



# **The North Spur Quick Clay Instability & Landslide Problem:**

## **The weak link in Nalcor's Muskrat Falls Project**

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March 9, 2013**

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## NOTE ON SOURCES

The following presentation is based on public sources all of which are available on line.

**Where possible an active link is provided to the document referenced.**

The vast majority of these documents were generated by hearings and reviews before the Federal Provincial Joint Review Panel (JRP) and the NL PUB, both of whom reviewed the Muskrat Falls Project and found the information provided by Nalcor to be incomplete and so did not approve it.

**Free access to these documents proves the value of these beleaguered democratic processes.**

An active link to an important Norwegian video of the Rissa landslide of 1978 is on slide 41.

**A chronology of key events and Further References will be added.**

## **EXECUTIVE SUMMARY**

**The proposed 825 MW Muskrat Falls hydro project is located in the Lower Churchill River Valley in central Labrador.**

**The project consists of an existing natural feature (the North Spur) and two new concrete dams . The North Spur would provide a major part of the river impoundment system (next slide). The current project ,and all alternatives, must use the North Spur.**

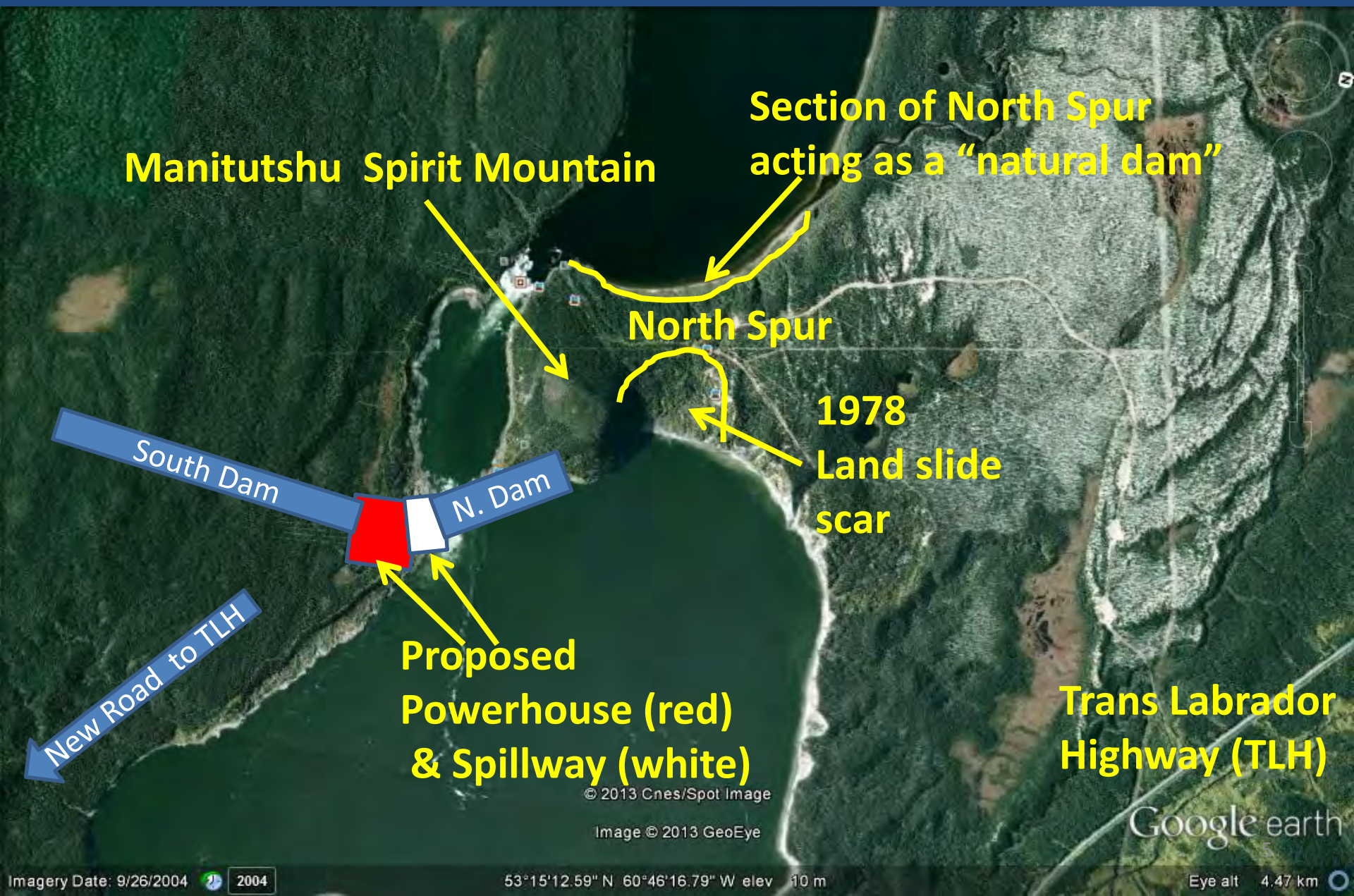
**The ground conditions at the North Spur are very unstable as they include significant amounts of glacio-marine clay (Quick Clay) that is highly prone to liquefaction and failure.**

**A significant landslide took place at the North Spur in 1978 with lesser slides in 1980 and 1981. A series of other major slides have taken place both upriver and downriver from Muskrat Falls, the latest in 2010.**

**As of March 1, 2013, Nalcor had not conducted the geotechnical field work and collected the data necessary to fully assess the North Spur instability problem and design a suitable, cost effective solution.**



# Overhead view of North Spur showing its key role in the Muskrat Falls reservoir containment system



**Thus Nalcor is not yet in a position to know what the cost of an acceptable solution to the North Spur instability problem will be.**

**Yet the Muskrat Falls project was sanctioned in December 2012 without an answer to the North Spur issue.**

**Nalcor's EPCM contractor SNC Lavalin must first carry out field work and design activities in 2013 to address the North Spur issue.**

**This also leaves Nalcor in a position where it does not know whether a technically feasible solution can be devised for the North Spur instability problem.**

**Without an acceptable, safe solution to the North Spur instability problem, the whole Muskrat Falls project will have to be cancelled.**

## What is the North Spur ?

The North Spur is a relatively young, post glacial/marine deposit of clay and sand sticking out into the Churchill River from its north bank to a massive rock mountain in mid valley at Muskrat Falls.

The North Spur is 1000m long, 500m wide and 45 to 60m high .

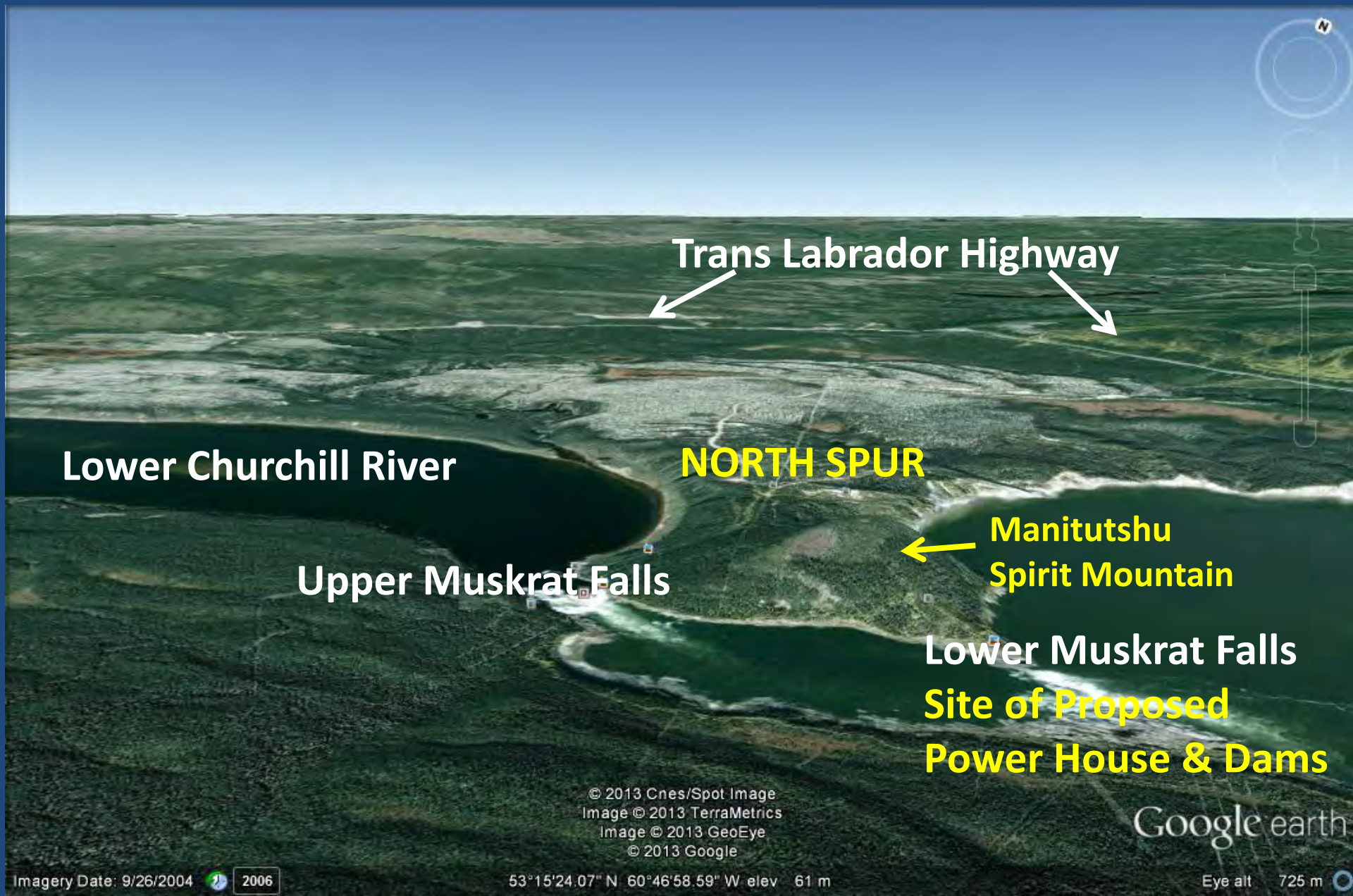
The North Spur contains a significant amount of **glacio-marine clay** or “**Quick Clay**” mixed at the top with some sandy layers. This quick clay overlies a thick sandy aquifer.

It forms an essential part of the reservoir containment system at Muskrat Falls.

A significant landslide took place on the North Spur in 1978.



# Google Earth Image of Muskrat Falls Site looking North



Trans Labrador Highway

Lower Churchill River

**NORTH SPUR**

Manitutshu  
Spirit Mountain

Upper Muskrat Falls

Lower Muskrat Falls  
Site of Proposed  
Power House & Dams

© 2013 Cnes/Spot Image  
Image © 2013 TerraMetrics  
Image © 2013 GeoEye  
© 2013 Google

Google earth



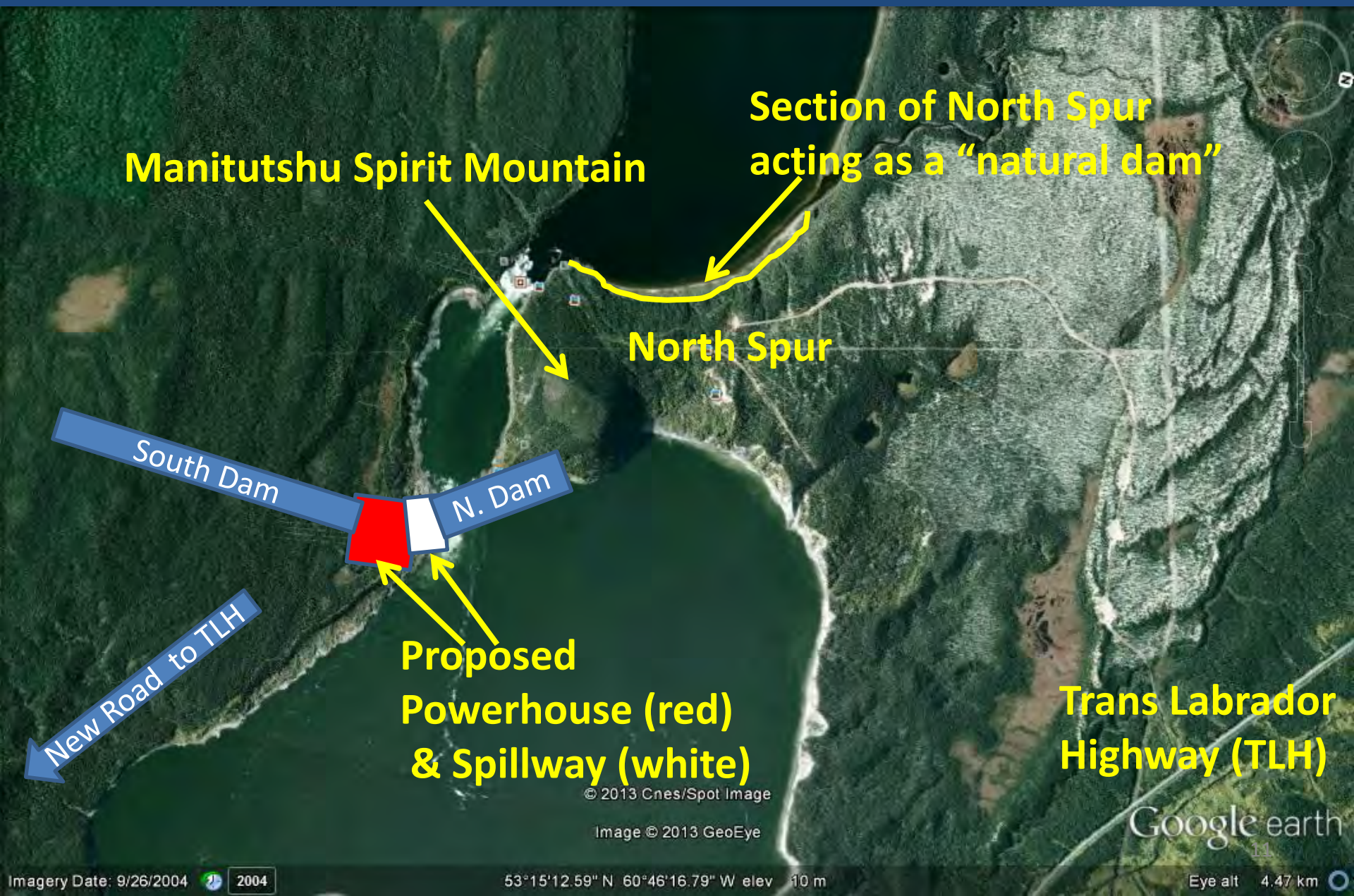
- The previous slide shows on the left, the upstream section of the fresh water Lower Churchill River at an elevation of 18m above sea level.
- After dam completion, the Muskrat Reservoir will rise to 35m above sea level.
- On the right, below the Upper and Lower Muskrat Falls, is the downstream section of the Lower Churchill River at an elevation approaching 0 m above sea level.
- The impact of tidal/sea water influences immediately downstream from the North Spur seem to deserve more attention.
- Consideration of hydraulic forces on the downstream side of the North Spur are greatly complicated by ice damming .
- For a view of ice damming downstream from the North Spur see the first photo icon downstream from Muskrat Falls on Google Earth at 53 degrees 14 min 19.48 sec North; 60 degrees 46 min 38.56 sec West.

