Environment

Yukon Energy Corporation

Marsh Lake Storage Concept: 2011 Geomorphology Field and Associated Studies Report

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Concept Number:

60197181

Date:

December 2011

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December 13th, 2011

Hector Campbell
Director, Resource Planning
Yukon Energy Corporation
#2 Mile Canyon Rd
Whitehorse, YT Y1A 6S7

Dear Mr. Campbell:

Project No: **60197181** – Tasks 1.1.2 and 1.1.3

Regarding: **Marsh Lake Storage Concept: 2011 Geomorphology Field and Associated Studies Report**

I am pleased to present the 2011 Geomorphology Field Study Report regarding the Marsh Lake Storage Concept. This report outlines the data collected during the summer of 2011, data analyses and results. Feel free to contact me should you have any questions or comments

Sincerely,
AECOM Canada Ltd.

Jena Gilman P.E., P.Eng
Principal Technical Specialist
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JG:aj

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Executive Summary

This report summarizes the field and related geomorphology work completed for the Marsh Lake Storage Concept in 2011. This work included aerial overflights of Marsh Lake and portions of Tagish and Bennett Lakes, ground-based shoreline inspection of sites along Marsh and Tagish Lakes, bathymetry data collection along various shorelines of Marsh Lake and Tagish River, beach sediment grab samples, and a laboratory wave attack simulation.

A qualitative analysis concerning the level of active shoreline erosion along Marsh, Tagish and Bennett Lakes was conducted. The level of erosive activity (high, moderate, and low) in areas exhibiting shoreline erosion was ranked using four factors: height of bank, sediment calibre, shoreline aspect, and presence of colonizing vegetation on bank. Overall, 51 areas of erosion along Marsh and Tagish Lakes were observed, with several sites experiencing high levels of erosive activity. The White Pass & Yukon Railway (WP&YR) along Bennett Lake appears to need periodic embankment revetment repair due to wave attack along the shoreline adjacent to the railway. The remainder of the shoreline along Bennett Lake is stable and naturally well armoured.

Additional bathymetric surveys were conducted in 2011 to fill in data gaps along the North M'Clintock, Judas Creek and California Beach areas. These bathymetric surveys can be used for future wave modeling and design purposes as needed. Additional soil and beach grab samples were also collected along Judas Creek and Tagish River.

Additional site reconnaissances were conducted at the North M'Clintock and Judas Creek subdivisions in response to concerns raised by local residents and to complement the information already collected. A detailed survey was conducted at Lots 77 and 78 in the Judas Creek subdivision. This survey was conducted to delineate a weak, fine grained soil deposit that appears to be quite susceptible to wave attack. A qualitative wave attack simulation was conducted with samples of the deposit to assess the resistance of the material to relative levels of wave agitation and the efficacy of riprap bank protection. Results show that dissolution is rapid and a significant component of the clay material deteriorates in water. However, riprap provided some protection to the soil from wave agitation.

Finally, this report offers recommendations for resolving some of the remaining uncertainties concerning the effect of the concept on lakeshore geomorphology for the 2011 study year. The following model studies would further establish the concept's baseline and future effects:

- North M'Clintock/Swan Haven Erosion Modeling
  - Numerically model interaction of M'Clintock River and wind/waves at bluff and over mudflat important to swans.
- Ice Cover Timing Model
- Model potential changes in timing for freeze-up and break-up based on concept
- Tagish River Erosion Model
  - HEC-RAS model evaluation of Tagish River erosion utilizing existing NHC model data.

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1. Introduction

1.1 Background and rationale

Yukon Energy Corporation (YEC) has engaged AECOM to assist with planning key energy development and enhancement concepts as identified in YEC's 20-Year Resource Plan. One of the concepts identified for YEC's Resource Plan is the Marsh Lake Storage Concept. The concept envisions raising the licensed Full Supply Level (FSL) on Marsh Lake by 30cm. This level is within the natural range of variation of the water levels during the summer season, but significantly lower (75 cm lower) than the extreme peak flood level of 2007. The result of the raised FSL would be higher lake levels during fall and early winter months, allowing more water to be held in storage for the winter hydroelectric generation at the Whitehorse Rapids Generating Station (WRGS). This report satisfies the requirements of tasks 1.1.2 and 1.1.3 of the phase 1b of the Marsh Lake concept.

One key concern to be addressed is the potential for increased shoreline erosion due to the higher fall lake levels. Extensive data collection took place in 2010 at Marsh, Tagish and Bennett Lakes as part of the Baseline Data Collection Phase. The data collection also focused on areas of concern regarding erosion potential as raised by stakeholders.

1.2 Scope of Work

Further areas were investigated in 2011 to complement the baseline data collection phase. They included areas with gaps in the information and new areas of concern raised by stakeholders.

The work completed during 2011 included the following elements:

- Mapping and ranking of the erosive potential of the shorelines of Marsh, Tagish and Bennett Lakes;
- Bathymetric surveying and mapping of North M'Clintock Bay, Judas Creek, South Tagish River and California Beach for future modelling purposes;
- Soils sampling and analysis at selected locations (Judas Creek, North M'Clintock, Tagish River);
- Detailed survey along a shoreline erosion prone area in the North M'Clintock subdivision, in the Swan Haven Area;
- Detailed survey along a shoreline erosion prone area in the Judas Creek subdivision; and
- Wave attack simulation on a weak clay deposit found along the shoreline of the Judas Creek subdivision.

2. Erosion Activity – Marsh, Tagish and Bennett Lakes

AECOM performed three helicopter surveys of the shoreline along Marsh, Tagish and Bennett Lakes. One survey was conducted in early June 2010 and two follow-up surveys were completed in mid-July 2011. Each survey was conducted at slow speeds approximately 60m above the shoreline. During the June 2010 survey, Marsh Lake's surface elevation was approximately 654.3m above Mean Sea Level (MSL); thus it was possible to observe the lower elevations of the beach. In contrast, the July 2011 helicopter surveys were conducted at a higher Marsh Lake surface elevation of approximately 655.6m above Mean Sea Level (MSL). This higher elevation showed wave propagation on the upper shore area and, in some cases, active erosion of the shoreline was observed, such as on the northwest shore of Marsh Lake.

The main purpose of the helicopter surveys was to locate and identify areas of shoreline that are currently eroding or indications of erosion from the recent past. Surface geology maps were also used to help identify areas predisposed to shoreline erosion. Shorelines that were identified as erosive contained one or more of the following characteristics: shorelines with a partially or completely exposed sediment bank upshore, trees immediately adjacent to the shoreline that are leaning towards the water ('drunken forest'), and turbid water along the shoreline not associated with a tributary outlet.

In addition to mapping the location of shoreline erosion, qualitative observations of each erosion area was made to rank the level of erosive activity observed. The following qualitative factors were used to rank each area exhibiting shoreline erosion:

- Height of Bank: High banks will tend to erode quicker as wave action will undercut the bank, causing the upper bank to fall or slump.
- Sediment Size: Smaller calibre sediments are more easily eroded and transported away from the shoreline than larger calibre sediments.
- Aspect: Shoreline aspect is important as shorelines that are facing the prevailing wind direction(s) will be subject to more frequent and higher waves. The prevailing wind direction along Marsh, Tagish and Bennett Lake is from the southeast. Less frequent but strong winds can also occur from the northwest. Thus, shorelines facing the southeast, and to a lesser extent, the northwest, along Marsh, Tagish and Bennett Lakes, will be more susceptible to wave attack.
- Vegetation Bank Cover: This factor was used mainly to help assess the rate of erosive activity. Shorelines that are exhibiting signs of erosion and have upshore banks completely bare of vegetation suggest that the rate of active erosion is high enough to prohibit the growth of colonizing vegetation. In contrast, shorelines exhibiting signs of erosion that have some colonizing vegetation suggest that erosive activity is occurring at a slower rate.

Three rankings were used to describe the level of erosive activity for each area based upon the qualitative factors listed above: High, Moderate, and Low. As an example, a High ranking for an erosive shoreline would be characterised by one or more of the following: high bank height, fine grained sediments, aspect is facing prevailing wind direction(s), and/or absence of vegetation on bank. In contrast, a Low ranking for an erosive shoreline would be characterised by one or more of the following: low bank height, coarse grained sediments, aspect not facing prevailing wind direction, and/or colonizing vegetation on bank.

Table 2-1 outlines the shoreline erosion occurring at each identified site on Marsh and Tagish Lakes, and provides the associated rank and photo number (refer to photolog in Appendix A). The presence of a dwelling adjacent to an erosive shoreline is also noted. Figures 2-1 to 2-3 show the locations of observed shoreline erosion areas and their associated erosion rank for Marsh Lake, Tagish Lake and Taku Arm, respectively. Cabins, both abandoned and maintained, are also mapped on Figures 2-1 to 2-3, as well as two areas of observed beach sediment accretion.

The surface geology map of the Marsh and Tagish Lake area (Morison and Klassen 1991) is quite coarse in resolution, however, it does help explain some of the shoreline erosion observed. The north end of Tagish Lake has two large areas with a high rank of erosive shoreline (Figure 2-2: #12 and #29). In addition to the aspect of these shorelines, the surface geology mainly consists of high banks of a glaciolacustrine deposit consisting of clay, silt and sand. These deposits are not cohesive and thus very susceptible to erosion. The high ranking areas along the Tagish River (Figure 2-2: #10 and #110) are also characterized by a surface geology consisting of a glaciolacustrine deposit (Morison and Klassen, 1991). In addition to wave attack, erosion by moving water within the Tagish River is likely contributing to the high level of erosion here.

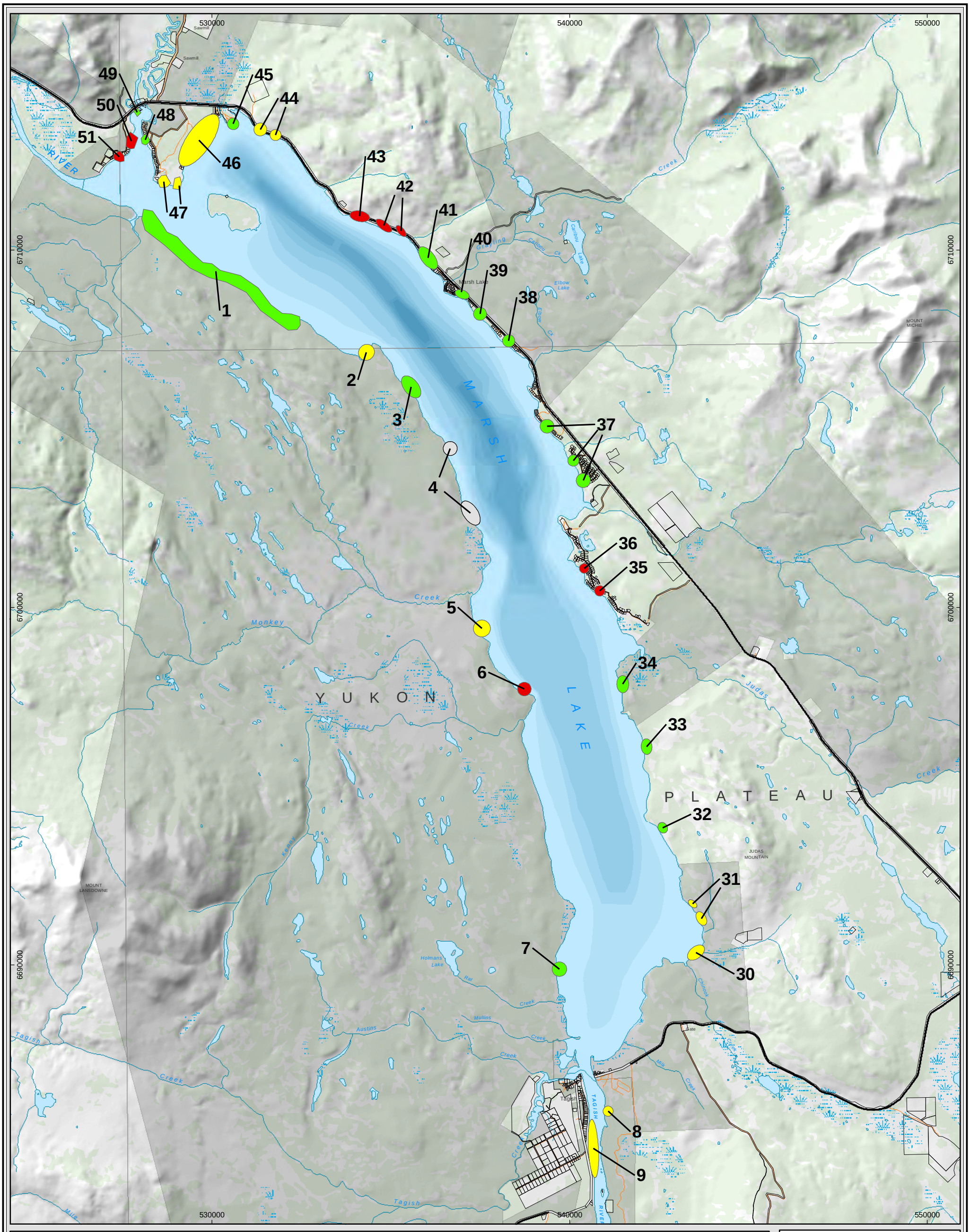
The high level of erosion along the shore of Judas Creek subdivision (Figure 2-1: #35 and #36) at lots 77 and 78 is primarily due to a weak clay deposit overlain by coarse gravel (see memorandum in Appendix E). This area is characterised by a fluvial-glacial delta plain, with a mixture of clay, silt, sand and gravel (Morison and Klassen 1991). The high activity of erosion at sites #42 and #43 (Figure 2-1) are primarily due to shoreline aspect and easily erodible glaciolacustrine sediments. Army Beach locations (Figure 2-1: #46 and #47) were ranked at a moderate level of erosion because of the shoreline aspect towards prevailing winds but with a low bank height. In fact, accretion of sand along the beach was observed during the July 2011 survey. Although the North M'Clintock shoreline does not appear to have a long fetch to generate large waves, the shoreline erosion here is considered high. This is primarily due to the high bank of a glaciolacustrine deposit observed here. In addition, it's assumed that the M'Clintock River is contributing to the erosion of the bank along this shore.

