



December 2016

BACK RIVER OFFSETTING OPTION

Nulahugyuk Creek Habitat Remediation

Submitted to:
Sabina Gold & Silver Corp.

Suite 375, Two Bentall Centre
555 Burrard Street
Box 220
Vancouver, BC V7X 1M7

REPORT



Report Number: Doc 009-1545534.4000 Ver 0





Table of Contents

ACKNOWLEDGMENTS	1
1.0 INTRODUCTION.....	2
2.0 STUDY AREA.....	2
3.0 METHODS	4
3.1 Construction.....	5
3.1.1 Environmental Data.....	6
4.0 RESULTS	6
4.1 Community Engagement	6
4.2 Remediation Results.....	10
4.2.1 Overview	10
4.2.2 Post-Remediation Changes in Flows	10
4.2.3 Post-Remediation Changes in Substrate Composition	11
4.3 Site Remediation Reports.....	12
5.0 SUMMARY.....	39
6.0 REFERENCES.....	41

TABLES

Table 3-1: Summary of Potential Locations for Fish Passage Remediation (Enhancement)	4
Table 4-1: Field Personnel Involved in the 2016 Nulahugyuk Creek Remediation Project.....	7
Table 4-2: Site Locations and Summary of Effort for the 2016 Nulahugyuk Creek Remediation Program.....	10
Table 4-3: Low-flow Channel Depths and Velocities at Site Locations Pre-and Post- Remediation.....	11
Table 4-4: Low-flow Channel Substrate Composition at Site Locations Pre- and Post- Remediation.....	12

FIGURES

Figure 2-1: Bernard Harbour Offsetting Option, July 2016	3
--	---

PHOTOGRAPHS

Photo 4-1: Local student dissecting a juvenile Arctic Char as part of a biology lesson provided by Golder staff. 23 July 2016.	8
Photo 4-2: Local student and Golder aquatic biologist processing a captured Arctic Char. 21 July 2016.	8



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Photo 4-3: Local student and field assistants constructing the low-flow channel at Site 1. 18 July 2016.	9
Photo 4-4: Local student and field assistants participating in the removal of a rock barrier at Site 13. 24 July 2016.	9
Photo 4-5: Upstream view of thalweg from the downstream extent of Site 1 prior to remediation. 18 July 2016.	14
Photo 4-6: Upstream view from elevated RDB showing low-flow channel and weirs constructed during remediation at Site 1. 18 July 2016.	14
Photo 4-7: Upstream view of thalweg from the downstream extent of Site 2 prior to remediation. Note the exposed substrate along the LDB. 18 July 2016.	16
Photo 4-8: Upstream view of low-flow channel A including upstream extent of low-flow channel B (top-left) at Site 2. 18 July 2016.	16
Photo 4-9: Upstream view of thalweg from the downstream extent of Site 3 prior to remediation. Note the pool at the upstream extent along the RDB. 19 July 2016.	18
Photo 4-10: Upstream view of low-flow channel A and Weir A at Site 3 post-remediation. Note the directional weir facilitating fish passage towards the channel and away from problem area. 19 July 2016.	18
Photo 4-11: Upstream view of the RDB from the downstream extent of Site 4 prior to remediation. Note the lack of discernible channel across the creek. 19 July 2016.	20
Photo 4-12: Upstream view of low-flow channels A and B constructed at Site 4. 19 July 2016.	20
Photo 4-13: Upstream view of problem area from the downstream extent of Site 4 prior to remediation. Note the lack of discernible channel. 20 July 2016.	22
Photo 4-14: Upstream view of low-flow channel A from the downstream extent of Site 4 post-remediation. Note the large boulders left within channel. 20 July 2016.	22
Photo 4-15: Upstream view of the problem area from the downstream extent of Site 6 prior to remediation. Note the lack of a discernible channel. 21 July 2016.	24
Photo 4-16: Upstream view of low-flow channel as viewed from elevated LDB at Site 6 post-remediation. Note the large pool at the downstream extent of the low-flow channel. 21 July 2016.	24
Photo 4-17: Downstream view of the location of low-flow channel B from the upstream extent of Site 7 prior to remediation. Note the absence of a continuous channel connecting to the pool along the LDB at the downstream extent. July 24, 2016.	26
Photo 4-18: Downstream view of low-flow channel B from the upstream extent of Site 7 post-remediation. Note connectivity with the pool along the LDB at the downstream extent. 24 July 2016.	26
Photo 4-19: Upstream view of the problem area facing the LDB at Site 8 prior to remediation. Note the absence of a continuous migratory channel across centre of creek. 23 July 2016.	28
Photo 4-20: Upstream view of the low-flow channel constructed at Site 8. Note the large boulders left in the low-flow channel to act as velocity breaks and cover for fish. 23 July 2016.	28
Photo 4-21: Downstream view of the problem area, facing the LDB at Site 9 prior to remediation. Note the absence of a continuous migratory channel across centre of creek. 23 July 2016.	30
Photo 4-22: Downstream view from above the RDB of the low-flow channel constructed at Site 8. 23 July 2016.	30
Photo 4-23: Upstream view of problem area at Site 10 prior to remediation. Note the dispersed flows across the creek. 22 July 2016.	32
Photo 4-24: Upstream view of low-flow channel A and B constructed at Site 10. Note that the channel provides fish passage beyond the pond (in foreground). 22 July 2016.	32
Photo 4-25: Upstream view of problem area from downstream extent of Site 11 prior to remediation, note dispersed flows across creek. 20 July 2016.	34



Photo 4-26: Upstream view of low-flow channel at Site 11 post-remediation, note that the channel provides fish passage along the RDB of creek. 20 July 2016.34

Photo 4-27: downstream view of problem area looking towards RDB at Site 12 prior to remediation, note dispersed flows across creek. 21 July 2016.....36

Photo 4-28: Downstream view of the low-flow channel constructed at Site 12 post-remediation, note that the channel provides fish passage across the creek. 21 July 2016.36

Photo 4-29: Upstream view of rock barrier impeding fish passage under low-flow conditions at Site 13 prior to remediation. 24 July 2016.38

Photo 4-30: Upstream view of Site 13 post-remediation. Note several small channels available to facilitate upstream migration. 24 July 2016.38

APPENDICES

APPENDIX A

Project Photographs

DRAFT



ACKNOWLEDGMENTS

Funding for the remediation of Nulahugyuk Creek was provided by Sabina Gold & Silver Corp. (Sabina) as part of the Back River Project. The successful execution of this work is credited to the community of Kugluktuk and the staff at the Hunters and Trappers Organization (HTO). Their hard work in the creek and on-going support of the conservation objectives for Bernard Harbour are acknowledged as critical components to the successful completion of creek remediation. This project was also successful because of the logical support provided by Johnny Nivingalok (HTO Manager), Larry Adjun (HTO chairperson), and John Kaiyogana (Sabina).

DRAFT



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was contracted by Sabina Gold & Silver Corp. (Sabina) to assist with the implementation of the Back River offsetting plan submitted with Final Environmental Impact Statement (Golder 2015a). The plan includes the Bernard Harbour offsetting option to counterbalance losses incurred by the Back River Project.

The primary objective of the Bernard Harbour offsetting option is to improve passage for fish migrations in Nulahugyuk Creek by removing boulder barriers in the creek and increasing water depths within specified paths or movement corridors within the channel. The general approach uses 'soft' engineering methods (without the use of heavy machinery), considers local knowledge of creek flows, and is based on methods developed by the Kugluktuk HTO and Golder in 2012 (Golder 2013).

The creek remediation (i.e., habitat enhancement) approach is similar to the low-flow channel concept, where a low-flow channel is the 'narrowing' or diversion of flows within a creek bed (Fischenich 2002). The implementation of this concept at Bernard Harbour was initially adapted and tested in 2012 (Golder 2013) under the goal of improving conditions for fish passage. For example, low-flow channels were designed as an unobstructed path to connect downstream locations with suitable habitat for passage to upstream locations with suitable habitat. The channels were created by relocating boulders from the assumed thalweg to adjacent areas as a boundary to concentrate flows within the creek bed. Where needed, weirs above the low-flow channel were also constructed to augment flows and increase water depths in the channel (i.e., as flow deflectors), and weirs below the low-flow channel were constructed to direct fish to the channel versus shallow boulder gardens where stranding may occur (i.e., as fish deflectors).

In addition to the objective outlined above, the remediation work was intended to complement and integrate community objectives of the Kugluktuk HTO. This was to be achieved by incorporating students, and community members and by designing an offsetting option that fosters education, stewardship and community involvement in conservation initiatives. Past studies (e.g., Stern et al. 2008) have demonstrated a lasting positive change in environmental attitude, action, and knowledge following environmental education programs, such as the one implemented at Bernard Harbour.

2.0 STUDY AREA

The Hingittok Lake-Nulahugyuk Creek (HLNC) system at Bernard Harbour is located approximately 100 kilometres (km) directly north of the hamlet of Kugluktuk, Nunavut (the community), along the south coast of Dolphin and Union Strait (Figure 2-1). The site is about 4.5 hours (h) travel time by boat from the community. Nulahugyuk Creek, the outflow from Hingittok Lake (882 hectares [ha] in size), flows north for approximately 10 km before entering the sea at 68°44'52"N, 114°45'27"W, approximately 5 km southeast of the abandoned DEW-Line site at Bernard Harbour. The contributing basin area at the mouth of Nulahugyuk Creek is approximately 125 square kilometres (km²) in area, and is characterized by limited groundwater derived flows punctuated by precipitation-driven peak flows. It is expected that most of the precipitation falls as rain during the open water season. Based on 1981 to 2010 Canadian climate normal station data for Kugluktuk, mean total precipitation is approximately 247 millimetres (mm), of which 144 mm falls during June, July, August, and September (see <http://climate.weather.gc.ca>). Daily maximum temperatures, on average, are above zero for June through September, peaking in July at 15.6 degrees Celsius (°C), and below zero degrees Celsius for the remaining months of the year.