The next slide shows the Muskrat Falls project layout superimposed on an existing view of Muskrat Falls on Google Earth.

As you can see, the North Spur is just as important to damming off the Lower Churchill River as are Nalcor's two proposed concrete dams .

Note that Manikutshu – the 120m high solid rock Innu sacred Spirit Mountain – is located between the North Spur and the area of Nalcor's two proposed concrete dams at Muskrat Falls.

# Overhead view of North Spur showing key role in Muskrat Falls reservoir containment system





# Muskrat Falls layout from Nalcor EIS

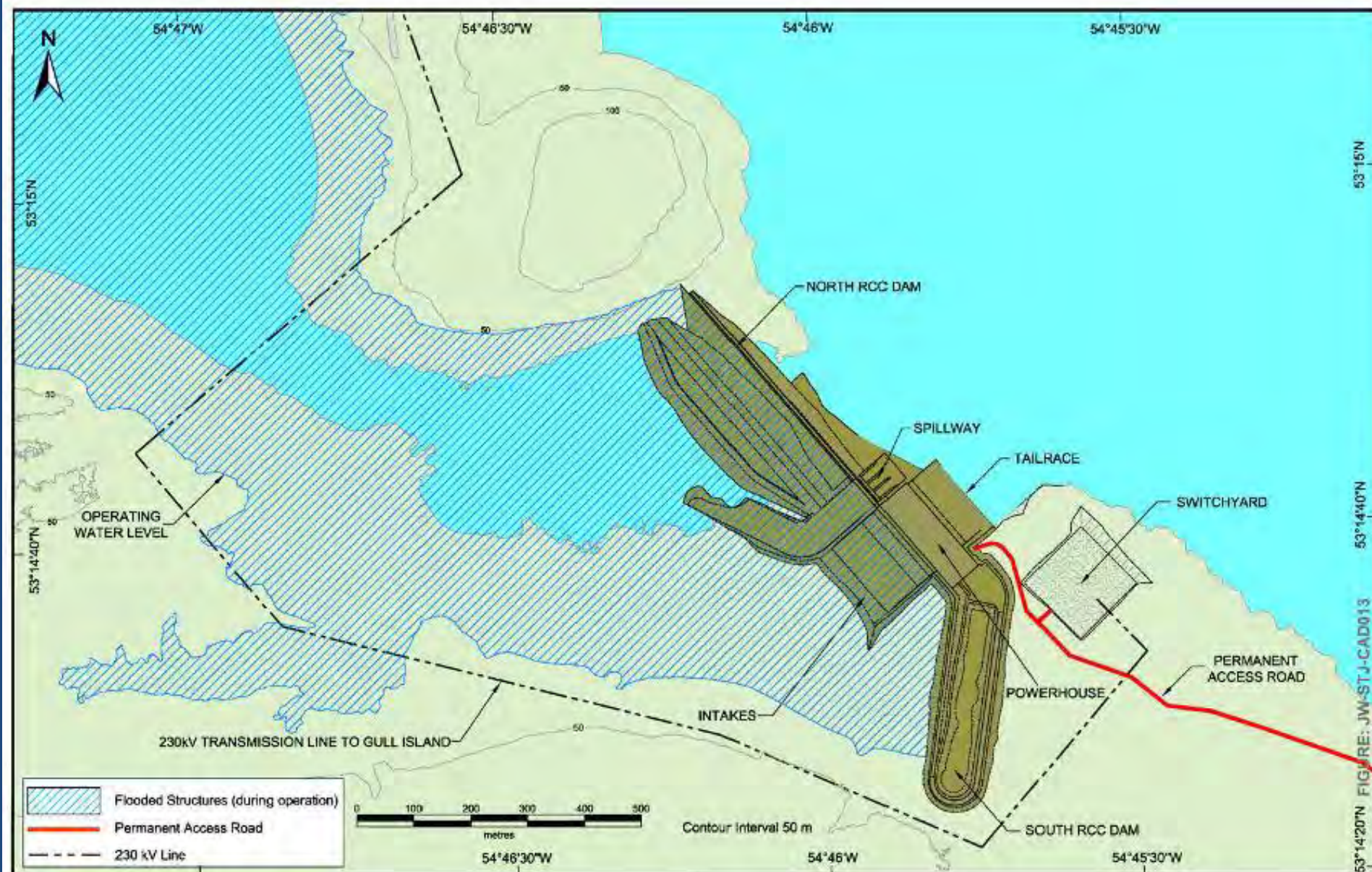


Figure 4-9 Muskrat Falls Layout

## Nalcor Depiction of the Muskrat Falls Project from downstream (from a January 23, 2013 presentation)





# The North Spur : a long known problem

The key role of the North Spur and its precarious nature has been well known in Muskrat Falls development process for over 30 years as described by Hatch Ltd. in July, 2008 :

“Early studies in the late 1970s concluded that the land spur which reaches from the north bank of the Churchill river at Muskrat Falls to the large rock knoll closer to the south bank could be incorporated with a natural embankment dam at this location. In this context the natural spur constituted a considerable capital asset, if it could be maintained. Natural mass wasting processes, however, were quickly eroding the spur but it was determined that these could be arrested with the installation of a pump well system. Such a system was installed in 1981.”

Click <http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit39.pdf> to see Exhibit 39.

The carved out contour features on the next slide attest to the “mass wasting processes” or landslides on the North Spur caused by a major landslide in 1978 .

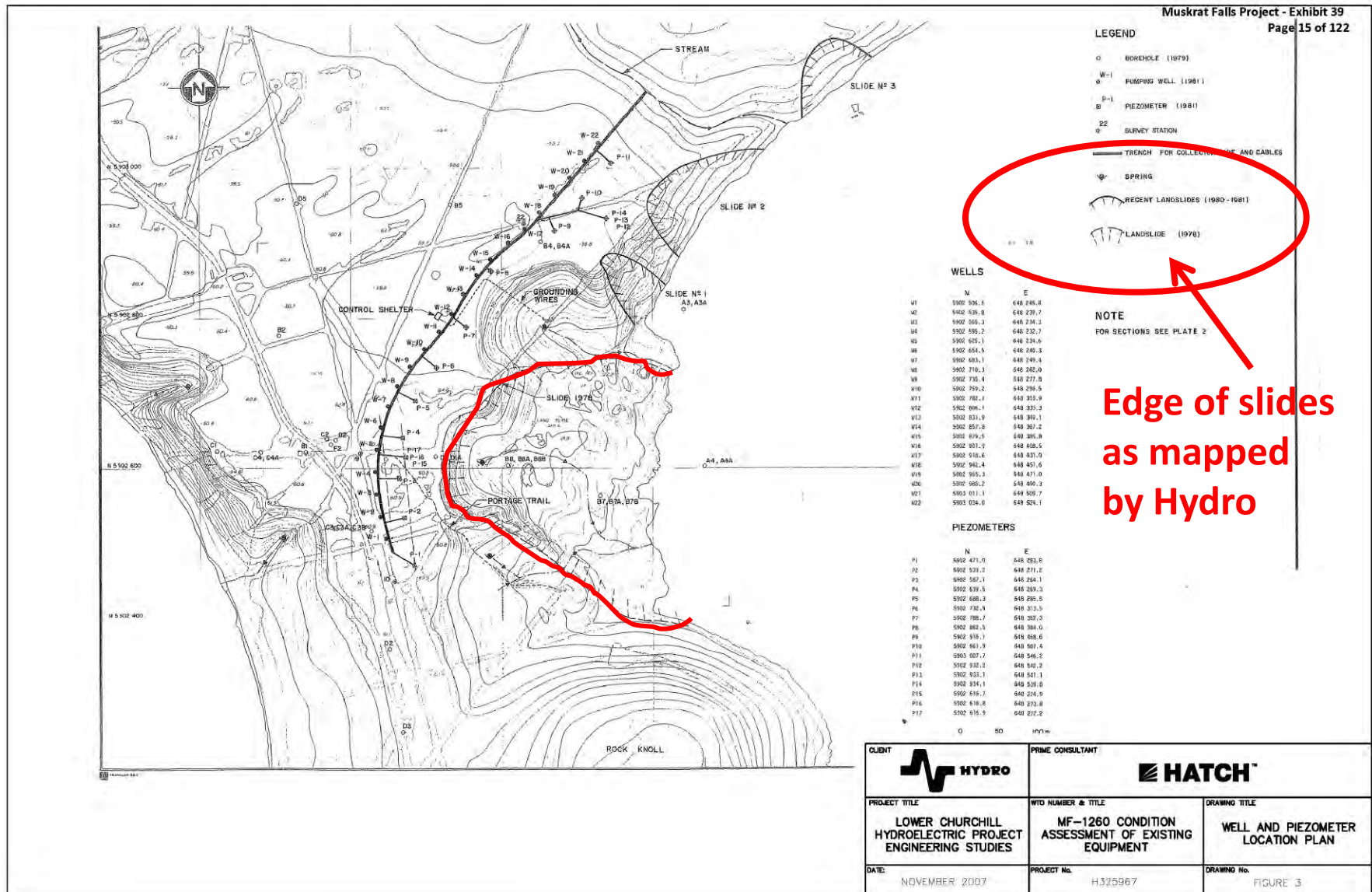


**In February 1978, a large landslide took place on the North Spur.**

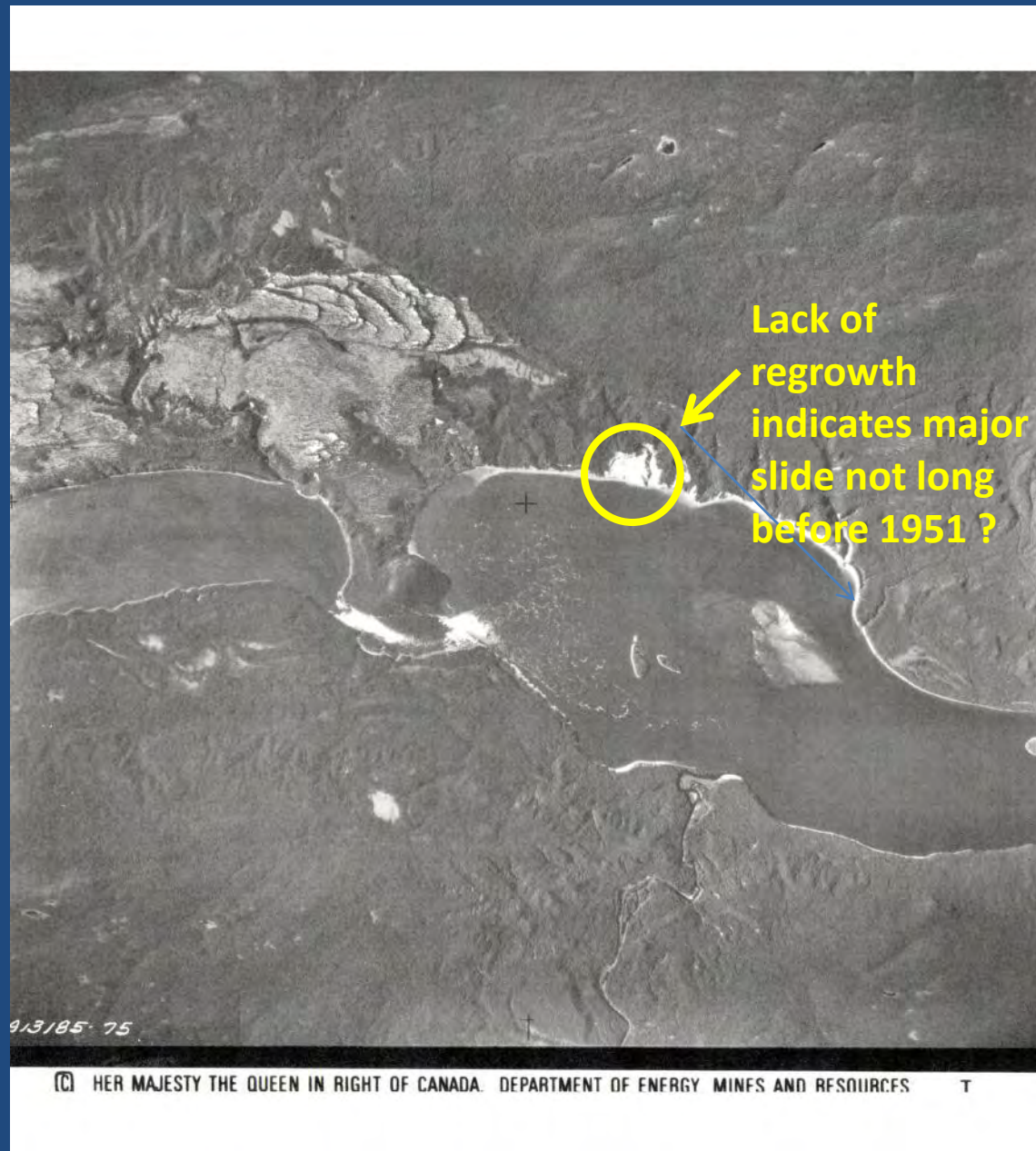
# THE MAJOR NORTH SPUR LANDSLIDE of 1978

