetland. Fish habitat was assessed along the shoreline of the lake between the two outlets.

Habitat along the shoreline between the outlets consisted of coarse material banks with grasses and shrubs and large cobble and boulders.

The substrate of the near shore area mainly consisted of sand and gravel with large boulders and cobble clusters as in-water cover. The bed slope into the lake was gradual with depths of 1 m about 50 m from the shoreline.

Photo 3-1 Western outlet of Lake Fundo looking north

Photo 3-2 Lake Fundo between the two outlets, looking north

3.3.1.2 Mid-Point between Fundo Lake and the Wetland (62.843558° -69.902418°)

At the mid-point between the western outlet of Lake Fundo and the beginning of the area known as the wetland, the watercourse was well-defined and has a high gradient. There is good vegetative cover along both banks, as well as good instream cover from boulders. Substrates ranged from small gravels in the lower gradient areas to boulders in the steep section. In the mid-point of this reach, there is a cascade, step-pool section for approximately 25 m. The cascades start with an 80 cm drop into a shallow pool, followed by a two more 30 cm drops. The pools associated with each of the drop were relatively deep, ranging from 20 to 30 cm and had cover in the form of boulders and overhanging vegetation. The bankful width of the channel was around 4.8 m in this reach.

Above the cascade is the only location of a man-made impact to the watercourse. At this location an all-terrain vehicle trail crosses the watercourse at a constructed ford. The downstream edge of the ford is built up with large rock resulting in a 60 cm drop from the wide sand and gravel substrate of the crossing to the natural cobble substrate of the channel below.

Photo 3-3 Looking south (downstream) from Mid-point between Lake Fundo and the Wetland

Photo 3-4 Looking north (upstream) from Mid-point between Lake Fundo and the Wetland

Photo 3-5 Cascade section below watercourse crossing

Photo 3-6 Looking west at watercourse crossing below Lake Fundo outlet

3.3.1.3 Inlet to the Wetland (62.840015° -69.905671°)

At the inlet to the wetland, the majority of the flow was in a defined low gradient channel, although there is a wide pooled area upstream, a pooled area downstream of the reach, and standing pools of water in the adjacent tundra. This area is immediately downstream of the proposed wastewater treatment lagoon discharge location. The sampled reach consists of a narrow and deep meandering channel with stable steep banks. Substrates consist of sand and fine materials interspaced with gravels and clusters of cobbles and boulders. There is a pool approximately 1.5 m deep in the lower section of the reach and one over 0.8 m in the mid-section, but the depths of the rest of the section were between 0.1 m and 0.6 m deep. The average bankful for this reach is 4.1 m. The riparian area is grasses and sedges with exposed roots holding up banks made of fine materials. Cover in the reach consists primarily from boulder clusters embedded in the substrate and the presence of undercut banks.

A small side channel enters the main channel from the east in the midpoint of the sampled reach. The channel has similar substrate and bank compositions, but is shallower and has more cover from overhanging grasses.

Photo 3-7 Looking north (upstream) from the Inlet to the Wetland reach

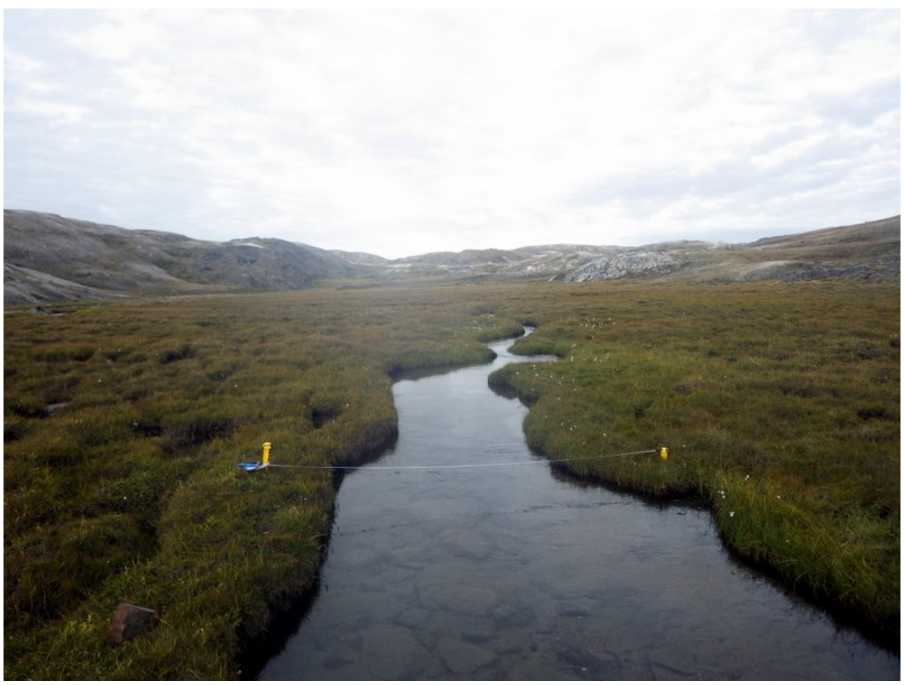

Photo 3-8 Looking north (upstream) at the Inlet to the Wetland reach

3.3.1.4 Mid-Point of the Wetland (62.836699° -69.907927°)

At the mid-point of the wetland, the majority of the flow comes from a wide pool into a well-defined channel, and then flows into a wide boulder garden section of channel with small side channels in the adjacent tundra. The substrate through this section ranges from sand to cobbles, with depths less than 20 cm in boulder garden and up to 37 cm deep in the side channels. The average channel at the boulder garden is approximately 21.5 m wide, with exposed boulders and grass covered islands providing instream cover.

Upstream of the wide boulder garden, the defined channel is approximately 4 m wide, and has pools and runs as deep as 45 cm. The substrate mainly consists of sand gravels and boulders. Undercut banks and boulders provide significant cover in this section.

The banks of the entire reach are composed of fines and grass roots and covered by grass. Most of the banks appeared stable, although there is some evidence of slumping within the wide boulder garden section of the reach and in the side channels around the boulder garden. There were aquatic macropytes present on boulders and growing in the sand of this reach.

Photo 3-9 Mid-point of the wetland, looking east (downstream)

Photo 3-10 Looking south (downstream) through the lower section of the mid-point of wetland reach

3.3.1.5 Outlet of the Wetland (62.832606° -69.910820°)

At the outlet of the wetland, the channel is well defined and flows through a reach with boulder garden. Substrates consist of gravels and cobble with many large boulders providing instream cover. The bankfull width of the channel is averaged at 23.4 m wide through the reach and depths ranged from less than 10 cm in riffle areas and over 40 cm deep in some of the pools around the boulder clusters. The thalweg appears to run along the south bank, with cover in the form of boulders, undercut banks, and backeddies. The north side of the channel has pools and channels through the grass, but most were shallow or not connected to the main channel.