- LEGEND**
- CAMP
 - KILOMETRE MARKER
 - LOW-FLOW CHANNEL PROJECT 2012
 - REMEDIAION SITE 2016
 - ELEVATION CONTOUR
 - WATERCOURSE
 - WATERBODY



DRAFT



REFERENCE(S)
1. GOOGLE EARTH IMAGERY: © 2014 DIGITAL GLOBE
2. CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 11 DATUM: NAD 83

PROJECT
BACK RIVER PROJECT
NUNAVUT, CANADA

TITLE
BERNARD HARBOUR OFFSETTING OPTION, JULY 2016

PROJECT NO.	PHASE	REV.	FIGURE
1545534	4000	A	2-1

CLIENT			
CONSULTANT			
	YYYY-MM-DD	2016-12-13	
	DESIGNED	CS	
	PREPARED	ANK	
	REVIEWED	-	
	APPROVED	-	
			



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

3.0 METHODS

In early July 2016 prior to creek remediation that followed later in the summer (Golder 2016), the entirety of Nulahugyuk Creek was evaluated for problem locations where Arctic Char (*Salvelinus alpinus*) movement may be impeded by lack of depth, and boulder barriers. Problem locations identified in 2014 (Golder 2015a) and 2015 (Golder 2015b) were also re-evaluated for current conditions. Thirteen problem locations were confirmed and are described in detail in Golder (2016). These locations are where fishery productivity, characterized by Arctic Char production (i.e., available biomass for harvesting), may benefit from low-flow channel projects (Table 3-1). Three problem locations were identified as rank 3, the highest priority for site remediation, followed by five rank 2 locations, and five rank 1 locations. Based on information collected during these surveys, a detailed plan for constructing the low-flow channels and directional weirs at each site was developed (Appendix C in Golder 2016). The implementation of these remediation plan took place from 18 to 24 July 2016. The remediation program included the construction of low-flow channels, directional weirs, and removal of barriers at 13 sites to facilitate upstream migration

Table 3-1: Summary of Potential Locations for Fish Passage Remediation (Enhancement)

Site Identification	Stream Section	Approximate Distance Upstream of Bernard Harbour (km)	Ranking Based on Expected Risk of Mortality and Blockage (Higher Ranking = Higher Risk)	Minimum Required Low-Flow Channel Length to Improve Passage (m)
Site 1 ^a	Section 1	1.40	Rank 3	41
Site 2	Section 1	1.63	Rank 2	42 ^b
Site 3	Section 1	1.69	Rank 2	34 ^c
Site 4	Section 1	2.03	Rank 2	30
Site 5	Section 1	2.15	Rank 3	22
Site 6	Section 1	2.50	Rank 3	45
Site 7	Section 1	3.05	Rank 2	14
Site 8	Section 2	4.87	Rank 1	20
Site 9	Section 2	5.76	Rank 1	40
Site 10	Section 3	7.89	Rank 1	15
Site 11 ^d	Section 1	2.22	Rank 1	38
Site 12 ^d	Section 1	2.40	Rank 1	19
Site 13 ^d	Section 1	3.10	Rank 1	15

^a the site was initially described as two separate problem locations in 2014 but was later characterized in 2015 as one problem site requiring an extended low-flow channel (versus two separate consecutive channels).

^b two parallel low-flow channels recommended (length represents combined length of parallel channels).

^c requires further evaluation; a directional weir may be a viable alternative for this location.

^d problem sites identified in 2015.

km = kilometres; m = metre; extended rock weirs are recommended for most sites, for example, to direct migrating fish upstream through the low-flow channel.



3.1 Construction

The Golder field crew along with an HTO field assistant surveyed each project site identified in Table 3-1 prior to remediation. The thalweg was identified and the design of the remediation site was finalized. The field crew then outlined the boundaries of the remediation features by placing small rock stacks to effectively guide the remediation crew in their removal and placement of rocks during channel and weir construction.

Design considerations included the following:

- Where a low-flow channel or weir must be oriented against the natural direction of flows, the largest available boulders were positioned on the upstream side of the channel boundary or weir to prevent blow-outs at high velocities during the spring freshet.
- When a low-flow channel was constructed in an area where the creek was relatively wide, multiple channels or extended directional weirs were considered to aid upstream navigation.
- Where possible, large boulders were included as a natural feature in the low-flow channels to provide in-stream cover and enhance the structural integrity of the channels.
- Where low-flow channel water depths remained low post-remediation, weirs were extended (using large boulders) at the upstream end of the channel to direct flows towards, and increase water depths in the channel.

Physical manipulation of the creek bed began by rolling large boulders within the outlined channel towards the left or right side of the channel boundary, creating a wall of rock bordering the unobstructed path of the channel. Some of these boulders required multiple individuals to relocate. Once most of the large boulders were cleared, smaller boulders were removed and stacked with the large boulders and along the outside of the rock wall to further armor the low-flow channel. Larger cobble substrates were also removed and placed in gaps in the channel walls to maintain flows within the channel. For some sites, the low-flow channels included boulders within the channel to create a velocity break and cover for migratory fish. Similarly, some of the low-flow channels were constructed with a meandering design to diversify flows and create resting areas for fish during their upstream migration.

Upon construction of the low-flow channel at a site, weirs were constructed to direct migratory fish (directional weirs) and to augment flows (flow-augmenting weirs) through constructed low-flow channels. Directional weirs were placed at the downstream extent of problem areas that were adjacent to the low-flow channels. The problem areas were typically characterized by boulder gardens, 'broken' thalwegs, and a lack of water depth for fish migration. The weirs connected with the downstream extent of low-flow channels to assist with guiding migratory Arctic Char towards the newly created channels. Weirs designated for augmenting flows were installed at the upstream extent of low-flow channels. The flow-augmenting weirs were constructed from either the left or right downstream bank, whichever side had the greatest quantity of water to divert towards the constructed channel. The objective was to provide additional water directed towards the constructed low-flow channel to increase water depths. The method for constructing weirs was similar to the principles used for the low-flow channel boundaries. Large boulders made up the base, with smaller boulders and cobble substrate positioned to armor the structure and fill any gaps.



3.1.1 Environmental Data

A suite of environmental data, including water temperature and creek discharge measurements, were collected during the baseline program and summarized in the baseline report (Golder 2016). Common habitat types were also described throughout the entirety of the creek as part of continued baseline studies (see Golder 2016). Site-specific habitat data were also collected at each of the remediation sites.

Habitat types were described at each problem site prior to remediation. Identification of habitat types followed a modified classification by Hawkins et al. (1993), which included:

- riffle = moderately high velocity water (0.5 to 1.0 m/s); surface broken due to submerged and/or exposed bed material; coarse substrate; usually less than 0.5 m deep
- run = generally deep, typically slow flowing water (0.05 to 1.0 m/s); coarse substrate; irregular, rarely broken surface; deeper water has more in-stream cover and higher class rank (Class 1 to 3)
- pool = a discrete section of increased depth and lower water velocities (0.05 to 0.3 m/s); substrate is variable; deeper water has more in-stream cover and higher class rank (Class 1 to 3)
- flat = section characterized by low gradient, smooth water surface, reduced velocity relative to run habitats and differentiated from pool habitat by high channel uniformity
- boulder garden = dominating occurrence of large boulders providing instream cover; in association with an overall channel unit such as riffle or run

Channel depth, velocity, and substrate composition were also measured. Data were collected every 2 m along the assumed thalweg of the proposed channel pre- and post-construction to confirm improvements to fish passage. Velocity and depth were measured using Swoffer™ Model 2100 water velocity meter and top-set wading rod. Substrate composition was determined by assessing the relative abundance of substrate types within a 1-m² area at each 2-m sampling interval. Substrates were classified using a modified Wentworth scale as follows:

- boulder (Bo) = greater than 256 mm diameter
- cobble (Co) = 64 to 256 mm diameter
- gravel (Gr) = 2 to 64 mm diameter
- fines (Fi) = less than 2 mm diameter

Pre- and post-construction photographs were also taken at the downstream, center, and upstream extent of the low-flow channels with upstream and downstream orientations. An additional measurement of low-flow channel wetted width was also collected during the post-construction survey.

4.0 RESULTS

4.1 Community Engagement

As a local partner, the HTO provided community involvement in nearly all aspects of the project. Equipment, and field personnel were contracted locally by the HTO whenever possible. Five local students, two bear monitors, two camp cooks, one camp supervisor, and five boat captains were provided by the HTO and joined Golder staff in the field to participate in the remediation program (Table 4-1). The HTO manager provided logistical support in



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Kugluktuk. Equipment vital to the successful completion of the project provided by the HTO included, but was not limited to, boats, ATV's, ATV trailers, generators, a local cabin, and wall tents (Appendix A; Photo 3 to 5).

Over the 11-day period in July 2016, Golder staff, local students, and community members worked together in the field sharing traditional and scientific knowledge with each other (Photo 4-1 to 4-4). Golder staff discussed and demonstrated scientific monitoring techniques for Arctic Char and discussed conservation issues as they relate to Nulahugyuk Creek. Discussion topics included the benefits of creek remediation for the Bernard Harbour Arctic Char stock. Community members and students shared their local knowledge of the fishery, personal experiences on the land, and historically significant archeological sites within the Bernard Harbour area. Outside of daily work tasks, Golder staff and local students engaged each other during game nights, career development discussions, and a fish biology lesson instructed by Golder staff. The biology lesson gave students the opportunity to dissect juvenile Arctic Char and learn about Arctic Char internal anatomy (Photo 4-1, Appendix A; Photo 1). Students were also encouraged to assist with ongoing baseline monitoring, including trap checks and processing fish (Photo 4-2, Appendix A; Photo 2). Upon return to Kugluktuk, the feedback from the manager of the HTO (Johnny Nivingalok) was that the students enjoyed the experience at Bernard Harbour.