Figure 2-4 shows the locations of erosion occurring on Bennett Lake. Only one location on Bennett Lake was identified (#1 on Figure 2-4) as an eroding shore of fine grained sediment (Photo 55, Appendix A). With the exception of the White Pass & Yukon Railway (WP&YR) embankment, the majority of the Bennett Lake shoreline is stable and contains naturally well armoured beaches (Photo 56, Appendix A). An erosion ranking system was not employed along the shoreline adjacent to the WP&YR (which parallels the majority of the southeast shoreline); rather all locations along the railway that appeared to have had recent revetment repair were noted and are shown in Figure 4. Several long sections of the WP&YR are located immediately adjacent to the shore of Bennett Lake. In most instances, these sections of railway embankment are experiencing erosion from wave attack (Photos 53 and 54, Appendix A). As a result, WP&YR has historically performed regular repair of its embankment.

Table 2-1 Erosion Areas of Marsh and Tagish Lakes

Site #	Category	Photolog Number	Presence of Dwelling adjacent to shore	Description
1	Low	1	-	'drunken forest' on shore with eroding fine grained sediment bank. Turbid water directly offshore.
2	Moderate	2	-	Moderately high, fine grained sediment bluff that is actively eroding from north wind wave action and/or melting permafrost.
3	Low	3	-	Low bank erosion of fine grained sediment. Turbid water directly offshore.
4	-	4	-	Accretion of sand along bank
5	Moderate	5	-	High bank, fine grained sediment eroding along shore.
6	High	6	Yes	High bank, fine grained sediment eroding along shore. Cabins and small dock adjacent to eroding bank.
7	Low	7	-	Low bank, fine grained sediment eroding along shore.
8	Moderate	8	-	Tagish River bank erosion. High bank, erosion of fine grained sediment.
9	Moderate	9	Yes	Tagish River erosion. High bank, erosion of fine grained sediment. Some vegetation is colonizing erosion bank. Houses all along eroding bank.
10	High	10	-	Tagish River erosion. High bank, erosion of fine grained sediment.
11	High	11, 12	Yes	Tagish River erosion. High bank, erosion of fine grained sediment. Houses all along eroding bank.
12	High	13, 14	Yes	California Beach erosion. High bank, erosion of fine grained sediment. Houses all along eroding bank.
13	Low	15	-	Low bank, fine grained sediment eroding.
14	Low	16	-	Low bank, fine grained sediment eroding.
15	Low	NA	-	Low bank, fine grained sediment eroding.
16	Low	17	-	High bank, fine grained sediment eroding along shore.
17	Low	18	-	Low bank, fine grained sediment eroding.
18	-	19	-	Deposit of large woody debris on shore.
19	-	20	-	Accretion of sand on large beach.
20	Low	21	-	Undercut erosion on bedrock cliff
21	Moderate	22	-	Slumping low bank, fine grained sediment eroding.
22	Moderate	23	-	Slumping, high bank, fine grain erosion.
23	Low	24	-	Low bank, fine grained sediment eroding.
24	Low	25	-	High bank, fine grained sediment eroding along shore.
25	Low	NA	-	Low bank, fine grained sediment eroding.
26	Low	26	-	Low bank, fine grained sediment eroding.
27	Low	27	-	Low bank, fine grained sediment eroding.
28	Low	28	-	High bank, fine grained sediment eroding along shore.
29	High	29	-	High bank, fine grained sediment eroding along shore.
30	Moderate	30	-	Low bank, fine grained sediment eroding.
31	Moderate	31	-	Low bank, fine grained sediment eroding.
32	Low	32	-	Low bank, fine grained sediment eroding.

33	Low	33	-	Low bank, fine grained sediment eroding.
34	Low	34	-	'drunken forest' on shore with eroding fine grained sediment bank.
35	High	35	Yes	Low to medium high bank with very fine grained sediment eroding. Anderson's property in Judas Creek subdivision.
36	High	36	Yes	High bank, fine grained sediment eroding along shore within Judas Creek subdivision.
37	Low	37	Yes	Low bank, fine grained sediment eroding. Properties adjacent to eroding bank.
38	Low	38	Yes	Low bank, fine grained sediment eroding. Properties adjacent to eroding bank.
39	Low	39	Yes	Low bank, fine grained sediment eroding. Properties adjacent to eroding bank.
40	Low	40	Yes	Low bank, fine grained sediment eroding. Properties and boat launch adjacent to eroding bank.
41	Low	41	Yes	Low bank, fine grained sediment eroding. Properties adjacent to eroding bank with revetment.
42	High	42	Yes	Low to medium bank, fine grained sediment eroding. Richard Mulleurs property flanked by eroding banks.
43	High	43	Yes	High bank, fine grained sediment eroding along shore. Property adjacent to eroding bank.
44	Moderate	44	-	High bank with revetment along highway, erosion is evident along shore.
45	Low	45	-	Low bank, fine grained sediment eroding.
46	Moderate	46	Yes	Low bank, fine grained sediment eroding along shore. Army Beach properties all along shore, most with some form of revetment.
47	Moderate	47	Yes	Low bank, fine grained sediment eroding. Bank is largely protected.
48	Low	48	Yes	Low bank, fine grained sediment eroding. Erosion appears to be mainly from M'Clintock River.
49	Low	49	-	Low to medium high bank, fine grained sediment eroding. Erosion appears to be mainly from M'Clintock River.
50	High	50	Yes	High bank, fine grained sediment eroding along shore. North M'Clintock properties adjacent to eroding bank.
51	High	51	Yes	High bank, fine grained sediment eroding along shore. North M'Clintock properties adjacent to eroding bank.



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N
W E
S

Kilometers
0 1 2 3 4 5

1:100,000

UTM Zone 8N, NAD 83

Legend

- Wetland
- First Nation Settlement Land
- Land Parcel
- Highway
- Local Road
- Accretion

Erosion Rank

- Low
- Moderate
- High

YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Marsh Lake Erosion Areas

March 2012
Project 60197181

AECOM

Figure 2-1

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Map Sources/Notes:
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N
W E
S

Kilometers
0 1 2 3 4 5

1:200,000

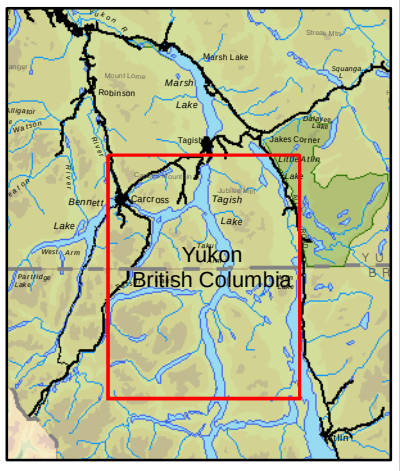
UTM Zone 8N, NAD 83

Legend

- Wetland
- First Nation Settlement Land
- Highway
- Local Road
- Cabins

Erosion Rank

- Low
- Moderate
- High



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MARSH LAKE FALL-WINTER STORAGE

Tagish Lake Erosion Areas

March 2012
Project 60197181

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Figure 2-2

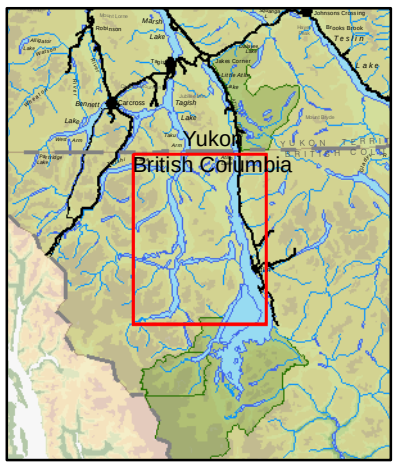
White Range
RANGE
530000
540000
550000
560000
570000
TESLIN
PLATEAU
TESLIN
LAKE
ATLIN
TAGISH
HIGHLAND
PLATEAU
TAKU (TAGISH) ARM (LAKE)
TALAHA BAY
Stovel Peak
Lanning, Mount
Potter Point
22
21
16
17
18
19
20
Sunday Peak
Ear Mountain
Taku Mountain
Red Island
Eight Mile Point
Table Mountain
Sand Point
Big Island
Brook, Mount
Atlin
Third Island
Clive, Mount
Golden Mountain
Hale Mountain
Fetterly, Mount
Atlin Mountain
Bee Peak
Five Mile Point
Gleaner Mountain
Engineer Mountain
White Moose Mountain
Section Mountain
Birch Mountain
Teresa Island
Twelve Mile Point
Tagish Highland
Cameron, Mount
6640000
6630000
6620000
6610000
6600000
6590000

Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. All Rights Reserved. Yukon Land Tenure from Yukon Territorial Government, 2010.

N
W E
S
Kilometers
0 1 2 3 4 5
1:200,000
UTM Zone 8N, NAD 83

Legend
- Wetland
- Highway
- Local Road
- Cabins
- Cabin Site
- Accretion

Erosion Rank
- Low
- Moderate
- High



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MARSH LAKE FALL-WINTER STORAGE

Taku Arm Erosion Areas

March 2012
Project 60197181

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Figure 2-3

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105D03

105D02

500000

510000

520000

6660000

6650000

6640000

BENNETT LAKE

WEST ARM

GEORGE RANGE

BENNETT LAKE

TAGISH LAKE

TUTSHI LAKE

YUKON PLAT

LAND

TAGISH HIGHLAND

1

Watson

Pennington

Carcross

STONY MOUNTAIN

FINGER MOUNTAIN

BRUTE MOUNTAIN

MONTANA MOUNTAIN

MOUNT MATHESON

DUNDAS MOUNTAIN

MOUNT BRADEN

MOUNT DEWEY

MOUNT RACINE

Millhaven Creek

Millhaven Bay

Munroe Creek

Lorraine Creek

Ourdale Creek

Podunk Creek

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N
W E
S

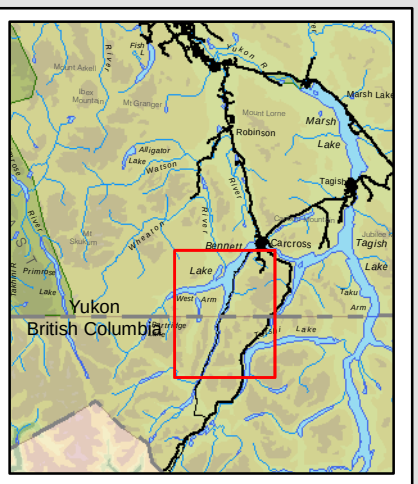
Meters
0 750 1,500 2,250 3,000

1:100,000

UTM Zone 8N, NAD 83

Legend

- Wetland
- Highway
- Main Road
- White Pass & Yukon Railway (WPYR)
- Area of Low Potential Erosion
- Apparent WPYR Revetment Repairs



YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Bennett Lake Erosion

August 2011
Project:60219833

AECOM

Figure 2-4

3. Bathymetric Surveying and Mapping

AECOM performed further bathymetric surveys and sediment sampling in 2011 to augment the data that was collected in 2010. Bathymetric surveys were completed in North M'Clintock Bay, Judas Creek and California Beach in mid-July 2011. The main purpose of collecting the additional bathymetric surveys was to fill in data gaps for future modeling in the three areas mentioned above.

The bathymetric survey was conducted using a Sonarmite v2.0 Portable Bluetooth Echo Sounder, while geographic location was collected using a Trimble GeoXT GPS unit. The resolution for the echo sounder is 0.025 m. The echo sounder was mounted on the transom of the boat, and depth of the sounder below the water surface was recorded and corrected for in the data processing. Lake levels on the dates data were collected were provided by Water Survey of Canada (WSC). Depths recorded during data collection are subtracted from the lake levels provided by Water Survey of Canada (Station 09AB004 – Marsh Lake and Station 09AA017 – Tagish Lake) to enable all mapping to be presented in metres above sea level (m asl).

The water levels on the days of the bathymetric surveys were:

Tagish Lake – July 12: 655.65m asl
Marsh Lake – July 13 and 14: 655.59m asl

At California Beach and Judas Creek, the bathymetric survey was extended to approximately 250 to 300m offshore, to a water depth of approximately 3 to 4m. The M'Clintock Bay bathymetric survey covers areas of the bay that were not covered in the 2010 bathymetry survey.

The level surveys of beach transects were conducted using an engineers level. The starting point of each transect was at the lake bottom beneath the echo sounder at the closest point to shore accessible by boat. The transects include the following measurements: in the water (near sounder), at the water line, at any break points in the beach and at the toe of bank. The end point of each transect is the top of bank when it was feasible to measure an elevation; if this was not possible the geometry and height of the bank was estimated. This data provides the basic beach topography at erosion prone shorelines along the Southern Lakes. Photos 57 to 68 show the shore profiles that were surveyed (Photolog – Appendix A). Bathymetric maps and survey data are provided in Appendix B.

Sediment grab samples were collected along the beach and bank of Judas Creek and California Beach at the outlet of Tagish River. Table 3-1 outlines the locations of each of these samples. The results of the sediment size analyses of the grab samples are provided in Appendix C. The samples and the related analysis will allow assessing the risk of erosion potential (particle entrainment) at these locations under a higher FSL.

Table 3-1 Sediment grab samples locations collected in 2011.