The banks on both sides are stable and covered in grass and sedges. There are a few small channels entering the main channel form the southeast, which appear to contribute flows from a lake that is visible to the southeast of the valley.

Photo 3-11 Looking west (downstream) through the Wetland Outlet reach

Photo 3-12 Looking east (upstream) through the Wetland Outlet reach

3.3.1.6 Inlet to Tuullitsut Lake (62.832600° -69.912960°)

The inlet to Lake Tuullitsut is a large mud flat delta within the lake. The substrate consists mainly of fine materials and sand with large boulders providing cover on the delta and courser sands and gravels on the edge of the delta. Depths in the lake drop off to over a meter deep approximately 80 m from the shoreline near the inlet. There is deeper water surrounding the boulder clusters. In the area to the north of the stream outlet, a shallow bay has abundant growth of emergent vegetation. Deeper channels ran through the delta from the stream outlet into the deeper portion of Lake Tuullitsut.

Photo 3-13 Looking north from Lake Tuullitsut at the stream outlet

Photo 3-14 Looking west across the stream outlet into Lake Tuullitsut

Photo 3-15 Looking south across the stream outlet on Lake Tuullitsut

3.3.2 Fish Inventory

Fish sampling was conducted at each of the six sites; four in the Tuullitsut watercourse, one at the Lake Fundo outlet, and one at the Lake Tuullitsut inlet. A total of 244 fish were caught at the six sites. Three fish species were captured in the study area: threespine stickleback (*Gasterosteus aculeatus*), ninespine stickleback (*Pungitius pungitius*) and Arctic char (*Salvelinus alpinus*). Several size classes of Arctic char were observed ranging from approximately 30 mm to 260 mm in fork length and 0.79 g to 131.6 g in weight.

Table 3-4 Fish Species captured in the Tuullitsut River System

Common Name	Scientific Name	Total Caught
Arctic Char	*Salvelinus alpinus*	168
Ninespine Stickleback	*Pungitius pungitius*	23
Threespine Stickleback	*Gasterosteus aculeatus*	53

3.3.2.1 Lake Fundo

All three species of fish were captured along the shoreline of Lake Fundo and near both outlets. Most of the fish were caught in the deeper water and crevices around the submerged and exposed boulder, which was expected as that is the primary cover in that area of Lake Fundo. Larger Arctic char were observed in a deep pool in the western outlet, but were not sampled because of depths and the deep soft substrate. A total of 25 fish; 15 Arctic char, 2 ninespine stickleback, and 8 threespine stickleback were captured in 750 seconds of electrofishing along a route approximately 100 m long. Arctic char sizes ranged from 54 mm to 166 mm long (fork length) and from 1.26 g to 37.44 g in weight. No deformities or parasites were noted on any of the fish.

3.3.2.2 Mid-Point between Fundo Lake and the Wetland

All three species of fish were captured in the reach at the mid-point between Lake Fundo and the Wetland Inlet. A total of 132 fish; 89 Arctic char, 16 ninespine stickleback, and 17 threespine stickleback were captured in 1206 seconds of electrofishing along a stream length of 100m. Arctic char sizes ranged from 44 mm to 257 mm and 0.79 g to 131.6 g in weight. A ninespine stickleback was observed with a black stomach and another with fungus around its mouth, but no deformities or parasites were noted on the other fish.

Many of the fish were caught in the deeper water and boulder crevices at the base of the cascades in the higher gradient section of the sampled reach.