Table 4-1: Field Personnel Involved in the 2016 Nulahugyuk Creek Remediation Project

Name	Role
Eztiaan Groenewald	Golder Aquatic Biologist
Corby Shurgot	Golder Aquatic Biologist
Johnny Nivingalok	Logistical Support
Adrian Kudlak	HTO Bear Monitor
Perry Klengenberg	HTO Bear Monitor
Cathy Anablak	HTO Field Assistant
Andrew J Atatahak	HTO Field Assistant
Evan Nivingalok	HTO Student
Antoin Nivingalok	HTO Student
Kaelan Panioyak	HTO Student
Keegen Taptuna	HTO Student
Amber Adjun	HTO Student
David Enogaloak	Camp Supervisor
Margo Nivingalok	Camp Cook/Attendant
Shirly Hatogina	Camp Cook/Attendant
Jack Himiak	Boat Captain
Shaun Klengenberg	Boat Mate
Richard Akana	Boat Captain
OJ Bernhardt	Boat Mate
Jonathan Niptanatiak	Boat Captain



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-1: Local student dissecting a juvenile Arctic Char as part of a biology lesson provided by Golder staff. 23 July 2016.

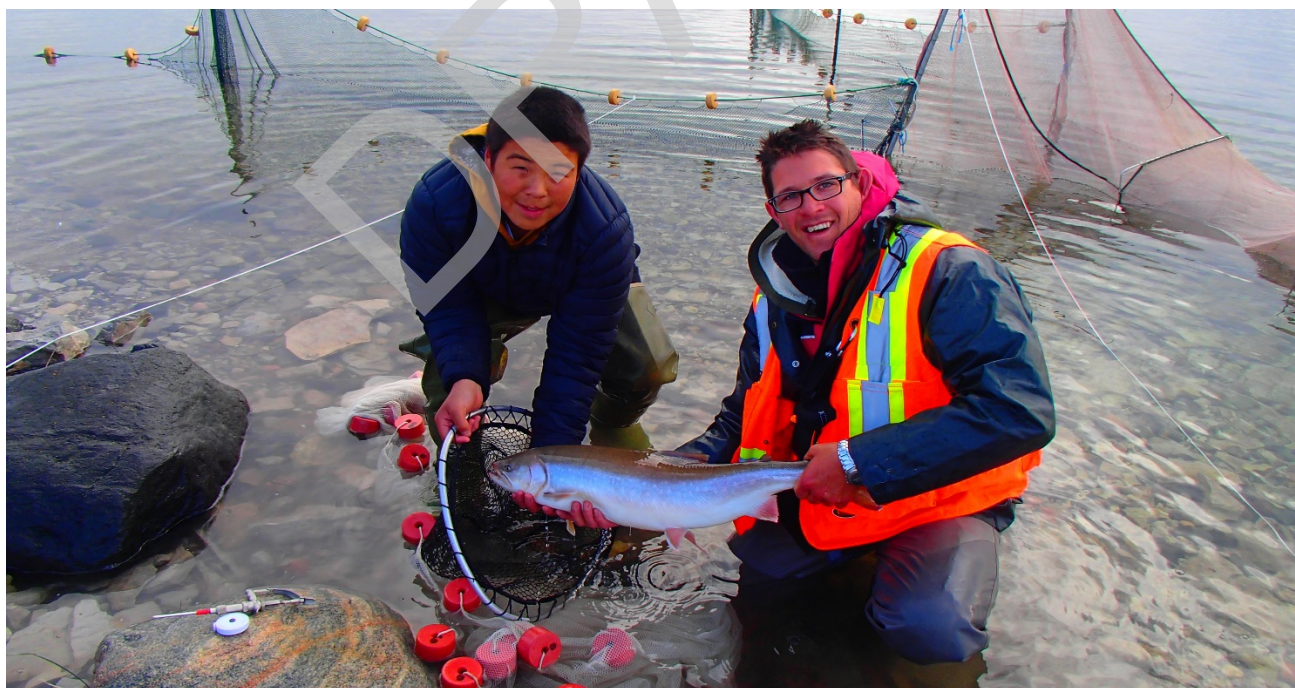


Photo 4-2: Local student and Golder aquatic biologist processing a captured Arctic Char. 21 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-3: Local student and field assistants constructing the low-flow channel at Site 1. 18 July 2016.



Photo 4-4: Local student and field assistants participating in the removal of a rock barrier at Site 13. 24 July 2016.



4.2 Remediation Results

4.2.1 Overview

A total of 13 sites in the creek were manipulated during the 2016 remediation program (Table 4-2). The sections were characterized by low water levels, dispersed flows through boulder gardens, and a lack of connectivity between navigable sections of creek. The remediation sites were located 1.4 to 7.9 km upstream of the mouth of Nulahugyuk Creek. Ten sites were located within the lower 3.1 km of the creek, with only three sites occurring further upstream. Each problem area took 4 to 10 people and less than 2.25 hours in duration to remediate, where enhanced sections ranged in length from 10 to 110 m. A total of 17 low-flow channels and 11 directional weirs were constructed during the project, resulting in a total of 597 m of manipulated creek bed (Table 4-2).

Table 4-2: Site Locations and Summary of Effort for the 2016 Nulahugyuk Creek Remediation Program

Site ID	Date	Site Location ^a (Zone 11 W)		Distance to Creek Mouth ^b (km)	Golder Staff (#)	HTO Staff (#)	HTO Students (#)	Duration (h)	Length ^c (m)	Low-flow Channels (#)	Weirs (#)
		Easting	Northing								
1	18-Jul	591281	7627022	1.40	2	2	5	2.25	110	1	2
2	18-Jul	591206	7626879	1.63	2	2	5	1.25	76	2	2
3	19-Jul	591164	7626841	1.68	2	1	3	0.75	33	1	1
4	19-Jul	590926	7626616	2.02	2	1	5	1.25	57	2	1
5	20-Jul	590826	7626554	2.14	2	1	5	1.25	35	1	1
6	21-Jul	590558	7626411	2.51	2	1	5	1.25	33	1	0
7	24-Jul	590173	7626215	3.05	2	1	5	1.0	46	2	1
8	23-Jul	589989	7625427	4.86	2	2	5	1.0	18	1	0
9	23-Jul	589243	7625158	5.75	2	2	5	1.0	35	1	1
10	22-Jul	587564	7624538	7.88	2	1	1	1.0	60	3	1
11	20-Jul	590813	7626475	2.21	2	1	5	1.25	45	1	0
12	21-Jul	590673	7626400	2.40	2	1	5	1.25	39	1	1
13	24-Jul	590132	7626189	3.09	2	1	5	0.25	10	0	0

^a Location is based on downstream extent of site.

^b Approximate distance upstream of Bernard Harbour measured to the downstream extent of project.

^c Site length is a cumulative distance of all low-flow channels and direction weirs constructed during remediation efforts.
km=kilometre; #=number; h=hours; m=metres

4.2.2 Post-Remediation Changes in Flows

Pre-manipulation mean depths within the thalweg of proposed low-flow channels ranged from 5.0 to 14.0 cm and velocities ranged from 0.07 to 0.46 m/s (Table 4-3). In all cases, remediation efforts increased flows at the assumed thalweg location where low-flow channels were constructed. Post-manipulation mean depths within the thalweg of the constructed low-flow channels ranged from 12 to 19 cm and velocities ranged from 0.35 to 0.64 m/s. (Table 4-3). Overall, mean water depth increased by 5.6 cm, or by 69% post-manipulation. The mean wetted width of constructed low-flow channels was 2.9 m and ranged from 2.0 to 4.7 m. During the timeframe of the remediation project, maximum and minimum discharges recorded in Nulahugyuk Creek were 0.26 m³/s and 0.17 m³/s, respectively (Table 4-3).



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-3: Low-flow Channel Depths and Velocities at Site Locations Pre-and Post- Remediation

Site and Channel ID	Date	Discharge (m ³ /s)	Mean Depths (cm)			Mean Velocity (m/s)			Mean Wetted Width ^b (m)
			Pre	Post	% Change	Pre	Post	% Change	
Site 1	18-Jul-16	0.264	9	14	55.6	0.36	0.58	61.1	3.0
Site 2 LDB	18-Jul-16	0.264	10	13	30.0	0.34	0.48	41.2	3.1
Site 2 Centre	18-Jul-16	0.264	11	16	45.5	0.45	0.53	17.8	2.8
Site 3	19-Jul-16	0.248	12	15	25.0	0.35	0.56	60.0	4.0
Site 4 Centre	19-Jul-16	0.248	10	15	50.0	0.32	0.49	53.1	2.9
Site 4 RDB	19-Jul-16	0.248	8	14	75.0	0.21	0.43	104.8	2.3
Site 5	20-Jul-16	0.214	7	13	85.7	0.07	0.35	400.0	2.1
Site 6	21-Jul-16	0.218	10	17	70.0	0.26	0.45	73.1	3.2
Site 7 LDB	24-Jul-16	0.171	8	14	75.0	0.27	0.49	81.5	2.2
Site 7 RDB	24-Jul-16	0.171	8	19	137.5	0.23	0.43	87.0	2.4
Site 8	23-Jul-16	0.191	6	13	116.7	0.12	0.53	341.7	2.0
Site 9	23-Jul-16	0.191	5	12	140.0	0.12	0.4	233.3	2.2
Site 10 LDB	22-Jul-16	0.214	8	12	50.0	0.34	0.38	11.8	4.7
Site 10 Centre	22-Jul-16	0.214	7	13	85.7	0.46	0.64	39.1	2.9
Site 10 RDB	22-Jul-16	0.214	10.0	13	30.0	0.5	0.61	22.0	3.4
Site 11	20-Jul-16	0.214	14.0	18	28.6	0.26	0.55	111.5	3.4
Site 12	21-Jul-16	0.218	9.0	16	77.8	0.19	0.36	89.5	3.4
Site 13 ^a	24-Jul-16	0.171	NA	NA	NA	NA	NA	NA	NA

^a This project did not require the construction of a low-flow channel; therefore, no site characteristics data was collected

^b Wetted width measured once low-flow channels were constructed

LDB=left downstream bank channel; RDB=right downstream bank channel; Centre=centre channel; cm=centimetre; m=metre; m/s=metres per second; m³/s= metres cubed per second; NA=not available

4.2.3 Post-Remediation Changes in Substrate Composition

Pre-manipulation mean substrate composition across all remediation sites consisted of 58% cobble, 27% boulder, and 15% gravel. Cobble substrate composition ranged from 36 to 79%, boulder substrate ranged from 5 to 48%, and gravel substrate ranged from 5 to 59%. After low-flow channels were constructed, mean substrate composition consisted of 53% cobble, 43% gravel, and 4% boulder. Cobble substrate composition ranged from 29 to 81%, boulder substrate ranged from 0 to 19%, and gravel substrate ranged from 19 to 71% (Table 4-4).