Note the steep scalloped contour lines;

Major slide of 1978 in red – lesser ones date from 1980 and 1981

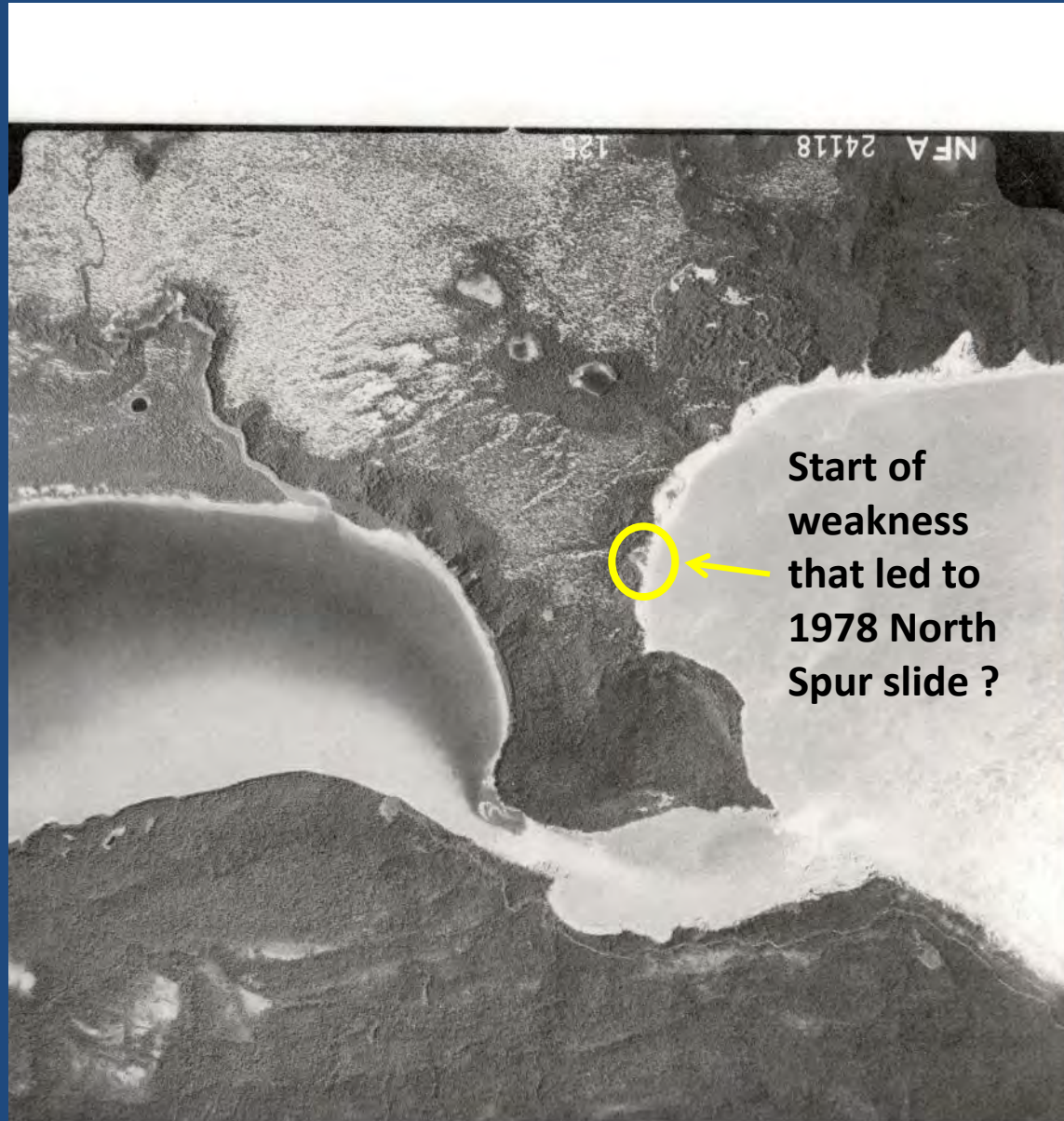


## General Overview of Muskrat Falls in 1951 showing unstable ground at Muskrat Falls





## 1975 – 3 years before the North Spur landslide of 1978



## 1988 – 10 years after the 1978 North Spur landslide



North Spur  
Slide area  
without regrowth.  
Trees at foot of slide  
indicate mass flow?

## View in 1998 showing 20 years of growth on 1978 slide



1978 North Spur  
slide area  
partially overgrown



## View in 2007 showing line of pumping wells



Line of 17  
pumping wells  
installed by  
NL Hydro  
in 1981 after  
1978 North Spur  
Landslide

## View in 2007 showing line of slides downriver from North Spur



**The SNC – AGRA Final Muskrat Falls Feasibility Study of 1999 also emphasised how important the North Spur was and the need for stabilization.**

## **“ 7.0 RECOMMENDED SCHEME OF DEVELOPMENT**

### **7.1 GENERAL**

Development of the Muskrat Falls site will include stabilization of the natural dam, called the north spur, which connects the rock knoll to the north bank of the original river valley, and power development facilities in the river channel, including diversion, reservoir control and power facilities. **The stabilization of the spur is a common element to any alternative power development schemes, of which several were considered.”**

**Click**

**<http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit19-MuskratFallsFeasibilityStudy1999.pdf> to see Exhibit 19.**



**Volume 1 of the SNC-AGRA 1999 Final Feasibility Study discussed the North Spur problem at length and proposed a set of remedial actions to prevent North Spur collapse.**

**Click**

**<http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit19-MuskratFallsFeasibilityStudy1999.pdf> to see  
Section 10.0 of Volume 1 at pages 178 to 192**

**Unfortunately the critical Jacques Whitford Geotechnical study of 1998 conducted for NL Hydro, though often referred to in various Nalcor documents, does not seem to be publically available.**

**It is presumably contained as an appendix labeled “Volume 2: 1998 Geotechnical Investigations”.**

**The Foreword of Volume 1 states that:**

**“Volume 2 contains the results of the geotechnical investigations carried out in the summer of 1998 together with the relevant plates and appendices incorporated after the text of the report. This volume is presented in limited copies to be distributed per request only.”**

**This is most unfortunate as it presumably contains the most detailed field and analytical analysis of the North Spur issue to date.**

# North Spur looking South: the filled Muskrat Falls Reservoir will flood part of the North Spur



© 2013 Cnes/Spot Image

© 2013 Google

Image © 2013 GeoEye

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth  
26



# 1979 Hydro Contour map of the North Spur



## LEGEND:

- ◆ B4a VERTICAL BOREHOLE (B4a)
- C6 INCLINED BOREHOLE (C6)
- ⊙ F2 PUMPING WELL (F2)
- SL 2 — SEISMIC LINE (N° 2)

## NOTES:

- 1) FOR SECTIONS "A-A" & "B-B" SEE PLATE 8
- 2) FOR SECTIONS "C-C" & "D-D" SEE PLATE 9
- 3) FOR SECTIONS "E-E", "F-F" & "G-G" SEE PLATE 10
- 4) FOR RESULTS OF SEISMIC SURVEYS SEE VOLUME II APPENDIX 3

Reference: Volume 1, Plate 7/SNC Lavalin Newfoundland Ltd. (1980)  
Muskrat Falls Power Development & 345 kV Transmission Inter tie To  
Churchill Falls Engineering Report Vols. I to IV, March 1980.

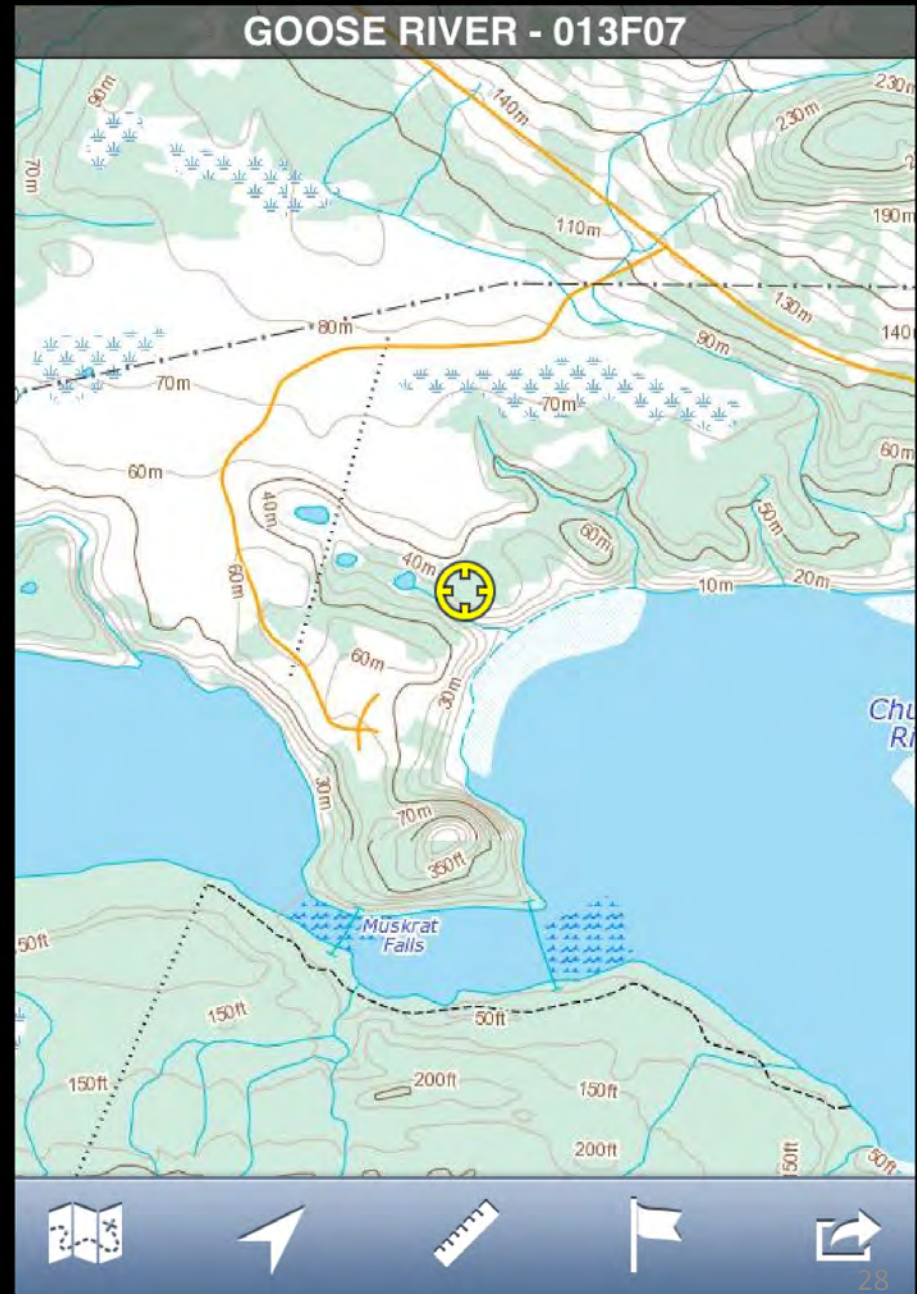
NOTE  
ABOVE WATER CONTOURS ARE BASED ON GSC  
DATUM PRE 1978  
TO OBTAIN CORRECTED GEODETIC DATUM  
(MSL) SUBTRACT 0.97m  
BATHYMETRIC CONTOURS ARE ADJUSTED TO  
THE 1979 CORRECTED DATUM (MSL).

FIELD EXPLORATION  
SUMMER 1979  
LOCATION PLAN

Figure 1

The wasting topography of the North Spur and surrounding area is well demonstrated by this low resolution topographical Map.

Source :  
Topographic Maps Canada



## **GLACIO-MARINE CLAY:** Source of the North Spur Problem

Glacio-marine clay (otherwise known as “Quick Clay” is a well-known, high latitude, circumpolar geological hazard in places such as Labrador, Quebec, Alaska, Russia and Norway.

In Ontario and Quebec equivalent quick clays are known as “Leda Clay” .

Click <http://www.nrcan.gc.ca/earth-sciences/products-services/mapping-product/geoscape/ottawa/6098> to see this page.



After the last ice age, the whole Lower Churchill Valley was inundated by the sea up as far as Gull Island and a bit beyond. Consequently, marine clays were laid down in these areas, after which these clays were covered by more sediments as the land uplifted. The general limit of glacio-marine clays in the North Spur/Muskrat Falls area is at 130m above sea-level (Liverman (1997)).