Photo 3-16 A 257 mm Arctic char captured below the 80cm high cascade

Photo 3-17 Young Arctic char photographed in a pool below a cascade

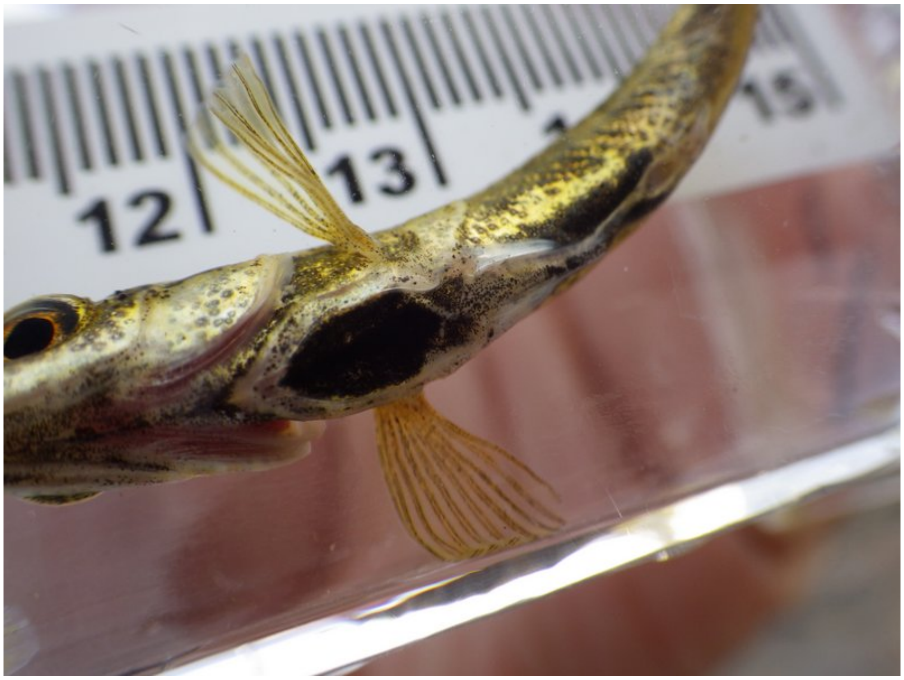

Photo 3-18 Black belly observed on a ninespine stickleback

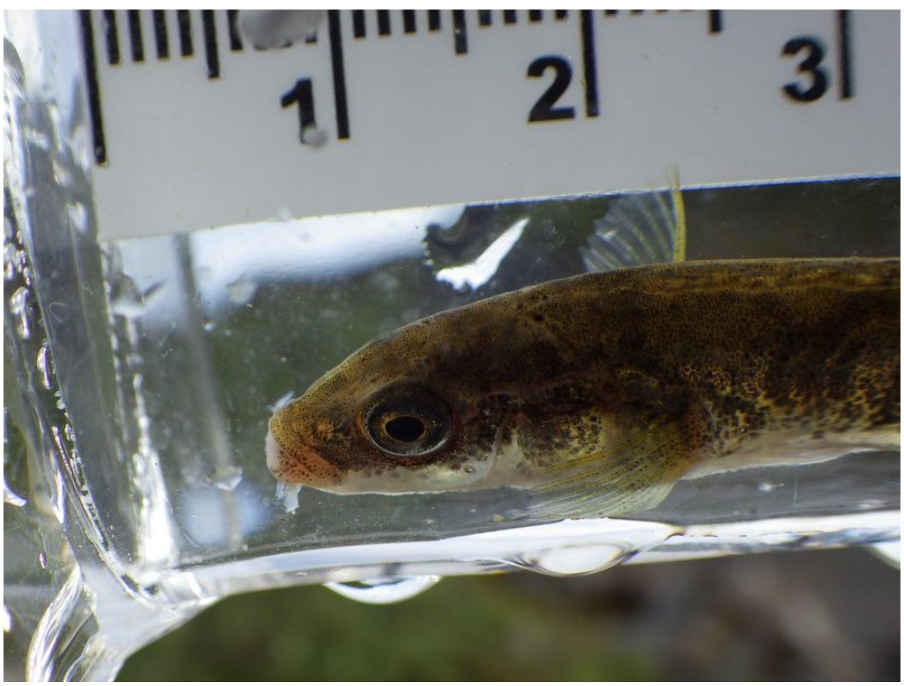

Photo 3-19 Fungus on mouth of a ninespine stickleback

3.3.2.3 Wetland Inlet

All three species of fish were captured in the reach at the mid-point between Lake Fundo and the Wetland Inlet. Thirteen fish; 8 Arctic char, 1 ninespine stickleback, and 4 threespine stickleback were captured in 863 seconds of electrofishing along a stream length of 120m. Arctic char sizes ranged from 89 mm to 142 mm and 6.43 g to 24.93 g in weight. No deformities or parasites were noted on the fish.

A short section in the tributary that comes in from the northeast was electrofished and Arctic char were caught hiding in undercut banks and boulders in the small low flow channels. In this reach a number of arctic char were observed, but escaped under boulders and deep into undercuts along the banks.

3.3.2.4 Mid-Point of the Wetland

Arctic char and threespine stickleback were captured in the reach at the mid-point of the Wetland. Twenty-three fish including, 16 Arctic char, and 7 threespine stickleback were captured in 1385 seconds of electrofishing along a stream length of 125m. A minnow trap was set and baited with catfood for 24 hours in a pool at the upstream end of the reach, but no fish were captured.

An additional 25 m of stream length was sampled at the upstream end of the reach to capture the complete habitat unit. In this reach, fish were observed and caught in some of the small connected side channels on the east side of the main channel through the boulder garden area. Unidentifiable dead stickleback were observed in some of the isolated pools outside of the main channel the reason for their death is unknown. The sizes of arctic Char caught ranged from 49 mm to 142 mm and 0.82 g to 27.45 g in weight. One threespine stickleback was observed with air blisters on the abdomen, but no other deformities or parasites were noted on fish.

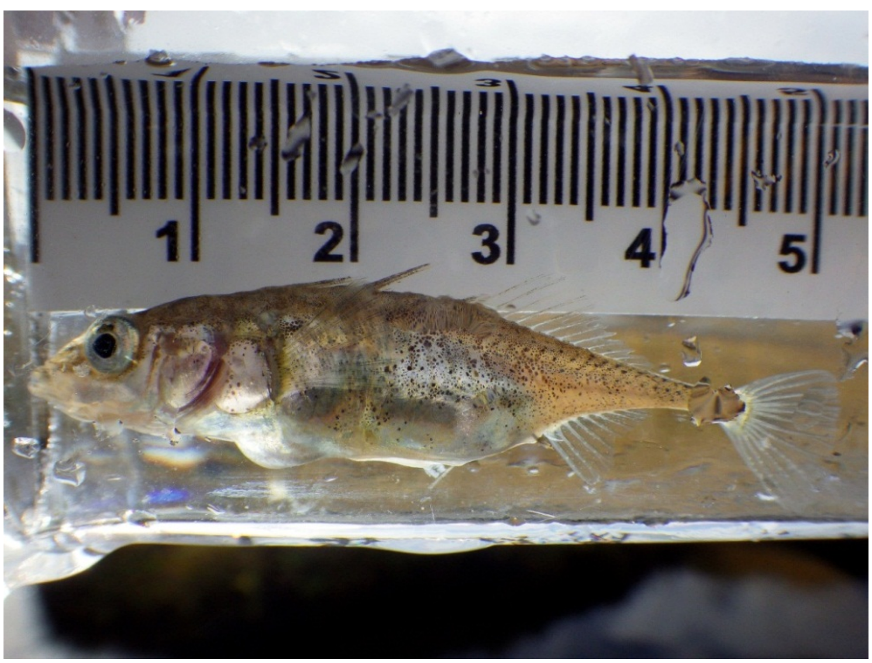

Photo 3-20 Blister on abdomen of threespine stickleback

3.3.2.5 Wetland Outlet

All three species of fish were captured in the reach at the mid-point between Lake Fundo and the Wetland Inlet. Forty fish including, 33 Arctic char, 2 ninespine stickleback, and 5 threespine stickleback were captured in 1041 seconds of electrofishing along a stream length of 100m. Arctic char sizes ranged from 79 mm to 250 mm and 0.82 g to 27.45 g in weight. High winds during the sampling prevented fish weights from being measured. No deformities or parasites were noted on the fish.

Arctic char were mainly caught in the deeper pools around the exposed boulders in the boulder garden, as well as in the thalweg along the south bank.

3.3.2.6 Lake Tuullitsut

All three species of fish were captured along the shoreline of Lake Tuullitsut near the inlet. Twenty-one fish including, 7 Arctic char, 2 ninespine stickleback, and 12 threespine stickleback were captured in 547 seconds of electrofishing along a shoreline length of approximately 100 m. Arctic char sizes ranged from 58 mm to 198 mm. High winds during the sampling prevented fish weights from being measured. A threespine stickleback was captured with a missing tail fin, but no other deformities or parasites were noted on fish.

Both stickleback species were observed and captured in the emergent vegetation in the small bay to the north of the inlet as well as in the area of the inlet. Arctic char were captured in boulder clusters at the inlet and in the rockier area to the south of the inlet.