Date	Sample ID	Easting	Northing	Comment
May 25th, 2011	J1	540515	6700604	Bank sample at Judas Creek
May 25th, 2011	J2	540515	6700604	Sample at toe of bank at Judas Creek
May 25th, 2011	J3	540515	6700604	Beach sample at Judas Creek
July 21st, 2001	J4	540515	6700604	Assay sample of clay sediment from bank at Judas Creek (same as J1, taken for chemical analysis)
May 23rd, 2011	SS30	527671	6712721	Bank sample at North M'Clintock
July 19th, 2011	SS40	534197	6710867	Bank sample near Richard Mueller's property (Marsh Lake)
July 19th, 2011	SS41	539595	6680626	Bank sample of sand material taken near church property along Tagish River
July 19th, 2011	SS42	539633	6680646	Bank sample of clay silt material taken near church property along Tagish River

4. North M'Clintock Shoreline Survey

A site visit was conducted on May 23rd, 2011 to observe the shoreline of the North M'Clintcock subdivision. This survey was in response to concerns raised by local residents. The main purpose of the recon was to observe the M'Clintock River in relation with the shoreline erosion occurring along the silt bluffs. It allowed visualizing areas potentially at risk of erosion along the shoreline. At the time of the visit, the Marsh Lake water level was near its Low Supply Level (653.80 m asl) such that there was no water from the lake entering the North M'Clintock Bay.

Evidence of active eroding shoreline was observed along a few lots in the area. The eroded bluff consists of sand and silt with a layer of clay underneath. A soil sample was taken at the site during the visit for further analysis (see Table 3-1 above). Some property owners have planted willows at the base of some of the bluffs and beach to protect against erosion from wave action and flooding. It is believed that the material that gets eroded from the bluffs in this area tends to get transported and deposited along the large beaches and shallow areas of North M'Clintock Bay.

A memorandum outlining the observations made during this site reconnaissance is presented in Appendix D.

5. Judas Creek Shoreline Survey

An initial site visit occurred on May 22nd, 2011 at the Judas Creek subdivision in response to residents' requests during public meetings in 2010. The purpose of this site visit was to meet residents and allow them the chance to outline their concerns/observations regarding the shoreline erosion that is currently evident along portions of the Judas Creek Subdivision shoreline. Meeting minutes of this site visit are presented in Appendix E, summarizing the discussion that took place with various residents of the subdivision and observations made by AECOM staff regarding the site visit. A map of the area visited and photo log is attached to the meeting minutes

A second, more focused site visit occurred on July 21st, 2011 along the Judas Creek subdivision (Lot 77) revealed a very weak sediment layer in the bluff along the shore. A memorandum along with a photo log is presented in Appendix E. In particular, a weak, fine-grained soil deposit overlain by coarse gravel was reported by local residents to dissolve when in contact with water. Given the height of the bank, and aspect of the shoreline to prevailing winds, a further detailed survey was indicated. A site survey of the area was conducted on July 21st, 2011 to determine the areal extent of this erosion bank for future assessment and mitigation studies. Figure 1 in Appendix E outlines the preliminary survey of the shoreline area along lots 77, 78, and 79 of the Judas Creek subdivision. Photo 69 shows the collection point of the sediment grab sample J4 (Table 3-1) of the weak clay deposit (Appendix A). Soil samples J1 and J4 are of the same weak clay deposit. The chemical and grain-size analyses of these soils samples are presented in Appendix C.

The exact nature and sedimentology of the soil exposed in the erosion bank has yet to be determined. The soil is a white to light grey fine grained soil that has a near vertical exposure. Maximum exposure is almost 2m vertically. Some bedding is observed and there are organic horizons in the soil profile. The soil seems to almost "dissolve" when exposed to water. A grain size analysis suggests the material is very uniform course sand (see Appendix C which also includes a metal assay of the sample). It is suspected that this is not representative of the particle size; rather it is the fragments of the soil that are adhered together due to the cohesive nature of the soil.

The soil was examined under a reflected light microscope with the Yukon Geological Survey's surficial geologist. No shell fragments were found in the soil and so a marl is eliminated as a soil genesis. A sample split was analyzed for mineralogical composition using x-ray diffraction (XRD) at the University of British Columbia (results are in Appendix C). The results were reviewed by Mr. Ian Power of UBC who has written several papers on the hydromagnesite deposits in the Atlin area. Based on the mineralogy Mr. Power concluded the soil is not a salt or hydromagnesite deposit (I. Power, pers. comm. 2011), which is formed by precipitation from mineralized groundwater.

In summary, the genesis of the soil exposed at this location has not been determined, but it is not a marl, salt or other precipitate type deposit. It is most likely a very fine, calcareous rich sediment deposits in a very calm wetland environment. Similar areas of "bleached" sediments are found in the wetlands adjacent to the mouth of Judas Creek nearby. From an engineering perspective, this soil is likely very weakly consolidated fine grained sediment that disassociates readily in the presence of water.

6. Laboratory Wave Attack Simulation

A qualitative laboratory simulation of wave attack was conducted on samples of the weak clay deposit observed at Lots 77 and 78 of the Judas Creek subdivision shoreline. The main purpose of the simulation was to observe any gross relative effects of wave agitation strength on the rate of deterioration of the clay samples. In addition, the mitigating effects of riprap protection were examined, again only in qualitative terms.

The simulation was conducted within a large Rubbermaid container (70cm by 42cm, and 40cm deep). Each clay sample was placed within a Styrofoam template cut so that front was flush with the face of the sample to prevent the wave from attacking the sides of the sample and to prevent a wave from overtopping the sample. The Styrofoam template holding the clay samples was positioned at one end of the Rubbermaid container and held in place using weights. Water filled the Rubbermaid up to the top of the clay sample; a cone was placed in front of the clay sample during the filling to minimize agitation of the sample until the water reached the appropriate level. Time was recorded once the water level reached the top of the clay sample. For agitation trials, a hand motion was used to create the waves with approximate 1 second periods. The period was identical for both the low and high agitation trials. A stronger hand movement was used for the high agitation trials. Coarse gravel (16-32mm) was used to armour the face of the clay sample for the bank revetment trials. Each trial was considered finished when the clay sample had lost most of its original shape and its integrity. At this point its texture was more of a 'pudding'.

The results of each trial are listed in Table 6-1 below. Since the sample size of each clay sample varied in mass and size, the deterioration of each sample is described by the number of grams deteriorated per second to allow a rough comparison between trials. Photos of the experiment (70-72) are provided in the photolog (Appendix A).

In all trials, a significant portion of the clay sample dispersed in the water, with a small amount of 'pudding' remaining on the bottom of the Rubbermaid container. As expected, the higher agitation trial resulted in a faster rate of deterioration (Table 6-1). During the two trials with no agitation, both samples deteriorated after 2 minutes, yet one sample was more than twice as heavy as the other. The results emphasize the weakness of these particular soils under even minor wave agitation. The presence of revetment did slow the decay of these samples (Table 6-1).

Table 6-1 Results of wave attack simulation on clay samples taken from Judas Creek bank near Lot 78.

Trial	Deterioration Time (s)	Rate of Deterioration (g/s)
No agitation	120*	4.33*
Low agitation	195*	6.28*
High agitation	360	9.48
Low agitation with bank revetment	420	2.44
High agitation with bank revetment	420**	5.33**

* average of two trials

** revetment collapsed during trial

7. Recommendations for Geomorphology Impact Assessment

There are several specific areas for which further study is recommended to better define the hydrodynamic and geomorphologic effects of the proposal on Marsh, Tagish and Bennett Lakes and their associated shorelines. Based on the work to date, further study is recommended as follows:

- North M'Clintock/Swan Haven Erosion Modeling
  - Numerically model interaction of M'Clintock River and wind waves at bluff adjacent to several homes and a First Nations cemetery and over mudflats important to swans. This can be done in a two-phase program depending on agency requirements. The first is to do a HEC_RAS model primarily focusing on erosion caused by the M'Clintock River. The second modeling effort would utilize a two-dimensional hydrodynamic model of Marsh Lake to predict depositional and erosional forces on the lakebed/mudflats in the Swan Haven area. The model results will provide additional insight into risks of changes to the mudflats important to migratory swans under a range of water levels and seasonal conditions. It will also augment understanding of the erosive effects of the M'Clintock River.
- Ice Cover Timing Model
  - Model potential changes in timing for freeze-up and break-up based on concept so as to assess the anticipated effects on the Marsh Lake ice sheet due to a raised FSL and associated increase in the winter drawdown.
- Tagish River Erosion Model
  - HEC-RAS model evaluation of Tagish River erosion utilizing existing NHC model data. The purpose of this model is to assess the erosion potential of the shoreline materials under modified flow conditions in the Tagish River that would result from the change in water levels on Marsh Lake.

8. References

Morison, S.R. and Klassen R.W. 1991.Surficial Geology, Whitehorse, Yukon Territory. Geological Survey of Canada, Map 12- 1990. (Scale 1:250,000).

Appendix A

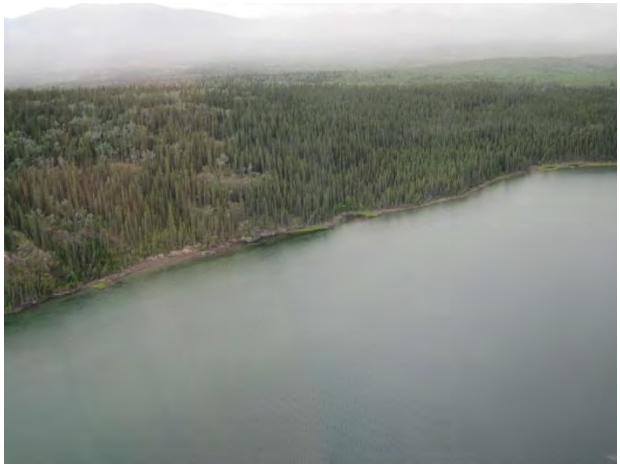
Photo Log of Erosion Activity in Marsh, Tagish and Bennett Lakes

Photograph 1
'Drunken forest', with minor bank erosion and turbid water at shore.

Photograph 2
Fine grained bluff eroding from North winds and/or melting permafrost.

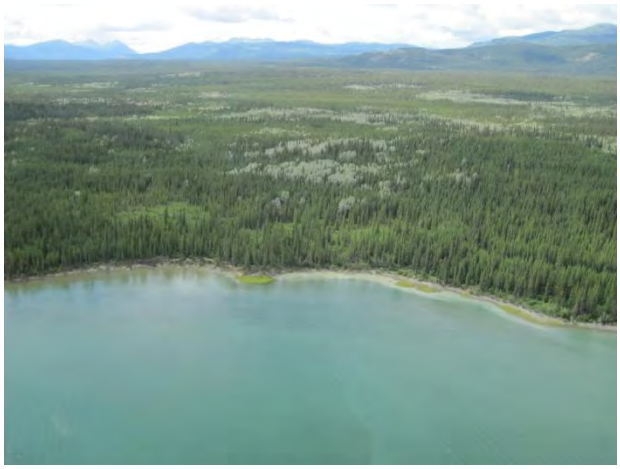
Photograph 3
Fine grained sediment eroding at low bank with turbid water offshore.

Photograph 4
Accretion of sand along shore.



Photograph 5
Fine grained sediment eroding along high bank.

Photograph 6
High, fine grained bluff eroding from North winds. Cabins and small dock directly adjacent to eroding bluff.

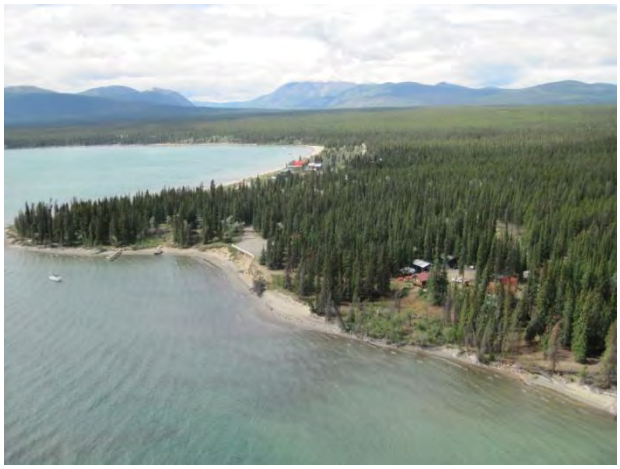


Photograph 7
Fine grained sediment eroding at low bank.

Photograph 8
Tagish River bank erosion.

Photograph 9
Fine grained sediment eroding along high bank. Houses all along bank.

Photograph 10
High, fine grained bluff eroding along Tagish River.



Photograph 11
High, fine grained bluff eroding along Tagish River. Houses all along eroding bank.

Photograph 12
High, fine grained bluff eroding along Tagish River. Houses all along eroding bank.

Photograph 13
Fine grained sediment eroding along high bank. Houses all along bank.

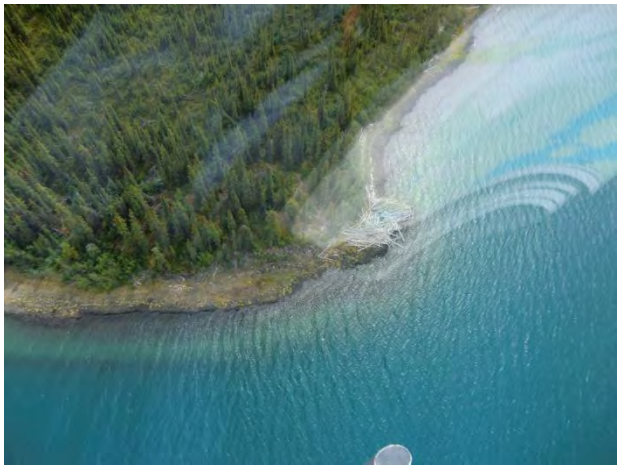
Photograph 14
Fine grained sediment eroding along high bank. Houses all along bank.