**Click**

<http://www.nr.gov.nl.ca/nr/mines/geoscience/publications/currentresearch/1997/liverman.pdf> **to see this document.**

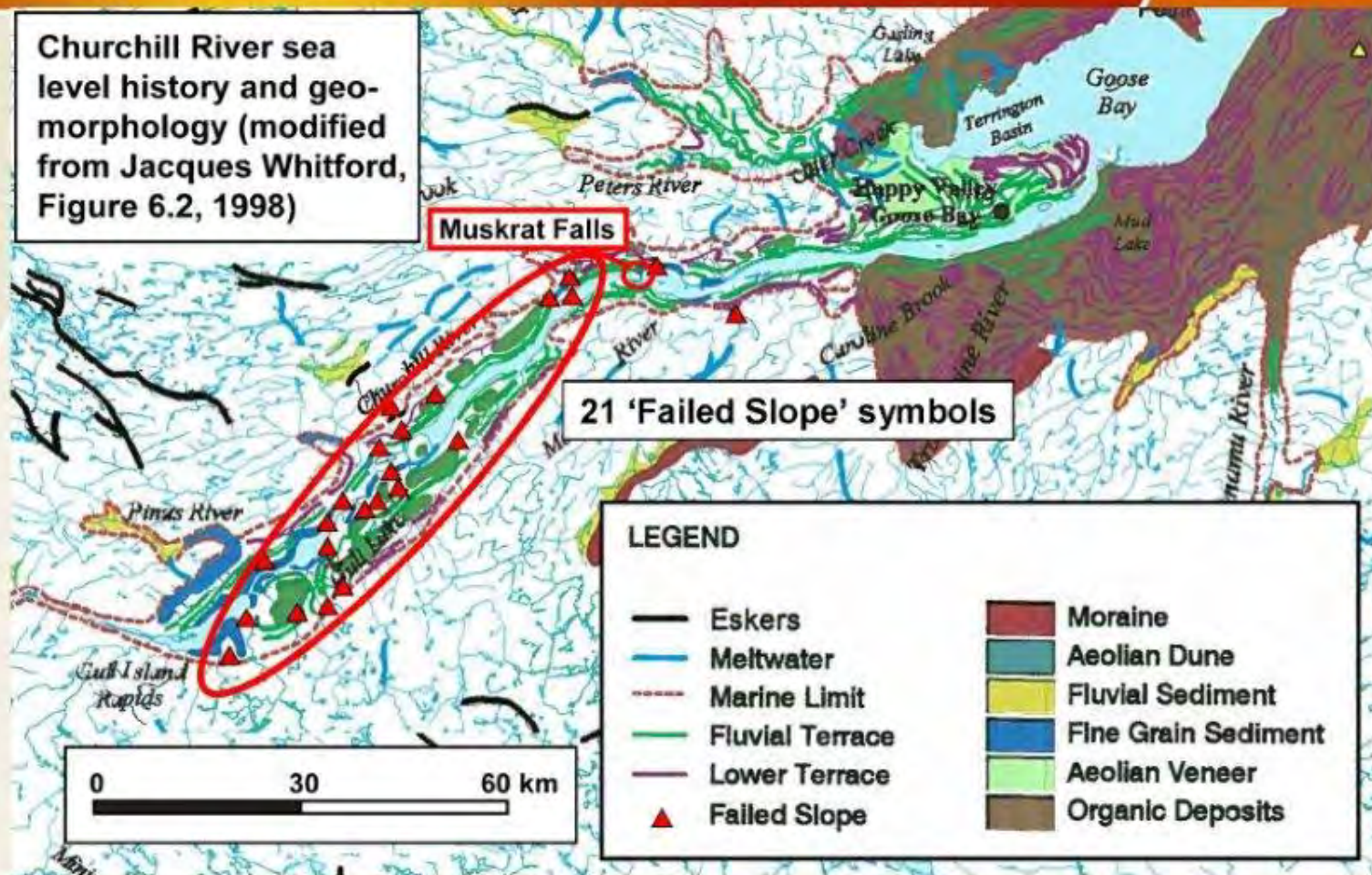
These “glacio-marine” clays have very peculiar properties that make them infamous as a cause of massive rapid landslides (see red triangles on next slide).

**As the next slide shows, landslides (“failed slope”) are common along the Lower Churchill Valley.**



# NRCan's Views on Impacts, Risks and Uncertainties

Churchill River sea level history and geomorphology (modified from Jacques Whitford, Figure 6.2, 1998)



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

## North Spur Soil Conditions

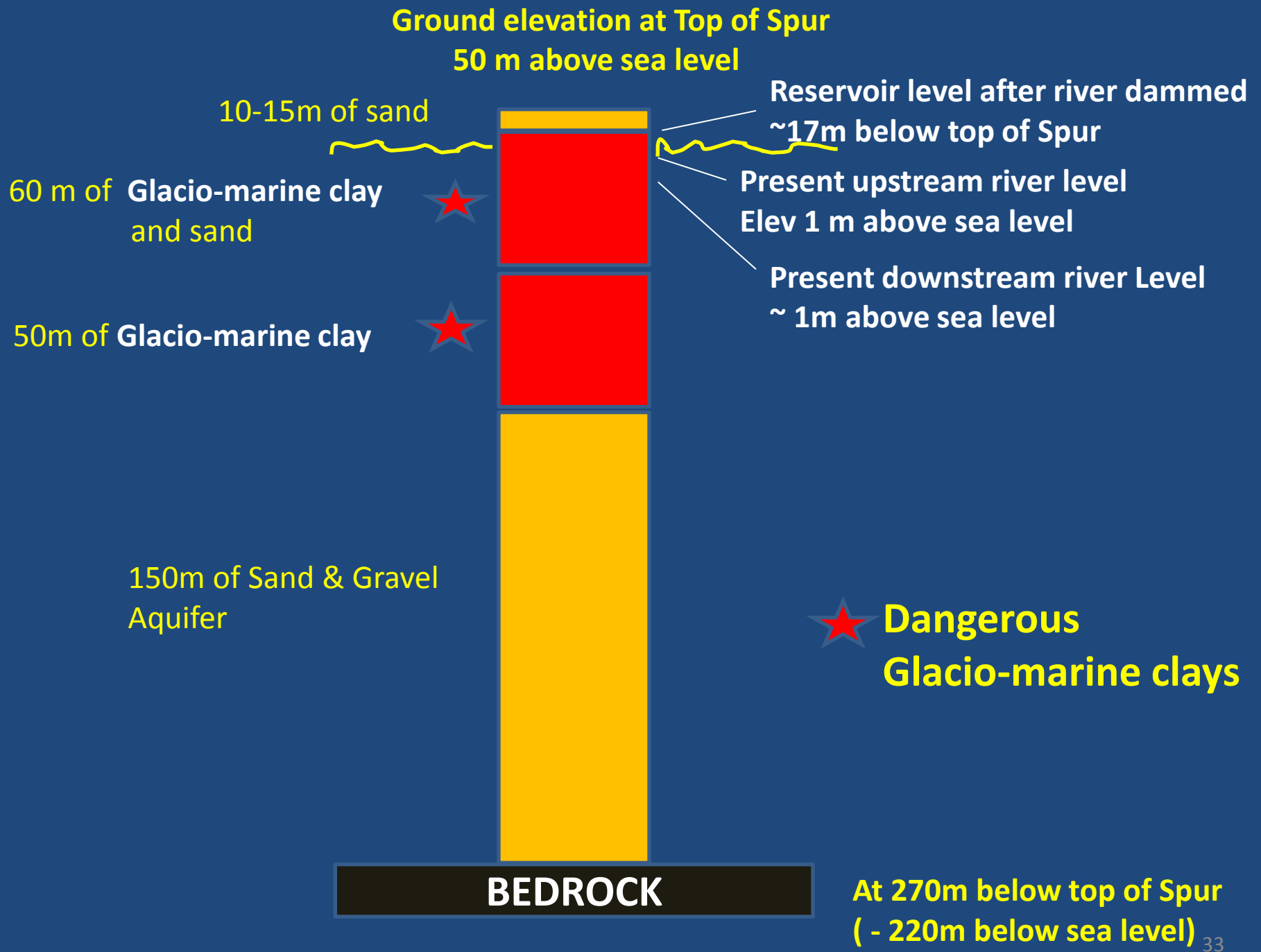
As can be seen on the next slide, the North Spur consists largely of unstable glacio-marine clay.

True bedrock is at about 230m below the current water level in the Churchill River on the upstream side of the North Spur.

**The sediments in the North Spur consist of four units.** Measuring from the top of the Spur at elevation 50m there is:

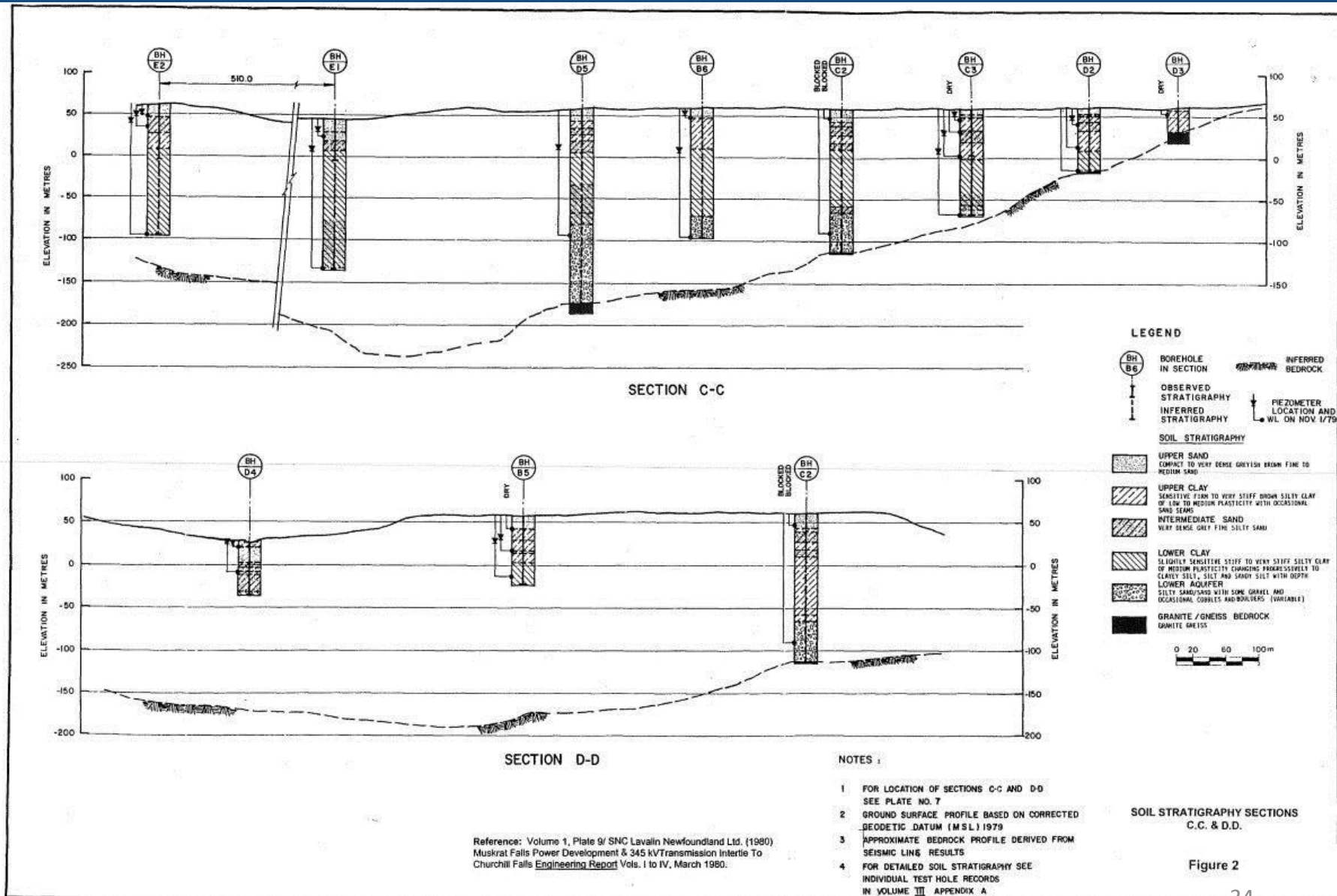
- 1) An Upper Sand approximately 10 to 15m thick;**
- 2) Followed by a Stratified Drift approx 60m thick consisting of an Upper Glacio-Marine clay deposit generally underlain with a varying thickness of sand.**
- 3) Followed by a Lower Glacio-Marine Clay approx 50m thick .**
- 4) Followed by a Lower Sandy “Aquifer” approx 150m thick occupying the lower part of a buried valley.**





# Borehole Results on the North Spur :

## Section C-C' runs NS ; Section D-D' runs E-W ( See slide 27)



In a Muskrat Falls Final Feasibility Study dated 1999, SNC AGRA sets out a construction plan aimed at the North Spur Stabilization problem (layout on next slide).