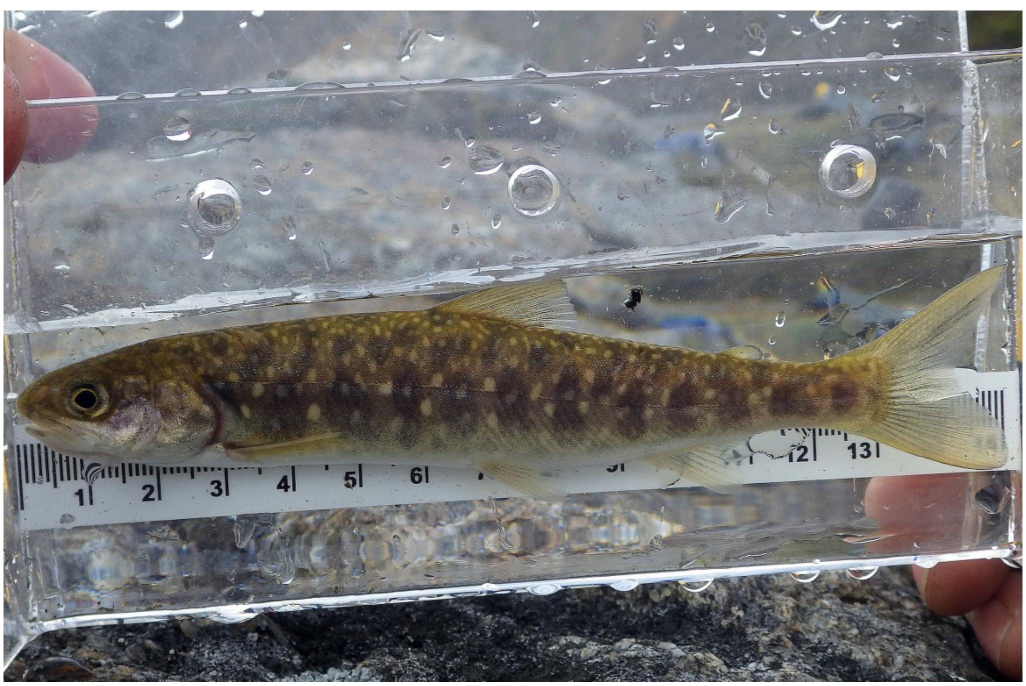

Photo 3-21 Arctic char captured in the nearshore area of Lake Tuullitsut

3.3.2.7 Migration Habitat

There are potential fish barriers formed by an 80cm drop at a steep cascade and a 60 cm drop at a built up all-terrain vehicle crossing at the mid-point between Lake Fundo and the inlet to the wetland. The drops may restrict the upstream movement of Arctic char into Lake Fundo through the western outlet. Evans et al (2002) found that Arctic char were known to travel upstream through riffles 10-15 cm deep and jump waterfalls as high as 1.5m, although the rocks at the base of the drop may limit opportunity for the Arctic char to jump. There is an alternative route possibility that fish could migrate upstream through a defined channel in the wetland, east into the intermediate lake to the east of the wetland, and then up to the eastern outlet of Lake Fundo. With the defined channel with measurable flow observed through the wetland area, and the channel through an intermediate lake and between Lake Tuullitsut and the wetland, it is possible for Arctic char to travel between the two lakes.

3.3.2.8 Rearing and Feeding Habitats

The overall habitat available in the channel is considered excellent for young of year and juvenile Arctic char, as well as good for adult char. There are riffles with good areas of gravels and cobbles that would support the production of aquatic invertebrates, as well as some deep pools and runs, wide impounded areas, and cascade/step pool habitats. There is good cover in the form of boulders and undercut banks through the entire area, and overhanging vegetation. The substrates ranged from fines to large boulders and bedrock outcrops.

Aquatic invertebrates observed included diptera (blackfly and cranefly) and caddis larva, as well as *Baetis* mayfly duns, adult water beetles, and at least two species of caddis fly adults on Lake Tuullitsut and within the wetland area. The presence of these aquatic invertebrates and the abundance of midge, mosquitoes, and black fly adults indicate that there is good food within the watercourse for juvenile arctic char. Evans et al. (2002) identify that juvenile Arctic char feed on plankton and invertebrates along shallow shorelines of lakes and in water up to 30 cm deep in streams.

Juvenile arctic char will remain in the freshwater streams and lacustrine systems, moving to deeper lacustrine areas to overwinter each season and potentially migrating to the sea at 1 to 8 years of age (Evans et al. 2002, Richardson et al. 2001). Scott and Crossman (1973) indicate that Arctic char from the Frobisher Bay area are under 90 mm when they are 4 years of age and younger, around 130 mm at 5 years, 139 mm at 6 years, around 172 mm at 7 years, and around 302 mm at 8 years of age. The lengths of the Arctic char we sampled were grouped into 5 mm increments and was plotted against the frequency that they were caught. The resultant graph indicates that there was a number of age classes captured in the wetland; a group around 50 mm in size, a group around 90, a group around 120 mm, a group around 160 mm, a group around 200 mm, and a couple of individuals around 250 mm. These groups could represent the age classes of fish below 7 years, which would be similar to those identified in Scott and Crossman (1973). The absence of parr marks on the larger arctic char capture (see photo 3-16) indicate that fish of this size may be adults that have moved into the stream from deeper lake habitat or from the sea.

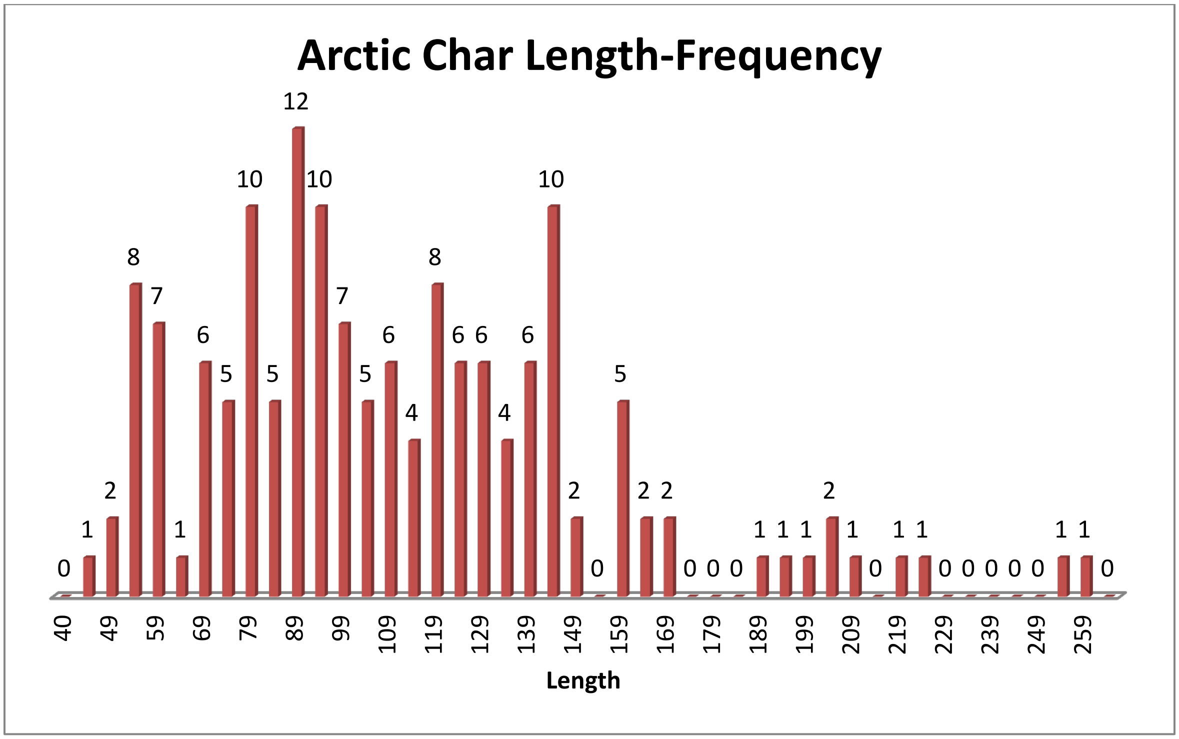

Figure 3-2 Length-Frequency chart for Arctic char caught between Lake Fundo and Tuullitsut

3.3.2.9 Spawning Habitat

Adult Arctic char are known to spawn in lacustrine gravel and cobble substrates approximately 1 to 11 m deep, as well as in areas with emergent aquatic vegetation (Richardson et al 2001). Arctic char are known to spawn in riverine habitats on gravels below rapids in rivers and streams, 0.5 m to 1.5 m deep (Evans et al. 2002), although spawning substrates vary from sand to large gravels. Both of these lacustrine and riverine spawning habitats are available in and between Lake Fundo and Tuullitsut.

