

# Surveying Chinook Salmon spawning areas in the Beaver River watershed to establish conservation strategies for Na-Cho Nyäk Dun First Nation

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Final Report Prepared for: Yukon River Panel Restoration and Enhancement Fund

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## Introduction

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The Beaver and Rackla drainages are tributaries to the upper Stewart River, located in the boreal mountains of central Yukon and within the traditional territory of the First Nation of Natcho Nyäk Dun (NND) (Fig. 1). Unlike the Mayo River, salmon spawning sites and reaches have not been comprehensively or accurately mapped along the Beaver and Rackla Rivers due to their rugged terrain and remoteness (Brown et al. 2017). Much of the area is alpine tundra and exposed rock, with valley-bottom wetlands and patchy spruce and aspen forests (O'Donoghue et al. 2013). There are no year-round access routes in the area, but mineral staking and exploration have greatly increased the amount of industrial human activity in the watershed since the mid-2000's. The NND community continue to use the Beaver and Rackla Rivers as a traditional fishing/hunting route, and have strong concerns for overall Chinook Salmon stocks in their territory and the potential impacts of a new road and mineral exploration and development on spawning areas within the watershed. Indigenous knowledge accounts of Chinook Salmon have been reported by NND citizens as far upstream in the Beaver River as Scougale Creek and Clark Lakes, and in the Rackla River upstream to Kathleen Lakes (NND pers. comm., 2019).

In 2016, ATAC Resources drafted an access management plan to build a 65 km mining exploration road through the Beaver River Watershed to its Rackla Gold Project, 55km northeast of Keno City (see Fig 1). The planned route will cut through 73 rivers and streams, including Indigenous known spawning grounds for Chinook Salmon, although ATAC has only documented low numbers of juvenile Chinook Salmon at the entrances of two tributaries to the Beaver River and Rackla River mainstream (ATAC Resources, 2016). As a result of grievances from the NND First Nation about concerns for the road and its projected impacts on fish and wildlife, the Government of Yukon and the First Nation of NND have agreed to a sub-regional Beaver River land use plan (BRLUP) that will take into account traditional land use by NND citizens. Compliance with the plan will include an environmental monitoring scheme, and NND involvement will be heavily mandated both with developing a monitoring program and conducting the environmental monitoring. But, ATAC has not agreed to do any further assessments of Chinook Salmon spawning despite NND highlighting salmon and their spawning habitat as a priority. Wildlife Conservation Society Canada (WCS Canada) is assisting NND in its involvement with the planning process and preparations for the environmental monitoring. Through this project, we are committed to building the stewardship capacity within NND and the community while identifying Chinook Salmon population and their habitat, and investigating water quality and permafrost melt as a risk for salmon.

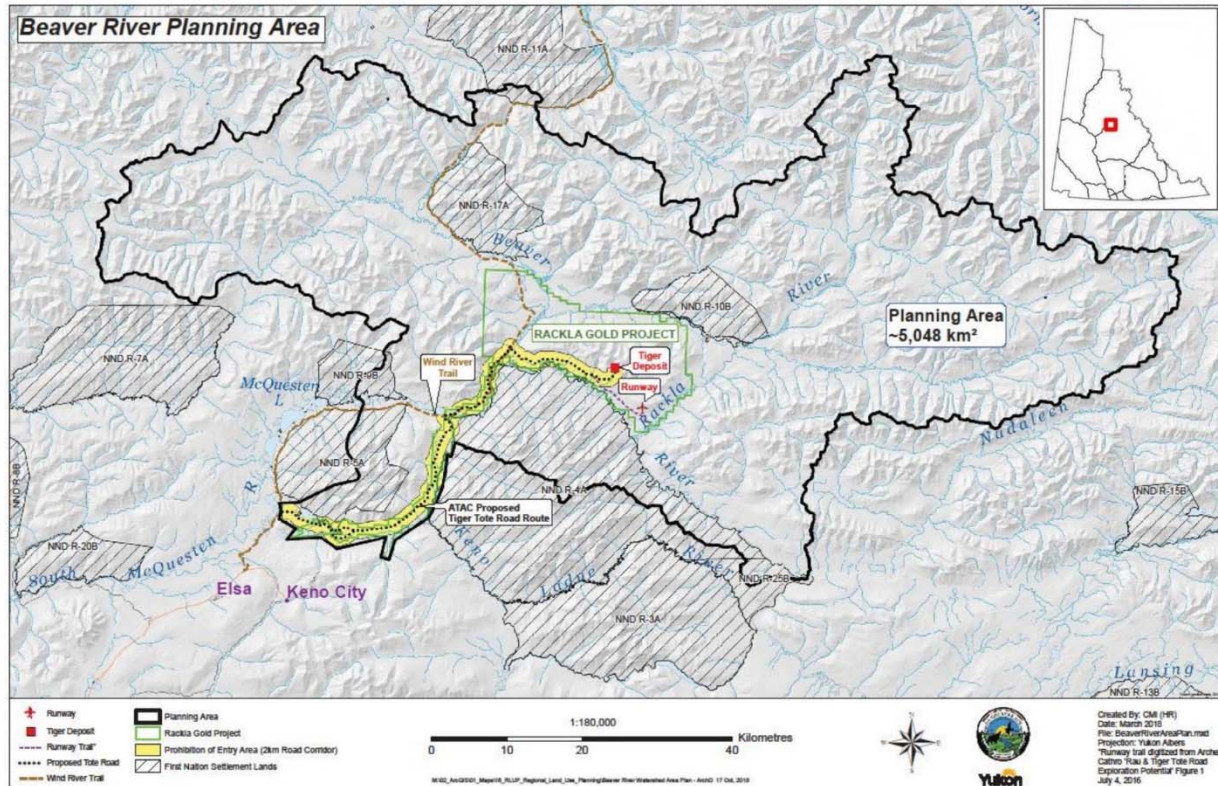


Fig. 1 The Beaver River Planning Area showing the planning area, proposed road, and location of planning area within Yukon (Map downloaded from: <http://www.emr.gov.yk.ca/r lup/beaver-river-land-use-plan.html>)

## Results and Discussion

### ***Objective 1: Inventory of Chinook Salmon spawning in the Beaver and Rackla drainages.***

With help from WCS Canada, NND has recently mapped their community knowledge about Chinook Salmon spawning sites and their traditional fishing and hunting activities within the Beaver and Rackla drainages. The current knowledge is limited to a handful of Elders and harvesters who still visit the area regularly or periodically and who have expressed concerns about changes in the number of Chinook Salmon returning to the area. In August 2019, NND and WCS Canada conducted a pilot project to plan the 2020 field work. NND counted nine Chinook Salmon by canoe between the mouth of the Rackla River and the mouth of the Beaver River. Al von Finster (Fisheries Biologist on contract) counted 40 Chinook Salmon in the same stretch of river the following week and 24 redds (a red is a spawning gravel bed; see Table 1). We used this Indigenous traditional and local knowledge gathered to help design a full monitoring survey of the region based on traditional fishing sites to identify where Chinook Salmon spawn in the drainages.

Table 1. Locations of individual salmon and redds seen along the Lower Beaver River, surveyed August 20<sup>th</sup> 2019.