**These civil construction works are quite invasive for a sensitive area.**

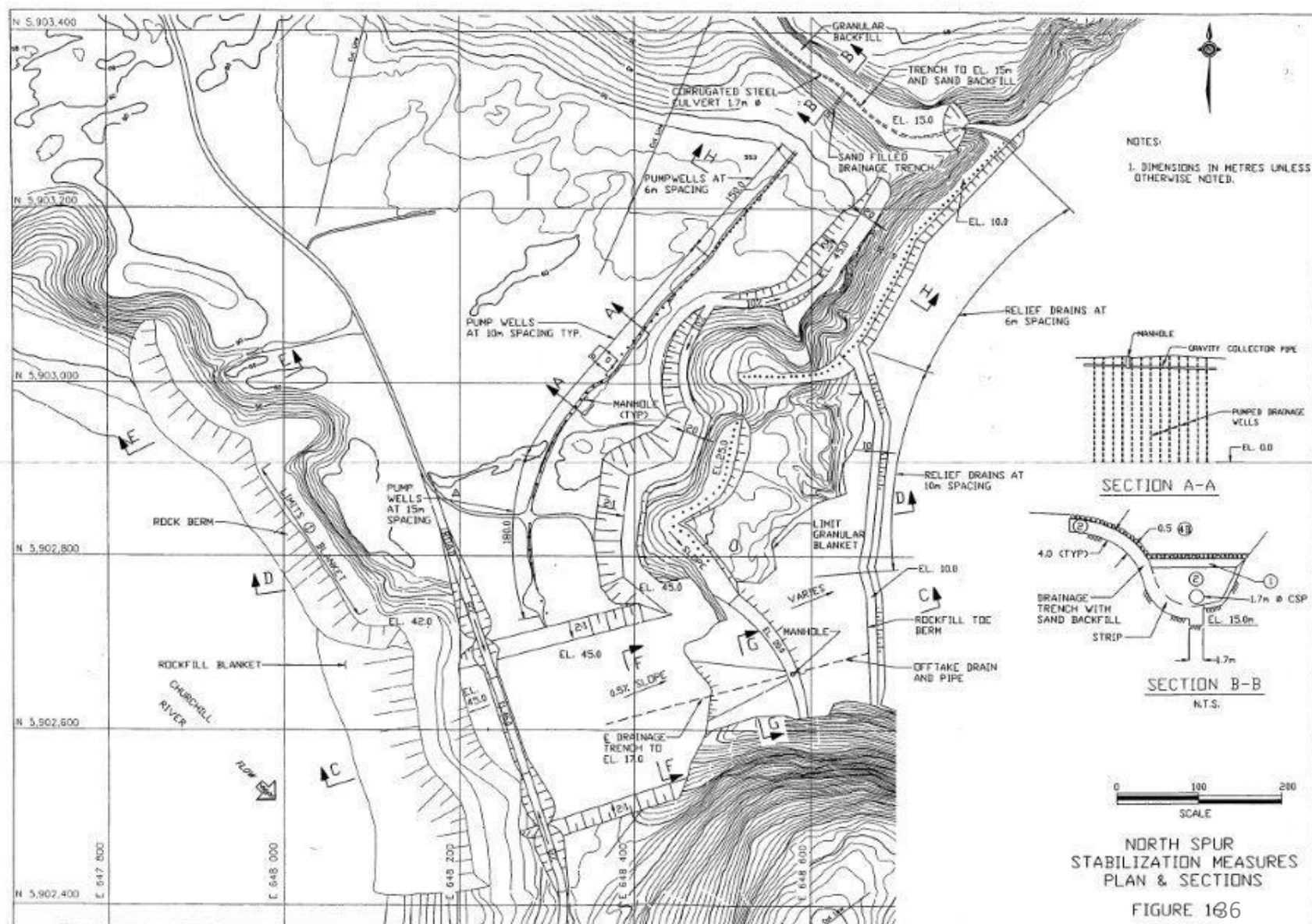
Ironically, the same SNC AGRA report also states that :

**“It is recommended that the construction of any services, roads or structures in the vicinity of the reservoir shorelines be restricted only to areas where large-scale sliding is unlikely in the event of drawdown [i.e. areas with flat banks, low groundwater tables, and where sensitive marine clays do not occur in the slope in the range of possible emergency drawdown (i.e. El. 39-25 m)].”**

Click <http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit19-MuskratFallsFeasibilityStudy1999.pdf> to see Exhibit 19.



## SNC- AGRA's 1999 North Spur Plan: heavy civil works in a sensitive area



## **The North Spur Stabilization Plan in 1999 SNC Final Feasibility Study was quite detailed**

### **“b) Geotechnical**

- The north spur, which is an important feature of the site, provides a natural dam for development of a reservoir on the River.
- Stabilization of the north spur will be required to prevent further slope failures along its upstream and downstream sides and prevent the potential loss of this important structure.

**The information gained from installation and operation of the interim pumpwell system since 1982 shows that control of the groundwater in the spur is the most cost-effective and reliable approach to spur stabilization. However, a combination of stabilization measures is necessary for the most effective and economical approach.**

### **Stabilization measures will require:**

- lowering the groundwater table in the downstream part of the spur;
- **provision of downstream erosion protection and downstream stabilizing fill in selected areas to improve local toe stability, and eliminate the potential for retrogressive failures due to presence of sensitive marine clays in the Upper Clay unit;**
- local top cutting of the spur and unloading of portions of the high steep side slopes to improve local stability;
- provision of erosion protection and of a stabilizing upstream berm to prevent raveling of the upstream slopes from reservoir wave action and eliminate the potential for sliding in the unlikely (but possible) event of rapid drawdown during future project operation.”

## **The North Spur Stabilization Plan in 1999 SNC Final Feasibility Study : 2**

### **e) North Spur Stabilization**

**It is recommended that the north spur be stabilized by:**

- lowering the groundwater table in the downstream part of the spur by the installation of additional pumpwells in the line of pumpwells installed in 1982, with the final pumpwell spacing selected based on the existing subsurface conditions and the performance of the existing pumpwell system;**
- provision of toe relief drains and a major drainage trench for further lowering of the water table;**
- provision of downstream erosion protection and downstream stabilizing fill in selected areas to improve local toe stability and eliminate potential for retrogressive failures due to presence of sensitive marine clays in the Upper Clay unit;**
- local top cutting of the spur and unloading of portions of the high, steep downstream side slopes to improve local stability; and**
- provision of erosion protection and a stabilizing upstream berm to prevent raveling of the upstream slopes from reservoir wave action and eliminate the potential for sliding in the unlikely (but possible) event of rapid drawdown during future project operation.**



## WHY ARE GLACIO–MARINE CLAYS SO DANGEROUS ?

**Glacio-marine clays (also called “Quick Clays”) have very peculiar properties.**

**Most importantly, it only takes a small disturbance to turn them suddenly from a solid to a liquid.**

## Clay on the downstream side of the North Spur



# The Rissa Video

Co-incidental to the 1978 slide at the North Spur, in 1978, a quick clay landslide took place at Rissa, Norway and led to an immediate investigation and action.

In 1981, an instructional video was issued by the prestigious Norwegian Geotechnical Institute which very graphically illustrates the problem – to better understand the “quick clay” problem you should view it.

Click <http://www.youtube.com/watch?v=3q-qfNIEP4A> to see this video.



**“Quick Clay” conditions caused the 1978 Rissa slide in Norway and in the opinion of the Geological Survey of Canada (GSC) , “quick clay” landslide conditions are present throughout the Lower Churchill Valley.**

**Nalcor consultant Jacques Whitford stated that:**

**“Although preliminary investigations suggests that the fine-grained sediments [at Muskrat Falls] are somewhat more stable than brackish-water clays in eastern Canada and elsewhere, particularly as regards their susceptibility to liquefaction, further research is required to more definitely establish the susceptibility of these materials to failure, the frequency of failure events, and the effects of water saturation and changes in fluvial activity or base resulting from reservoir formation.”**

Jacques Whitford Environment Limited “Sea Level History and Geomorphology of the Churchill River and Strait of Belle Isle “ (LHP98-23) December 1, 2000 “

**The North Spur data base was (and remains) very poor and the problem consequently poorly defined even after all this time.**

**And even if there are differences between the Rissa and North Spur clays, there are many key similarities.**

Ontario and Quebec have considerable experience with “quick clay” landslides as seen in a 2008 article in the Ottawa Citizen at the link below.

Click

<http://www.canada.com/ottawacitizen/news/story.html?id=311775e1-da21-4291-a4a2-bc0fe7ef963a> to see this article.

**Nalcor's Bank Stability Study of June 2008  
conducted by Amec discusses the issues  
of slope stability at the North Spur**

Click

[http://www.ceaa.gc.ca/050/documents\\_statisticpost/26178/31993/ae2-hy-01.pdf](http://www.ceaa.gc.ca/050/documents_statisticpost/26178/31993/ae2-hy-01.pdf)  
to see this document.



On May 22, 2009, NRCan set out its concerns in writing regarding the **deficiencies in Nalcor's analysis of the faulting and seismic risk at Muskrat Falls.**

NRCan requested that Nalcor install a seismic monitoring system at Muskrat Falls.

NRCan took the position that the Lower Churchill Valley has a seismic character linked in some way to the relatively seismically unstable St Lawrence Lowlands area by the regional fault system.

Click <http://www.ceaa-acee.gc.ca/050/documents/35087/35087E.pdf> to see this document.

## **NRCan 's concerns came under four main headings:**

**Natural seismic risk**

**Reservoir Induced Seismicity (RIS)**

**Reactivation of Regional Faults**

**Landslide soil conditions at the North Spur**

**The Federal Provincial Joint Review Panel (JRP) in 2009 had a number of questions concerning the North Spur.**

**For instance, it observed that :**

“Without an accurate understanding of the groundwater system and groundwater-surface water interactions, the proposed dams at Gull Island and Muskrat Falls could be at risk of failure. Modelling of seepage from the reservoir to groundwater and through the dam is required together with a determination of the critical amount of seepage that would cause dam collapse. It is unclear whether groundwater will discharge into the reservoir or whether the reservoir will feed the groundwater system. It is important to document how this relationship may change.”

**Click [http://www.ceaa-acee.gc.ca/050/documents\\_staticpost/26178/39444/v2-03.pdf](http://www.ceaa-acee.gc.ca/050/documents_staticpost/26178/39444/v2-03.pdf) to see page 3 of this document.**



**The Joint Review Panel (JRP) also asked NRCan to provide answers to certain question regarding faulting and seismicity at Muskrat Falls as NRCan had indicated that Nalcor had not adequately considered the potential reactivation of normal faults of the Melville Rift System which is a major fault system in the area linking back to the seismically sensitive St Lawrence Lowlands**

**Nalcor had stated that “There is currently no evidence of seismic activity having occurred at the Lower Churchill sites in recent (geological) times.”**

**NRCan had indicated that this comment is not warranted by the evidence presented in the EIS.**

On October 5, 2009, Nalcor issued a study entitled:

**“Report on Earthquake Hazard Analysis: Gull Island and Muskrat Falls Dam sites” IR#JRP.59 October 5, 2009**

This report is restricted to the application of a set of “Hard Rock” standards.

**Click**

**[http://www.ceaa.gc.ca/050/documents\\_staticpost/26178/39444/v2-02.pdf](http://www.ceaa.gc.ca/050/documents_staticpost/26178/39444/v2-02.pdf) to see this document.**

**The 2008 SNC report filed by Nalcor on October 5, 2009 sets out the restrictions on their work clearly when it said:**

**“The seismic hazard results have been obtained for NEHRPA (Hard Rock) site conditions, as given in Table 3-1. These results apply to the Muskrat Dam site as it is founded on hard rock”**

**However, this is true only as to the concrete, man-made part of the reservoir containment system at Muskrat Falls as they are on rock.**

**They do not seem appropriate for North Spur soil conditions .**

**A separate study does not seem to have been done for the North Spur using less robust numbers than for the “Hard Rock” standards.**

**Click [http://www.ceaa.gc.ca/050/documents\\_staticpost/26178/39444/v2-02.pdf](http://www.ceaa.gc.ca/050/documents_staticpost/26178/39444/v2-02.pdf) to see this document.**



**The SNC Report further states that :**

“As has been noted earlier, the results of this analysis refer to natural seismicity, and do not address the probability of reservoir-induced seismicity (RIS).

Thus the scenarios outlined do not include an RIS scenario or its associated ground motions.”

Click

[http://www.ceaa.gc.ca/050/documents\\_staticpost/26178/39444/v2-02.pdf](http://www.ceaa.gc.ca/050/documents_staticpost/26178/39444/v2-02.pdf) to see page 31 of this document.

The filling of the Muskrat Reservoir may cause seismic tremors .

These seismic tremors are called “**reservoir induced seismicity**” or “**RIS**” and would be in addition to normal seismic risk.

RIS refers to tremors caused by the extra weight of the water in the reservoir after it is filled, for instance acting on a fault system pre-disposed to fail .

In the case of quick clay, the impact of adding either groundwater pressure or RIS could disturb the delicate internal balance between the quick clay particles causing the quick clay to rapidly change from a solid to a liquid and consequently to suddenly fail.

On December 18th, 2009, NRCan again wrote the Lower Churchill Joint Review Panel (JRP) concerning large scale mass earth movements in relation to the Muskrat Falls Project .

Click

<http://www.ceaa.gc.ca/050/documents/45351/45351F.pdf>

to see this document.