3.3.2.10 Overwintering Habitat

Overwintering habitat in the wetland may be limiting, with the deepest location sampled in a run at 1.5 m deep. There may be other deep areas within the channel and wetland, but they may only provide limited overwintering for adult Arctic char. Adult and juvenile Arctic char are known to migrate to lakes to overwinter (Evans et al 2002, Richardson et al 2001, Scott and Crossman 1973). With the short distance between the lakes and any point in the wetland, overwintering would not be limiting for the local Arctic char population.

3.3.3 Forage Fish

Threespine and Ninespine stickleback are known to move into shallow streams during the spring and summer and move back into deeper lakes to overwinter (Evans et al 2002, Scott and Crossman 1973). Male stickleback will construct a nest in shallow vegetation or in crevices between boulders in the summer. The females will deposit the egg in the nest and the male will fertilize and guard the eggs until the young hatch (Evans et al 2002). Habitat is good through the wetland and in Lakes Fundo and Tuullitsut for both species of stickleback.

4 DISCUSSION AND CONCLUSIONS

The fall fish and fish habitat assessment of the Kimmirut wetland area and adjoining lakes, found Arctic char throughout the wetland system and adjoining lakes. The wetland area likely provides important fish habitat to Arctic char and some forage fish species. The addition of effluent into the wetland area may degrade fish habitat in the wetland area; thus, affecting Arctic char, which utilize this system. Further discussion and conclusions are provided below.

4.1 Hydrology

Key Question: What is the hydrology of the WWT System and how will the increase in flow affect the flow patterns within the wetland?

Eight (8) discharge measurements were obtained in the wetland upstream and downstream of the WWT system. Two discharge measurements were performed below the lower lagoon. Predicted sewage release from the lower lagoon into the wetland would last from mid-May to the end of September contributing 81,301 m3 of sewage over 138 days (Trow 2008). Stantec measurements indicate flow in the wetland for the same time period is at least 1,288,230 m^3 at Q4 and 1,574,166 m^3 into Lake Tuullitsut.

No seasonal discharge data was obtained, nor is it available, though it is assumed that spring snowmelt would result in higher early season flows and hydrologic response to rainfall events would be evident. There are channels and zones within the wetland that would indicate connectivity to the main channel when water levels are higher. This implies there is seasonal variability in discharge and a seasonal variation of +/- 10% change in flow is likely. A 0.03 m increase in water level at Q4 would not be uncommon.

There is potential for the sewage release to alter the physical conditions of the watercourse at the base of the slope where sewage would enter the channel. In its current condition, sewage released from the lower lagoon would likely saturate the surrounding organic material at the base of the slope prior to entering the channel. Over time, this seasonal contribution would likely become channelized and the transit time from the lower lagoon into the wetland would increase. Further, an increase in water level can lead to an increase in water velocity and as such, its erosive capability. However, based on the measurements obtained and the observations made within, the effect of the WWT System on the hydrology (water level and discharge) of the wetland is likely to be minimal.

4.2 Surface Water Quality

Key Question: What is the baseline water quality of the wetland?

Baseline water chemistry samples collected in fall 2013 indicate that at the time of sampling, the system was pristine with very low biological productivity. These results only provide a snapshot of the water chemistry. Water chemistry varies annually and seasonally, and baseline data for the watercourse are currently not available for more than one year or for other seasons than fall.

The flux of nutrients, organic carbon and other constituents from the WWT System to the watercourse would likely have a measurable effect on water chemistry of the watercourse and Lake Tuullitsut. Input of nutrients and organic carbon into an aquatic ecosystem can result in increased biological productivity and associated changes in fish habitat quality.

It is recommended that the potential effects of effluent in the watercourse and Lake Tuullitsut are quantified through water chemistry modelling prior to start of releases from the WWT System. Previously made predictions of the downstream water chemistry (Earth Tech 2008) need to be updated with the baseline water chemistry, and the assumptions related to system retention time need to be revisited based on the observation of flow and channel morphology of the watercourse. It is also recommended that additional seasons of baseline water chemistry data are collected prior to start of releases to gain an understanding of the natural range of seasonal and annual variability.

4.3 Fish and Fish Habitat

No species at risk were observed or captured during the fisheries assessment, but both consumable (Arctic char) and non-consumable (threespine stickleback and ninespine stickleback) fish species were captured. With the connectivity between Lake Fundo and Tuullitsut and the good quality of habitat, the Arctic char in the wetland system support fisheries in both Lake Fundo and Lake Tuullitsut.

Arctic char are potentially susceptible to pollutants and effluent would potentially alter the fish habitat in the wetland area over time, including changing the productivity, temperature, and chemical characteristics of the water. Additionally, changing the seasonal flows through the channel in the wetland may change the available habitat as well as alter the use of that habitat.

Key Question: Effect of effluent on fish and fish habitat-will the operation of the wastewater treatment system cause disruption, destruction or harmful alteration to the fish habitat? Are the types of fish in the wetland susceptible to pollutants? Do the regulations under section 36(3) of the Fisheries Act apply to the waters in the wetland system?

Section 36(3) of the *Fisheries Act* would apply to the wetland area. Data collected during the fall field survey characterizes baseline conditions in the wetland system. These data can support a risk assessment to fish and fish habitat (currently not in Nunami's scope).

Key Question: Seasonal migration patterns/potential migration routes- are there fish travelling through the wetland year round or only seasonally? Can the flow of wastewater effluent be diverted away from their migration routes or habitat locations?

It is anticipated that the wetland would provide seasonal fish habitat during the open water period. The wetland area is assumed to freeze to the bottom during the winter period, but this assumption requires verification. Diverting wastewater effluent from the main watercourse in the wetland may be difficult and potentially lead to other fish habitat issues. Further study may be required.

Key Question: How will the increase in flow affect fish and fish habitat- will the addition of effluent flow increase the likelihood for fish habitat? Will it negatively affect fish habitat? How will it change the flow patterns within the wetland?