Photograph 15
Low, fine grained bluff eroding.

Photograph 16
Low, fine grained bluff eroding.

Photograph 17
Fine grained sediment eroding along high bank.

Photograph 18
Fine grained sediment eroding along high bank.



Photograph 19
Deposit of large woody debris.

Photograph 20
Accretion of sand on large beach.

Photograph 21
Undercut erosion on bedrock cliff.

Photograph 22
Slumping fine grained sediment eroding along low bank.

Photograph 23
Slumping fine grained sediment eroding on high bank.

Photograph 24
Low bank erosion of fine grained sediment.

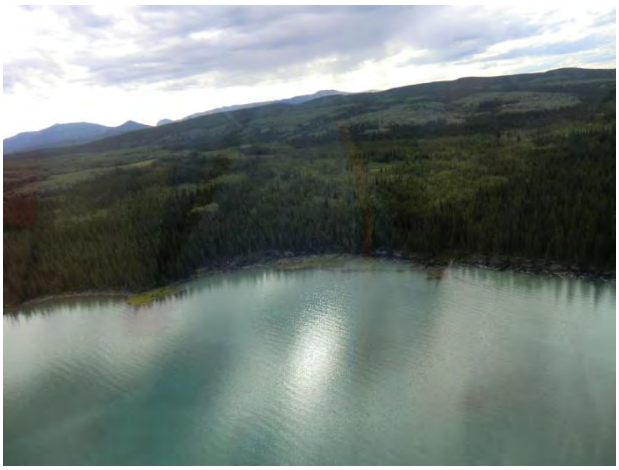
Photograph 25
High bank erosion of fine grained sediment.

Photograph 26
Low bank, fine grained sediment eroding along shore.

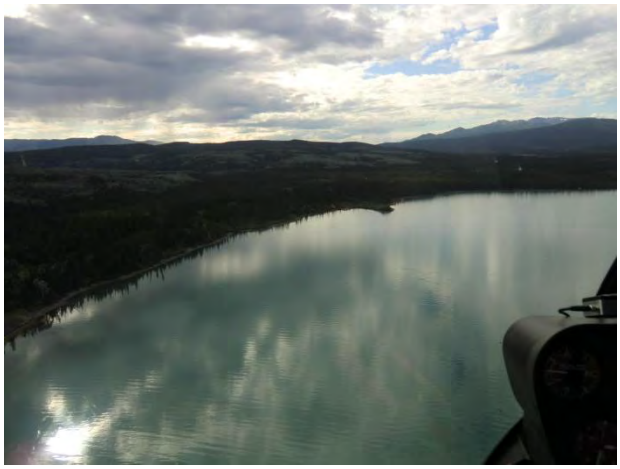
Photograph 27
. Low bank, fine grained sediment eroding along shore.

Photograph 28
High bank erosion of fine grained sediment.

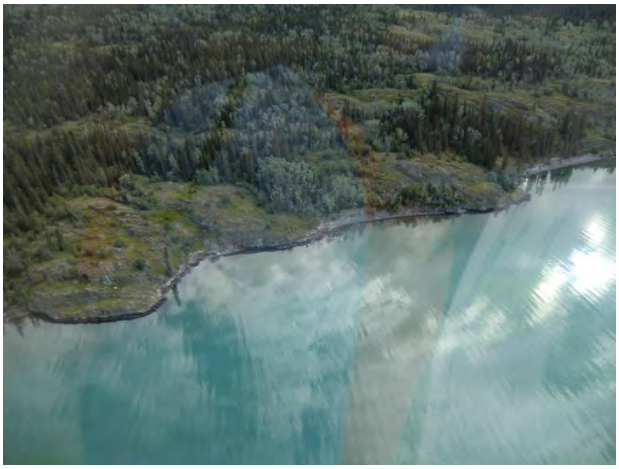
Photograph 29
High bank erosion of fine grained sediment.



Photograph 30
Low bank, fine grained sediment eroding along shore.



Photograph 31
Low bank, fine grained sediment eroding along shore.



Photograph 32
Low bank, fine grained sediment eroding along shore.

Photograph 33
Low bank, fine grained sediment eroding along shore.

Photograph 34
Low bank, fine grained sediment eroding along shore. 'Drunken forest' offshore.

Photograph 35
Low to medium high bank with very fine grained sediment eroding along shore. Anderson's property.

Photograph 36
High bank, fine grained sediment eroding along shore within Judas Creek Subdivision.

Photograph 37
Low bank, fine grained sediment eroding along shore. Properties/houses along shore.

Photograph 38
Low bank, fine grained sediment eroding along shore. Properties/houses along shore.

Photograph 39
Low bank with fine grained sediment eroding along shore. Properties adjacent to erosion.

Photograph 40
Low bank with fine grained sediment eroding along shore. Boat launch adjacent to erosion.

Photograph 41
Low bank, fine grained sediment eroding along shore. Properties/houses along shore with revetment.

Photograph 42
Low to medium high bank, fine grained sediment eroding along shore. Rich Muelleur's property flanks erosion on both sides.

Photograph 43
High bank with fine grained sediment eroding along shore. Property adjacent to erosion.

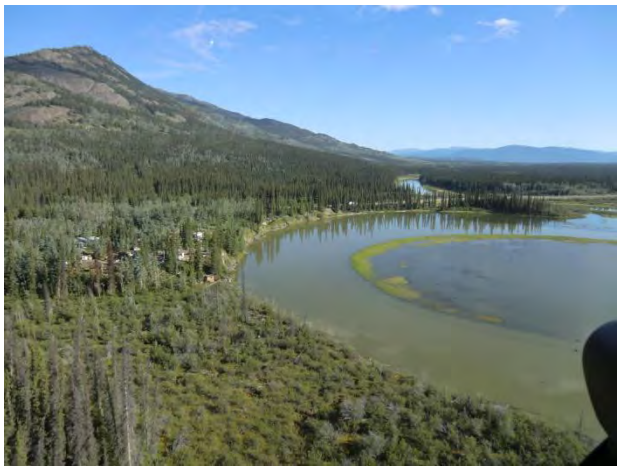
Photograph 44
High bank with revetment along highway, erosion is evident along shore.

Photograph 45
Low bank, fine grained sediment eroding along shore.

Photograph 46
Low bank, fine grained sediment eroding along shore. Army Beach properties all along shore, most with some form of revetment.

Photograph 47
Low bank, fine grained sediment eroding along shore. Bank is largely protected.

Photograph 48
Low bank with fine grained sediment eroding along shore. Bank erosion appears to be from M'Clintock River.



Photograph 49
Low to medium high bank with fine grained sediment eroding along shore. Bank erosion appears to be from M'Clintock River

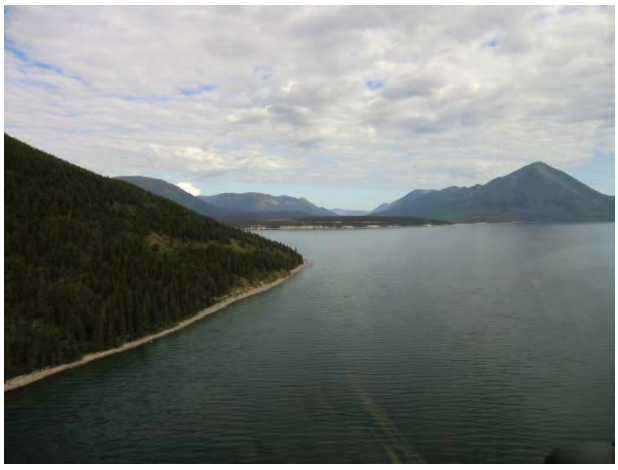
Photograph 50
High bank with fine grained sediment eroding along shore. North M'Clintock properties adjacent to erosion.

Photograph 51
High bank with fine grained sediment eroding along shore. North M'Clintock properties adjacent to erosion.

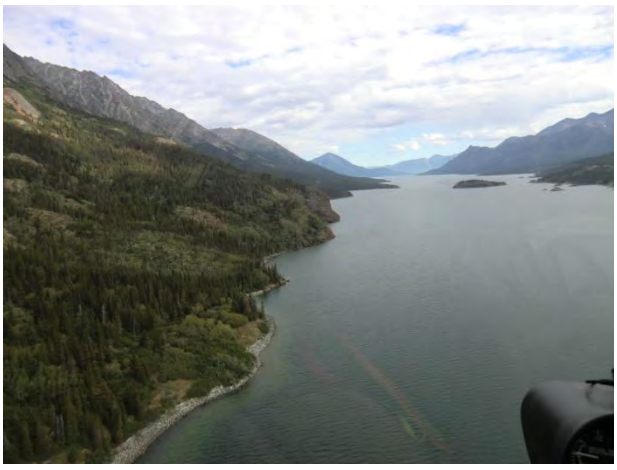
Photograph 52
Whitepass railway near shore of Bennet Lake. Revetment repair appears recent (white boulders).

Photograph 53
Whitepass railway near shore of Bennet Lake. Revetment repair appears recent (white boulders). Some erosion is evident.

Photograph 54
Whitepass railway near shore of Bennet Lake. Several revetment repairs range from recent (white boulders) to old. Some erosion is evident.



Photograph 55
Low to moderate high bank with fine grained sediment eroding along shore of Bennet Lake.



Photograph 56
Typical shore of Bennet Lake. Very coarse, well defined beach. Bedrock outcrops is also a common feature of the shoreline.

Photograph 57
Shoreline on Tagish River

Photograph 58
Level Survey 1 on the south shore of M'Clintock Bay

Photograph 59
Level Survey 2 on the north shore of M'Clintock Bay

Photograph 60
Level Survey 3 near Swan Haven

Photograph 61
Level Survey 4 at Judas Creek

Photograph 62
Level survey 5 at Judas Creek

Photograph 63
Level Survey 6 at Judas Creek

Photograph 64
Level survey 7 on the west shore of Tagish RIver

Photograph 65
Level Survey 8 near the mouth of Tagish Lake (west side)

Photograph 66
Level survey 9 on California Beach

Photograph 67
Level survey 10 on the west side of California Beach

Photograph 68
Level survey 11 to the south of California Beach

Photograph 69
Sediment collection point at Judas Creek lot 77.

Photograph 70
Turbid water resulted even when no agitation was conducted.

Photograph 71
Experimental design for wave agitation test.

Photograph 72
Bank revetment trial.

Appendix B

Bathymetry Maps and Beach Profiles

Survey 1

Survey 2

Survey 3

Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. Underhill Geomatics Ltd 2011.

N
W E
S

0 100 200
Metres

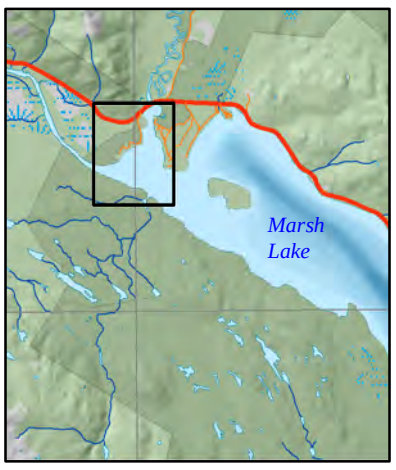
1:10,000

UTM Zone 8N, NAD 83

Legend

Shore Profile

Contour Interval 0.5 m



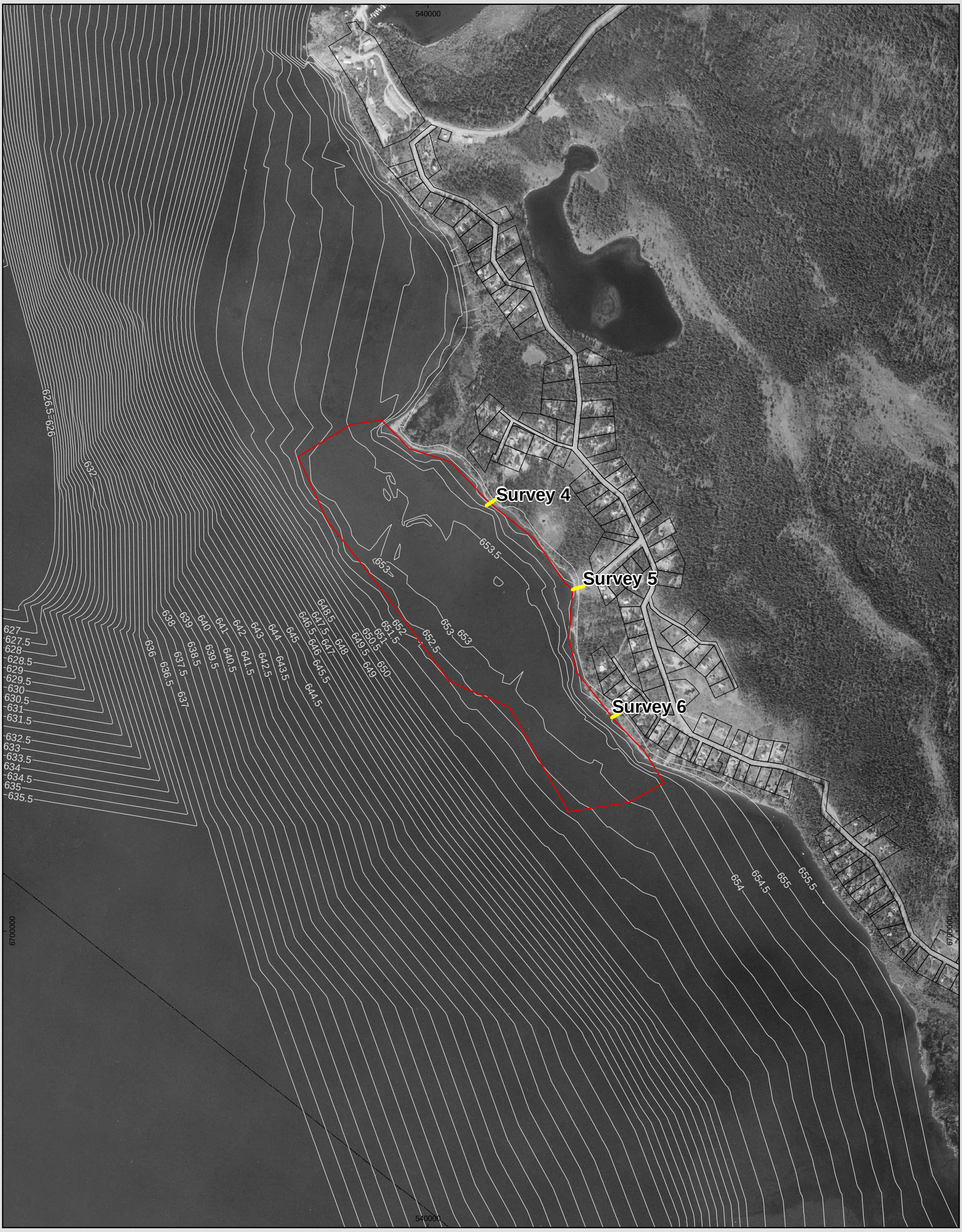
YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Bathymetry Mapping
M'Clintock Bay

November 2011
Project:60219833

AECOM

Figure 1



Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. Underhill Geomatics Ltd 2011.