**In February 2010, a major landslide took place  
at Edwards Island, 40km upstream from Muskrat Falls**

## **THE MAJOR QUICK CLAY SLIDE OF 2010**

**In February 2010, a major landslide took place at Edwards Island 40km miles upstream from Muskrat Falls.**

**The extent of the landslide is evident in the next slide taken from a study conducted for Nalcor by AMEC in the fall of 2010.**

**The size of the Edwards Island slide was estimated by the Geological Survey of Canada as 3.5 million cubic meters .**

**Note that the slide has floated whole slabs of ground, with trees still upright, out into the river – a mass earth flow reminiscent of Norway's 1978 Rissa slide.**

**View of February 2010 landslide area on south side of Churchill River upstream from Muskrat Falls caused by “Quick Clay”**



**In October and November of 2010, Amec, acting for Nalcor, conducted a drilling program on two landslide areas upriver from the North Spur – including the Edwards Island slide of February 2010.**

**The results of this 2010 drilling program fully supported NRCan's concerns as to the presence and character of glacio-marine clays in the Lower Churchill Valley and their direct connection to the Valley's many landslide scars.**

**This directed field work included the physical measurement of the glacio-marine clay characteristics that make them susceptible to liquefaction and landslide activity.**

**Click**

**[http://www.ceaa.gc.ca/050/documents\\_staticpost/26178/47685/G.pdf](http://www.ceaa.gc.ca/050/documents_staticpost/26178/47685/G.pdf) to see this document.**



**In August, 2010, Nalcor Energy, responding to a Request for Information from the Joint Review Panel, indicated that a number of sites which show evidence of large earth flow activity would be investigated during the 2010 field season.**

**Unfortunately, the North Spur was apparently not included in the 2010 geotechnical Program.**

•

**SNC's 2010 Geotechnical Program was confined to the south side of the river and did not include Muskrat Falls.**

**Click**

**<http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/abridged/CE-19-Public.pdf> to see this document.**

**The work by Hatch Ltd. on the North Spur in 2010 was confined to work on the pumpwell system and not to gather basic geological and engineering facts.**

**Click**

**<http://www.pub.nf.ca/applications/MuskratFalls2011/files/exhibits/Exhibit40.pdf> to see this document**

**Click**

**<http://www.pub.nf.ca/applications/MuskratFalls2011/files/exhibits/Exhibit41.pdf> to see this document.**

On August 30, 2010, the JRP asked NRCan if it was satisfied with Nalcor's response to NRCan concerns on seismic and landslide issues.

On September 23, 2010, NRCan again indicated that certain of their questions remained unanswered and that Nalcor "had not, by and large, addressed" certain faulting, seismic and landslide issues.

**Click**

**<http://www.ceaa.gc.ca/050/documents/45351/45351F.pdf>**

**to see this document.**

## **NRCan's Participation in the JRP Public Meeting**

**On March 9, 2011, NRCan gave a detailed presentation to a public hearing conducted by the Joint Review Panel in Goose Bay.**

**As noted on the next Slide, as of March 2011, NRCan felt that Nalcor had not adequately addressed landslide issues in it's EIS and listed a number of outstanding issues.**



The Norwegian Geotechnical Institute stresses that glacio-marine “quick clays” are very sensitive – like a “house of cards”- and can rapidly change from a solid to a liquid.

As seen in the next 4 slides, the Federal Department of Natural Resources (NRCan) emphasised these same points in their presentation to the Muskrat Falls Joint Review Panel.

And NRCan also concluded that the Quick Clay problem existed at the North Spur but that Nalcor had not adequately addressed the problem in its EIS.

Click <http://www.ceaa.gc.ca/050/documents/48555/48555F.pdf> to see the full NRCan presentation.



# NRCan's Views on Impacts, Risks and Uncertainties

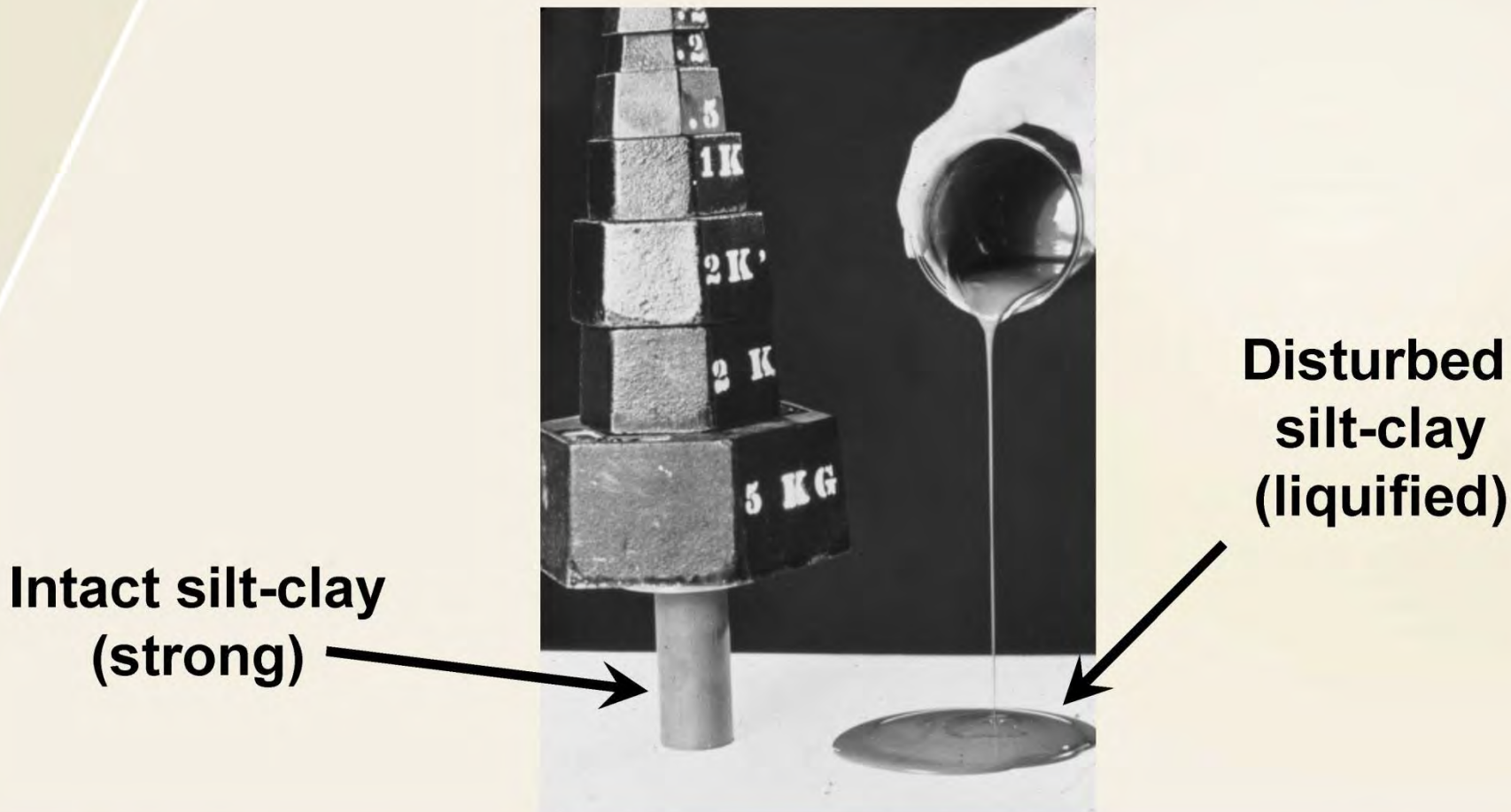
## Loose framework structure



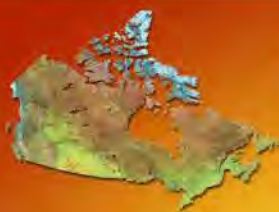


# NRCan's Views on Impacts, Risks and Uncertainties

## Characteristics of sensitive glaciomarine sediments







# NRCan's Views on Impacts, Risks and Uncertainties

## Initial concerns (cont'd)

- Possibility of occurrence of large-scale slope failures along valley bottom of proposed Muskrat Falls reservoir not adequately addressed in the EIS:
  - Existence of failures recognized in component study of Jacques Whitford (1998), including recommendations to study:
    - Susceptibility of [local] glaciomarine silt and clay to failure
    - Frequency of failure events
    - Effects of water saturation and changes in fluvial activity or base level resulting from reservoir formation.
- NRCan requested that the proponent address the recommendations of Jacques Whitford (1998).







# NRCan's Views on Impacts, Risks and Uncertainties

In IR JRP. 159(e) the proponent was asked:

*What are the geotechnical properties and conditions within the glaciomarine deposits of the lower Churchill River Valley that makes them susceptible to large-scale earth slide–earth flows?*

**Proponent's Attachment G to Information Supplements #9 (IS#9)** contains summary geotechnical data indicating that, for example:

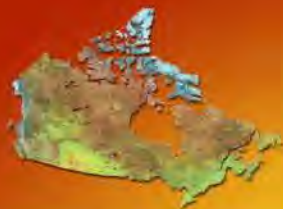
- Failure planes at two earth flow scars are deep-seated and situated within silt and clay glaciomarine deposits
- Sediment with sensitivities >30 are present within deposits.
- Some soil samples have moisture contents above liquid limits.

**NRCan agrees with IS#9 that these geotechnical properties are consistent with soils in areas elsewhere in Canada that experience large-scale earth slide-earth flow activity.**



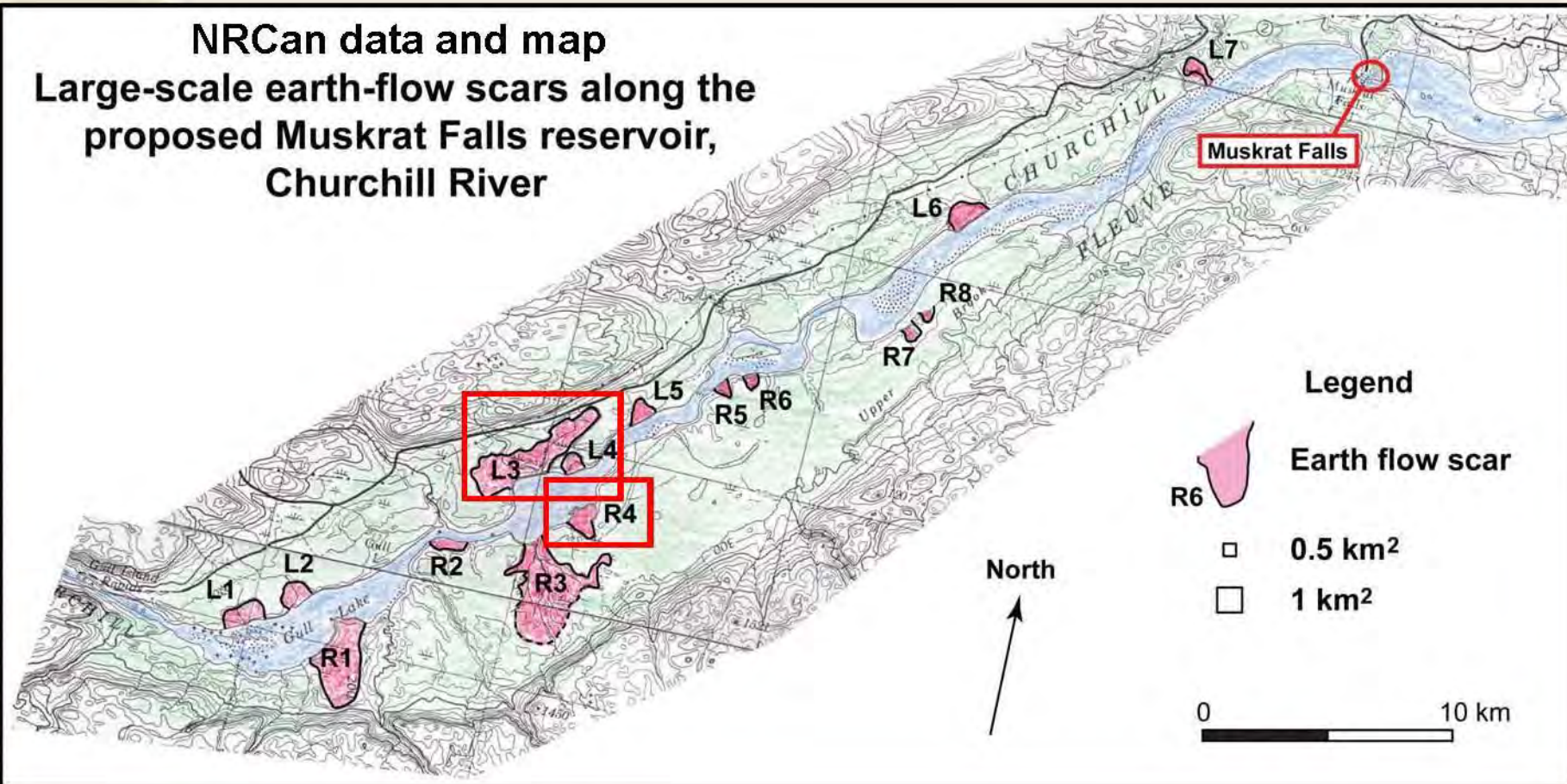
**The next two slides from NRCan show many Quick Clay related landslides scattered along the Lower Churchill Valley.**





# NRCan's Views on Impacts, Risks and Uncertainties

NRCan data and map  
Large-scale earth-flow scars along the  
proposed Muskrat Falls reservoir,  
Churchill River





# NRCan's Views on Impacts, Risks and Uncertainties

## NRCan's interpretation of scars

- Analogous to earth flow scars formed in sensitive glaciomarine sediments in eastern Canada
- 15 large-scale earth flow scars along valley sides of proposed Muskrat Falls reservoir
- Represent 'earth slide-earth flow' failures, many in excess of 10 Mm<sup>3</sup>
- Failures likely occurred rapidly, in minutes to hours
- Pre-existing problem not related to the proposed hydroelectric development
- Potential occurrence of large-scale earth flow not adequately considered in the assessment of bank stability in the EIS
- (Proponent's response to IR.JRP.159a indicates failure of 3.5 Mm<sup>3</sup> occurred March 2010)



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On March 9, 2011, the Joint Panel specifically asked NRCan to review Nalcor's documentation with respect to the North Spur issue.

To which, NRCan replied on March 28, 2011, that :

**“NRCan does not have the engineering expertise to review and comment on the specific technical details of the proposed spur stabilization measures presented in SNC-AGRA (1999a). It is NRCan's opinion, however, that the proponent has an adequate fundamental understanding of the geotechnical and groundwater conditions that contribute to the existing instabilities as well as those that will arise from the creation of the Muskrat Falls reservoir. The proposed stabilization approaches thus seem reasonable.** NRCan notes that *6.0 Future work, Appendix C* (p. 6-1) identifies that additional field investigations are required for the final design of seepage control measures on the spur.”