Waypoint	Longitude	Latitude	Notes	Legend	Number of Salmon
005	-134.25102112800	64.05328581100	Spawning site	redd	0
007	-134.26046518600	64.04866503600	Spawning salmon	redd	1
008	-134.25957586600	64.04818391400	4 salmon & Water quality monitoring site (B1)	salmon	4
009	-134.24473453300	64.05156165400	Redd with 3 salmon	redd	3
010	-134.26252218900	64.04857065500	5 salmon	salmon	5
011	-134.27231158100	64.05693210700	Redd with 1 salmon	redd	1
012	-134.28464119300	64.05986577300	1 salmon	salmon	1
013	-134.30040461900	64.05732572100	2 salmon	salmon	2
015	-134.33481903700	64.07415188800	5 salmon	salmon	5
017	-134.36151087300	64.08914418000	5 salmon	salmon	5
018	-134.35920350300	64.09463273400	1 compound redd + 1 salmon	compound redd	1
019	-134.35361612600	64.09627701200	3 salmon	salmon	3
021	-134.34744168100	64.10046964000	1 compound redd + 2 salmon	compound redd	2
022	-134.36892508500	64.10239454400	1 salmon	salmon	1
023	-134.37043944400	64.10872908300	1 redd, 1 salmon	redd	1
029	-134.11830274400	64.21133304900	Water quality monitoring B3 good salmon habitat but no salmon	habitat	0
N/A	-134.23654774600	64.04962136920	2 bald eagles, 2 compound redds, one salmon (Lawrence's coordinates)	compound redd	1

In 2020, Peter Etherton with Metla Environmental Inc. was contracted to assist with the field surveys and to help mentor NND in Chinook salmon spawning aerial survey techniques. The selection of dates for maximizing the opportunity for an assessment of spawning habitat was determined by a review of radio telemetry reports from 2002-2004 (Mercer and Eiler., 2003, 2004; Osborne et al., 2002). A date of August 14, 2020 was selected to undertake the first aerial survey with the anticipation that this date would approximate peak spawning activity. A second survey proposed for the following week on August 21 was also assumed reasonable to capture late arriving fish. A third survey was conducted on August 28 in the event that the fish were late arriving.

The Beaver River was flowing high and somewhat turbid in contrast to flow conditions observed in 2019. The pilot held the machine at an altitude between 30 and 100 metres and travelled between 0 (hovering) to 100 km/hr (survey over substandard spawning habitat). On average the team travelled at approximately 30km/hr over proven or potentially good spawning reaches. All aboard were alerted to concurrent biological indicators that may be associated with spawning salmon; specifically, bald eagles. The team was also advised to be attentive to headwater flows immediately above gravel riffles where, typically, the most favourable spawning habitat is located. This was part of the mentoring component.

The lower reach of approximate 14 km appeared substandard for Chinook spawning although there were select, minor stretches of gravel and gravel recruitment sites from cut banks that may be conducive to Chinook spawning. Above this reach the river is composed of a series of riffles and pools ending at the confluence of the Rackla River. The gravels associated with the reach appeared to be conducive to Chinook spawning gravels based on our aerial and foot survey experiences. The presumed ample inter-gravel flow through the riffle area could provide adequate oxygenation to the incubating eggs through the autumn and winter season when flows and water temperatures dramatically drop. The pools also serve as escape habitat for spawning Chinook from predators such as eagles, bears, wolves, etc. Indeed, this was the only stretch of river where redds and active spawning was observed during the 2019 surveys.

No spawners or vacant redds were observed during the 2020 survey. Even though viewing conditions were slightly impaired by high, turbid water, it is our opinion that spawning Chinook would have been located. Moreover, only one bald eagle in the area where spawning occurred in 2019 was observed in 2020 (Fig 2, bald eagle a). Upon sighting of this biological indicator, the team circled the area and re-surveyed the site with intense scrutiny focussing on the gravel riffles, pools and cut banks to sight spawning Chinook salmon.



Fig. 2 Beaver River watershed showing seining sites and catches, and location of bald eagles on 14 and 21 August 2020.

The Beaver River above the confluence of the Rackla River changes dramatically and becomes a low velocity meandering water course, through a network of wetlands which extend upstream approximately 15 km. The authors concur that this reach has low Chinook spawning potential. This reach of river in concert with the Rackla River flow may be key in the maintenance of adequate winter flow through the salmon redds located in the Beaver River below the mouth of the Rackla River. However, this is speculative and begs field investigation.

The potential spawning habitat above the wetland network was observed to be very good and characterized by “classic” pool/riffle sequences, complemented with good flow conditions. One bald eagle was observed (Fig 2, bald eagle b). As such, the area was re-surveyed with intense focus on the river, pool and cut banks in the area. No fish were observed. The Beaver River discharge during this survey was high, twice the average, but less than  $\frac{1}{2}$  the average flow during the 2019 survey. Whether the flow regime in the upper Beaver River (and Rackla River) is adequate on an annual basis to flush and nourish overwintering eggs is questionable given the flow in these reaches of the river do not have the influence of a wetland complex as does the lower reach of the river where spawning was observed in 2019.

Scougale Creek was flown after completing the upper reach of the Beaver River. This creek harboured little in the way of Chinook spawning habitat. Its course consisted of slow

meandering flow; little potential spawning gravel was observed. The last area surveyed was the Rackla River. The river was running more turbid than the Beaver River above its confluence; however, visibility was adequate to observe Chinook spawning activity and to assign a loose status as to its spawning potential. No fish were observed. The spawning habitat mimicked, in many respects, the favourable habitat observed in the upper Beaver River, albeit this river had a stretch of four wetlands near the outlet of Kathleen Lakes which were not deemed suitable for Chinook spawning, but probably would serve as a reliable source to maintain winter flow.

In concert with aerial surveys, water samples were collected at select sites along the route of the survey. Water sampling (and beach seining) took 20-40 minutes at each site. 15 beach seines were conducted at water sampling sites along the route. Not all water sample sites had suitable areas to beach seine. Two juvenile Chinook salmon were caught at two different sites near the 2019 spawning sites (Fig 2, Table 2). Juvenile Grayling was the most abundant species caught, n=46. Juvenile Sculpin, most probably, Slimy Sculpin, were also captured.

Table 2. Beach seining sites and catches of juvenile Grayling, Chinook salmon and Sculpin, 14, 21 August 2020.

Date	Co-ordinate	# Seines <sup>a</sup>	Catch			River
			jv Grayling	jv Chinook	jv Sculpin	
14-Aug	N64°01.138 W134°08.883	2	10	1	0	Beaver
14-Aug	N64°03.965 W134°19.320	2	12	1	0	Beaver
14-Aug	N64°13.100 W134°06.866	2	2	0	0	Rackla
14-Aug	N64°11.443 W134°39.663	3	10	0	0	Beaver
21-Aug	N64°06.825 W134°22.738	2	0	0	0	Beaver
21-Aug	N64°08.946 W134°16.641	2	0	0	0	Rackla Beaver
21-Aug	N64°12.122 W134°36.159	2	12	0	2	
Total		15	46	2	2	
<sup>a</sup> beach seine 5 metre long; 1.5 metre deep; mesh 2mm						

The lower reach of the Mayo River upstream to the hydro electric dam was also surveyed on August 21. A total of 15 Chinook salmon was observed. The fish were paired up and on or near what appeared to be spawning gravels, i.e. appeared to be actively spawning. This stretch of river was surveyed by Environmental Dynamics Inc. (EDI) the previous week. It was reported anecdotally to our pilot the count tallied in 2020 was only 10 percent of the average of previous years counts. Note that the Mayo River is regulated for hydro-electrical generation. The nature of its annual flow poorly represents the natural systems in the remainder of the Stewart River watershed. Results of the Mayo River monitoring should be used cautiously.

***Objective 2: Map and assess sources of sedimentation at spawning sites***

WCS Canada mapped the prominent sources of sediment loading entering the Beaver and Rackla rivers over the past few years (2016 to 2019) to create an inventory of erosion sites using Google Earth Engine and Sentinel-2 time lapse data. The location and type/classification of sediment loading (e.g., cut bank erosion, gully erosion, permafrost slump, permafrost slide, other sources of sedimentation) were recorded and documented in a separate file entitled WCS\_ErosionMapping\_Documentation (see Appendix 1).

When possible, pre-mapped sediment sources that were located along the salmon survey flight path were verified, photographed, documented with field notes and georeferenced. Not all sites were photographed and some new sediment sources were identified, photographed, classified and mapped using a GPS.