The report produced by Earth Tech (Canada) Inc. in 2008, indicates that the valley between Lake Fundo and Lake Tulsit (Lake Tuullitsut) is a large wetland area with multiple streams embedded within the muskeg's dwarf birch, willows, and grasses. The late summer field-sampling program conducted by Nunami-Stantec found that the valley was a large wetland area with many pools of water and small channels, some connected and some not, but there was a primary well-defined channel flowing from Lake Fundo to Lake Tuullitsut through the wetland area. This channel provides connectivity between Lakes Fundo and Tuullitsut, as well as provides riverine habitat for Arctic char and threespine and ninespine stickleback found in the watercourse. Effluent flow into the wetland is likely to have a minimum effect on flow patterns within the wetland however the effluent flow may have an effect on the quality of the fish habitat.

5 REFERENCES

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6 CLOSURE

Nunami believes the information and data summarized in this report provides an understanding the hydrology, surface water quality and fish and fish habitat of the wetland area and will support the GN-CGS with the licence renewal application with the NWB for the WWT system.

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APPENDIX A **Water Chemistry Data**

A.1 Water Quality Guidelines

Table A-1 Water Quality Guidelines

Analyte	Unit	CCME AL
Ammonia (Total) [a]	mg/L	1.38 to 1.81
Chloride	mg/L	120
Nitrate-N	mg/L	2.9
Nitrite-N	mg/L	0.06
pH	pH unit	6.5 to 9.0
Aluminum	mg/L	0.005
Arsenic	mg/L	0.005
Boron	mg/L	1.5
Cadmium [b]	mg/L	0.000177
Copper [b]	mg/L	0.00264
Iron	mg/L	0.300
Lead [b]	mg/L	0.00376
Mercury - total	mg/L	0.000026
Molybdenum	mg/L	0.073
Nickel [b]	mg/L	0.11
Selenium	mg/L	0.001
Silver [b]	mg/L	0.0001
Thallium	mg/L	0.0008
Zinc [b]	mg/L	0.030
Benzene	mg/L	0.370
Ethylbenzene	mg/L	0.090
Toluene	mg/L	0.002

NOTES: CCME AL = Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (CCME 2014)

[a] Guideline is pH and temperature-dependent. Median laboratory-measured pH of 7.98 and the minimum (3.58°C) and maximum (7.01°C) field-measured temperatures were used to calculate the guideline range.

[b] Guideline is hardness-dependent. Median hardness of 114 mg/L was used to calculate guideline.

A.2 Water Chemistry Analytical Results

Table A-2 Field-Measured Water Chemistry

Site ID	Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)
W1	1-Sep-13	3.58	151.0	6.48	13.00	0.72
W2	1-Sep-13	6.20	223.1	7.99	12.17	0.09
W3	1-Sep-13	6.80	217.4	8.05	12.66	0.03
W4	1-Sep-13	7.01	220.2	8.08	10.76	0.05

Table A-3 Analytical Results for Water Chemistry

Site ID	W1	W2	W3	W4	Detection Limit	Unit
Date Sampled	01-SEP-13	01-SEP-13	01-SEP-13	01-SEP-13		
Time Sampled	10:15	13:00	13:30	15:00		
Sample ID	L1356511-1	L1356511-2	L1356511-3	L1356511-4		
Physical Tests						
Total Suspended Solids	<4.0	<4.0	<4.0	<4.0	4.0	mg/L
Ions and Nutrients						
Alkalinity, Total (as $CaCO_3$)	75.8	76.8	72.1	70.3	5.0	mg/L
Ammonia, Total (as N)	<0.050	<0.050	<0.050	<0.050	0.050	mg/L
Bicarbonate (HCO_3)	92.5	93.6	87.9	85.7	5.0	mg/L
Carbonate (CO_3)	<5.0	<5.0	<5.0	<5.0	5.0	mg/L
Chloride (Cl)	5.62	5.79	4.36	5.09	0.10	mg/L
Conductivity (EC)	252	249	241	242	3.0	uS/cm
Hardness (as $CaCO_3$)	116	114	114	111	-	mg/L
Hydroxide (OH)	<5.0	<5.0	<5.0	<5.0	5.0	mg/L
Ion Balance	101	101	102	99.0	-	%
Nitrate and Nitrite (as N)	<0.071	<0.071	<0.071	<0.071	0.071	mg/L
Nitrate (as N)	<0.050	<0.050	<0.050	<0.050	0.050	mg/L
Nitrite (as N)	<0.050	<0.050	<0.050	<0.050	0.050	mg/L
Total Kjeldahl Nitrogen	<0.20	<0.20	<0.20	<0.20	0.20	mg/L
pH	7.99	8.01	7.97	7.96	0.10	pH
Phosphorus (P)-Total Dissolved	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	mg/L
Phosphorus (P)-Total	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	mg/L
TDS (Calculated)	142	140	138	138	-	mg/L
Calcium (Ca)-Dissolved	33.6	33.4	32.8	32.3	0.10	mg/L

Table A-3 Analytical Results for Water Chemistry

Site ID	W1	W2	W3	W4	Detection Limit	Unit
Date Sampled	01-SEP-13	01-SEP-13	01-SEP-13	01-SEP-13		
Time Sampled	10:15	13:00	13:30	15:00		
Sample ID	L1356511-1	L1356511-2	L1356511-3	L1356511-4		
Magnesium (Mg)-Dissolved	7.77	7.40	7.70	7.46	0.10	mg/L
Potassium (K)-Dissolved	0.76	0.78	0.72	0.70	0.50	mg/L
Sodium (Na)-Dissolved	5.9	5.9	5.2	5.2	1.0	mg/L
Sulfate (SO_4)	43.3	40.4	43.9	45.5	0.50	mg/L
Organic Carbon						
Total Organic Carbon	1.4	1.5	2.0	1.4	1.0	mg/L
Total Metals						
Aluminum (Al)-Total	0.0308	0.0076	0.0040	0.0074	0.0030	mg/L
Antimony (Sb)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Arsenic (As)-Total	0.00011	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Barium (Ba)-Total	0.00813	0.00800	0.00728	0.00739	0.000050	mg/L
Beryllium (Be)-Total	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
Boron (B)-Total	0.013	0.013	0.014	0.012	0.010	mg/L
Cadmium (Cd)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.000010	mg/L
Calcium (Ca)-Total	32.8	32.8	31.9	31.6	0.10	mg/L
Chromium (Cr)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Cobalt (Co)-Total	0.00024	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Copper (Cu)-Total	0.00095	0.00049	0.00086	0.00048	0.00010	mg/L
Iron (Fe)-Total	0.040	0.032	0.037	<0.030	0.030	mg/L
Lead (Pb)-Total	<0.000050	<0.000050	<0.000050	<0.000050	0.000050	mg/L
Lithium (Li)-Total	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	mg/L
Magnesium (Mg)-Total	7.50	7.29	7.46	7.18	0.10	mg/L
Manganese (Mn)-Total	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	mg/L
Mercury (Hg)-Total	<0.000050	<0.000050	<0.000050	<0.000050	0.000050	mg/L
Molybdenum (Mo)-Total	0.000603	0.000603	0.000622	0.000591	0.000050	mg/L
Nickel (Ni)-Total	0.00280	0.00189	0.00181	0.00181	0.00010	mg/L
Potassium (K)-Total	0.73	0.72	0.66	0.68	0.50	mg/L
Selenium (Se)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Silver (Ag)-Total	0.000035	0.000029	0.000028	0.000025	0.000010	mg/L
Sodium (Na)-Total	5.8	5.8	5.1	5.1	1.0	mg/L
Thallium (Tl)-Total	<0.000050	<0.000050	<0.000050	<0.000050	0.000050	mg/L
Tin (Sn)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	mg/L
Titanium (Ti)-Total	<0.00030	<0.00030	<0.00030	<0.00030	0.00030	mg/L
Uranium (U)-Total	0.000433	0.000494	0.000446	0.000398	0.000010	mg/L