N
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Metres

1:10,000

UTM Zone 8N, NAD 83

Legend

- Shore Profile
- Contour Interval 0.5 m
- Survey Area

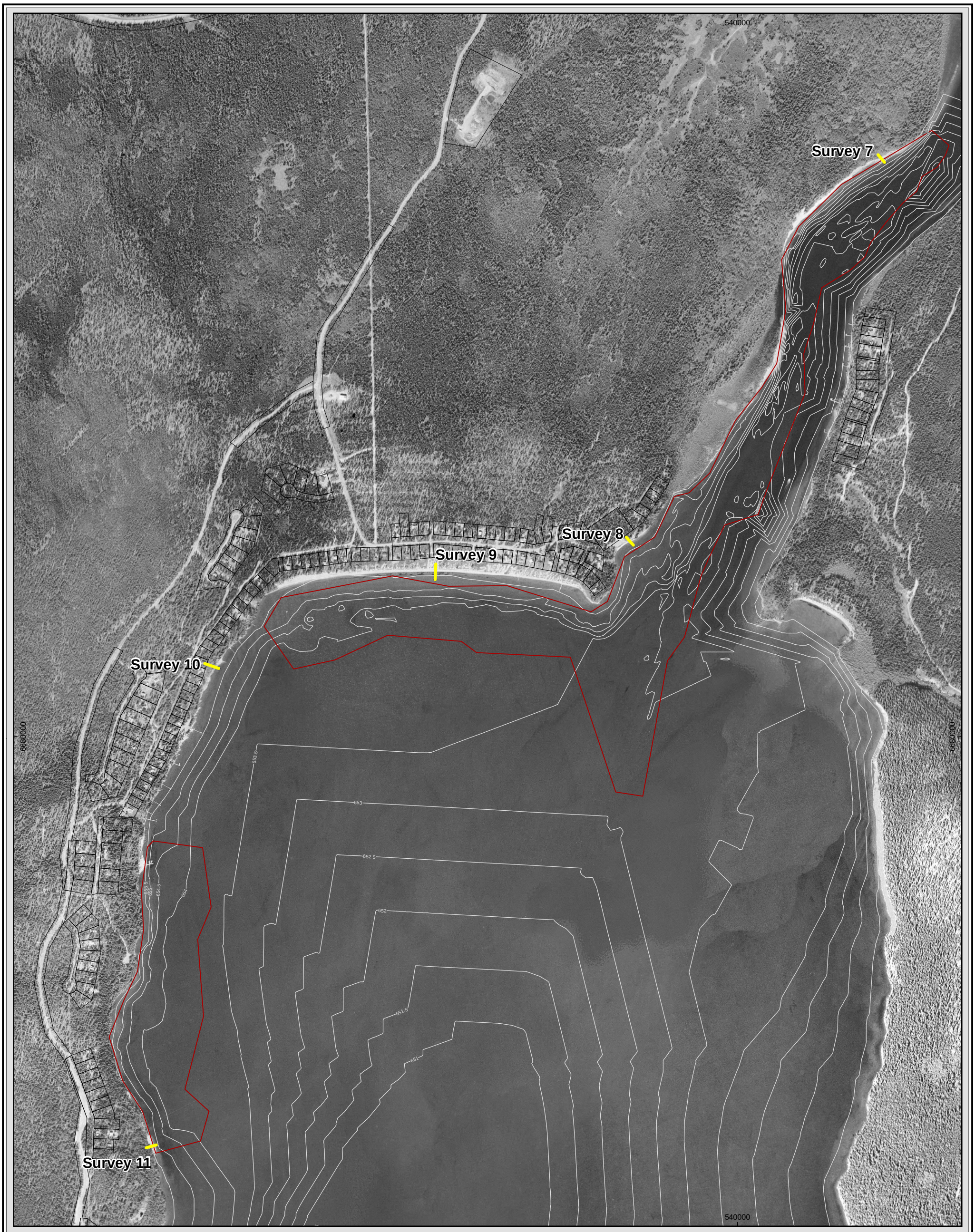
YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Bathymetry Mapping
Judas Creek

November 2011
Project:60219833

AECOM

Figure 2



Map Sources/Notes:
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Metres

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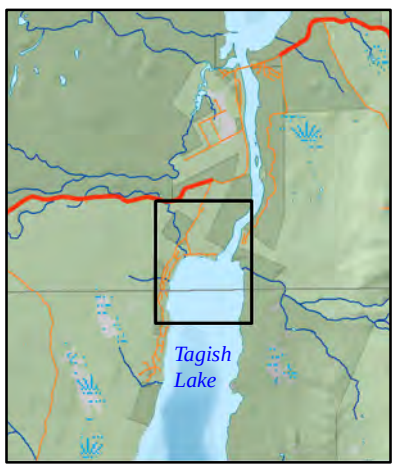
UTM Zone 8N, NAD 83

Legend

- Shore Profile
- Contour Interval 0.5 m
- Survey Area



YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Bathymetry Mapping
Tagish Lake

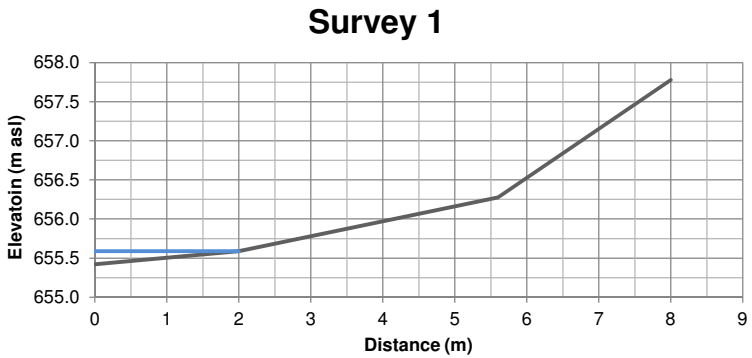
November 2011
Project:60219833

AECOM

Figure 3

Table 1 - M'Clintock Bay Shore Profiles

Survey 1			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	655.42	0.0	In the water
FS2	655.59	2.0	Wetted edge
FS3	656.28	5.6	Beach transect - Toe of bank
FS4	657.78	8.00	Top of bank



Survey 2			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	655.48	0.0	In the water
FS2	655.59	2.0	Wetted edge
FS3	656.27	10.2	Beach transect - Toe of bank
Bank height (approx.): 4 - 4.5 m (sloping 45 degrees)			

Survey 3			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	655.41	0.0	In the water
FS2	655.59	2.0	Wetted edge
FS3	655.70	2.8	Beach transect
FS4	656.42	11.8	Beach transect - Toe of bank
Bank height (approx.): 4.5 - 5 m (steep, sloping 60 degrees)			

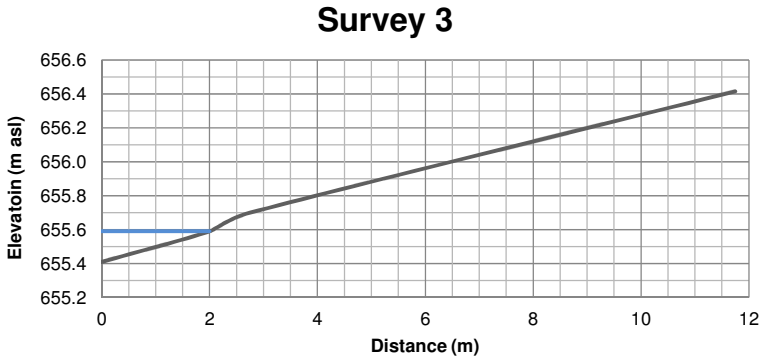
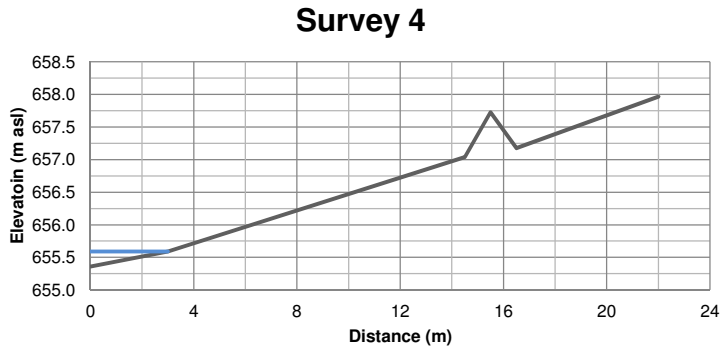
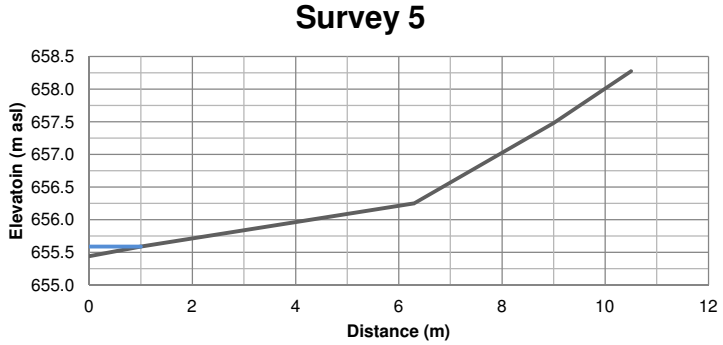


Table 2 - Judas Creek Shore Profiles

Survey 4				
Shot	**Level (m)**	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	4.2	655.4	0.0	In water at transducer (water depth: 17 cm)
FS2	3.9	655.6	3.0	Wetted edge
FS3	2.5	657.0	14.5	Beach transect - Toe of bank
FS4	1.8	657.7	15.5	Beach transect - Top of bank
FS5	2.3	657.2	16.5	Beach transect - Behind bank
FS6	1.6	658.0	22.0	Beach transect



Survey 5				
Shot	**Level (m)**	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	3.3	655.4	0.0	In water at transducer
FS2	3.2	655.6	1.0	Wetted edge
FS3	2.5	656.3	6.3	Beach transect - Toe of bank
FS4	1.3	657.5	9.0	Beach transect
FS5	0.5	658.3	10.5	Beach transect
Bank height (approx.): 10 m (sloped at 45 degrees)				



Survey 6				
Shot	**Level (m)**	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	5.6	655.4	0.0	In water at transducer
FS2	5.4	655.6	2.0	Wetted edge
FS3	3.9	657.1	13.2	Beach transect - Toe of bank
FS4	1.9	659.1	14.0	Top of bank

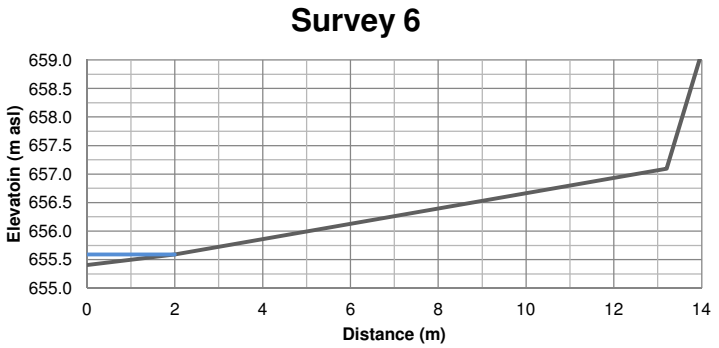
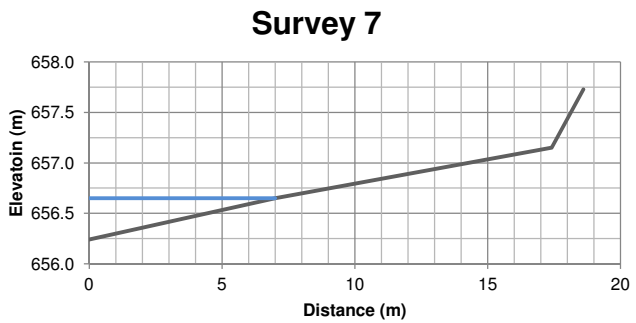
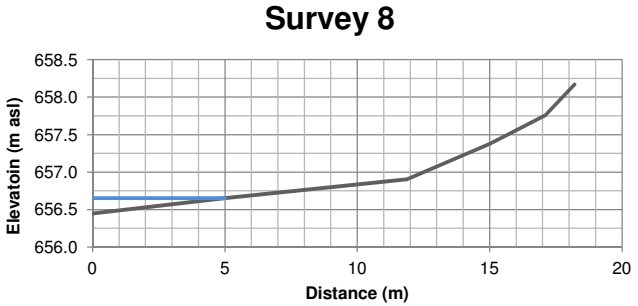