Chrystal Mantyka-Pringle with the support of Lawrence McLaren and Peter Etherton sampled water quality throughout the Beaver, Rackla and Stewart Rivers (see Map 1 and Table 3) with an YSI Model Pro DSS meter and a separate turbidity probe rented from Laberge Environmental Services. Water samples were also taken and stored in coolers for transportation to CARO Analytical Laboratory Services in BC for testing of total organic carbon (TOC) and total suspended solids (TSS; reports can be shared on request, but results are summarized in Table 3). All water quality data was recorded in a field book and then transferred into an excel workbook and WCS Canada mapped the locations of water sampling using ArcMap GIS 10.7.4. Additional water quality measurements were taken in 2019 during the pilot study (see Table 4) and during an organized canoe trip with NND citizens.

Table 3. Water quality measurements for each site along the Beaver, Rackla and Stewart Rivers, collected in August 2020.

Site	Time	Date	latitude	longitude	Temp (oC)	mmHg	DO (%)	DO (mg/L)	SPC	TDS (mg/L)	pH	Turbidity (NTU)	TOC (mg/L)	TSS (mg/L)
WS1	11:11am	08.14.2020	63.991242	134.052947	9.1	704.7	100.6	10.76	*	258	8.26	13.75	3.11	30.4
WS2	12:07pm	08.14.2020	64.015997	134.140457	8.9	704.2	100	10.74	386.9	251	8.48	11.10	2.41	24
WS3	1:18pm	08.14.2020	64.066034	134.322005	9.2	703.4	101.2	10.74	398.1	259	8.61	6.07	1.74	11
WS4	1:41pm	08.14.2020	64.066154	134.318974	9.2	703.6	101	10.7	398.6	259	8.38	5.60	2.2	79.2
WS5	3:19pm	08.14.2020	64.170044	134.474828	5.2	702.8	99.9	11.75	432.1	281	8.66	0.44	1.49	8
WS6	4:45pm	08.14.2020	64.190248	134.6434	9.5	701.7	101.7	10.73	366.9	239	8.86	0.58	2.31	11.2
WS7	6:04pm	08.14.2020	64.132418	134.317507	9	700.9	101.1	10.79	430.3	280	8.84	5.06	1.6	<2.0
WS8	6:29pm	08.14.2020	64.151594	134.276612	9	700.1	101.6	10.84	370.7	280	8	4.21	2.14	11.6
WS9	7:01pm	08.14.2020	64.225522	134.112693	8.9	696.2	99.5	10.61	435.8	283	8.98	3.04	1.63	9.8
WS10	7:29pm	08.14.2020	64.195323	134.703162	10.2	700.5	102.1	10.58	352.9	229	8.74	-1.84	2.42	<2.0
WS11	9:00am	08.21.2020	63.47403	135.126027	11.2	711.8	101.4	10.41	359.3	234	8.64	26.12	4.97	34.2
WS12	9:37am	08.21.2020	63.652565	133.776103	10.8	708.7	100.7	10.4	402.6	262	8.74	9.85	3.3	17.2
WS13	10:11am	08.21.2020	63.690253	133.556301	10.6	708.3	101.4	10.5	400	260	8.67	7.96	3.18	18.6
WS14	10:38am	08.21.2020	63.789366	133.481299	10.6	707.3	101.4	10.49	412.5	268	8.65	6.73	3.24	18.8
WS15	11:41am	08.21.2020	64.049735	134.252336	10.2	701.3	101	10.46	420.7	273	8.74	2.38	2.21	4.2
WS16	1:15pm	08.21.2020	64.113783	134.378392	9.4	699.8	101.2	10.64	461.3	300	8.99	2.16	1.75	4
WS17	2:28pm	08.21.2020	64.149049	134.277348	9.3	698.1	103.7	10.9	461.1	300	9.12	0.72	1.7	4
WS18	3:24pm	08.21.2020	64.205667	133.818483	8.7	691.7	100.6	10.69	479.8	312	9.33	0.37	2.02	2.6
WS19	4:23pm	08.21.2020	64.202059	134.602587	10.3	699.2	103	10.62	385.3	250	8.75	0.39	1.88	2.6
WS20	4:44pm	08.21.2020	64.202501	134.603092	10.4	699.1	102.6	10.56	385.4	251	8.71	0.44	1.97	2

\*No conductance/specific conductance (SPC) value recorded

Table 4. Water quality measurements for each site along the Beaver and Rackla Rivers, collected on August 20<sup>th</sup>, 2019.

Site	Turbidity (NTU)	Temperature (degrees)	Saturation (%)	DO	latitude	longitude
B1	1.45	7.1	No data*	11.24	64.048184	-134.259576
B2	5.32, 2.85, 3.17, 3.17, 2.79	7.2	91.79	11.11	64.066334	-134.31731
B3	0.69	7.7	92.8	11.09	64.211333	-134.118303
B4	0.34	6.6	89.9	11.06	64.203975	-133.828302

\*No saturation value recorded

### ***Objective 3: Building NND stewardship capacity to conserve or improve habitat of Chinook Salmon***

Training and mentorship was provided to NND Lands Officer, Lawrence McLaren, during all Chinook Salmon aerial surveys, water quality testing and when validating permafrost slumping and landslides in the field. Lawrence was a quick learner and demonstrated competence that he could replicate a third survey solo without Peter and Chrystal on August 28<sup>th</sup>, 2020 in which he then mentored another NND field personnel. Unfortunately, there was no Chinook Salmon present in the Beaver River watershed this year, but Lawrence was able to test his survey skills in the Mayo River and while seine netting juvenile fish. NND now has plans to continue environmental monitoring in the Beaver River and track water quality, spawning and erosion in future years.

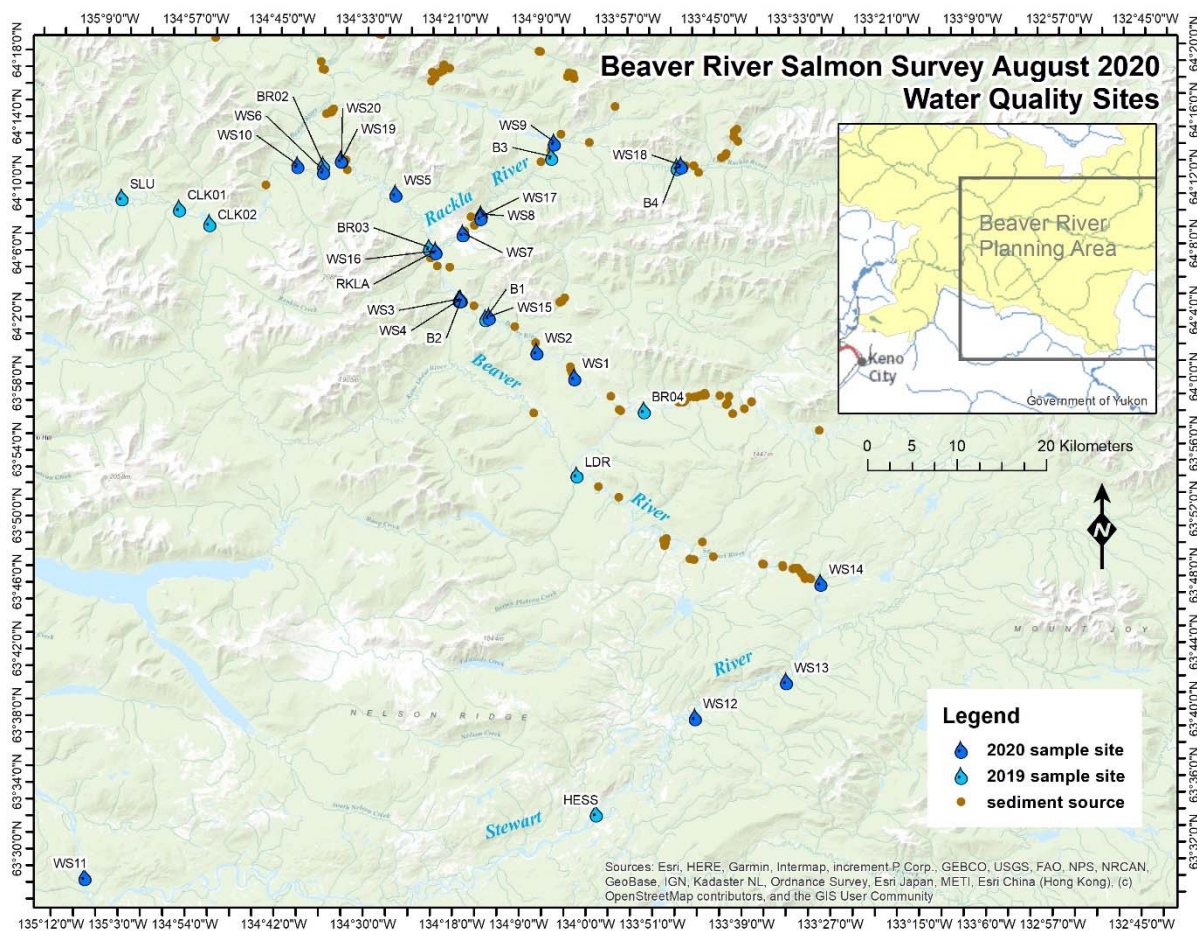
Due to COVID-19 guidelines, WCS Canada abandoned the idea of visiting classrooms in Mayo and organizing a field day with grade 6 & 7 students. Instead, WCS Canada worked with NND to produce a storymap