Table A-3 Analytical Results for Water Chemistry

Site ID	W1	W2	W3	W4	Detection Limit	Unit
Date Sampled	01-SEP-13	01-SEP-13	01-SEP-13	01-SEP-13		
Time Sampled	10:15	13:00	13:30	15:00		
Sample ID	L1356511-1	L1356511-2	L1356511-3	L1356511-4		
Vanadium (V)-Total	0.00028	0.00021	0.00024	0.00026	0.00010	mg/L
Zinc (Zn)-Total	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	mg/L
Aggregate Organics						
Oil And Grease (Visible Sheen)	No Visible Sheen	No Visible Sheen	No Visible Sheen	No Visible Sheen	-	-
Phenols (4AAP)	<0.0010	<0.0010	<0.0010	0.0088[a]	0.0010	mg/L
Hydrocarbons						
Benzene	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
Ethylbenzene	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
Toluene	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
o-xylene	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
m+p-Xylene	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
Xylenes	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	mg/L
F1(C6-C10)	<0.10	<0.10	<0.10	<0.10	0.10	mg/L
F1-BTEX	<0.10	<0.10	<0.10	<0.10	0.10	mg/L
F2 (>C10-C16)	<0.25	<0.25	<0.25	<0.25	0.25	mg/L
F3 (C16-C34)	<0.25	<0.25	<0.25	<0.25	0.25	mg/L
F4 (C34-C50)	<0.25	<0.25	<0.25	<0.25	0.25	mg/L
Biological						
Fecal Coliforms[b]	1	1	ND	ND	1	CFU/ 100 mL
BOD[b]	<2	<2	<2	<2	2	mg/L

NOTES: Gray shaded values exceed CCME Water Quality Guideline for the Protection of Aquatic Life (CCME 2014)
ND = not detected
[a] Reported result verified with repeat analysis.
[b] Biochemical Oxygen Demand and Fecal Coliform analysis performed by Paracel Laboratories Ltd. in Ottawa, Ontario.

A.3 Water Chemistry Quality Control Results

Table A-4 Sample Hold Time Exceedances

Analyte	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Nitrate-N	W1	01-SEP-13 10:15	05-SEP-13 12:39	48	98	hours	EHTR
	W2	01-SEP-13 13:00	05-SEP-13 12:39	48	96	hours	EHTL
	W3	01-SEP-13 13:30	05-SEP-13 12:39	48	95	hours	EHTL
	W4	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	Dup	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	FBlank	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	TBlank	01-SEP-13	05-SEP-13 12:39	48	97	hours	EHTL
Nitrite-N	W1	01-SEP-13 10:15	05-SEP-13 12:39	48	98	hours	EHTR
	W2	01-SEP-13 13:00	05-SEP-13 12:39	48	96	hours	EHTL
	W3	01-SEP-13 13:30	05-SEP-13 12:39	48	95	hours	EHTL
	W4	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	Dup	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	FBlank	01-SEP-13 15:00	05-SEP-13 12:39	48	94	hours	EHTL
	TBlank	01-SEP-13	05-SEP-13 12:39	48	97	hours	EHTL

NOTES:
Rec. = recommended
HT = hold time
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.

Table A-5 Water Chemistry Quality Control Results

Sample ID	W4	DUPLICATE (W4)	Sample and Duplicate Mean Over 10*MDL	Relative Percent Difference	FIELD BLANK	TRIP BLANK	Detection Limit	Unit
Date Sampled	01-SEP-13	01-SEP-13			01-SEP-13	01-SEP-13		
Time Sampled	15:00	15:00			15:00	00:00		
ALS Sample ID	L1356511-4	L1356511-5			L1356511-6	L1356511-7		
Physical Tests								
Total Suspended Solids	<4.0	<4.0	N/A	-	<4.0	<4.0	4.0	mg/L
Ions and Nutrients								
Alkalinity, Total (as $CaCO_3$)	70.3	69.6	TRUE	-1%	<5.0	<5.0	5.0	mg/L
Ammonia, Total (as N)	<0.050	<0.050	N/A	-	<0.050	<0.050	0.050	mg/L
Bicarbonate (HCO_3)	85.7	84.9	TRUE	-1%	<5.0	<5.0	5.0	mg/L
Carbonate (CO_3)	<5.0	<5.0	N/A	-	<5.0	<5.0	5.0	mg/L
Chloride (Cl)	5.09	5.14	TRUE	1%	<0.10	<0.10	0.10	mg/L
Conductivity (EC)	242	241	TRUE	0%	<3.0	<3.0	3.0	uS/cm
Hardness (as $CaCO_3$)	111	112	N/A	-	<1.0	<1.0	-	mg/L
Hydroxide (OH)	<5.0	<5.0	N/A	-	<5.0	<5.0	5.0	mg/L
Ion Balance	99.0	99.7	N/A	-	Low TDS	Low TDS	-	%
Nitrate and Nitrite (as N)	<0.071	<0.071	N/A	-	<0.071	<0.071	0.071	mg/L
Nitrate (as N)	<0.050	<0.050	N/A	-	<0.050	<0.050	0.050	mg/L
Nitrite (as N)	<0.050	<0.050	N/A	-	<0.050	<0.050	0.050	mg/L
Total Kjeldahl Nitrogen	<0.20	<0.20	N/A	-	<0.20	<0.20	0.20	mg/L
pH	7.96	7.99	TRUE	0%	6.19	5.92	0.10	pH
Phosphorus (P)-Total Dissolved	<0.0050	<0.0050	N/A	-	<0.0050	<0.0050	0.0050	mg/L
Phosphorus (P)-Total	<0.0050	<0.0050	N/A	-	<0.0050	<0.0050	0.0050	mg/L
TDS (Calculated)	138	138	N/A	-	<1.0	<1.0	-	mg/L
Sulfate (SO_4)	45.5	45.6	TRUE	0%	<0.50	<0.50	0.50	mg/L
Calcium (Ca)-Dissolved	32.3	32.6	TRUE	1%	<0.10	<0.10	0.10	mg/L