**Click <http://www.acee-ceaa.gc.ca/050/documents/49157/49157E.pdf> to see this document.**

**Note that NRCan was particularly interested in whether Nalcor had addressed the recommendations regarding the North Spur set out in the 1998 North Spur study conducted by Jacques Whitford Consultants for NL Hydro.**

**See slide 5 in NRCan presentation at  
<http://www.ceaa.gc.ca/050/documents/48555/48555F.pdf>**

## Nalcor North Spur Technical Note

On July 20,2011 Nalcor filed a “North Spur Technical Note” in response to a JRP question **stating that :**

“The long term stability of the North Spur will be further addressed during the current detailed design phase of the Lower Churchill Project.

The conceptual design outlined in the 1999 Study will be analyzed and further developed based on current information and **additional geotechnical information that will be obtained in a site investigation program planned for 2012.”**

Click

<http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit38.pdf> to see this document.

There does not seem to have been a North Spur Geotechnical Program at the North Spur in 2012 .

## **The North Spur Technical Note states that:**

**“A site investigation is also planned for 2012 to gather additional geotechnical information relating to the North Spur which will be required to complete the detailed design.**

**The capital cost estimate for Muskrat Falls includes the work identified in the 1999 study relating to the North Spur stabilization .”**

## The Nalcor North Spur Technical Note and 3 related documents were filed with the NL PUB as Exhibit 38.

Several other exhibits are also of interest :

**Exhibit 39** - a 122 page report dated July 2008 by Hatch Ltd. detailing groundwater monitoring activities.

**Exhibit 40** - a report on the pumpwell system by Hatch Ltd dated March 2010 (**see in particular “2.2 Geology and Sediments”**)

**Exhibit 41** – a report on the installation of new piezometer s in the pumpwell system by Hatch Ltd dated April 2010. Attachment B contains the geology encountered in 17 boreholes to a maximum depth of 45m. Attachment C contains a stratigraphic Xsection based on 5 boreholes to a depth of 45m over a distance of 250m showing variable geology (sand and “silty clay”).

**Click <http://www.pub.nf.ca/applications/muskratfalls2011/files/exhibits/Exhibit38.pdf> to see this document.**



## **The “Technical Note” stated that:**

**“The long term stability of the North Spur will be further addressed during the current detailed design phase of the Lower Churchill Project. The conceptual design outlined in the 1999 Study will be analyzed and further developed based on current information and additional geotechnical information that will be obtained in a site investigation program planned for 2012.”**

## **Nalcor's "Technical Note" states:**

### **"Conclusions and Recommendations**

**The dewatering system has operated continuously since November 1981 and there has been no further major landslide activity on the spur.**

**The purpose of the installation has, therefore, been fulfilled.**

**Rehabilitation work recommended in previous reports has been completed."**

**In a January 2012 report to the PUB, MHI stated that**

**“ The Final Feasibility Study [by Nalcor] included an analysis [of the North Spur] to substantiate the design concept but the detailed design studies must demonstrate the long term viability of this concept. The long term viability of this scheme is subject to further analysis and detailed design of the necessary stabilization works.”**

**MHI went on to state that :**

**“The consultants involved have undertaken a comprehensive review of the stability of the north spur including the response of the structure to changes in water levels. There is no reason to believe that the north spur would not be stable during the life of the project.”**

**Click <http://www.pub.nf.ca/applications/muskratfalls2011/files/mhi/MHI-Report-Volumell-Muskrat.pdf>**  
**to see page 88 of this document.**

**On December 17, 2012**

**Nalcor sanctioned the Muskrat Falls Project.**



**On January 23, 2013, Nalcor stated that a “North Spur Geotechnical Program” was part of Nalcor’s 2013 work program.**

**35 years after the warning given by the major North Spur landslide of 1978, critical geotechnical, and so safety and cost questions remain unanswered with respect to the absolutely most important part of the Muskrat Falls Project.**

## **SNC Lavalin seeks Package Leader - North Spur Stabilization Team**

On February 6, 2013, SNC Lavalin as EPCM contractor to Nalcor posted a public notice seeking a senior engineer with far reaching responsibilities to head up a “North Spur Stabilization Project” (see next slide).

The initiation of a major 2013 “North Spur Stabilization Project “ confirms that there is still a major unresolved North Spur “instability” problem .

The SNC North Spur job description of February 6, 2013 clearly shows that there is still a tremendous amount of work to be done. SNC’s first task in 2013 is to collect critical North Spur field data needed to do North Spur Stabilization engineering design activities.

**The bottom line is that an engineering solution to the North Spur instability problem has not yet been found.**

# SNC LAVALIN JOB OPENING - posted February 6, 2013

SNC-Lavalin :: Package Leader – North Spur Stabilization

Page 1 of 3

SNC-Lavalin :: Package Leader – North Spur Stabilization

Page 2 of 3



## Package Leader – North Spur Stabilization

Reference Number POW-22674

### WORK LOCATION

St. John's, NL, Lower Churchill Project

### COUNTRY OF EMPLOYMENT

Canada

### DESCRIPTION

#### SUMMARY OF JOB FUNCTION:

Working within an Owner / EPCM Consultant Project Delivery Team, and with accountability residing with the Area Manager – N. Spur Stabilization, Reservoir Clearing, and Habitat Compensation Works, the Package Leader – North Spur Stabilization is responsible for the overall delivery, including scope, cost and schedule management, of the North Spur Stabilization. Responsibilities span from geotechnical investigations, detailed engineering phase, contract formation, contract and construction management, through to completions and handover to operations.

The Package Leader – North Spur Stabilization will provide project engineering and management throughout the development and execution phases (engineering, procurement and construction) of the North Spur Stabilization works. The incumbent will be a key member of the Project Delivery Team and will interface extensively with the Area Manager – N. Spur Stabilization, Reservoir Clearing, and Habitat Compensation Works and EPCM Consultant's Engineering Manager – CI, as well as with the team's senior personnel.

#### PRINCIPAL ACTIVITIES, DUTIES AND RESPONSIBILITIES:

The duties and job functions of the North Spur Stabilization shall include, but are not limited to, the following:

- Responsible to Area Manager for the overall delivery of allocated package(s) in accordance with the approved budget;
- Work closely with the respective Project Services / Planner(s), Engineering Manager(s), Company's Technical and Design Integrity group, Construction & Completions Managers, Quality Assurance, and other functional expertise during the design, procurement and construction phases of the Project;
- Stewardship of Management of Change for scope.
- Stewardship of detailed engineering deliverables production and schedule to meet contract package(s) requirements.
- Manage 2013 geotechnical program, and ensure timely completion of all deliverables in order to support the engineering and contracting schedule.
- Provide proactive safety leadership and establish and maintain a positive safety culture at site.

- Work with Buyer / Contract Administrator to ensure key contracting / procurement activities and recommendations are undertaken, including review and approval of contracting strategy, bidder's list, bid evaluation plan, award recommendation, final contract for execution, and that the necessary financial authorizations (i.e. requisitions) are in-place.
  - Following award, work with Contract Administrator to ensure obligations of both Company and Contractor are adhered to.
  - Work with Project Controls to ensure effective cost and schedule control for package(s).
  - Oversee Contractor's / Suppliers' preparation of Design Documentation; in addition perform review and coordinate comment response sheets.
  - Establish Deliverable Distribution Matrix based on Supplier Document Registers.
  - Monitor project deliverables and milestones and ensure compliance with project schedule.
  - Ensure all package interfaces (including external interfaces) are clearly identified and scheduled with responsibility allocated; liaise with LCP and Contractor Interface coordinators to ensure interfaces are progressed in a timely manner.
  - Highlight and monitor critical items in cooperation with other team members;
  - Ensure the required level of readiness is achieved prior to commencement of site works, including supporting IT and office infrastructure, work processes, procedures, and all required contractor's plans (e.g. H&S plan, EPP, and Execution Plan).
  - Work with Regulatory Compliance team to ensure all permits are in-place to support work schedule and conditions are adhered to by Nalcor and contractor.
  - Work with functional managers for Quality, Engineering, H&S, Environment, and Project Controls to identify and secure all necessary field engineering, inspection and support personnel required for the earth works / site development program.
  - Organize and lead meetings, including meetings at the Muskrat Falls site, related to delivery of package(s), working to resolve issues that could impact overall delivery.
  - On-site presence at work locations for surveillance of contractor's work to ensure adherence to all aspects of the Agreement.
  - Work with Labor Relations Advisor to ensure contractor's compliance to the collective agreement.
  - Coordinate response to contractor's site queries in a timely manner to avoid schedule impact.
  - Work with the contractors / suppliers to ensure that the installed facilities:
    - (a) meet all Design, Safety, Quality, Schedule, Construction and Regulatory Requirements
    - (b) meet Project Goals for Safety, Operability, Reliability and Environmental Performance
  - Liaise with Site Resident Engineers / Construction to determine the need for Design and Construction Specialists and Inspectors as required;
  - Assist with implementing an Engineering & Completions Surveillance Plan. Work with Quality group to assign appropriate Criticality level.
  - Coordinate Project Documentation Turnover Plan with Contractor(s) / Supplier(s).
  - Coordinate Company's response to contractor / supplier site queries in a timely manner to avoid schedule impact.
  - Ensure a daily site report is produced covering all field operational activities.
  - Provide input into PMT Weekly and Monthly Reports.
- Primary location is St. John's Project Office, with possibility to transition to site as contractors mobilize.

#### Qualifications:

- Graduation from a recognized university with a Bachelor's Degree in Civil or Geotechnical Engineering. 15 to 20 years successful experience on delivery of major civil packages for large projects, in technical as well as project management and construction roles.
- Strong background in geotechnical engineering.
- Knowledge / experience with deep cut-off walls, road design and construction considered an asset.
- Prior experience interfacing with and managing delivery of large civil scopes in a large project execution environment.
- Strong understanding of project management processes and management systems.
- Must be able to work effectively as a key member of the Owner / EPCM Consultant Project Delivery Team within a multi-functional team environment (matrix style organization structure).
- Must be able to work in a collaborative/supportive manner with stakeholders.

The incumbent will work primarily in an office environment; however, travel to both construction and supplier sites will be required. The incumbent may be required to work from time to time in construction or industrial environments and may be exposed to environments that are dirty, noisy, and potentially hazardous.

## What is Nalcor/SNC Lavalin's North Spur "Package Leader" going to do ?

SNC Lavalin considers a knowledge of and experience with **"deep cut off walls"** to be an asset for any candidate wishing to become "Package Leader - North Spur Stabilization ".

In dam building parlance, a **"deep cut off wall"** is a barrier impervious to water keyed into bedrock in such a way that it prevents the passage of water and forms the essential core of a man made dam of earth or concrete.

It is to be hoped that Nalcor will not consider attempting to design and build essentially a massive, and extremely expensive, additional dam at the North Spur leading to enormous cost overruns.

If not, we would be in uncharted waters indeed, as it would seem to indicate that the stabilization plan set out in the SNC – AGRA Final Feasibility Study of 1999 is deficient in some way and that additional , as yet unknown, tactics must be employed.

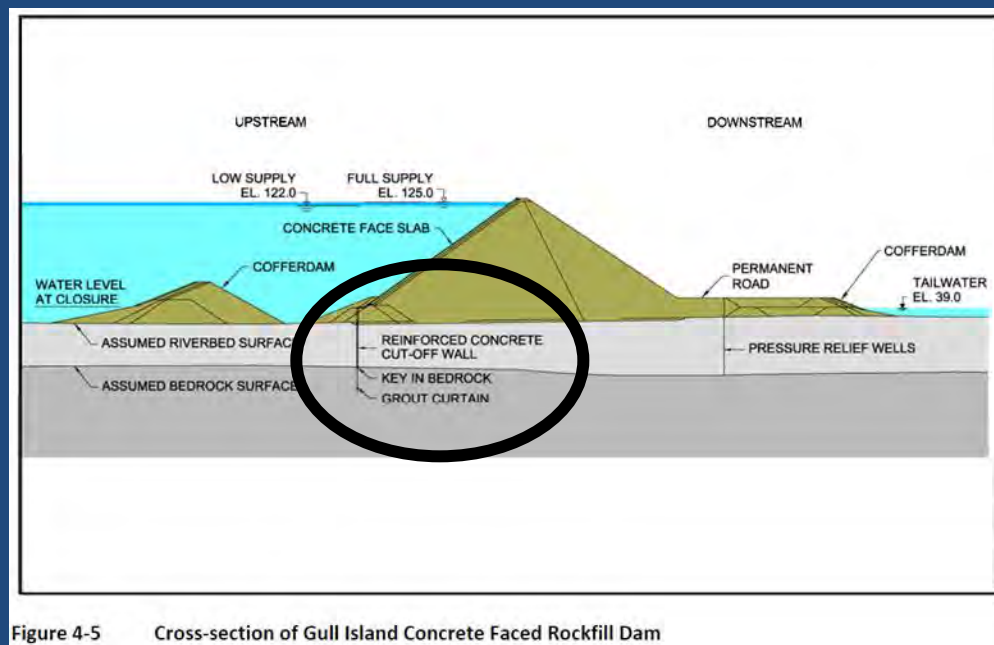


Figure 4-5 Cross-section of Gull Island Concrete Faced Rockfill Dam

The slide above shows cut off wall designed for Gull Island.

The use of deep cut off walls at the North Spur would mark a radical departure from the 1999 North Spur Stabilization Plan as set out in the 1999 Muskrat Falls Final Feasibility Study as prepared by SNC-AGRA for NL Hydro.

The bedrock at the North Spur is up to 270m or 885 feet down with hundreds of feet of quick clay in the middle.