(<https://storymaps.arcgis.com/stories/8eba6b85803b4b56b6389abcc74708a8>) that was shared on social media platforms and NND's website for any citizen to learn about the project and to encourage continuous stewardship and guardianship of NND's Chinook Salmon and waters within their traditional territory. NND Elder, Jimmy Johnny, accompanied the first of the three aerial surveys in 2020 and shared his traditional knowledge of the land and the importance of protecting the watershed from mining for the next seven generations. Please view the storymap (link provided above) for photos, quotes and videos.

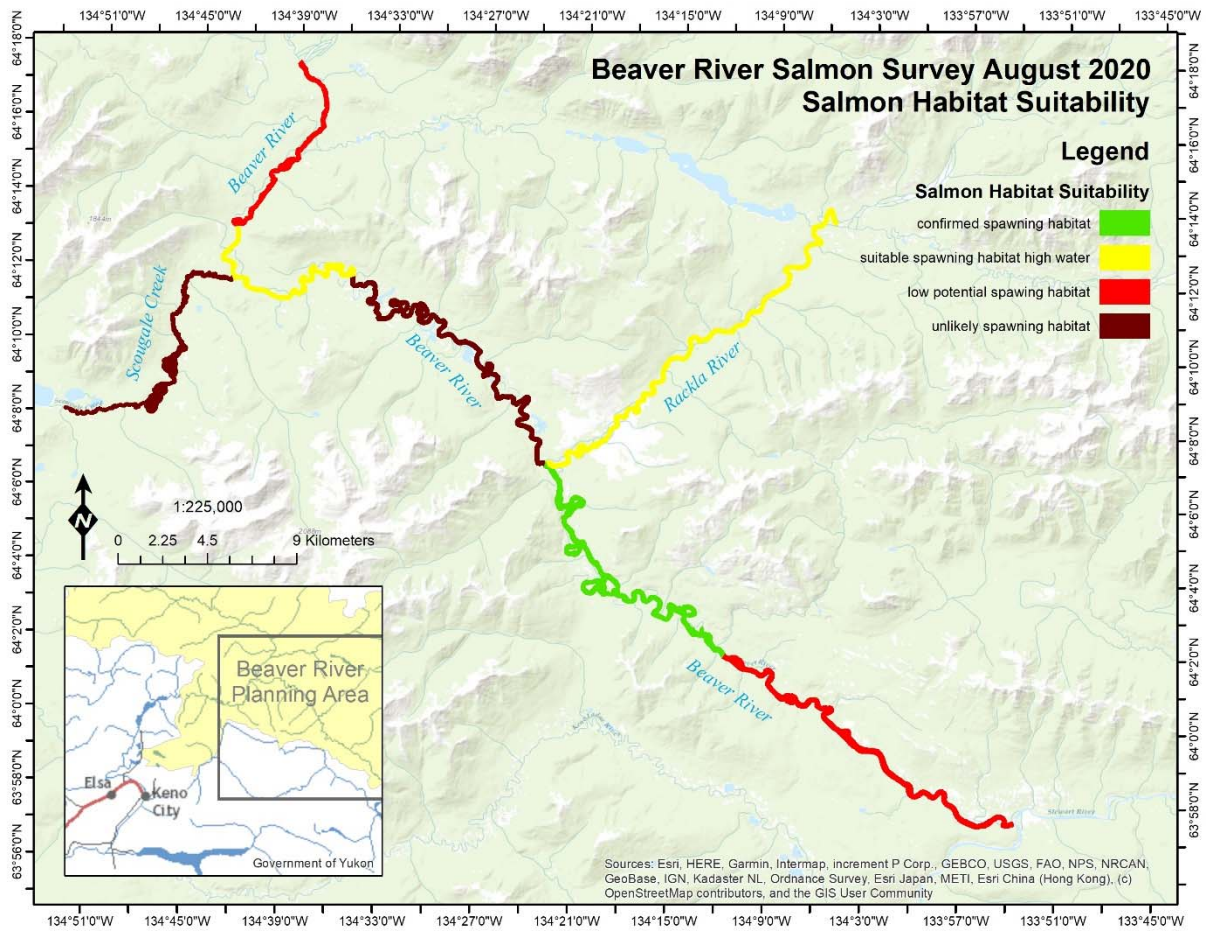
## Maps

The following maps and database have been provided for visual interpretation of the field notes and to summarize the findings of salmon spawning and key sediment sources in the Beaver River Watershed.

Map 1. The location of water sampling and key sediment sources in the Beaver and Rackla Rivers. For metadata and information on shapefiles refer to Appendix 2. For a full list of sediment locations and classification see Appendix 3.



Map 2. Salmon spawning habitat suitability for the Beaver River Land Use Planning area. For metadata and information on shapefiles refer to Appendix 2.



## Conclusions

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With the combination of a 2019 pilot study and 2020 field study, the core of the Beaver River Chinook Salmon spawning area is now documented (see Map 2). We suggest the green area be called the “Lower Beaver River Chinook Spawning Reach”. This will allow the yellow section of river between the upper section of the sand bottomed area and the proposed Tote Road Bridge to be called the “Upper Beaver River Chinook Spawning Reach” if information of spawning is collected in the future. Although we saw neither salmon or redds in the Rackla river, the habitat is generally similar to the upstream habitat that is used by salmon. Spawning will likely occur here at some time in the future and based on traditional knowledge it has taken place in the past.

We did not observe Chinook Salmon spawning or redds in any of the other sites identified by Indigenous traditional knowledge sources as supporting spawning Chinook Salmon in the past. The sand bottomed section of the Beaver upstream of the mouth of the Rackla River and the Scougale Creek watershed are unlikely to support spawning Chinook in the near or distant future. No further Chinook spawning surveys in these waters are, in our opinion, justified.

The section of the Beaver from the upstream end of the sand bottomed section to the proposed bridge location should be surveyed for spawning Chinook in the future as a priority. This is due to the proximity of the road to the river, should it be built. Scientific/Technical records of Chinook spawning would buttress the existing Indigenous traditional knowledge.

No spawning Chinook were observed in all three surveys in 2020. The lack of fish observed this year may be due to high water conditions which could make passage through the Fraser River falls, located below the mouth of the Beaver River, difficult or impossible. The paucity of spawning Beaver River Chinook may simply be due to the low numbers of Chinook entering Canada as determined by the Eagle Sonar program as well as three other sonar projects on the upper Yukon River system. The absence of observed Beaver River spawning Chinook in 2020 may be due to the confluence of the two factors mentioned above as well as interannual variability in run sizes.