Cobble remained the dominant substrate within all remediated sites, with only a 6% decrease in mean occurrence post-remediation. Mean boulder substrate occurrence within problem areas decreased by 89% post-remediation. The largest change in substrate was the occurrence of gravel. After low-flow channels were constructed, mean gravel substrate increased by 304% within the low-flow channels (Table 4-4).



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-4: Low-flow Channel Substrate Composition at Site Locations Pre- and Post- Remediation

Site and Channel ID	Boulder (%)			Cobble (%)			Gravel (%)		
	Pre	Post	% Change	Pre	Post	% Change	Pre	Post	% Change
1	25.0	0.0	-100.0	70.0	45.0	-35.7	5.0	55.0	1000.0
2-LDB	13.5	0.5	-96.3	78.5	69.0	-12.1	8.0	30.5	281.3
2-Centre	11.3	0.0	-100.0	71.2	61.3	-14.0	17.5	38.8	121.4
3	13.8	0.0	-100.0	65.6	80.6	22.9	20.6	19.4	-6.1
4-Centre	32.5	5.0	-84.6	53.3	62.1	16.4	14.2	32.9	132.3
4-RDB	22.1	1.8	-91.7	55.8	51.3	-8.0	22.1	46.8	111.8
5	47.5	18.6	-60.9	42.5	43.2	1.7	10.0	38.2	282.1
6	45.0	4.4	-90.3	52.5	75.6	44.1	2.5	20.0	700.0
7-LDB	40.9	8.2	-80.0	50.9	47.7	-6.2	8.2	44.1	439.0
7-RDB	36.0	6.5	-81.9	55.5	68.0	22.5	8.5	25.5	200.0
8	45.5	5.0	-89.0	44.5	42.0	-5.6	10.0	53.0	430.0
9	34.2	0.0	-100.0	55.8	51.2	-8.3	10.0	48.9	388.5
10-LDB	5.0	0.0	-100.0	36.3	28.8	-20.7	58.8	71.3	21.3
10-Center	24.0	0.0	-100.0	64.0	34.0	-46.9	12.0	66.0	450.0
10-RDB	10.0	0.0	-100.0	66.0	46.0	-30.3	24.0	54.0	125.0
11	28.7	11.3	-60.6	57.2	58.9	3.0	14.1	29.8	110.8
12	31.7	8.3	-73.7	58.0	42.3	-27.0	10.3	49.3	377.5
13 ^a	NA	NA	NA	NA	NA	NA	NA	NA	NA

^a This project did not require the construction of a low-flow channel; therefore, no substrate characteristics data was collected LDB=left downstream bank channel; RDB=right downstream bank channel; Centre= centre channel; %=percent; NA=not available

4.3 Site Remediation Reports

The following tables provide a detailed summary of the remediation sites on Nulahugyuk Creek. The tables include notes of pre- and post-remediation conditions, the final designs of the low-flow channels and any connecting weirs, as described in the field. Each table follows with photographs of each remediation site.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-5: Remediation Site 1 Report, Nulahugyuk Creek, 18 July 2016

Date:	18 July 2016	Start (creek km):	1.40	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Andrew J Atatahak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m ³ /s):	0.264	End (creek km):	1.47	
Duration (hrs):	2.25	Start Easting:	591281	
Number of Persons:	9	Start Northing:	7627022	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 38 m wide, and located downstream of a sharp bend in the creek. Flows were dispersed across the creek with flow concentrated near the left downstream bank (LDB) at the upstream extent and near the right downstream bank (RDB) at the downstream extent. Shallow riffle habitat (and shallow thalweg) connected the concentrated flows between banks. Deeper water (0.4 m) along the LDB at the downstream extent of problem area provided suitable habitat as cover or refugia for fish to rest during upstream migration. Fish passage may be impeded along the RDB due to lack of depth and the presence of a boulder garden with several sections of dry streambed. Similarly, passage along the LDB was restricted due to dispersed flows through cobble and boulder substrates. Site 1 was ranked as a risk level 3-highest priority for remediation. See Photo 4-5 and Photo 11 and 12 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	65	Centre connecting RDB to LDB diagonally	Photo 4-6; Photo 13 and 14 in Appendix A
Weir A	13	Centre towards channel A	Photo 15 in Appendix A
Weir B	22	RDB toward channel A	Photo 16 in Appendix A

Construction Notes:

Site 1 was the longest low-flow channel of those constructed, and required the most effort to complete compared to all remediation sites. Due to the length of the low-flow channel, a meandering design was added by modifying the boundaries of the channel to create velocity breaks (e.g., refugia) within the channel for migratory fish (Photo 13 in Appendix A). At the upstream extent of the channel, a gap was maintained on the left downstream boundary to allow passage around a small island where sufficient flows were present on both sides (Photo 14 in Appendix A). Due to the lack of large boulders within the problem area, the small to medium-sized substrate along channel boundaries may be susceptible to movement during spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	25	0	70	45	5	55	9	14	0.36	0.58	3.0

Post-remediation Site Evaluation:

A passage free of obstructions (e.g., boulder/cobble bars) was established. Substrates were dominated by gravel and small cobble post-manipulation. Weirs were constructed at the downstream end of channel to direct migratory fish towards the channel and away from problem areas. Mean water depths and velocities within the identified thalweg increased by 56 and 61 %, respectively, due to removal of large substrate and directed flows within the channel.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Date & Time: Mon Jul 18 09:39:08 MDT 2016
Position: 11 N 590716 7627793
Altitude: 10m
Datum: NORTH AMERICAN 1983, Canada
Azimuth/Bearing: 118° S62E 2098mils (True)
Elevation Grade: -015%
Horizon Grade: -000%
Zoom: 1X



Photo 4-5: Upstream view of thalweg from the downstream extent of Site 1 prior to remediation. 18 July 2016.



Photo 4-6: Upstream view from elevated RDB showing low-flow channel and weirs constructed during remediation at Site 1. 18 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-6: Remediation Site 2 Report, Nulahugyuk Creek, 18 July 2016

Date:	18 July 2016	Start (creek km):	1.63	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Andrew J Atatahak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m ³ /s):	0.264	End (creek km):	1.67	
Duration (hrs):	1.25	Start Easting:	591206	
Number of Persons:	9	Start Northing:	7626879	

Pre-remediation Habitat Description:

The site was within a stream section approximately 48 m wide, and was characterized by riffle habitat dominated by cobble/boulder substrate. Flows were dispersed across the creek, with most of the flow concentrated along the centre of channel at the upstream extent and near the LDB at the downstream extent. Fish passage may be impeded along the LDB at the downstream extent of problem area due to lack of water depth and presence of a boulder garden further upstream. The thalweg was difficult to locate, and there was no obvious continuous route for fish passage. Site 2 was ranked as a risk level 2 with a medium priority for remediation. See Photo 4-7 and Photo 17 and 18 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	21	LDB diagonally towards centre	Photo 4-8; Photo 19 to 20 in Appendix A
Low-Flow Channel B	35	Centre of creek	Photo 4-8; Photo 19 to 20 in Appendix A
Weir A	9	LDB towards Channel A	Photo 21 in Appendix A
Weir B	11	Upstream extent of right downstream boundary of Channel B	Photo 22 in Appendix A

Construction Notes:

Due to dispersed flows and the presence of cobble bars across a relatively wide area of the creek, two low-flow channels were constructed. A natural cobble bar was maintained as the centre boundary between the two low-flow channels (Photos 18 to 20 in Appendix A; Photo 4-8). Weir A eliminated potential migration upstream along the LDB, where barriers were present further upstream. Weir B was installed at the upstream extent of channel B to augment flows towards the constructed channel.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	13.5	0.5	78.5	45.0	8.0	55.0	10	13	0.34	0.48	3.1
Low-Flow Channel B	11.3	0.0	71.2	69.0	17.5	30.5	11	16	0.45	0.53	2.8
Overall	12.4	0.3	74.9	65.1	12.7	34.6	10	15	0.40	0.51	3.0

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel where large cobble and small boulders were once prevalent. Weirs were constructed to direct fish away from problem areas and also to increase flow depths within the channels. Mean thalweg water depth and velocity within the low-flow channels increased by 38 and 30 %, respectively. The channels are expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-7: Upstream view of thalweg from the downstream extent of Site 2 prior to remediation. Note the exposed substrate along the LDB. 18 July 2016.