Table 3 - Tagish Lake Shore Profiles (1 of 2)

Survey 7			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	656.2	0.0	In water
FS2	656.7	7.0	Wetted edge
FS3	657.2	17.4	Beach transect - Toe of bank
FS4	657.7	18.6	Beach transect
Bank height (approx.): 8 - 9 m (near vertical bank)			



Survey 8			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	656.4	0.0	In water
FS2	656.7	5.0	Wetted edge
FS3	656.9	11.9	Beach transect
FS4	657.4	15.0	Beach transect
FS5	657.8	17.1	Beach transect - Toe of bank
FS6	658.2	18.2	Beach transect
Bank height (approx.): 4 m (sloping 45 degrees)			



Survey 9			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	656.4	0.0	In water
FS2	656.7	10.0	Wetted edge
FS3	656.6	15.0	Beach transect
FS4	656.7	21.1	Beach transect
FS5	657.3	24.7	Beach transect
FS6	657.4	28.2	Beach transect
FS7	658.6	40.2	Beach transect - Toe of bank
FS8	659.6	44.1	Beach transect
Bank height (approx.): 4 m (sloping 30 degrees)			

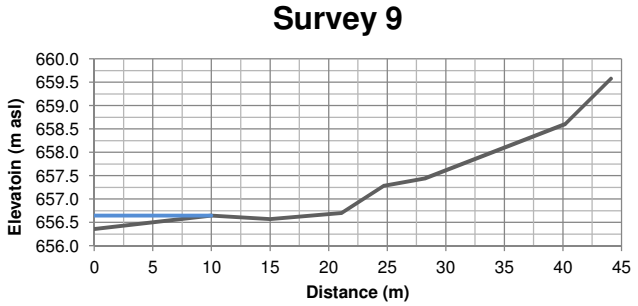
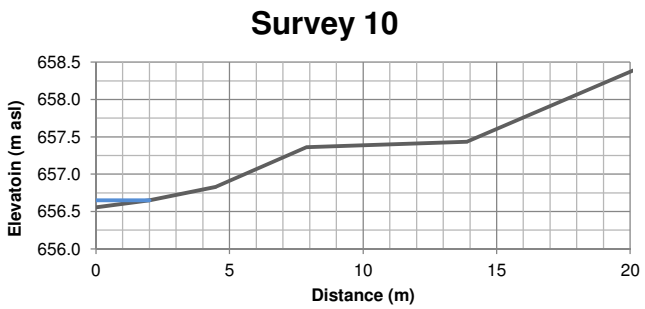
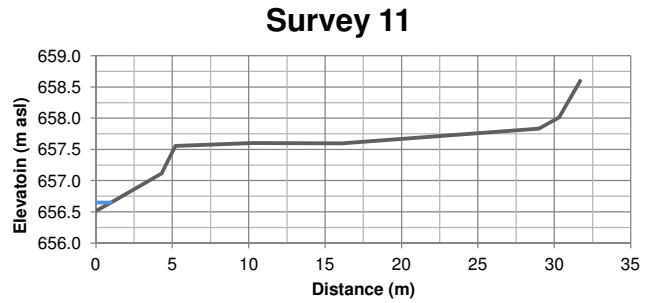


Table 3 - Tagish Lake Shore Profiles (2 of 2)

Survey 10			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	656.6	0.0	In water
FS2	656.7	2.0	Wetted edge
FS3	656.8	4.5	Beach transect
FS4	657.4	7.9	Beach transect
FS5	657.4	13.9	Beach transect - Toe of bank
FS6	658.4	20.1	Beach transect
Bank height (approx.): 3.5 - 4 m (steep)			



Survey 11			
Shot	**Elevation (m)**	**Distance (m)**	**Comment**
FS1	656.5	0.0	In water
FS2	656.7	1.0	Wetted edge
FS3	657.1	4.3	Beach transect
FS4	657.6	5.2	Beach transect
FS5	657.6	10.2	Beach transect
FS6	657.6	16.1	Beach transect
FS7	657.8	29.0	Beach transect - Toe of bank
FS8	658.0	30.3	Beach transect - High water mark, edge of trees
FS9	658.6	31.7	Beach transect



Appendix C

Sediment Sample Lab Data

QUANTITATIVE PHASE ANALYSIS OF ONE POWDER SAMPLE USING THE RIETVELD METHOD AND X-RAY POWDER DIFFRACTION DATA.

Forest Pearson
Aecom Canada Limited
2251 2nd Avenue
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Mati Raudsepp, Ph.D.
Elisabetta Pani, Ph.D.
Jenny Lai, B.Sc.
Edith Czech, M.Sc.

Dept. of Earth & Ocean Sciences
The University of British Columbia
6339 Stores Road
Vancouver, BC V6T 1Z4

October 11, 2011

EXPERIMENTAL METHOD

The sample **"J4"** was reduced into fine powder to the optimum grain-size range for X-ray analysis (<10µm) by grinding under ethanol in a vibratory McCrone Micronising Mill for 7 minutes. Step-scan X-ray powder-diffraction data were collected over a range 3-80°2θ with CoKa radiation on a Bruker D8 Focus Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

RESULTS

The X-ray diffractogram was analyzed using the International Centre for Diffraction Database PDF-4 and Search-Match software by Siemens (Bruker). X-ray powder-diffraction data of the sample were refined with Rietveld program Topas 4.2 (Bruker AXS). The results of quantitative phase analysis by Rietveld refinements are given in Table 1. These amounts represent the relative amounts of crystalline phases normalized to 100%. The Rietveld refinement plot is shown in Figure 1.

Note that the broad calculated peak indicated by the vertical line in Figure 1 is used to better fit the X-ray pattern and is the result of the presence of a small amount of an unknown clay mineral which could not be refined and measured.

Table 1. Results of quantitative phase analysis (wt.%)

Mineral	**Ideal Formula**	**J4**
Quartz	SiO_2	33.8
Clinochlore	$(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$	7.3
Muscovite-Illite	$KAl_2(AlSi_3O_{10})(OH)_2$-$K_{0.65}Al_{2.0}Al_{0.65}Si_{3.35}O_{10}(OH)_2$	8.0
Actinolite	$Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$	4.7
Plagioclase	$NaAlSi_3O_8 – CaAl_2Si_2O_8$	30.4
K-Feldspar	$KAlSi_3O_8$	13.3
Calcite	$CaCO_3$	2.3
Ankerite-Dolomite ?	$Ca(Fe^{2+},Mg,Mn)(CO_3)_2/CaMg(CO_3)_2$	0.3
Total		100.0

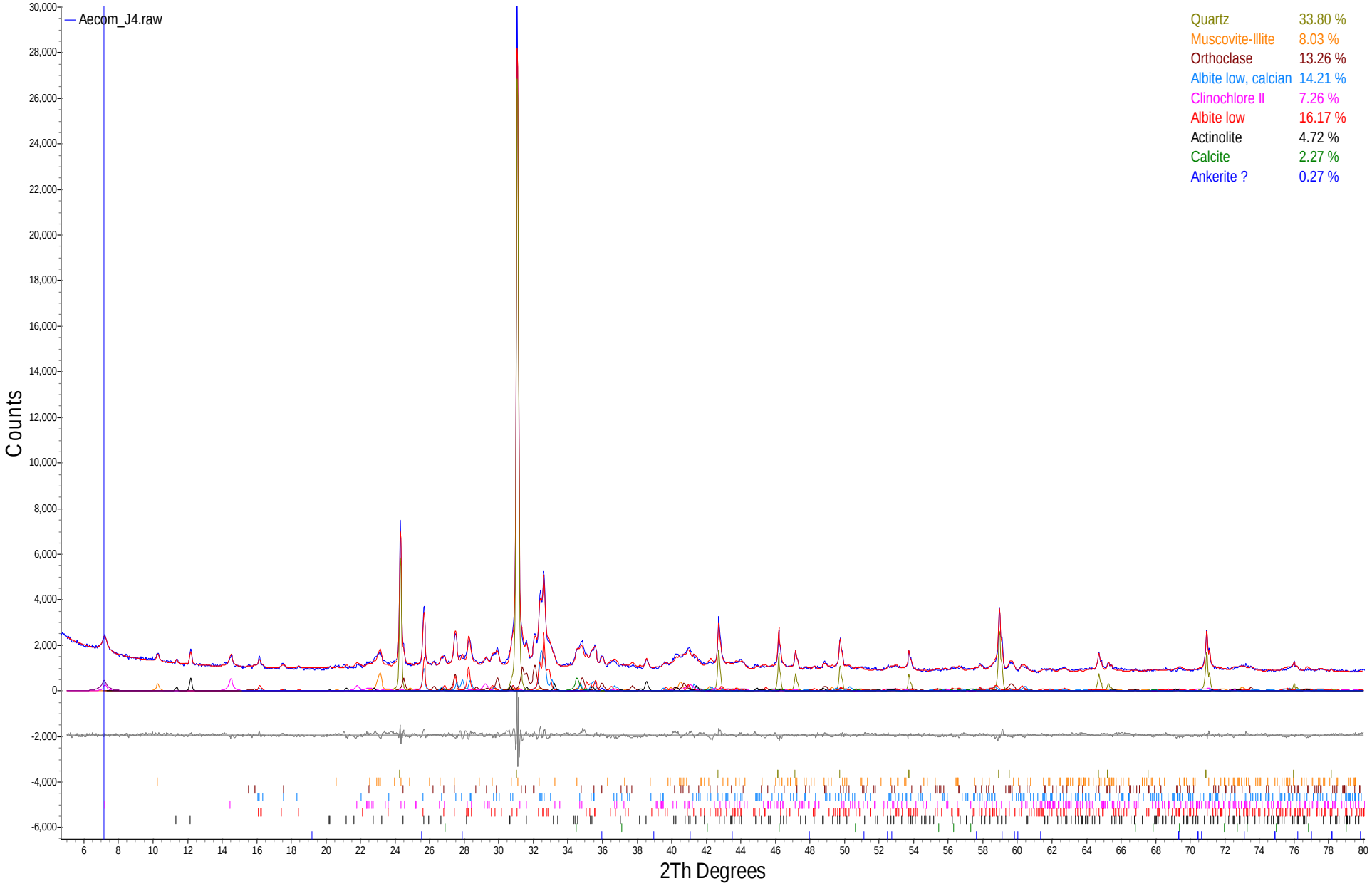

Figure 1. Rietveld refinement plot of sample **Aecom "J4"** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below – difference between observed and calculated intensities; vertical bars, positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

Grain Size - Mass Retained (in g)

	Sieve Size (mm)									
Sample	**4**	**2**	**0.850**	**0.425**	**0.180**	**0.106**	**0.075**	**0.045**	**pan**	**Total mass (g)**
J1	1,350	879	564	286	186	79	57	37	128	3,565
J2	909	786	770	356	185	66	42	37	166	3,316
J3	6,000	303	534	1,059	345	22	7	5	5	8,280
SS 30	159	317	297	151	163	418	633	566	511	3,214
SS 40	19	231	622	493	278	84	26	14	19	1,786
SS 41	102	12	17	406	2,256	1,018	107	53	44	4,014
SS 42	449	132	230	375	719	296	236	305	521	3,262

Metal analysis of samle J4

Component	Unit	Value
Ag	ppm	< 0.5
Al	%	6
As	ppm	19
Ba	ppm	1380
Be	ppm	1.50
Bi	ppm	<2
Ca	%	2.71
Cd	ppm	<0.5
Co	ppm	16
Cr	ppm	101
Cu	ppm	44
Fe	**%**	3.4
Ga	ppm	20
K	%	1.84
La	ppm	30
Mg	%	1.74
Mn	ppm	533
Mo	ppm	1
Na	%	1.74
Ni	ppm	80
P	ppm	740
Pb	ppm	15

Component	Unit	Value
S	%	0.01
Sb	ppm	<5
Sc	ppm	14
Sr	ppm	330
Th	ppm	<20
Ti	%	0.34
Tl	ppm	<10
U	ppm	<10
V	ppm	112
W	ppm	<10
Zn	ppm	85