Absence of evidence is not evidence of absence. Notwithstanding the 2020 survey outcome, given the results of the 2019 pilot study as well as documentation of a radio tagged Chinook in previous radio telemetry studies, it can be concluded that viable Chinook salmon spawning habitat is present in the Beaver/Rackla systems.

Scientific/Technical information of spawning on the Rackla River is stronger due to Mercer’s 2002 report of a radio-tagged adult Chinook. The Rackla should be lower priority than the mid-Beaver as it is further removed from the effects of the mine Tote Road.

As a final note, the Water Quality conditions were good to excellent for the parameters measured. The water temperatures were almost certainly colder than normal for the area due to the un-seasonally cool weather preceding the investigation. Levels of Dissolved Oxygen were high. Turbidity was low to very low at each site measured except those that were measured directly downstream of a permafrost slump. However, increases in turbidity are generally positively related to increases in river flow and rainfall. The behaviour of the Beaver and Rackla River in respect of its turbidity regime will have to be learned.

## **Data Ownership and Conditions for Use**

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This data jointly belongs to the First Nation of Na-Cho Nyäk Dun and Wildlife Conservation Society Canada who owns all the rights to the data. It is confidential information and cannot be shared without the prior written consent of WCS Canada and the First Nation of Na-Cho Nyäk Dun. No part of the material may be reproduced, published, or transmitted in any form without the prior written permission of the First Nation of Na-Cho Nyäk Dun and WCS Canada.

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## Appendix 1. Documentation of Erosion Mapping

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Prepared by: Stephanie Saal

### Data

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A variety of data sets were used to combine their benefits. World Imagery (Clarity) is a base map provided by Esri. It was created in 2017 and updated in 2019 (Esri, 2019). The data set has a high resolution while covering the entire study area. The specific resolution depends on the imagery available in a specific area. Sentinel-2 multispectral imagery is a product provided by Copernicus (ESA, 2019). The mission launched in 2016 and is currently active. Hence, it provides imagery more recent than the World Imagery (Clarity). The resolution of the 13 bands varies between 10m, 20m, and 60m. To expand the time series further into the past, Landsat imagery was added to the analysis. It is with 30m a lower resolution product than the other data sets, but has a higher temporal coverage starting in 1972 and continuing into the present (USGS, 2019). To gain a better understanding of the topography, the arctic DEM shaded relief was consulted. This pan-arctic DEM has a resolution of 2m (Porter et al., 2018).

### Mapping process and image interpretation

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The World Imagery (Clarity) provides the highest spatial resolution of the selected datasets. Therefore, features were mapped and identified based on this dataset in a first assessment. Mapping occurred on a scale of 1:5000. The identification was at times limited due to shadows and clouds. To study recent activity, Sentinel-2 data was analyzed online in the Google Earth Engine Code Editor. Images were filtered to the time period of June 1<sup>st</sup> to October 31<sup>st</sup> of each year between 2016 and 2019, and the image with the least percentage of clouds was selected. Using the time series, recent progressions and events could be identified. Using the Google Earth Engine Time Lapse (Google, 2019), past events and start dates of activities were extracted from Landsat imagery. The accuracy is limited to the quality of the imagery, which varies over time.

Four types of erosion were identified: cut banks, slides, slumps, and gully erosion. Fresh mass wastings are indicated by a break in vegetation with soil or rock being exposed, change in the angle of trees, depressions, sharp line of a head scarp, and hummocky topography of the deposited sediment. Old mass wastings appear more subtle, with differences to the surrounding landscape being less dramatic. They may be revegetated, however differences in type and height of vegetation can give an indication (Liang & Belcher, 1958).

Cut banks occur on the outer side of a river meander, caused by the erosive force of the high velocity of water (Christopherson, Birkeland, Byrne, & Giles, 2016a). In aerial images they show up as elongated steep slopes following the curve of the river. The shape extends farther along the river than it does uphill. Figure 1 shows an example of cut bank erosion. Since the river is the cause of erosion, contact or close proximity to the water is important for the classification. "Slide" is a broad term with many subcategories such as soil creep, translational slide, rotational slide, earthflow, rockfall, or debris avalanche (Christopherson, Birkeland, Byrne, & Giles, 2016b). For this analysis, these were combined into a "Slide" category. Figure 2 shows some examples in the imagery. Unlike cut banks, slides do not have to be in contact with a river. Slides extend downhill from their starting zone and are therefore generally taller than wide. Retrogressive thaw slumps are caused by exposed ice-rich soil after disturbance (Burn & Friele, 1988). Slumps were separated from slides

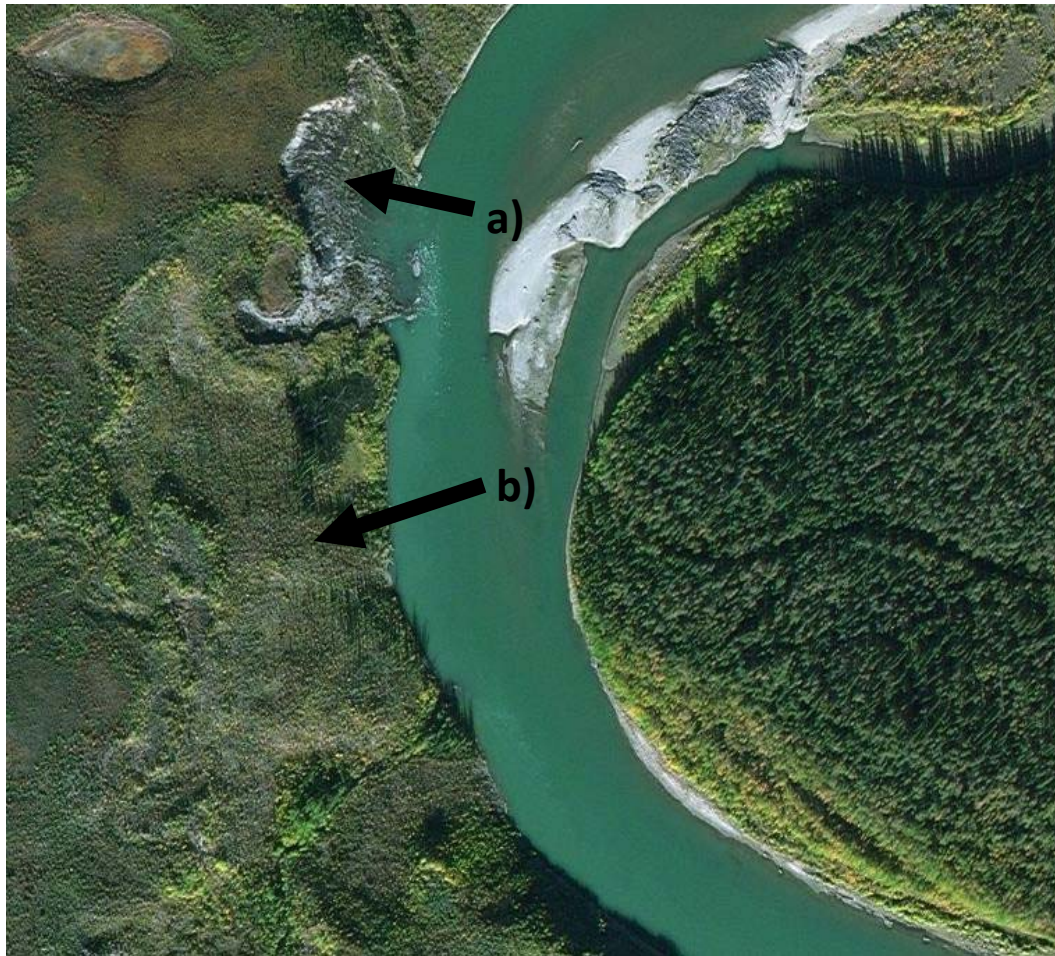
through the existence of a headwall. Figure 3 shows an active and stable thaw slump. Figure 4 shows the progression of the active slump in Sentinel-2 imagery. Gullies develop when runoff erodes unconsolidated material (Lillesand, Kiefer, & Chipman, 2004). Figure 5 shows a V-shaped gully with sediment deposited on the bottom. Categorization was performed as best as the imagery allowed. This is a first assessment, which needs to be confirmed in the field to achieve maximum accuracy.