Photo 4-8: Upstream view of low-flow channel A including upstream extent of low-flow channel B (top-left) at Site 2. 18 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-7: Remediation Site 3 Report, Nulahugyuk Creek, 19 July 2016

Date:	19 July 2016	Start (creek km):	1.68	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m³/s):	0.248	End (creek km):	1.71	
Duration (hrs):	0.75	Start Easting:	591164	
Number of Persons:	6	Start Northing:	7626841	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 61 m wide, located downstream of a sharp bend in the creek, and was characterized by riffle habitat dominated by cobble/boulder substrate. Flows were dispersed across the creek, with a discernible thalweg along the RDB connecting to a large pool at the upstream extent of the problem area, this pool is also the downstream extent of Project 3 (Golder 2013). A continuous route for fish passage from the centre of the creek towards the LDB was lacking due to shallow depths, no discernible thalweg, and the presence of a boulder garden with several sections of dry streambed. Site 3 was ranked as a risk level 2 with a medium priority for remediation. See Photo 4-9 and Photo 23 and 24 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	11	RDB	Photo 4-10; Photo 25 in Appendix A
Weir A	12	Centre towards Channel A	Photo 4-10; Photo 26 in Appendix A

Construction Notes:

Since an obvious thalweg along the RDB was present prior to remediation, low-flow channel A did not require heavily armoured boundaries, involving only the removal of some boulders and large cobble from within the low-flow channel (Photo 4-10, Photo 25 in Appendix A). Due to dispersed flows and the presence of cobble bars across most of the centre and LDB of the creek, weir A was constructed to deter fish passage and direct fish along the RDB thalweg (Photo 4-10, Photo 26 in Appendix A).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	13.8	0.0	65.6	80.6	20.6	19.4	12	15	0.35	0.56	4.0

Post-remediation Site Evaluation:

Substrates post-remediation were dominated by small cobble and gravel, where large cobble and small boulders were once prevalent. A weir was constructed at the downstream extent to direct migratory fish away from problem areas and towards the channel. Mean thalweg depth and velocity within the low-flow channels increased by 25 and 60 %, respectively. The channel is expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-9: Upstream view of thalweg from the downstream extent of Site 3 prior to remediation. Note the pool at the upstream extent along the RDB. 19 July 2016.



Photo 4-10: Upstream view of low-flow channel A and Weir A at Site 3 post-remediation. Note the directional weir facilitating fish passage towards the channel and away from problem area. 19 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-8: Remediation Site 4 Report, Nulahugyuk Creek, 19 July 2016

Date:	19 July 2016	Start (creek km):	2.02	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m ³ /s):	0.248	End (creek km):	2.07	
Duration (hrs):	1.25	Start Easting:	590926	
Number of Persons:	8	Start Northing:	7626616	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 33 m wide, and was characterized by riffle habitat dominated by a cobble/boulder substrate. Flows were dispersed across the creek, with most of the flow concentrated along the RDB and LDB. Fish passage may be impeded and any stranding in this area was likely due to lack of water depth and presence of boulder gardens across the entire creek within the problem area. The thalweg was difficult to locate, and there was no obvious continuous route for fish passage. Site 2 was ranked as a risk level 2 with a medium priority for remediation. See Photo 4-11 and Photo 27 and 28 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	33	RDB	Photo 4-12; Photo 30 to 31 in Appendix A
Low-Flow Channel B	16	Centre diagonally towards LDB	Photo 4-12; Photo 29 and 32 in Appendix A
Weir A	8	Centre towards Channel A	Photo 31 in Appendix A

Construction Notes:

Due to dispersed flows and the presence of boulder gardens across a relatively wide area of the creek, two low-flow channels were constructed. Natural concentrations of flow along the RDB and LDB were utilized to create two paths for fish passage (Photo 29 to 30 in Appendix A; Photo 4-12). Weir A eliminated potential migration upstream between the constructed low-flow channels where stranding was likely (Photo 31 in Appendix A). Large boulders were left within both constructed channels to create velocity breaks and cover for migratory fish (Photo 32 in Appendix A).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	22.1	1.8	55.8	51.4	22.1	46.8	8	14	0.21	0.43	2.3
Low-Flow Channel B	32.5	5.0	53.3	62.1	14.2	32.9	10	15	0.32	0.49	2.9
Overall	27.3	3.4	54.6	56.7	18.1	39.9	9	15	0.27	0.46	2.6

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel, where large cobble and boulders were once prevalent. The two constructed low-flow channels are predicted to allow fish passage along either bank of the creek. The weir between the channels directs fish away from problem areas. Mean thalweg water depths and velocities within the low-flow channels increased by 63 and 46%, respectively. The channels are expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-11: Upstream view of the RDB from the downstream extent of Site 4 prior to remediation. Note the lack of discernible channel across the creek. 19 July 2016.



Photo 4-12: Upstream view of low-flow channels A and B constructed at Site 4. 19 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-9: Remediation Site 5 Report, Nulahugyuk Creek, 20 July 2016

Date:	20 July 2016	Start (creek km):	2.14	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m³/s):	0.214	End (creek km):	2.17	
Duration (hrs):	1.25	Start Easting:	590826	
Number of Persons:	8	Start Northing:	7626554	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 44 m wide and was characterized by run/riffle habitat dominated by boulder substrate. Flows dispersed across the creek, with most of the flow concentrated along the centre of channel at the upstream extent and near the LDB at the downstream extent. A continuous route for fish passage was lacking along the LDB and towards the centre of the creek due to shallow depths, no discernible thalweg, and the presence of a boulder garden with several sections of dry streambed. A large pool suitable as refugia was present at the upstream extent within the centre of the creek. Site 5 was ranked as a risk level 3-highest priority for remediation. See Photo 4-13 and Photo 33 to 34 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	26	LDB diagonally towards centre	Photo 4-14; Photo 35 in Appendix A
Weir A	9	LDB towards channel A	Photo 36 in Appendix A

Construction Notes:

Due to the extensive boulder garden present, the low-flow channel was difficult to clear entirely of boulders. Several boulders were too large or too embedded within the streambed to be relocated (Photo 4-14; Photo 35 in Appendix A). The channel was narrowly constructed to reduce the amount of boulders to be removed. Due to the dry streambed located upstream along the LDB of the creek, a weir was constructed to deter fish passage along LDB and to direct fish towards the low-flow channel (Photo 36 in Appendix A).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	47.5	18.6	42.5	43.2	10.0	38.2	7	10	0.07	0.35	2.1

Post-remediation Site Evaluation:

Substrates post-remediation were dominated by small cobble and gravel, where boulders and large cobble were once prevalent. Some large boulders remained within the low-flow channel to act as velocity breaks and cover for migratory fish. A weir was constructed at the downstream extent to direct migratory fish away from problem areas and towards the low-flow channel. Mean thalweg water depth and velocity within the low-flow channel increased by 85 and 400%, respectively. Prior to remediation, a continuous path for fish passage was lacking; however, the low-flow channel connected upstream and downstream habitats and is expected to facilitate upstream movements of fish.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-13: Upstream view of problem area from the downstream extent of Site 4 prior to remediation. Note the lack of discernible channel. 20 July 2016.



Photo 4-14: Upstream view of low-flow channel A from the downstream extent of Site 4 post-remediation. Note the large boulders left within channel. 20 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-10: Remediation Site 6 Report, Nulahugyuk Creek, 21 July 2016

Date:	21 July 2016	Start (creek km):	2.51	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m³/s):	0.218	End (creek km):	2.52	
Duration (hrs):	1.25	Start Easting:	590558	
Number of Persons:	8	Start Northing:	7626411	

Pre-remediation Habitat Description:

The problem area was located within a meandering bend of the creek, approximately 65 m wide, and was characterized by run/riffle habitat dominated by cobble/boulder substrate. A large, deep pool (>0.5 m deep) suitable as refugia for fish was present at the downstream extent of the problem area with flows dispersed across the creek further upstream. At the upstream extent of problem area, most of the flow was concentrated along the centre of channel. A discernible shallow thalweg connected the two sections of stream; however, flow was dispersed through cobble and boulder gardens with a high potential for fish stranding. Site 6 was ranked as a risk level 3-highest priority for remediation. See Photo 4-15 and Photo 37 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	33	LDB curving diagonally towards centre	Photo 4-16; Photo 38 in Appendix A

Construction Notes:

Placement of the low-flow channel at Site 6 was difficult to determine due to dispersed flows entering a large pool at the downstream extent. Flows were concentrated along the centre of channel bending sharply towards the upstream extent of pool. These flows were used to guide the angle of low-flow channel construction. Due to the curvature of the low-flow channel, extra armouring at the bend was required along the right downstream boundary in order to maintain flows within the channel. Several boulders were too large or too embedded within the streambed to be relocated (Photo 4-16, Photo 38 in Appendix A).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	45.0	4.4	52.5	75.6	2.5	20.0	10	17	0.26	0.45	3.2

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel, where boulders and large cobble were once prevalent. Some large boulders remained within the channel to act as velocity breaks and cover for migratory fish. Mean thalweg water depth and velocity within the low-flow channel increased by 70 and 73%, respectively. Prior to remediation, a continuous path for fish passage was lacking at the site; however, the manipulation of the substrate connected habitats and remediation is expected to facilitate upstream movements of fish and reduce the potential for stranding and mortality.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-15: Upstream view of the problem area from the downstream extent of Site 6 prior to remediation. Note the lack of a discernible channel. 21 July 2016.