Table A-5 Water Chemistry Quality Control Results

Sample ID	W4	DUPLICATE (W4)	Sample and Duplicate Mean Over 10*MDL	Relative Percent Difference	FIELD BLANK	TRIP BLANK	Detection Limit	Unit
Date Sampled	01-SEP-13	01-SEP-13			01-SEP-13	01-SEP-13		
Time Sampled	15:00	15:00			15:00	00:00		
ALS Sample ID	L1356511-4	L1356511-5			L1356511-6	L1356511-7		
Magnesium (Mg)-Dissolved	7.46	7.39	TRUE	-1%	<0.10	<0.10	0.10	mg/L
Potassium (K)-Dissolved	0.70	0.68	FALSE	-	<0.50	<0.50	0.50	mg/L
Sodium (Na)-Dissolved	5.2	5.2	FALSE	-	<1.0	<1.0	1.0	mg/L
Organic Carbon								
Total Organic Carbon	1.4	1.5	FALSE	-	<1.0	<1.0	1.0	mg/L
Total Metals								
Aluminum (Al)-Total	0.0074	0.0200	FALSE	-	<0.0030	<0.0030	0.0030	mg/L
Antimony (Sb)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Arsenic (As)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Barium (Ba)-Total	0.00739	0.00767	TRUE	2%	<0.000050	<0.000050	0.000050	mg/L
Beryllium (Be)-Total	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
Boron (B)-Total	0.012	0.013	FALSE	-	<0.010	<0.010	0.010	mg/L
Cadmium (Cd)-Total	<0.000010	<0.000010	N/A	-	<0.000010	<0.000010	0.000010	mg/L
Calcium (Ca)-Total	31.6	32.3	TRUE	1%	<0.10	<0.10	0.10	mg/L
Chromium (Cr)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Cobalt (Co)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Copper (Cu)-Total	0.00048	0.00059	FALSE	-	<0.00010	<0.00010	0.00010	mg/L
Iron (Fe)-Total	<0.030	0.047	N/A	-	<0.030	<0.030	0.030	mg/L
Lead (Pb)-Total	<0.000050	<0.000050	N/A	-	<0.000050	<0.000050	0.000050	mg/L
Lithium (Li)-Total	<0.0050	<0.0050	N/A	-	<0.0050	<0.0050	0.0050	mg/L
Magnesium (Mg)-Total	7.18	7.38	TRUE	2%	<0.10	<0.10	0.10	mg/L
Manganese (Mn)-Total	<0.0050	<0.0050	N/A	-	<0.0050	<0.0050	0.0050	mg/L

Table A-5 Water Chemistry Quality Control Results

Sample ID	W4	DUPLICATE (W4)	Sample and Duplicate Mean Over 10*MDL	Relative Percent Difference	FIELD BLANK	TRIP BLANK	Detection Limit	Unit
Date Sampled	**01-SEP-13**	**01-SEP-13**			**01-SEP-13**	**01-SEP-13**		
Time Sampled	**15:00**	**15:00**			**15:00**	**00:00**		
ALS Sample ID	**L1356511-4**	**L1356511-5**			**L1356511-6**	**L1356511-7**		
Mercury (Hg)-Total	<0.000050	<0.000050	N/A	-	<0.000050	<0.000050	0.000050	mg/L
Molybdenum (Mo)-Total	0.000591	0.000604	TRUE	1%	<0.000050	<0.000050	0.000050	mg/L
Nickel (Ni)-Total	0.00181	0.00179	TRUE	-1%	0.00073 [a]	<0.00010	0.00010	mg/L
Potassium (K)-Total	0.68	0.67	FALSE	-	<0.50	<0.50	0.50	mg/L
Selenium (Se)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Silver (Ag)-Total	0.000025	0.000026	FALSE	-	<0.000010	<0.000010	0.000010	mg/L
Sodium (Na)-Total	5.1	5.2	FALSE	-	<1.0	<1.0	1.0	mg/L
Thallium (Tl)-Total	<0.000050	<0.000050	N/A	-	<0.000050	<0.000050	0.000050	mg/L
Tin (Sn)-Total	<0.00010	<0.00010	N/A	-	<0.00010	<0.00010	0.00010	mg/L
Titanium (Ti)-Total	<0.00030	0.00081	FALSE	-	<0.00030	<0.00030	0.00030	mg/L
Uranium (U)-Total	0.000398	0.000416	TRUE	3%	<0.000010	<0.000010	0.000010	mg/L
Vanadium (V)-Total	0.00026	0.00032	FALSE	-	<0.00010	<0.00010	0.00010	mg/L
Zinc (Zn)-Total	<0.0050	<0.0050	N/A	-	<0.0050	<0.0050	0.0050	mg/L
Aggregate Organics								
Oil And Grease (Visible Sheen)	No Visible Sheen	No Visible Sheen	N/A	-	No Visible Sheen	No Visible Sheen	-	-
Phenols (4AAP)	0.0088 [a]	<0.0010	N/A	-	0.0024 [a]	<0.0010	0.0010	mg/L
Hydrocarbons								
Benzene	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
Ethylbenzene	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
Toluene	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
o-xylene	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L

Table A-5 Water Chemistry Quality Control Results

Sample ID	**W4**	**DUPLICATE (W4)**	**Sample and Duplicate Mean Over 10*MDL**	**Relative Percent Difference**	**FIELD BLANK**	**TRIP BLANK**	**Detection Limit**	**Unit**
Date Sampled	**01-SEP-13**	**01-SEP-13**			**01-SEP-13**	**01-SEP-13**		
Time Sampled	**15:00**	**15:00**			**15:00**	**00:00**		
ALS Sample ID	**L1356511-4**	**L1356511-5**			**L1356511-6**	**L1356511-7**		
m+p-Xylene	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
Xylenes	<0.00050	<0.00050	N/A	-	<0.00050	<0.00050	0.00050	mg/L
F1(C6-C10)	<0.10	<0.10	N/A	-	<0.10	<0.10	0.10	mg/L
F1-BTEX	<0.10	<0.10	N/A	-	<0.10	<0.10	0.10	mg/L
F2 (>C10-C16)	<0.25	<0.25	N/A	-	<0.25	<0.25	0.25	mg/L
F3 (C16-C34)	<0.25	<0.25	N/A	-	<0.25	<0.25	0.25	mg/L
F4 (C34-C50)	<0.25	<0.25	N/A	-	<0.25	<0.25	0.25	mg/L
Biological								
Fecal Coliforms	ND	1	N/A	-	ND	ND	1	CFU/100 mL
BOD	<2	<2	N/A	-	<2	<2	2	mg/L

NOTES:
N/A = not applicable
ND = not detected
MDL = method detection limit
[a] Reported result verified with repeat analysis by ALS.