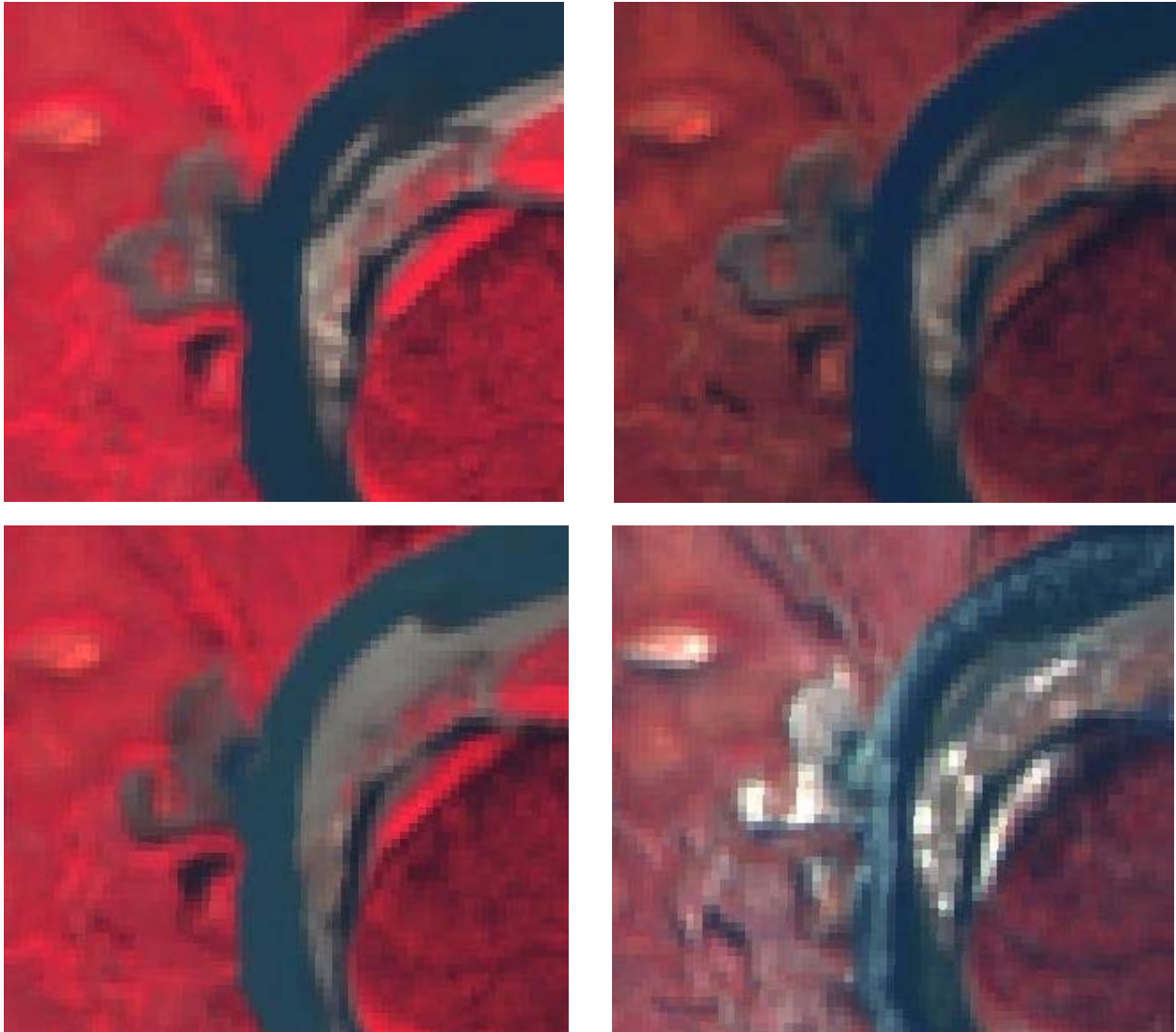
*Figure 1: Cut bank in World Imagery (Clarity).*



*Figure 2: Examples of slides in World Imagery (Clarity).*



*Figure 3: World Imagery (Clarity) showing a) an active retrogressive thaw slump and b) a stable, revegetated slump.*



*Figure 4: Sentinel-2 imagery showing the progression of slumping. Top left: 2019, top right: 2018, bottom left: 2017, bottom 2016. The biggest change can be observed between 2017 and 2018.*



*Figure 5: Gully erosion in World Imagery (Clarity)*

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## Appendix 2. Metadata - Salmon spawning habitat, water quality and erosion sources for the Beaver River Watershed, 2020

Prepared by Lisa Moore

### Tags

Na-Cho Nyäk Dun, Wildlife Conservation Society Canada, Beaver River Land Use Plan, BRLUP, Beaver River, Rackla River, digitized data, GIS, chinook salmon, salmon habitat suitability, redd, spawning, sediment sources, erosion, permafrost, slump, slide, gully, cut bank, climate change, temperature, specific conductivity, SPC, DO, dissolved oxygen, pH, turbidity, organic carbon, total suspended solids, TSS, total dissolved solids, TDS.

### Summary

2019 pilot study and 2020 field study for the Beaver River Land Use Planning Region (BRLUP) to identify salmon spawning habitat, potential sediment sources and examine cumulative effects (road, mining, climate change) on chinook salmon spawning grounds.

### Purpose of Work

- Identify and classify potential sources of sedimentation by mapping extent of permafrost slumps and slides, cut banks and gullies along the Beaver River;
- identify chinook Salmon spawning habitat (including river reaches occupied by salmon), count number of salmon, map salmon redd locations, classify redds;
- Ground truth location and class of permafrost slumps and slides, cutbanks and gullies (identified in June 2019 through satellite imagery interpretation) that may impact salmon spawning;
- Identify, map, classify and photograph new potential sources of sedimentation found during the 2019 field survey;
- measure water quality in the Beaver River watershed to see if it is affected by change in sediment loading caused by permafrost melt.

### Shapefiles

#### SalmonHabitatSuitability.shp

Salmon Habitat Suitability was classified by Al Von Finster based on observations and field notes taken during the 2019 and 2020 salmon survey.

Field	Field description	Field Values
ID	Unique ID	1-7
Sutiabilt	Chinook salmon habitat suitability	Confirmed spawning habitat, Suitable spawning habitat high water, Low potential spawning habitat, Unlikely spawning habitat
Notes	Any notes taken from the report and emails	

**SedimentSource.shp**

Sediment sources in the Beaver River watershed. Sources were identified and classified through image interpretation in the summer of 2019. Pre-mapped sediment sources located along the flight path were verified, georeferenced and photos were taken of the sediment sources. Not all sites were photographed. New sediment sources were mapped using a GPS, photographed and classified.

Field	Field description	Field Values
OBJECTID	Unique ID from GPS waypoint file	
Name	Name of site	Waypoint name or unique name from field monitoring
Lat	Latitude of site (WGS84)	
Long	Longitude of site (WGS84)	
Notes	Notes from the field work	
Photo	Name of photo	
Legend	Legend categories to view the data	Sediment source
Loc_source	Source of location	2019 fieldwork, imagery, estimated in arcGIS
Loc_notes	Additional information about how the location was determined	
Impact	Predicted impact of sediment source based on field observation (not determined for all sites)	no impact, big impact in spring, impact in spring rains
Sed_Type	Type of sediment source	Slide, cut bank, slump, gully
New	Sediment sites that were observed during 2019 fieldwork	yes, no

**WaterQuality2019.shp**

Water quality was recorded at four sites during the August 19, 2019 field survey. Water quality measures were also recorded during the week of August 13, 2019 during a canoe trip down the Beaver River.