Photo 4-16: Upstream view of low-flow channel as viewed from elevated LDB at Site 6 post-remediation. Note the large pool at the downstream extent of the low-flow channel. 21 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-11: Remediation Site 7 Report, Nulahugyuk Creek, 24 July 2016

Date:	24 July 2016	Start (creek km):	3.05	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m ³ /s):	0.171	End (creek km):	3.07	
Duration (hrs):	1.0	Start Easting:	590173	
Number of Persons:	8	Start Northing:	7626215	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 37 m wide and was characterized by run/riffle habitat dominated by boulder/cobble substrate. A large, deep pool (>0.4 m deep) suitable as refugia for fish was present along the LDB at the downstream extent with flows dispersed across the creek further upstream. At the upstream extent of the problem area, most of the flow was concentrated along the RDB. A discernible shallow thalweg connected the two sections of the stream; however, flow was dispersed through cobble and boulder gardens with a high potential for fish stranding. Fish passage may be impeded upstream along the LDB due to lack of water depth, no discernible thalweg, and the presence of a boulder garden with several sections of dry streambed. Site 7 was ranked as a risk level 2 with a medium priority for remediation. See Photo 4-17 and Photo 39 and 40 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	16	LDB diagonally towards RDB	Photo 41 to 42 in Appendix A
Low-Flow Channel B	18	Centre diagonally towards RDB	Photo 4-18; Photo 42 in Appendix A
Weir A	12	LDB diagonally towards channel A	Photo 43 in Appendix A

Construction Notes:

Due to dispersed flows and the presence of boulder gardens across a wide area of the creek, two low-flow channels were constructed at Site 7. Natural concentrations of flow along the RDB and LDB were used to create two routes for fish passage (Photo 41 to 42 in Appendix A; Photo 4-18). Weir A eliminated potential migration upstream along the LDB where stranding was likely (Photo 43 in Appendix A). Some boulders were too large or too embedded to relocate and were left within constructed channels to act as velocity breaks and cover for migratory fish (Photo 41 to 42 in Appendix A; Photo 4-18).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	40.9	8.2	50.9	47.7	8.2	44.1	8	14	0.27	0.49	2.2
Low-Flow Channel B	36.0	6.5	55.5	68.0	8.5	25.5	8	19	0.23	0.43	2.4
Overall	38.5	7.3	53.2	57.9	8.3	34.8	8	17	0.25	0.46	2.3

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel where large cobble and boulders were once prevalent. The two constructed low-flow channels create a continuous path across the creek, connecting the banks of the creek. The weir directs fish away from problem areas upstream along the LDB and towards the low-flow channels. Mean thalweg water depth and velocity within the low-flow channels increased by 106 and 84%, respectively. The low-flow channels are expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-17: Downstream view of the location of low-flow channel B from the upstream extent of Site 7 prior to remediation. Note the absence of a continuous channel connecting to the pool along the LDB at the downstream extent. July 24, 2016.



Photo 4-18: Downstream view of low-flow channel B from the upstream extent of Site 7 post-remediation. Note connectivity with the pool along the LDB at the downstream extent. 24 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-12: Remediation Site 8 Report, Nulahugyuk Creek, 23 July 2016

Date:	23 July 2016	Start (creek km):	4.86	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun, Adrian Kudlak.
Discharge (m³/s):	0.191	End (creek km):	4.87	
Duration (hrs):	1.0	Start Easting:	589989	
Number of Persons:	9	Start Northing:	7625427	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 34 m wide and was characterized by run/riffle habitat dominated by cobble/boulder substrate. A clear thalweg suitable for fish passage was present along the RDB; however, flows also dispersed across the centre of creek from a small pool with suitable flows further upstream located along the LDB. An unobstructed route for fish passage was absent between the RDB and the LDB. Site 8 was ranked as a risk level 1-lowest priority for remediation. See Photo 4-19 and Photo 44 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	18	RDB diagonally towards LDB across centre of creek	Photo 4-20; Photo 45 to 46 in Appendix A

Construction Notes:

Due to the presence of a clear thalweg along the RDB, the low-flow channel at Site 8 was constructed to provide an alternative passage across the centre of creek (Photo 45 to 46 in Appendix A). The low-flow channel connected to a small pool with suitable flows for fish passage along the LDB. (Photo 45 in Appendix A). Some large boulders were left within the constructed channel to provide refugia for migratory fish (Photo 4-20). Due to the availability of large boulders, the boundaries of the low-flow channel are well armoured and are expected to withstand spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	45.5	5.0	44.5	42.0	10.0	53.0	6	13	0.12	0.53	2.0

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel, where boulders and large cobble were once prevalent. Some large boulders remained within channel to act as velocity breaks and cover for migratory fish. Mean thalweg water depth and velocity within the low-flow channel increased by 117 and 342%, respectively. Prior to remediation, a continuous unobstructed route for fish passage across the creek was not available; however, after manipulation of the substrate, the low-flow channel connected habitats. Remediation is expected to facilitate upstream movements of fish and reduce the potential for stranding and mortality.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-19: Upstream view of the problem area facing the LDB at Site 8 prior to remediation. Note the absence of a continuous migratory channel across centre of creek. 23 July 2016.



Photo 4-20: Upstream view of the low-flow channel constructed at Site 8. Note the large boulders left in the low-flow channel to act as velocity breaks and cover for fish. 23 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-13: Remediation Site 9 Report, Nulahugyuk Creek, 23 July 2016

Date:	23 July 2016	Start (creek km):	5.75	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun, Adrian Kudlak.
Discharge (m³/s):	0.191	End (creek km):	5.77	
Duration (hrs):	1.0	Start Easting:	589243	
Number of Persons:	9	Start Northing:	7625158	

Pre-remediation Habitat Description:

The problem location was within a creek section approximately 31 m wide, and was characterized by run/riffle habitat and cobble/boulder substrate. Flows were dispersed across the creek, with some flow concentrated along the RDB of the stream at the upstream extent and near the LDB at the downstream extent. There was no continuous unobstructed route for fish passage along the LDB and towards the centre of the creek due to the presence of a boulder garden with several sections of dry streambed. A small pool suitable as refugia was present at the downstream extent of the problem area along the LDB. Site 9 was ranked as a risk level 1-lowest priority for remediation. See Photo 4-21 and Photo 47 to 48 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	27	LDB diagonally towards RDB across centre of creek	Photo 4-22; Photo 49 in Appendix A
Weir A	8	LDB towards channel A	Photo 50 in Appendix A

Construction Notes:

The low-flow channel was constructed to create a path for migrating fish, connecting the concentrated flows along the LDB with flows along the RDB. Due to the length of the low-flow channel, a meandering design was added by modifying the boundaries of the channel to create velocity breaks as resting areas within the channel for migratory fish (Photo 49 in Appendix A; Photo 4-22). Due to dispersed flows and the dry streambed located upstream along the LDB of the creek, a weir was constructed to deter fish passage along the LDB and to direct fish towards the low-flow channel (Photo 50 in Appendix A). Due to the lack of large boulders within the problem area, substrate along channel boundaries may be susceptible to movement during spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	34.2	0.0	55.8	51.2	10.0	48.8	5	12	0.12	0.40	2.2

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel where large cobble and boulders were once prevalent. A meandering design was used to create velocity breaks within the channel for migratory fish. A weir was constructed at the downstream extent to direct migratory fish away from upstream problem areas and towards the low-flow channel. Mean thalweg water depth and velocity within the low-flow channel increased by 140 and 233%, respectively. The manipulation of substrates at Site 9 is expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-21: Downstream view of the problem area, facing the LDB at Site 9 prior to remediation. Note the absence of a continuous migratory channel across centre of creek. 23 July 2016.



Photo 4-22: Downstream view from above the RDB of the low-flow channel constructed at Site 8. 23 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-14: Remediation Site 10 Report, Nulahugyuk Creek, 22 July 2016

Date:	22 July 2016	Start (creek km):	7.88	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Antoin Nivingalok.
Discharge (m³/s):	0.214	End (creek km):	7.90	
Duration (hrs):	1.0	Start Easting:	587564	
Number of Persons:	4	Start Northing:	7624538	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 45 m wide, located directly upstream of a large pond. The problem area was characterized by riffle habitat dominated by a cobble substrate. Flows were dispersed through cobble bars and exposed streambed across the creek section with no obvious migratory path beyond the large pond. At the upstream extent, flow was concentrated along the RDB. Fish passage may be impeded upstream along the LDB due to shallow water depths, and several sections of dry streambed. Site 10 was ranked as a risk level 1 with a low priority for remediation. See Photo 4-23 and Photo 51 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	22	LDB	Photo 4-24
Low-Flow Channel B	15	Centre	Photo 4-24
Low-Flow Channel C	17	LDB diagonally towards RDB	Photo 52 in Appendix A
Weir A	6	LDB diagonally towards RDB	Photo 52 in Appendix A

Construction Notes:

Multiple low-flow channels were constructed for Site 10. Substrate was manipulated within concentrated flows along the RDB to construct low-flow channels A and B (Photo 4-24). Low-flow channel C was constructed across the creek to connect LDB flow with the thalweg along the RDB (Photo 52 in Appendix A). Weir A eliminated potential migration upstream along the LDB and directed fish passage towards the thalweg along the RDB (Photo 52 in Appendix A). Due to the lack of large boulders within the problem area, substrate along channel boundaries may be susceptible to movement during spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	5.0	0.0	36.3	28.8	58.8	71.3	8	12	0.34	0.38	4.7
Low-Flow Channel B	24.0	0.0	64.0	34.0	12.0	66.0	7	13	0.46	0.64	2.9
Low-Flow Channel C	10.0	0.0	66.0	46.0	24.0	54.0	10	13	0.50	0.61	3.4
Overall	13.0	0.0	55.4	36.2	31.6	63.8	8.3	12.7	0.43	0.54	3.7

Post-remediation Site Evaluation:

Post-remediation substrates were dominated by gravel where large cobble was once prevalent. The constructed low-flow channels are expected to provide continuous unobstructed paths, with the weir to direct fish away from upstream problem areas. Mean thalweg water depth and velocity within the low-flow channels increased by 55 and 24%, respectively. The remediated site is expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-23: Upstream view of problem area at Site 10 prior to remediation. Note the dispersed flows across the creek. 22 July 2016.



Photo 4-24: Upstream view of low-flow channel A and B constructed at Site 10. Note that the channel provides fish passage beyond the pond (in foreground). 22 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-15: Remediation Site 11 Report, Nulahugyuk Creek, 20 July 2016

Date:	20 July 2016	Start (creek km):	2.21	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m³/s):	0.214	End (creek km):	2.26	
Duration (hrs):	1.25	Start Easting:	590813	
Number of Persons:	8	Start Northing:	7626475	

Habitat Description:

The problem area was within a stream section approximately 36 m wide, located downstream of sharp bend in the river, and was characterized by run/riffle habitat and cobble/boulder substrate. Large boulders and deep water provide suitable refugia at the downstream extent. At the upstream extent of Site 11, a deep run habitat suitable for fish passage was present. Flows were dispersed across creek, with no discernible path for fish passage within the problem area. Flow was concentrated along the centre of creek. Site 11 was ranked as a risk level 1-lowest priority for remediation. See Photo 4-25 and Photo 53 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	45	Centre	Photo 4-26; Photo 54 to 55 in Appendix A

Construction Notes:

The low-flow channel at Site 11 was constructed within the centre of the creek where flows were concentrated. The channel connected a small pool at the downstream extent to a deep run habitat unit at the upstream extent (Photo 54 in Appendix A; Photo 4-26). Some boulders were too large to be relocated and were left within the constructed channel to provide refugia for migratory fish (Photo 55 in Appendix A). Due to the availability of large boulders, the boundaries of the low-flow channel are well armoured and are expected to withstand spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	28.7	11.3	57.2	58.9	14.1	29.8	14	18	0.26	0.55	3.4

Site Evaluation:

Post-remediation substrates were dominated by small cobble and gravel, where boulders and large cobble were once prevalent. Some of the large boulders remained within the channel to act as velocity breaks and cover for migratory fish. Mean water depths and velocities within the low-flow channel increased by 29 and 112 % respectively. It is expected that the manipulation of substrates will facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-25: Upstream view of problem area from downstream extent of Site 11 prior to remediation, note dispersed flows across creek. 20 July 2016.