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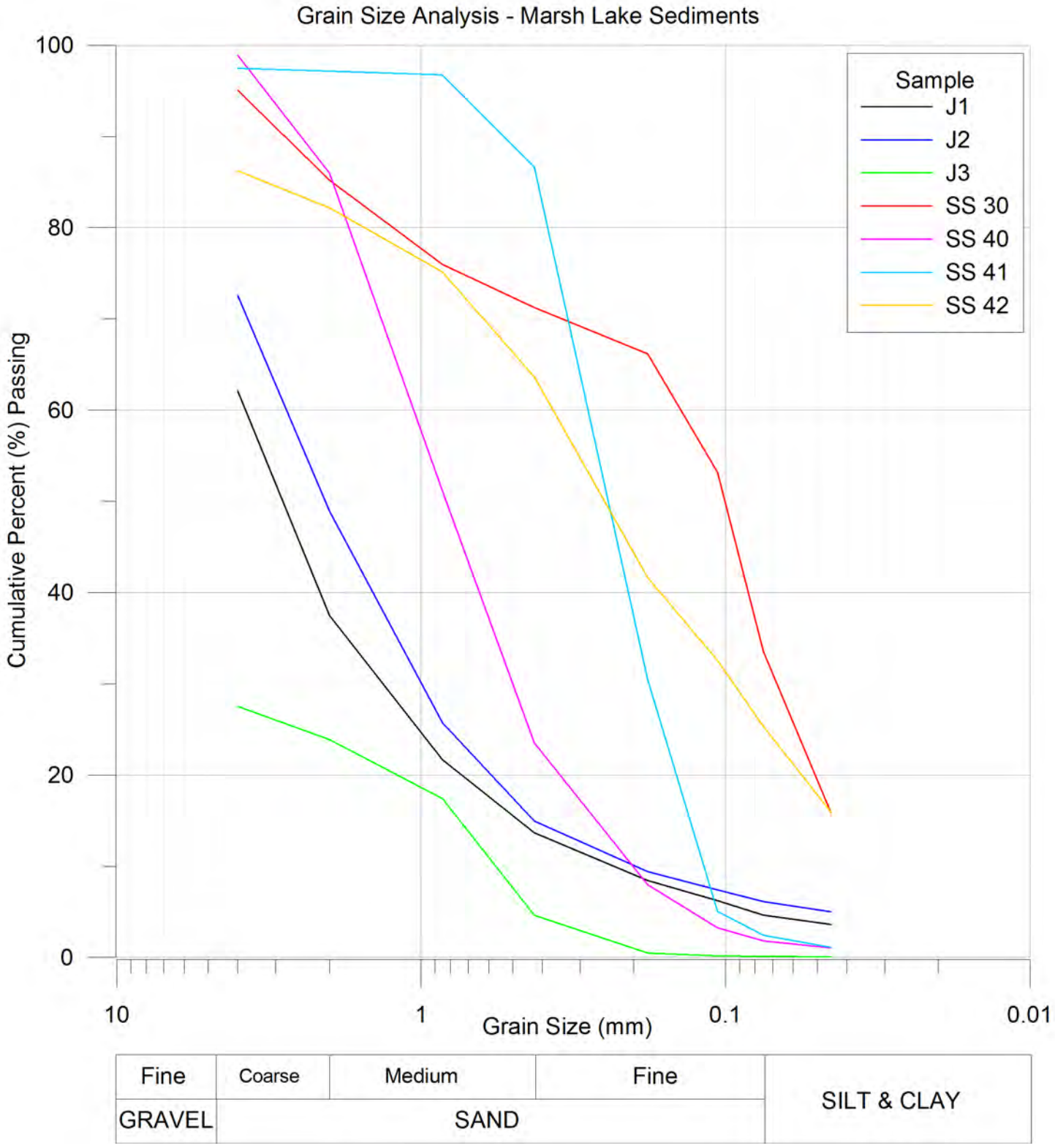

Appendix D

North M'Clintock Reconnaissance Memorandum

AECOM
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www.aecom.com

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867 633 6321 fax

Memorandum

To	Hector Campbell, YEC	Page	1
CC	Chad Davey, Jena Gilman,(AECOM)		
Subject	North M'Clintock reconnaissance		
From	Chad Davey, AECOM		
Date	May 30, 2011	Project Number	60197181

Purpose and Objectives

On May 23rd, 2011, AECOM performed a site reconnaissance of the shoreline of North M'Clintock. The purpose of the recon was to observe the M'Clintock River in relation to the shoreline erosion occurring along the silt bluffs. A photolog and map of the recon is provided.

Observations

The following observations were made:

- Lake waters were not high enough to enter North M'Clintock Bay.
- The M'Clintock River was flowing within the Bay and no ice was observed.
- The M'Clintock River splits into two channels immediately downstream of the Alaska Highway bridge (Photo 9) in M'Clintock Bay. The smaller of the two channels flows adjacent to Lots 1039, 1040 and 392.
- A small sand/silt spit was observed immediately north of Lot 1039. The approximate area of the spit was 250 m^2 and was about 1.0 m in height (Photo 1). This suggests that wave action may be transporting and depositing eroded bank and bluff sediments northwards along the beach of North M'Clintock.
- The beach along North M'Clintock surficially consists mainly of eroded bluff silt/sand sediments 10-20 cm in thickness, with a clay layer beneath (Photo 4). The water surface of the M'Clintock River flowing adjacent to Lots 1039, 1040 and 392 was primarily in contact with the clay layer.
- Rill erosion within the silt/sand beach and clay layer was evident along the river banks of the M'Clintock River (Photos 2 and 3).
- Owners of Lots 393, 392, 1040 and 1039 have employed shrub staking to help stabilize the beach and bluff from wave/flood erosion (Photo 5).
- A sediment sample (SS30) of the eroding silt/sand bluff (Photos 6 and 7) north of the bedrock outcrop was collected (E527697, N6712946, 08V).
- The bluff near Lots 396 and 1027, south of the bedrock outcrop on North M'CLintock (Photo 8), is shorter and experiencing less erosion than Lots situated north of the bedrock outcrop.

- A dock adjacent to Lot 375 shows some sand accretion along the north side of the dock, indicating that wave action is transporting and depositing sediments southward along this section of beach at North M'Clintock.
- The rocky point adjacent to Lot 1026 appears to be a node for littoral cells north and south with sediment being transported in opposite directions due to wave action.

527000
528000
6714000
6713000
6712000

KDFN R-77B/D1
1051
1052
KDFN S-42B/D
KDFN R-77B
1042A
1043A
811A
1065
810A
809A
808A
807A
806B
1010A
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900050
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801
800
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33A
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40A
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36A
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1048
1047
1046
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KDFN R-78B
KDFN R-78B/D2
1039
1040
392
393
394
1026
396
1027
Sand Spit
Bedrock Outcrop
11700
397
1033
399
455
KDFN S-164B/D
374
375
376
377
North M'Clintock
South M'Clintock
Area

Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. All Rights Reserved. Yukon Land Tenure from Yukon Territorial Government, 2010.

N
W
E
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0 0.1 0.2 0.3 0.4
1:9,142
UTM Zone 8N, NAD 83

Legend

Titled Property
- Lot with Title Information Provided
- Legal Survey
- Licence

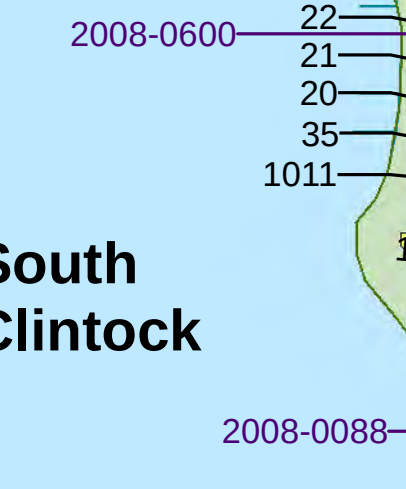
Other Tenures and Interests
- Land Tenure Application
- First Nations' Settlement Lands

Roads
- Highway
- Road

- Sand Spit

Titled Property and Disposition to Government are labelled by Lot Number

Leases, Licences, Notations and Applications are labelled by Application Number



YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Reconnaissance
M'Clintock Bay

May 2011
Project 60197181

AECOM

Figure 1

Path: W:\GIS\TEMP\MXD\60197181_M'ClintockBay_20110603.mxd
Date Revised: June 3, 2011 Prepared by: DL Project: 60197181

Photograph 1. Small sand/silt spit at north end of M'Clintock Bay, north extent just beyond view on left side of photo.

Photograph 2. M'Clintock River in proximity to Lot 1039, North M'Clintock.

Photograph 3. The two channels of M'Clintock River join (flow is from bottom to top of photo). Rill erosion along the M'Clintock river bank is also evident here (small gullies flowing right to left on photo)..

Photograph 4. Along the M'Clintock River banks a layer of silt washed from the erosion bank covers a clay deposit.

Photograph 5. Lots 393, 392, and 1040 have employed willow plantings to help reduce shoreline erosion from wave action.

Photograph 6. Typical silt deposit that consist of the erosion bluffs along North M'Clintock.

Photograph 7. A sediment sample was collected at the toe of the eroding silt bluff.

Photograph 8. Bluff south of bedrock outcrop (situated at Lot 1026) is more stable and shorter in height.

Photograph 9. M'Clintock River splits into two channels downstream of Alaska Highway bridge (left of photo out of view). Photo taken May 22nd, 2011.

Appendix E

Judas Creek Subdivision Site Visits Meeting Minutes and Memorandum

AECOM
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Minutes of Meeting

Date of Meeting	May 22, 2011	Start Time	2pm	Project Number	60197181
Project Name	Marsh Lake Fall Storage				
Location	Judas Creek Subdivision				
Regarding	Proposed Full Supply Level and Shoreline Erosion				
Attendees	Karen and Farell Anderson, Judas Creek Residents (Lot 77) Keith Kendall, Judas Creek Resident (Lot 79) Tom and Jill Carmichael, Judas Creek Residents (Lot 83) Brunhilde Baiker, Judas Creek Resident (Lots 135 to 137) Chad Davey, AECOM Jena Gilman, AECOM				
Minutes Prepared By	Chad Davey				

PURPOSE AND OBJECTIVES

In response to Judas Creek residents' requests, a meeting occurred on May 22nd, 2011 between property owners and AECOM staff (Chad Davey and Jena Gilman) to discuss shoreline erosion issues. A helicopter reconnaissance was also conducted on this date. The primary focus of the helicopter recon was to observe ice break-up conditions along Marsh, Tagish and Bennett Lakes (observations are included in a separate memo). The purpose of this memo is to outline the concerns/observations raised by Judas Creek property owners along or adjacent to the shoreline erosion that is currently evident along portions of the Judas Creek Subdivision shoreline. In addition, this memo outlines the observations made by AECOM staff regarding the site visit. A map of the area visited and photo log is attached.

Judas Creek property owners' concerns/observations:

Lot 77

- This property is owned by Farrell and Karen Anderson.
- The Andersons have observed waves striking the 1.5 m high bluff situated approximately 100 ft from their property line. Upon wave contact, the clay/silt portion of the bluff appears to "dissolve" rather than wash down beach.
- The Andersons observed significant erosion occurring along the bluff during the 2007 flood.
- The Andersons are concerned that higher water levels proposed by YEC will cause further erosion problems along the bluff near their property line.
- The Andersons indicated that the waves strike the shoreline directly and not at an angle.

Lot 79

- This property is owned by Keith and Rita Kendall.

- Keith is concerned that higher water levels proposed by YEC will accelerate erosion along the small bluff situated approx 100 ft from his property line.
- Keith has actively placed logs along the bluff near his property in efforts to stall shoreline erosion (photo 6).
- When Keith notices any trees that begin to lean due to the bluff erosion, he cuts them down and places the log parallel with the bluff to help reduce erosive wave action.
- During excavation of his foundation when he first built his house, Keith noticed seams of blue-coloured clay amongst gravel and sand deposits.

Lot 83

- This property is owned by Tom and Jill Carmichael.
- The Carmichael's are primarily concerned with flooding issues near their property.
- During the 2007 flood, the Carmichael's sandbagged the bluff located approx 100 ft from their property line (photo 9). The flooding inundated land within 20 ft of their property line.
- The Carmichael's expressed concerns about YEC's plan to raise the Full Supply Level (FSL) and how this may exacerbate flooding in the future. They are concerned about their drinking water quality within their well during flooding.

Lots 135 to 137

- These properties are owned by Brunhilde Baiker.
- Brunhilde is primarily concerned about ground saturation beneath her property since the 2007 flood. During the flood, Brunhilde observed 2-3 cm of water above the gravel floor of her basement. Brunhilde has had wet soil in the basement of her house since the 2007 flood. She has tried to dry the soil in her basement using fans and vents. Despite her efforts, the gravel continues to be moist.
- Brunhilde also mentioned that she has had to move her sauna back from the shoreline after the 2007 flood to ensure it was on stable ground.

AECOM observations:

- The observed shoreline erosion described here is situated on crown land only. The property lines of the lots in this area are typically 70 to 100 ft from the actually shoreline itself.
- A small section (75 m in length) of recent shoreline erosion adjacent to Lots 77 to 79 was visible from the aerial survey (See Figure 1 and photolog).
- A closer inspection on foot revealed the greatest shoreline erosion activity of crown land was occurring near the Anderson's property line (Lot 77) and the adjacent Lot 78. The bluff eroding here is approximately 2 m in height and extends the full width of the shoreline in front of the Anderson's property, Lot 78 and a portion of Lot 76 (photos 2 through 4). The height of the bluff gradually declines along either side of Lot 78 and reduces to approximately 30 to 50 cm in height – a height that appears to be typical of the remaining bluff along Judas Creek lots adjacent to the shoreline in this area.
- The eroding bluff adjacent to the Anderson's property (Lot 77) consists mainly of a brittle, dry clay (~1.7 m in height) that appears to lose all cohesion when in contact with water. This clay deposit is only visible along the eroding bluff in front of the Lots 77 and 78. Situated on top of the clay is a gravel/sand deposit (~0.3 m in height), this layer appears be typical of the