SNC has stated that all possible alternatives at MF involve a stabilized North Spur.



## **How the 2013 North Spur Geotechnical Program fits in**

Before the design of the new North Spur reservoir containment system can begin, Nalcor / SNC must conduct a Geotechnical Program in 2013 to acquire some very key geotechnical information.

Such a program will presumably include a number of boreholes some drilled 270m to bedrock ; many of the North Spur boreholes drilled to date go to 45 to 50m which marks the top of a 50m thick “quick clay” deposit.

Presumably the collection of such subsurface geological data will be followed by complex computer modelling to estimate the tendency of the North Spur to fail and the projected reasons for such failure.

It is only following such modelling that the design of engineering “tactics” and physical structures to “stabilise” or effectively “replace” the North Spur can begin.

It is not known if the “North Spur” geotechnical program will also include an investigation of the potentially unstable “quick clay” deposits upslope to the north towards the Trans Labrador Highway.

## Current Situation

It is accepted by all parties (including Nalcor and NRCan) that there is a “quick clay” related instability problem at the North Spur.

If the North Spur cannot be stabilized in a safe and cost effective manner, the whole Muskrat falls project will have to be cancelled.

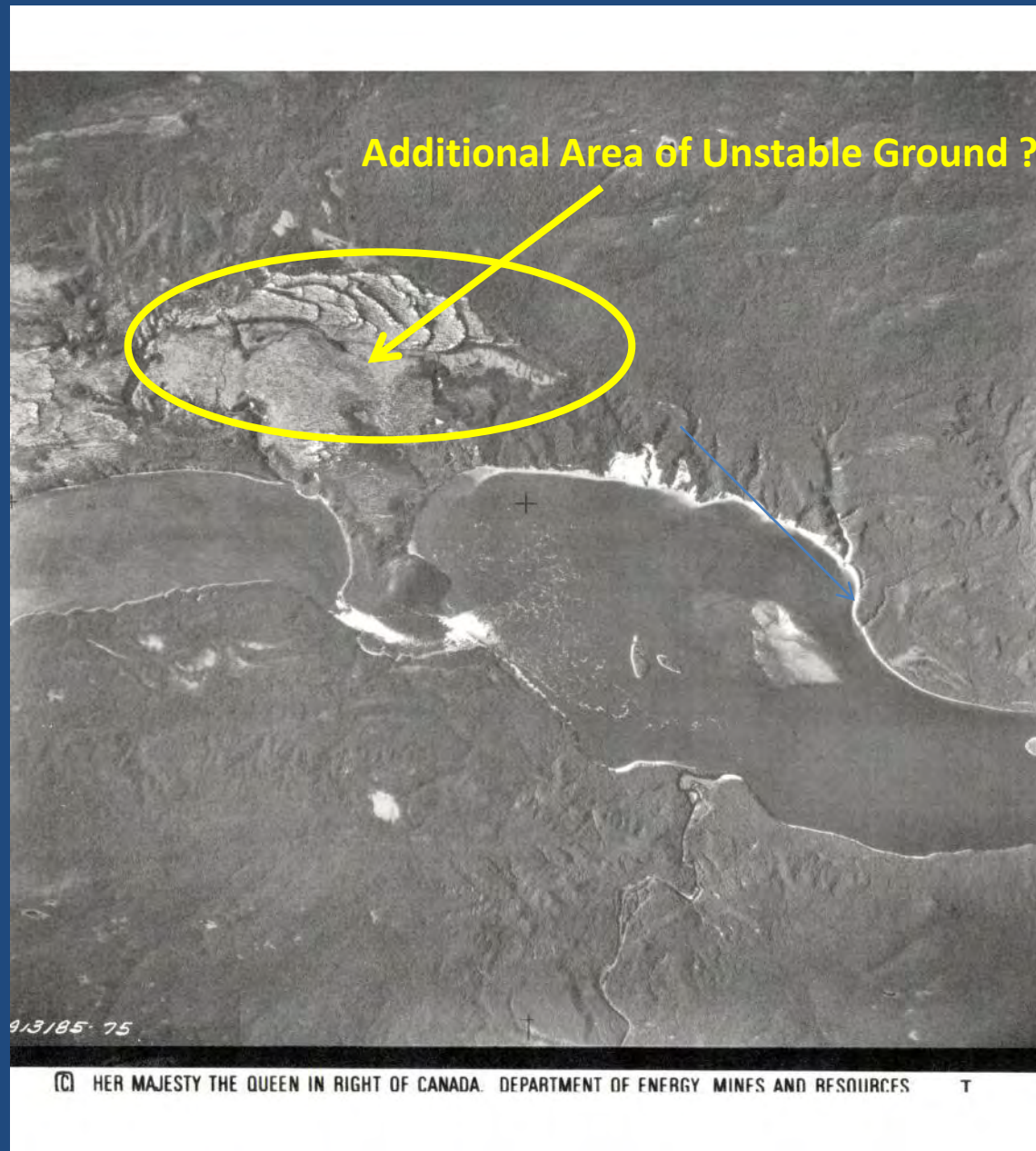
It certainly does not seem practical to excavate and remove all the glacio-marine clay at the North Spur because the clay/sand extends at least 200m below the surface of the Churchill River on the upstream side.

And if it were technically possible, it would also be enormously expensive and require the construction of an additional massive 1000m long concrete or earth filled dam.

**And there may be an additional, and possibly much larger problem, in that much larger glacio-marine quick clay slides may develop from a point upslope to the north of the Spur itself.**

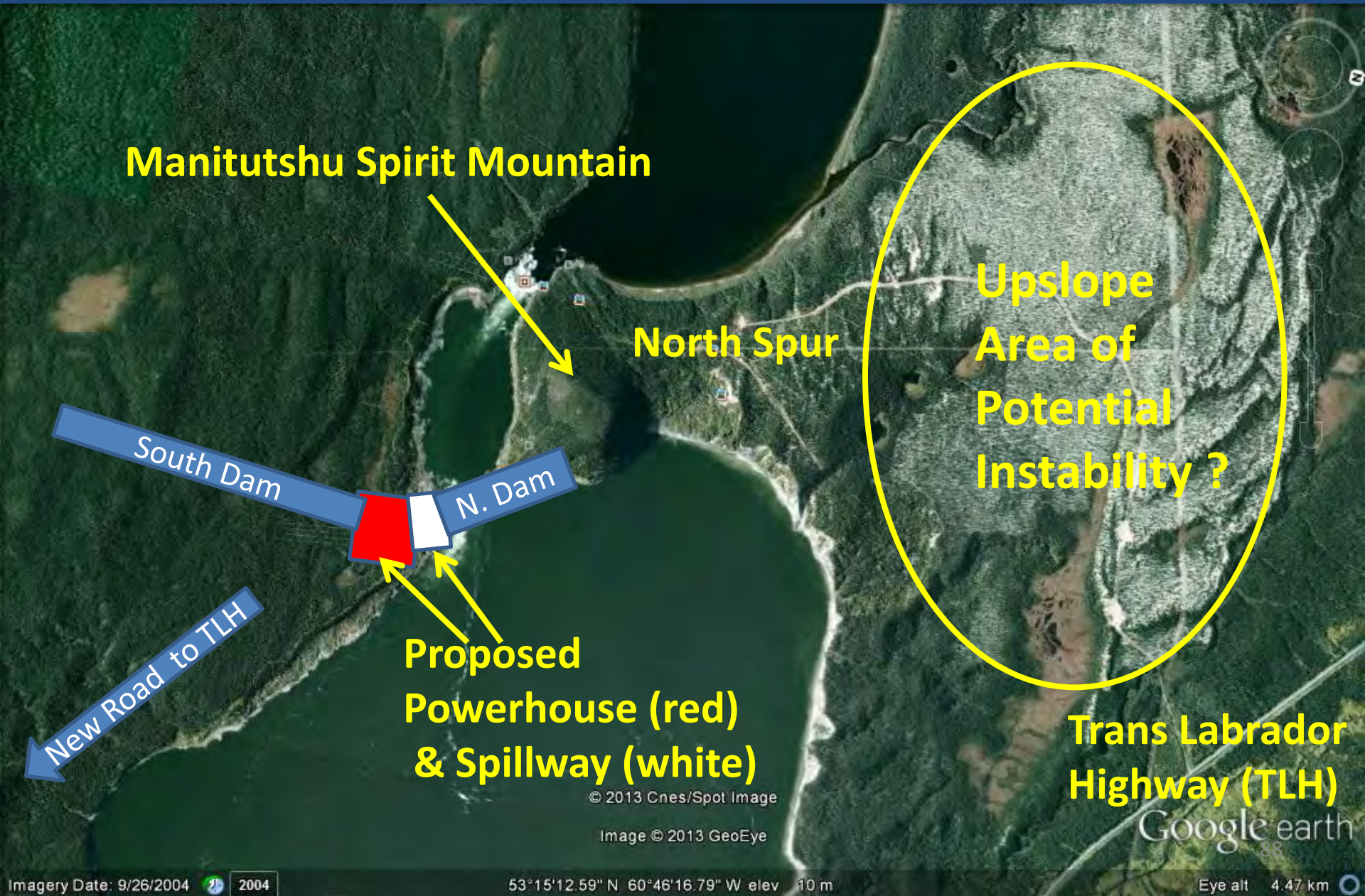
**Based on the very large scale slides that have occurred up and down the Lower Churchill Valley, this latter problem is far from theoretical.**

General 1951  
overview  
of Muskrat Falls  
looking north  
showing  
unstable ??  
ground





## Google Earth image of area upslope from the North Spur



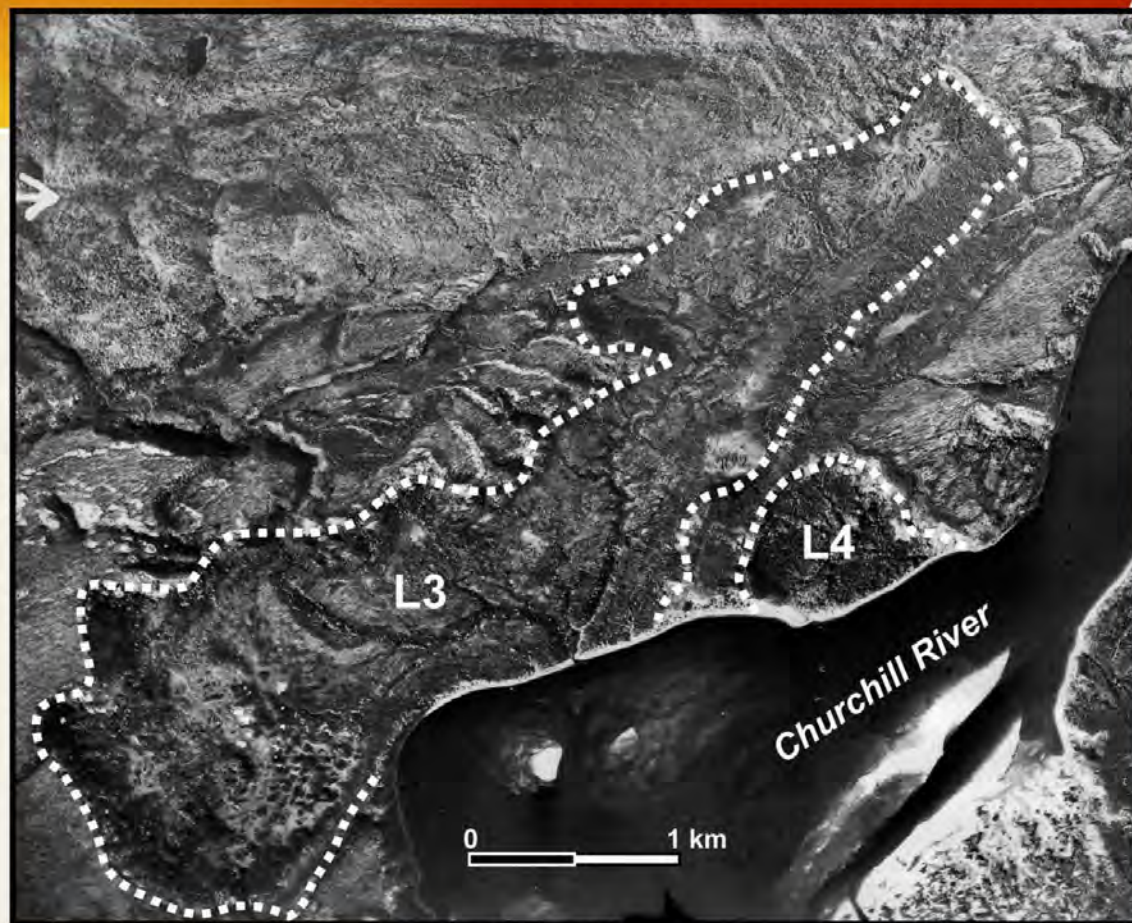


**A slide involving quick clay deposits upslope from the North Spur could have an area of up to several sq km -- compared to the 0.5 sq km area of the North Spur.**

**Norway's Rissa slide area was approximately 0.5 sq km.**

**The L3 slide area identified by NRCan from slide scars (next slide) is located some 40 km upstream from Muskrat Falls and had an area of 5 sq km.**

**Discussion of the L3 slide was part of the NRCan presentation to the Muskrat Falls Joint Review Panel in March 2011 (see next slide).**



## Examples of other scars



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**The response of the Government of Newfoundland and Labrador to the JRP Report 2011 is silent on the North Spur issue.**

Click <http://www.cbc.ca/news/pdf/NL-response-to-enviro-panel.pdf> to see this article.

**And the response of the Government of Canada to the JRP Report 2011 is also silent on the North Spur issue.**

Click <http://www.ceaa-acee.gc.ca/052/details-eng.cfm?pid=26178> to see this document.