Photo 4-26: Upstream view of low-flow channel at Site 11 post-remediation, note that the channel provides fish passage along the RDB of creek. 20 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-16: Remediation Site 12 Report, Nulahugyuk Creek, 21 July 2016

Date:	21 July 2016	Start (creek km):	2.40	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun, Adrian Kudlak.
Discharge (m³/s):	0.218	End (creek km):	2.42	
Duration (hrs):	1.25	Start Easting:	590673	
Number of Persons:	8	Start Northing:	7626400	

Habitat Description:

The problem area was within a stream section approximately 33 m wide, located downstream of a sharp bend in the river, and was characterized by run habitat and a dominance of cobble/boulder substrates. Flows were dispersed across the centre of creek, with some flow concentrated along the LDB of channel at the upstream extent and near the RDB at the downstream extent. Run habitat suitable for fish passage was noted along the LDB and RDB. There was no continuous unobstructed route for fish passage upstream along the RDB and towards the centre of the creek due to lack of depth, and the presence of a boulder garden with several sections of dry streambed. Site 12 was ranked as a risk level 1-lowest priority for remediation. See Photo 4-27 and Photo 56 in Appendix A.

Site Structures	Length (m)	Location in Creek	Photos
Low-Flow Channel A	24	RDB diagonally towards LDB across centre of creek	Photo 4-28; Photo 57 in Appendix A
Weir A	15	RDB towards channel A	Photo 58 in Appendix A

Construction Notes:

The low-flow channel was constructed to create an unobstructed path, connecting the run habitats suitable for migration along the RDB and LDB of the creek. A sinuosity or meandering design was added by modifying the boundaries of the channel to create velocity breaks as resting areas within the channel (Photo 57 in Appendix A; Photo 4-28). Due to dispersed flows and dry streambed located upstream along the RDB of the creek, a weir was constructed to deter fish passage along RDB and to direct fish towards the low-flow channel (Photo 58 in Appendix A). Some boulders were too large to be relocated and were left within the constructed channel to provide refugia for migratory fish (Photo 57 in Appendix A). Due to the availability of large boulders, the boundaries of the low-flow channel are well armoured and are expected to withstand spring freshet flow conditions.

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	31.7	8.3	58.0	42.3	10.3	49.3	9	16	0.19	0.36	3.4

Site Evaluation:

Post-remediation substrates were dominated by gravel and small cobble, where large cobble and boulders were once prevalent. A meandering design and large boulders were used to create velocity breaks and cover within the channel for fish. A weir was constructed at the downstream extent to direct migratory fish away from problem areas and towards the channel. Mean water depths and velocities within the low-flow channel increased by 78 and 90 % respectively. The manipulation of substrates within the creek bed is expected to facilitate upstream movements of fish and reduce the potential for stranding in the creek.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-27: downstream view of problem area looking towards RDB at Site 12 prior to remediation, note dispersed flows across creek. 21 July 2016



Photo 4-28: Downstream view of the low-flow channel constructed at Site 12 post-remediation, note that the channel provides fish passage across the creek. 21 July 2016.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS

Table 4-17: Remediation Site 13 Report, Nulahugyuk Creek, 24 July 2016

Date:	24 July 2016	Start (creek km):	3.09	Project Staff: Eztiaan Groenewald, Corby Shurgot, Cathy Anablak, Evan Nivingalok, Antoin Nivingalok, Kaelan Panioyak, Keegan Taptuna, Amber Adjun.
Discharge (m³/s):	0.171	End (creek km):	3.09	
Duration (hrs):	0.25	Start Easting:	590132	
Number of Persons:	8	Start Northing:	7626189	

Pre-remediation Habitat Description:

The problem area was within a stream section approximately 29 m wide, located upstream of a sharp bend in the creek and was characterized by run/riffle habitat and cobble/boulder substrates. Remediation Site 7 was located 30 m downstream of this problem area. A thalweg along the RDB may be suitable for fish passage under flow conditions; however, a rock barrier present in low-flow conditions may impede upstream passage. Site 13 was ranked as a risk level 1-lowest priority for remediation. See Photo 4-29.

Site Structures	Length (m)	Location in Creek	Photos
Unobstructed paths	10	Centre across thalweg	Photo 4-29

Construction Notes:

The remediation of Site 13 involved relocating a large amount of cobble and boulder substrates that may affect upstream passage of fish. Several small paths for fish migration were created (Photo 4-30).

Habitat Changes	Mean Substrate Composition (%)						Mean Depth (cm)		Mean Velocity (m/s)		Mean Wetted Width (m)
	Boulder		Cobble		Gravel						
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Low-Flow Channel A	-	-	-	-	-	-	-	-	-	-	-

Post-remediation Site Evaluation:

Prior to remediation, fish passage was likely impeded by a barrier of cobble and boulder under low-flow conditions. After substrate manipulation, several small migratory routes were established. It is expected that remediation efforts at this site will facilitate upstream movements of fish.



NULAHUGYUK CREEK HABITAT IMPROVEMENTS



Photo 4-29: Upstream view of rock barrier impeding fish passage under low-flow conditions at Site 13 prior to remediation. 24 July 2016.



Photo 4-30: Upstream view of Site 13 post-remediation. Note several small channels available to facilitate upstream migration. 24 July 2016.



5.0 SUMMARY

Golder technicians and HTO staff, including local students and other community members, worked together in the field sharing traditional and scientific knowledge towards a common goal of improving migration conditions for Arctic Char. As a local partner, the HTO provided community involvement in nearly all aspects of the project (e.g., both design and implementation of the remediation plans).

In total, habitat conditions were improved at 13 problem areas by modifying substrate to create low-flow channels for Arctic Char passage. If including previously completed remediation work by Golder (2013) in summer 2012, a total of 18 problem areas have been remediated on Nulahugyuk Creek to-date.

It is expected that the low-flow channels will extend the migration window and reduce mortalities for adult Arctic Char, and ultimately, increase the production of the local stock of Arctic Char. Future monitoring, as done in 2014 and 2016 (Golder 2015a, Golder 2016), will assist with the evaluation of the benefits of creek remediation for the fishery. Future monitoring and inspections of Nulahugyuk Creek are expected to provide continued opportunities for community involvement and integration of traditional knowledge.

DRAFT



REPORT SIGNATURE PAGE

GOLDER ASSOCIATES LTD.

DRAFT

DRAFT

Eztiaan Groenewald
Aquatic Biologist

Cameron Stevens
Associate, Aquatic Biologist

EG/CS/jr

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

[https://capws.golder.com/sites/p1545534typeawaterlicencebackriverproject/p4000_offsetting/_remediation report/report bernard harbour project 2016 remediation.docx](https://capws.golder.com/sites/p1545534typeawaterlicencebackriverproject/p4000_offsetting/_remediation%20report/report%20bernard%20harbour%20project%202016%20remediation.docx)



6.0 REFERENCES

- Fischenich C. 2002. Design of low-flow channels. EMRRP Technical Notes Collection (TN EMRRP-SR-19), U.S. Army Engineer Research and Development.
- Golder (Golder Associates Ltd.). 2013. 2012 Field Report: Stream Restoration and Community Stewardship of Arctic Char at Nulahugyuk (Bernard Harbour). Submitted to Environment Canada. Golder Project #10-1373-0075: 23 p. + appendices.
- Golder. 2015a. Back River Project: Conceptual Fish Offsetting Plan. Prepared for Sabina Gold & Silver Corp. by Golder Associates Ltd.
- Golder. 2015b. Arctic Char Run Baseline Report – 2014 Results. Report prepared for Sabina Gold & Silver Corp. Golder Project #14-1373-0004: 27 p + appendices.
- Golder. 2016. Arctic Char Run Baseline Report – 2016 Results. Report prepared for Sabina Gold & Silver Corp. Golder Project Doc 010 1545534.4000: 28 p + appendices.
- Hawkins CP, Kershner JL, Bison PA, Bryant MD, Decker LM, Gregory SV, McCullough DA, Overton CK, Reeves GH, Steedman RJ, Young MK. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.
- Stern MJ, Powell RB, Ardoin NM. 2008. What difference does it make? Assessing outcomes from participation in a residential environmental education program. Reports & Research 39: 31–43.



APPENDIX A

Project Photographs

DRAFT



APPENDIX A

Project Photographs



Photo 1: Golder aquatic biologist instructing students during fish dissection lesson. 23 July 2016.



Photo 2: Local student assisting in the measurement of fish captured during baseline monitoring study. 23 July 2016.



APPENDIX A

Project Photographs



Photo 3: HTO boat arriving on site with local students. 17 July 2016.



Photo 4: HTO boat loaded with supplied equipment prior to departure from Bernard Harbour. 25 July 2016.



APPENDIX A

Project Photographs



Photo 5: Equipment supplied by the HTO for the project. 21 July 2016.



Photo 6: Local students assisting in the construction of a low-flow channel at Site 1. 18 July 2016.



APPENDIX A

Project Photographs



Photo 7: Local students assisting in the construction of a low-flow channel at Site 2. 18 July 2016.