Field	Field description	Field Values
OBJECTID	Unique ID from GPS waypoint file	
Name	Name of site	Waypoint name or unique name from field monitoring
Latitude of site (WGS84)	Latitude of site (WGS84)	
Longitude of site (WGS84)	Longitude of site (WGS84)	
Notes	Notes from the field work	
Photo	Name of photo	

SiteName	Name of water quality site	B# = August 20, 2019 fieldwork, all other sites are from the canoe trip.
Turbidity	Turbidity of water at monitoring site	0.34-5.32
Temp	Water temperature	6.6-7.7
Saturat	Percent Oxygen saturation at monitoring site	89-93
DO	Dissolved oxygen	11

### WaterQuality2020.shp

Water quality was recorded at 20 sites during the August 2020 fieldwork

Field	Field description	Field Values
OBJECTID	Unique ID from GPS waypoint file	
SiteName	Name of site	Waypoint name or unique name from field monitoring, Naming convention: WS#
Latitude of site (WGS84)	Latitude of site (WGS84)	
Longitude of site (WGS84)	Longitude of site (WGS84)	
Time	Time of site visit	
Date	Date of site visit	
Description	Description of the location of the sample site	
Temp	Water temperature in degrees celcius	5.2-11.2
mmHg	Barometer	691.7-711.8
DO_prcnt	Percent Oxygen saturation at monitoring site	99.5 – 103.7
DO_mgL	Dissolved oxygen in milligrams per Liter	10.4-11.75
SPC	Specific conductance	352.9-479.8
TDS_mgL	Total dissolved solids in milligrams per liter	229-312
pH	Potential of hydrogen	8-9.33
Turb_NTU	Water turbidity measured in NTU (nephelometric turbidity units)	-2.23 to 26.88
organC_mgL	Total organic carbon in milligrams per liter	1.49-4.97
TSS_mgL	Total suspended solids in milligrams per liter	<2.0 – 9.8

### **Credits**

Data collected by Dr. Chrystal Mantyka-Pringle, Al von Finster, Peter Etherton, Lawrence McLaron and digitized by Lisa Moore of WCS Canada for the First Nation of and Na-Cho Nyäk Dun First Nation and the BRLUP Planning Committee.

### **Use limitations**

The data jointly belongs to the First Nation of Na-Cho Nyäk Dun and Wildlife Conservation Society Canada who owns all the rights to the data. It is confidential information and cannot be shared outside of the First Nation or the Beaver River Land Use Planning committee without the prior written consent of WCS Canada and the First Nation of Na-Cho Nyäk Dun.

### Appendix 3. Key Sediment Sources in the Beaver River Watershed.

For metadata and information on shapefiles refer to Appendix 2.

Name	Long	Lat	Notes	Photo	Loc_Source	Impact	Sed_Type
006	-134.253	64.049	Permafrost	?	2019 fieldwork		
014	-134.317	64.067	New permafrost landslide with picture	Permafrost10028.jpg	2019 fieldwork		slide
026	-134.657	64.299	New permafrost landslide	Permafrost10049.jpg	2019 fieldwork		slide
027	-134.588	64.192	listed as permafrost site but photo shows wetland	Permafrost10056.jpg	2019 fieldwork		
032	-133.992	63.881	New permafrost site	Permafrost10074.jpg	2019 fieldwork, exact location unknown		slide
033	-133.951	63.870	New permafrost site	Permafrost10076.jpg	2019 fieldwork, exact location unknown		slide
CB 1	-133.504	63.793			imagery		cut bank
CB 100	-132.566	64.049			imagery		cut bank
CB 101	-132.352	64.056			imagery		cut bank
CB 102	-132.358	64.056			imagery		cut bank
CB 103	-132.139	64.042			imagery		cut bank
CB 104	-132.132	64.041			imagery		cut bank
CB 105	-132.124	64.042			imagery		cut bank
CB 106	-132.101	64.042			imagery		cut bank
CB 107	-132.094	64.042			imagery		cut bank
CB 109	-131.986	64.056			imagery		cut bank
CB 111	-131.897	64.078			imagery		cut bank
CB 112	-131.900	64.078			imagery		cut bank
CB 113	-131.851	64.074			imagery		cut bank
CB 114	-131.751	64.094			imagery		cut bank

CB 168	-134.652	64.292	verified with picture but no major impact	Permafrost10047.jpg	imagery	no major impact	cut bank
CB 169	-134.649	64.291	verified with picture but no major impact	Permafrost10048.jpg	imagery	no major impact	cut bank
CB 170	-134.758	64.329	no impact	no photo	imagery	no impact	cut bank
CB 172	-134.803	64.330			imagery		cut bank
CB 173	-134.824	64.332			imagery		cut bank
CB 20	-133.569	63.804			imagery		cut bank
CB 27	-133.797	63.972			imagery		cut bank
CB 45	-133.699	63.975			imagery		cut bank
CB 49	-133.647	63.970			imagery		cut bank
CB 51	-132.900	64.008			imagery		cut bank
CB 52	-133.969	63.973	verified with picture	Permafrost10072.jpg	imagery		cut bank
CB 56	-134.287	64.060			imagery		cut bank
CB 57	-134.346	64.098	verified with picture, wpt 020	Permafrost10035.jpg	imagery & 2019 fieldwork		cut bank
CB 62	-134.313	64.134			imagery		cut bank
CB 65	-134.120	64.217			imagery		cut bank
CB 67	-134.097	64.234			imagery		cut bank
CB 69	-133.569	63.806			imagery		cut bank
CB 77	-134.032	64.226	verified with picture	Permafrost10061.jpg	imagery		cut bank
CB 79	-133.816	64.206	verified with picture	?	imagery		cut bank
CB 81	-133.789	64.206			imagery		cut bank
Gully 136	-134.437	64.333			imagery		gully
Gully 137	-134.518	64.328	verified with pictures; tons of gravel coming down in the spring	Permafrost10052.jpg	imagery	gravel in spring	gully
Gully 138	-134.524	64.329	verified with pictures; tons of gravel coming down in the spring	Permafrost10052.jpg	imagery	gravel in spring	gully

Gully 139	-134.530	64.332	verified with pictures; tons of gravel coming down in the spring	Permafrost10052.jpg	imagery	gravel in spring	gully
Gully 144	-134.552	64.351	big impact spring rain		imagery	big impact spring rain	gully
Gully 151	-134.514	64.354	big impact spring rain		imagery	big impact spring rain	gully
Gully 154	-134.511	64.361	big impact spring rain		imagery	big impact spring rain	gully
Gully 155	-134.513	64.357	big impact spring rain		imagery	big impact spring rain	gully
Gully 156	-134.517	64.361	big impact spring rain		imagery	big impact spring rain	gully
Gully 158	-134.516	64.364	big impact spring rain		imagery	big impact spring rain	gully
Gully 159	-134.517	64.365	big impact spring rain		imagery	big impact spring rain	gully
Gully 178	-133.439	64.201			imagery		gully
Gully 74	-134.374	64.099	verified with picture	Permafrost10036.jpg	imagery		gully
Gully 88	-133.698	64.235			imagery		gully
Slide 10	-133.532	63.803			imagery		slide
Slide 108	-132.004	64.050			imagery		slide
Slide 11	-133.534	63.803			imagery		slide
Slide 110	-131.982	64.057			imagery		slide
Slide 115	-134.193	64.040			imagery		slide

Slide 116	-134.090	64.066			imagery		slide
Slide 117	-134.088	64.067			imagery		slide
Slide 118	-134.086	64.067			imagery		slide
Slide 119	-134.080	64.070			imagery		slide
Slide 12	-133.535	63.803			imagery		slide
Slide 120	-134.086	64.292			imagery		slide
Slide 121	-134.083	64.293			imagery		slide
Slide 122	-134.073	64.293			imagery		slide
Slide 123	-134.083	64.295			imagery		slide
Slide 124	-134.073	64.294			imagery		slide
Slide 125	-134.071	64.290			imagery		slide
Slide 126	-134.150	64.316			imagery		slide
Slide 127	-134.153	64.316			imagery		slide
Slide 128	-134.400	64.283			imagery		slide
Slide 129	-134.392	64.287			imagery		slide
Slide 13	-133.536	63.804			imagery		slide
Slide 130	-134.380	64.293			imagery		slide