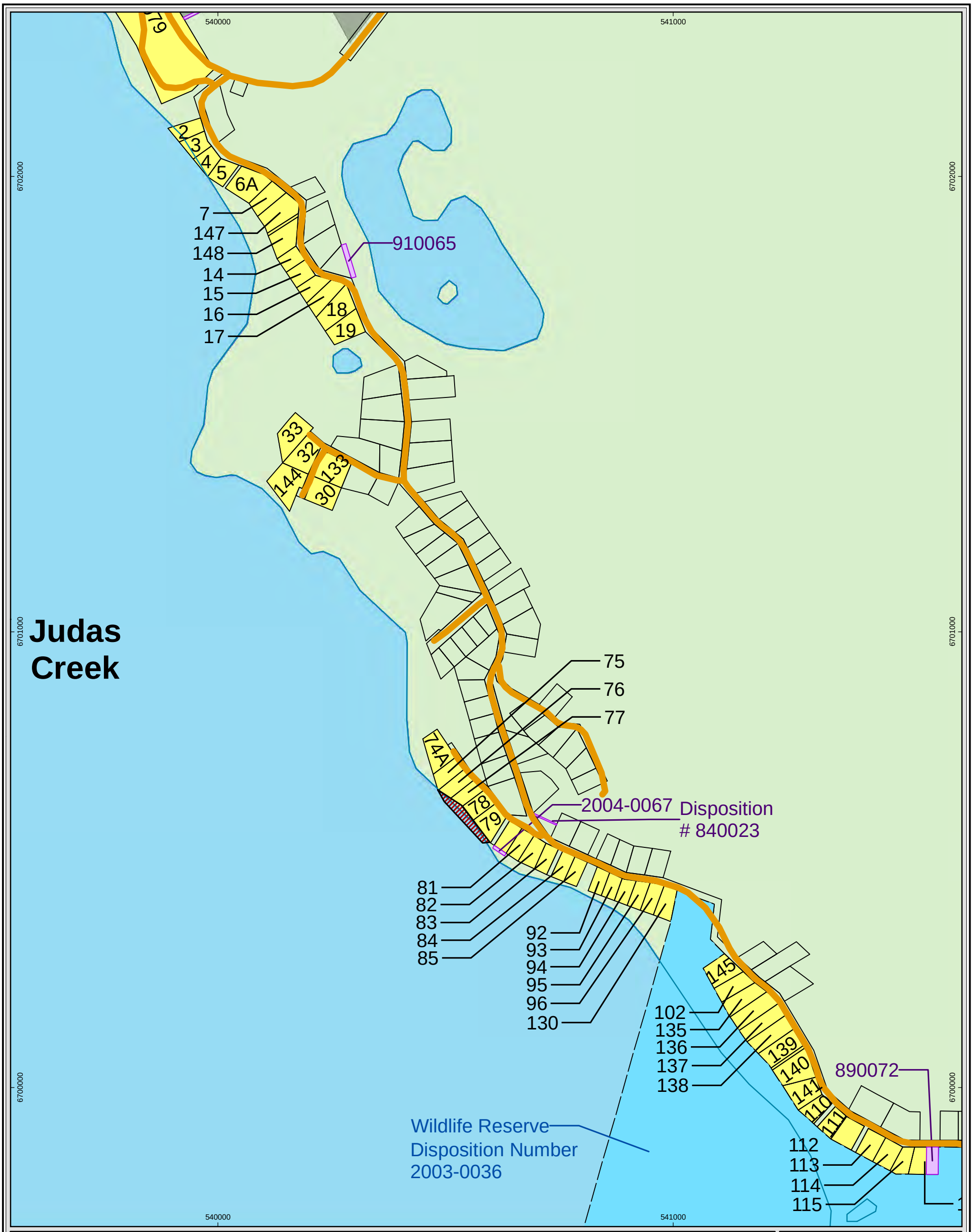
remaining bluff extending away in both directions from the Anderson's Lot. A thin vegetation veneer caps the surficial layer along the bluff.

- The bluff near Lot 78 has visible slump cracks where the bank is slowly breaking off onto the beach (photo 8).
- Three sediment samples were collected along the shoreline and bluff adjacent to the Anderson's property – see table 1 below.

Table 1

Sample	Location	UTM*	Comments
J1	**Clay bluff sediment**	**540515, 6700604**	**Sample was taken from eroding bluff and consists mainly of the brittle clay deposit.**
J2	**Toe of bluff**	**540515, 6700604**	**Sample was taken from the active eroding area at the toe of the bluff**
J3	**Beach**	**540515, 6700604**	**Sample was taken from the beach to represent typical beach sediments.**

*** Zone 08, Nad83**



Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. All Rights Reserved. Yukon Land Tenure from Yukon Territorial Government, 2010.

N
W E
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km
0 0.1 0.2 0.3 0.4

1:7,909

UTM Zone 8N, NAD 83

Legend

- Legal Survey
- Disposition to Government
- Lot with Title Information Provided
- Licence
- Shoreline erosion (approx)

Roads

- Street

Titled Property and Disposition to Government are labelled by Lot Number

Leases, Licences, Notations and Applications are labelled by Application Number

YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Judas Creek Shoreline erosion

May 2011
Project 60146345

AECOM

Figure 1

Path: W:\GIS\TEMP\MXD\FIG1_20110525_MarshFlood.mxd

Date Revised: May 26, 2011 Prepared by: DL Project: 60146345

Photograph 1. Areal view of erosion bluff near Andersons property line (Lot 77 – centre of photo).

Photograph 2. Ground view of erosion bluff near Andersons property line.

Photograph 3. View of erosion bluff near Lot 78, south of Andersons Lot 77.

Photograph 4. View of erosion bluff near Lot 76, north of Andersons Lot 77.

Photograph 5. Close-up of clay material at erosion bluff near Lot 77.

Photograph 6. View of erosion protection (logs) near Lot 79.

Photograph 7. Close-up of typical beach material along Judas Creek subdivision.

Photograph 8. View of slump cracks along erosion bluff near Lot 78.

Photograph 9. View of flood and erosion protection (boulders and sandbags) near lot 83.

Photograph 10. View of erosion bluff near Lot 77 with some erosion protection (logs and boulders).

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Memorandum

To	David Morissette, Engineering Lead, AECOM	Page	1 of 5
CC	Forest Pearson, AECOM; Hector Campbell, YEC		
Subject	Judas Creek Property Survey Field Memo – T.1.1.3		
From	Emilie Herdes, AECOM		
Date	August 31, 2011	Project Number	60197181

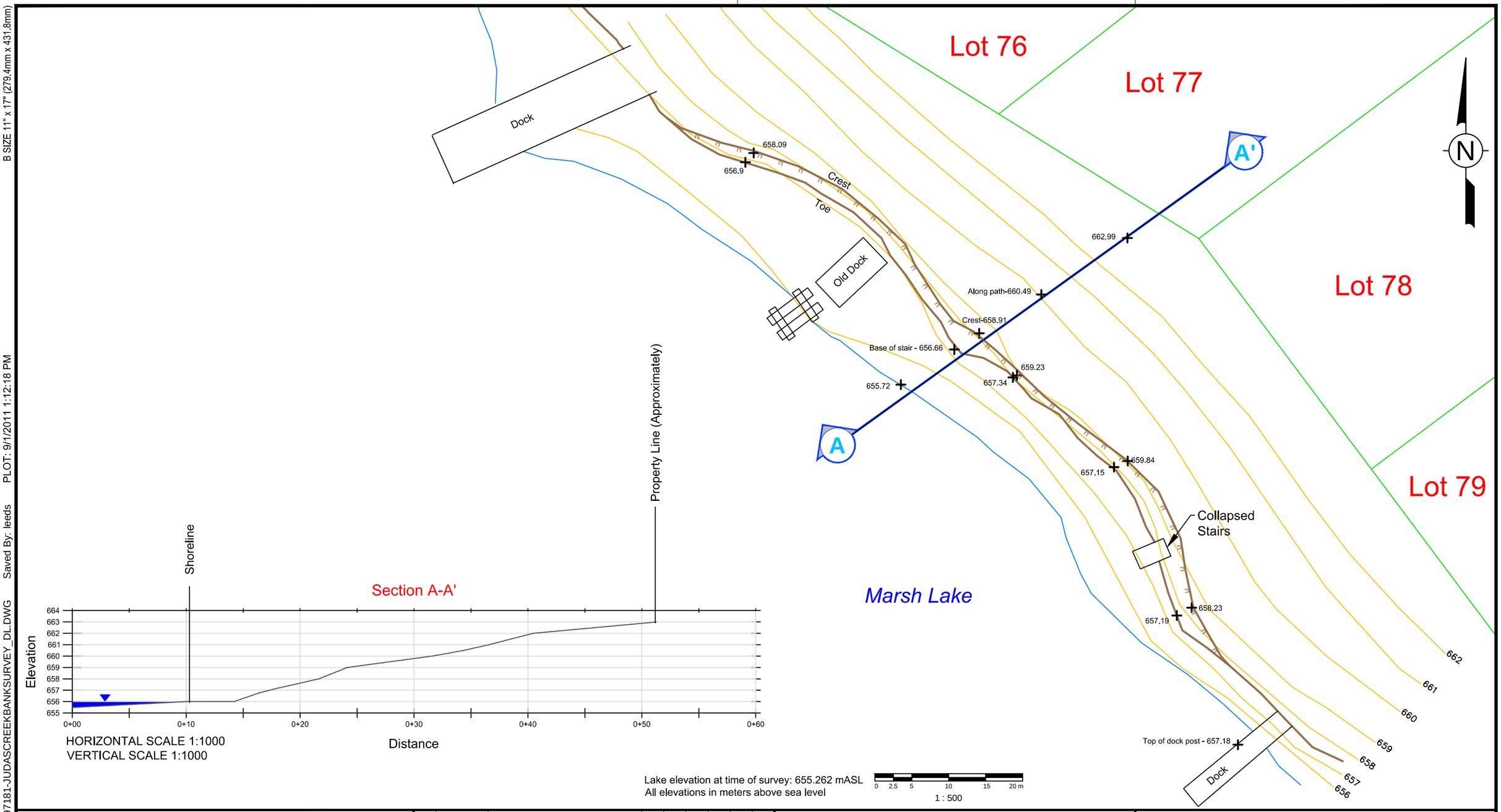
Trip Location: Judas Creek Subdivision
Trip Dates: July 21, 2011
Personnel: Forest Pearson, Jena Gilman and Emilie Herdes
Objectives: Preliminary topographic survey of Lot 77 and transect surveys of shoreline and bluff fronting properties in Judas Creek Subdivision (Marsh Lake).

Date: July 21, 2011
Weather: Sunny, 20°C, calm
Equipment: Jogger 24 engineers level and Vertex IV height measurer
Marsh Lake water level: 655.75 mASL

Tasks completed:

1. Preliminary topographic survey of shoreline in front of Lot 77, Judas Creek Subdivision using Vertex height measurer (see Figure 1). Sediment samples collected on from cutbank (photograph 1).

Photograph 1. Sediment collection point near Lot 77



I/R	YY/MM/DD	ISSUE/REVISION DESCRIPTION	DRN	CHK	DES	ENG	IDR	APP
1	11/08/19	ISSUED FOR REVIEW	DL	KW	FP			

AECOM

Judas Creek Bluff
Lots 76-79
Preliminary Survey
July 24, 2011

PROJECT NUMBER	DRAWING NUMBER	ISSUE/REVISION
60197181	Figure 1	1

2. Demarcation of proposed FSL with rebar installed near dock post adjacent to Lot 77. Top of rebar represents proposed FSL (656.54 mASL). Rebar may sink over winter due to soft substrate underlying beach gravel.

Photograph 2. Proposed FSL rebar installed (Lot 77)

3. Visit to low properties in Judas Creek Subdivision to survey transect up beach:
    - Lot 83 – Elevation at toe of slope is 656.6 mASL; land behind sand bags is at 657.1 mASL.
    - Lots 135-137 – Elevation at fence is 657.4 mASL; guest house foundation is at 658.2 mASL.

Photograph 3. Shoreline at Lot 83

4. Visit to shoreline bluff south of KDFN S-206 along Alaska Highway – high glacio-lacustrine bluff subject to erosion. Beach transect presented in Figure 2.

Photograph 4. Shoreline bluff south of KDFN S-206

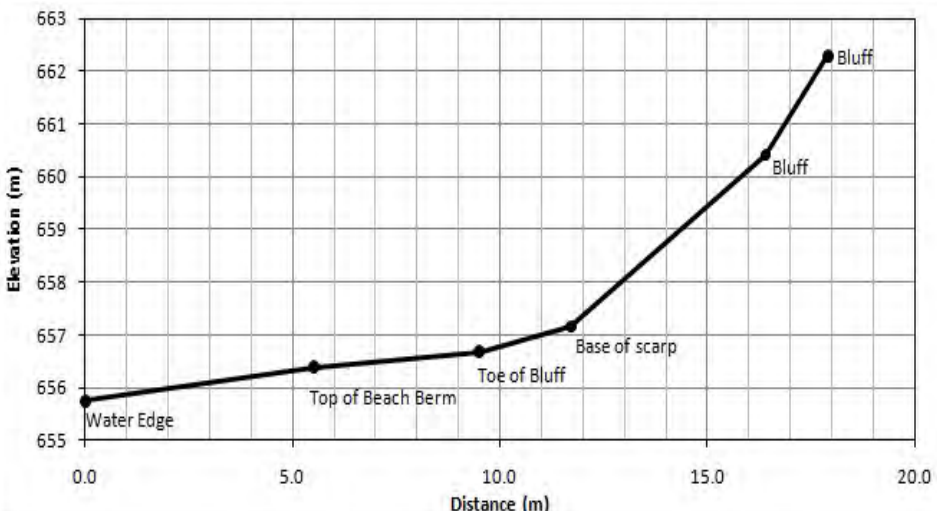


Figure 2. Beach transect at shoreline bluff south of KDFN S-206

- Survey locations are presented in Figure 3.
- All planned programs completed on schedule and with no major injuries to personnel.

Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. All Rights Reserved. Yukon Land Tenure from Yukon Territorial Government, 2010.

N
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0 0.4 0.8 1.2 1.6
1:60,000

UTM Zone 8N, NAD 83

Legend

- Survey Location
- Lot with Title Information Provided

Other Tenures and Interests

- Land Tenure Application
- Notation
- First Nations' Settlement Lands

Roads

- Highway
- Main Road
- Road

Titled Property and Disposition to Government are labelled by Lot Number

Leases, Licences, Notations and Applications are labelled by Application Number

YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Survey Locations

August 2011
Project 60197181

AECOM

Figure 3

Path: W:\GIS\Large Projects\YukonEnergy\Marsh Lake Fall-Winter Storage\Y2011\60197181\MXD\113_Fig3-20110803_SurveyLoc_60197181.mxd Date Revised: 08/03/2011 Prepared by: DL Project: 60197181