Photo 8: Local field assistant collecting post-construction habitat measurements at Site 4. 19 July 2016.



APPENDIX A

Project Photographs



Photo 9: Local students assisting in the construction of a low-flow channel at Site 11. 20 July 2016.



Photo 10: Local students working together to remove large boulders at Site 13. 24 July 2016.



APPENDIX A

Project Photographs

Date & Time: Mon Jul 18 09:39:27 MDT 2016
Position: 11 N 591279 7627023
Altitude: -7m
Datum: NORTH AMERICAN 1983, Canada
Azimuth/Bearing: 223° S43W 3964mils (True)
Elevation Grade: -024%
Horizon Grade: +000%
Zoom: 1X



Photo 11: Facing the LDB at the downstream extent of Site 1 pre-remediation. Note the presence of dispersed, low-flow conditions and cobble/ boulder bars. 18 July 2016.

Date & Time: Mon Jul 18 09:39:17 MDT 2016
Position: 11 N 591277 7627024
Altitude: -3m
Datum: NORTH AMERICAN 1983, Canada
Azimuth/Bearing: 108° S72E 1920mils (True)
Elevation Grade: -007%
Horizon Grade: +001%
Zoom: 1X



Photo 12: Facing upstream along the RDB at site 1 pre-remediation, showing diminishing flows and exposed streambed further upstream. 18 July 2016.



APPENDIX A

Project Photographs



Photo 13: Facing downstream at the upstream extent of Site1. Note the meander along the boundaries of the low-flow channel resulting in velocity breaks (i.e., refugia). 18 July 2016.



Photo 14: Facing upstream at the upper extent of Site 1 post-remediation. Note the opening along the LDB boundary to allow for fish passage in either direction around the island. 18 July 2016.



APPENDIX A

Project Photographs

Date & Time: Mon Jul 18 11:58:30 MDT 2016
Position: 11 N 591289 7627026
Altitude: 27m
Datum: NORTH AMERICAN 1983, Canada
Azimuth/Bearing: 199° S19W 3538mils (True)
Elevation Grade: -021%
Horizon Grade: -002%
Zoom: 1X



Photo 15 Upstream view of directional weir A at Site 1, guiding fish away from the area of exposed stream bed. 18 July 2016.

Date & Time: Mon Jul 18 11:49:40 MDT 2016
Position: 11 N 591284 7627027
Altitude: 12m
Datum: NORTH AMERICAN 1983, Canada
Azimuth/Bearing: 235° S55W 4178mils (True)
Elevation Grade: -028%
Horizon Grade: -000%
Zoom: 1X



Photo 16: Directional weir B as viewed from the RDB at Site 1, guiding fish away from potential barriers further upstream. 18 July 2016.



APPENDIX A

Project Photographs



Photo 17: Facing upstream along the LDB at the downstream extent of Site 2 prior to remediation. Note the barriers to fish passage upstream along the LDB. 18 July 2016.



Photo 18: Upstream view of Site 2 prior to remediation. Note the exposed substrate located directly behind the local field assistant. 18 July 2016.



APPENDIX A

Project Photographs



Photo 19: Upstream view of low- flow channel B, including portions of low-flow channel A, constructed at Site 2. 18 July 2016.



Photo 20: Downstream view of low-flow channels constructed at Site 2. Note the natural cobble bar which was utilized to separate the two channels. 18 July 2016



APPENDIX A

Project Photographs



Photo 21: Upstream view of weir A constructed at Site 2 to direct fish passage away from the LDB where flows diminish further upstream. 18 July 2016.



Photo 22: Directional weir B at the upstream extent of low-flow channel B at Site 2, constructed to direct flows towards the low-flow channel. 18 July 2016.



APPENDIX A

Project Photographs



Photo 23: Upstream view of Site 3 prior to remediation showing dispersed flow with no clearly defined thalweg. 19 July 2016.



Photo 24: Upstream view of Site 3 prior to remediation showing the clearly defined thalweg present along the RDB. 19 July 2016.



APPENDIX A

Project Photographs



Photo 25: Downstream view of low-flow channel A at Site 3 after remediation was completed, showing the clearly defined thalweg along the RDB. 19 July 2016



Photo 26: Upstream view of weir A constructed at Site 3 to deter fish migration along the LDB where stranding is likely. 19 July 2016



APPENDIX A

Project Photographs



Photo 27: Downstream view of Site 4 prior to remediation, showing dispersed flow with no clearly defined thalweg. 19 July 2016.



Photo 28: Downstream view from the upstream extent of Site 4 prior to remediation. Note the dispersed flow and lack of a clearly defined thalweg. 19 July 2016.



APPENDIX A

Project Photographs



Photo 29: Upstream view of low-flow channel B at Site 4. Note the large boulders left in the channel as cover for fish. 19 July 2016.



Photo 30: Downstream view from the upstream extent of low-flow channel A at Site 4. 19 July 2016.



APPENDIX A

Project Photographs



Photo 31: Upstream view of weir A constructed at Site 4 to direct fish passage towards low-flow channel A. 19 July 2016.



Photo 32: Upstream view of low-flow channel B constructed at Site 4, showing boulders placed within the channel to provide cover for migratory fish. 19 July 2016.



APPENDIX A

Project Photographs



Photo 33: Downstream view of Site 5, viewed from the center channel prior to remediation. Note the lack of a discernible thalweg and unobstructed path for passage. 20 July 2016.



Photo 34: Upstream view of the pool at the upstream extent of Site 5, showing suitable refuge for migratory fish during periods of low flow. 20 July 2016.



APPENDIX A

Project Photographs



Photo 35: Downstream view of the low-flow channel at Site 5. Boulders too large to move by hand were left within channel to provide cover for migratory fish. 20 July 2016.



Photo 36: Upstream view of the directional weir at Site 5 to direct fish away from dry sections of the LDB. 20 July 2016.



APPENDIX A

Project Photographs



Photo 37: Downstream view of Site 6 prior to remediation. Note the lack of a discernible channel connecting the large pool at the downstream extent of the problem area. 21 July 2016.



Photo 38: Downstream view of the low-flow channel at Site 6. This low-flow channel provides passage from the large pool located at the downstream extent of Site 6 to upstream locations. 21 July 2016.



APPENDIX A

Project Photographs



Photo 39: Downstream view of the proposed location of low-flow channel A at the upstream extent of Site 7. Note the lack of a discernible path for fish from the large pool downstream to locations further upstream. 24 July 2016.



Photo 40: Upstream view from the pool located along the LDB at the downstream extent of Site 7 prior to remediation. Note the absence of an unobstructed path for fish along the LDB. 24 July 2016.



APPENDIX A

Project Photographs



Photo 41: Downstream view of low-flow channel A at Site 7. Note the channel connecting to the large pool at the downstream extent of Site 7. 24 July 2016.



Photo 42: Upstream view of low-flow channels A and B from above the LDB at the downstream extent of Site 7. 24 July 2016.



APPENDIX A

Project Photographs



Photo 43: Upstream view from the pool along the LDB at the downstream extent of Site 7 post- remediation. Note weir A directing migratory passage towards the low-flow channels and away from the problem area along the LDB. 24 July 2016.



Photo 44: Upstream view of concentrated flow along the RDB of Site 8 prior to remediation. Note the suitable conditions for fish passage along the RDB but with no connectivity to flows along the LDB. 23 July 2016.



APPENDIX A

Project Photographs



Photo 45: Upstream view from centre of the low-flow channel at Site 8. Note the connectivity with the concentrated flow and pool along LDB. 23 July 2016.



Photo 46: Upstream view of the low-flow channel at Site 8. The channel provides passage across the creek towards the LDB, with the natural thalweg along the RDB still accessible. 23 July 2016.



APPENDIX A

Project Photographs



Photo 47: Upstream view from the downstream extent of Site 9 prior to remediation. Note the absence of an obvious migratory route connecting to flows along the RDB. 23 July 2016.



Photo 48: Upstream view from the downstream extent of Site 9 prior to remediation. Photograph shows diminishing flows and dry streambed upstream along the LDB. 23 July 2016.



APPENDIX A

Project Photographs



Photo 49: Upstream view of the low-flow channel constructed at Site 9, which created a clear route towards flows along the RDB. 23 July 2016.



Photo 50: Upstream view from the downstream extent of Site 9 post-remediation. Photograph shows the directional weir constructed to deter passage along the LDB and to direct migration towards the low-flow channel. 23 July 2016.



APPENDIX A

Project Photographs



Photo 51: Upstream view of Site 10 prior to remediation. Note the dispersed flow and cobble bars. 22 July 2016.



Photo 52: Upstream view of low-flow channel C and weir A constructed at Site 10. The channel provides passage toward the thalweg and the weir directs fish towards the RDB. 22 July 2016.



APPENDIX A

Project Photographs



Photo 53: Downstream view of Site 11 prior to remediation. Note the dispersed flow and lack of clear migratory routes for fish. 20 July 2016.



Photo 54: Upstream view from above the RDB of the low-flow channel constructed at Site 11. The low-flow channel provides an unobstructed path for fish through the centre of creek. 20 July 2016.



APPENDIX A

Project Photographs



Photo 55: Upstream view from the centre of the low-flow channel constructed at Site 11. The photograph shows large boulders left within channel to act as cover for migratory fish. 20 July 2016.



Photo 56: Upstream view of Site 12 prior to remediation. Note the absence of an unobstructed path for fish along the RDB. 21 July 2016.



APPENDIX A

Project Photographs



Photo 57: Upstream view of the low-flow channel constructed at Site 12, connecting suitable habitats to the LDB. Note the large boulders left within the channel to act as cover for migratory fish. 21 July 2016.



Photo 58: Upstream view of weir A constructed at Site 12 to direct fish towards the constructed low-flow channel and away from the dry streambed along the RDB. 21 July 2016.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
16820 107 Avenue
Edmonton, Alberta, T5P 4C3
Canada
T: +1 (780) 483 3499