Slide 131	-134.374	64.294			imagery		slide
Slide 132	-134.372	64.300			imagery		slide
Slide 133	-134.359	64.297			imagery		slide
Slide 134	-134.374	64.299			imagery		slide
Slide 135	-134.399	64.293			imagery		slide
Slide 14	-133.538	63.804			imagery		slide
Slide 140	-134.545	64.342	big impact spring rain		imagery	big impact spring rain	slide
Slide 141	-134.547	64.343	big impact spring rain		imagery	big impact spring rain	slide
Slide 142	-134.549	64.345	big impact spring rain		imagery	big impact spring rain	slide
Slide 143	-134.548	64.346	big impact spring rain		imagery	big impact spring rain	slide
Slide 145	-134.529	64.352	big impact spring rain		imagery	big impact spring rain	slide
Slide 146	-134.527	64.352	big impact spring rain		imagery	big impact spring rain	slide
Slide 147	-134.526	64.356	big impact spring rain		imagery	big impact spring rain	slide
Slide 148	-134.528	64.353	big impact spring rain		imagery	big impact spring rain	slide
Slide 149	-134.529	64.353	big impact spring rain		imagery	big impact spring rain	slide
Slide 15	-133.541	63.803			imagery		slide
Slide 150	-134.530	64.351	big impact spring rain		imagery	big impact spring rain	slide

Slide 152	-134.511	64.356	big impact spring rain		imagery	big impact spring rain	slide
Slide 153	-134.523	64.358	big impact spring rain		imagery	big impact spring rain	slide
Slide 157	-134.522	64.364	big impact spring rain		imagery	big impact spring rain	slide
Slide 16	-133.543	63.803			imagery		slide
Slide 160	-134.520	64.367	big impact spring rain		imagery	big impact spring rain	slide
Slide 161	-134.522	64.369	big impact spring rain		imagery	big impact spring rain	slide
Slide 162	-134.514	64.367	big impact spring rain		imagery	big impact spring rain	slide
Slide 163	-134.641	64.247			imagery		slide
Slide 164	-134.624	64.252			imagery		slide
Slide 165	-134.629	64.249			imagery		slide
Slide 166	-134.628	64.250			imagery		slide
Slide 167	-134.629	64.251			imagery		slide
Slide 17	-133.544	63.803			imagery		slide
Slide 171	-134.796	64.331	verified with picture; small impact	Permafrost10050.jpg	imagery		slide
Slide 174	-134.903	64.320			imagery		slide
Slide 175	-133.522	63.796			imagery		slide
Slide 176	-134.300	64.149			imagery		slide

Slide 177	-134.708	64.195	verified with picture	Permafrost10043.jpg	imagery		slide
Slide 179	-133.974	64.263			imagery		slide
Slide 18	-133.545	63.803			imagery		slide
Slide 19	-133.546	63.803			imagery		slide
Slide 2	-133.508	63.794			imagery		slide
Slide 21	-133.727	63.813	mapped & verified slump	Permafrost10080.jpg	imagery & 2019 fieldwork		slide
Slide 22	-133.771	63.810			imagery		slide
Slide 23	-133.780	63.811			imagery		slide
Slide 28	-133.790	63.974			imagery		slide
Slide 29	-133.795	63.973			imagery		slide
Slide 3	-133.509	63.794			imagery		slide
Slide 30	-133.770	63.974			imagery		slide
Slide 31	-133.761	63.975			imagery		slide
Slide 32	-133.759	63.975			imagery		slide
Slide 33	-133.753	63.976			imagery		slide
Slide 34	-133.753	63.976			imagery		slide
Slide 35	-133.753	63.977			imagery		slide
Slide 36	-133.754	63.978			imagery		slide

Slide 37	-133.755	63.977			imagery		slide
Slide 38	-133.755	63.977			imagery		slide
Slide 39	-133.756	63.976			imagery		slide
Slide 4	-133.518	63.793			imagery		slide
Slide 40	-133.755	63.976			imagery		slide
Slide 41	-133.719	63.976			imagery		slide
Slide 46	-133.689	63.958			imagery		slide
Slide 47	-133.662	63.963			imagery		slide
Slide 5	-133.524	63.798			imagery		slide
Slide 53	-134.059	63.996			imagery		slide
Slide 54	-134.061	63.998			imagery		slide
Slide 55	-134.063	64.001	not permafrost	no photo	imagery		slide
Slide 58	-134.391	64.106			imagery		slide
Slide 59	-134.389	64.106			imagery		slide
Slide 6	-133.525	63.798			imagery		slide
Slide 60	-134.388	64.107			imagery		slide
Slide 61	-134.774	64.174	not a major erosion site	Permafrost10042.jpg	imagery		slide
Slide 66	-134.114	64.224			imagery		slide

Slide 68	-134.144	63.954			imagery		slide
Slide 7	-133.525	63.799			imagery		slide
Slide 70	-133.612	63.807			imagery		slide
Slide 71	-133.614	63.807			imagery		slide
Slide 72	-133.615	63.807			imagery		slide
Slide 75	-134.276	64.149			imagery		slide
Slide 76	-134.112	64.224			imagery		slide
Slide 78	-133.826	64.205	verified with picture	Permafrost10064.jpg	imagery		slide
Slide 8	-133.527	63.799			imagery		slide
Slide 80	-133.809	64.205			imagery		slide
Slide 82	-133.789	64.205			imagery		slide
Slide 83	-133.778	64.199			imagery		slide
Slide 84	-133.726	64.214			imagery		slide
Slide 85	-133.718	64.216			imagery		slide
Slide 86	-133.716	64.218			imagery		slide
Slide 87	-133.715	64.218			imagery		slide
Slide 89	-133.698	64.240			imagery		slide
Slide 9	-133.531	63.802			imagery		slide

Slide 90	-133.692	64.243			imagery		slide
Slide 91	-133.689	64.230			imagery		slide
Slide 92	-133.753	63.828			imagery		slide
Slide 93	-133.814	63.969			imagery		slide
Slide 94	-133.806	63.968			imagery		slide
Slide 95	-133.801	63.969			imagery		slide
Slide 96	-133.799	63.970			imagery		slide
Slide 97	-133.778	63.974			imagery		slide
Slide 98	-133.765	63.975			imagery		slide
Slide 99	-133.773	63.974			imagery		slide
Slump 24	-133.837	63.826	mapped & verified slump	Permafrost10079.jpg	imagery & 2019 fieldwork		slump
Slump 25	-133.838	63.823			imagery		slump
Slump 26	-133.841	63.829	mapped & verified slump	Permafrost10078.jpg	imagery & 2019 fieldwork		slump
Slump 42	-133.703	63.968			imagery		slump
Slump 43	-133.702	63.968			imagery		slump
Slump 44	-133.704	63.967			imagery		slump
Slump 48	-133.646	63.970			imagery		slump

Slump 50	-133.491	63.943			imagery		slump
Slump 63	-134.292	64.140			imagery		slump
Slump 64	-134.291	64.141			imagery		slump
n01	-133.946	63.958	new sediment source, Permafrost10006.jpg	Permafrost10005.jpg	2019 fieldwork		slide
n02	-133.949	63.959	new sediment source	Permafrost10007.jpg	2019 fieldwork		slide
n03	-134.144	64.024	new sediment source, location uncertain	Permafrost10009.jpg	2019 fieldwork		slide
n04	-134.142	64.205	new sediment source, WPT027, actual location of slide	Permafrost10060.jpg	2019 fieldwork		slide
Slump 73	-133.834	63.831	mapped & verified slump	Permafrost10077.jpg	imagery & 2019 fieldwork		slump
n05	-134.592	64.202	new permafrost site wpt 024, Permafrost10040.jpg	Permafrost10039.jpg	2019 fieldwork		slide