



Luleå and Mölndal, Sweden, April 15th, 2019.

Hon. Siobhan Coady, Minister, Department of Natural Resources
7th Floor, Natural Resources Building, 50 Elizabeth Ave., P.O. Box 8700, St. John's, NL A1B 4J6
Telephone: 1-709-729-2920; Email: NRMinister@gov.nl.ca

Dear Honorable Siobhan Coady,

Investigation of the Safety of the North Spur

Thank you very much for your kind letter dated March 12, 2019.

We have three major points we want you to look into:

I: Considerations not addressed

You write in your letter: "...the responsible dam engineer or decision-maker must access and interpret the information provided in the guidelines, **identify any considerations not addressed by those documents, take into account advances in understanding and determine the appropriate dam safety requirements for specific situations.**"

This is exactly just what has *not* been done. The Geotechnical Peer Review Panel, GPRP, has only referred to Nalcor/SNC Lavalin Inc.(SLI) and concluded: "The GPRP has not performed any calculation to verify the accuracy, completeness or validity of the results obtained by SLI. The opinion of the GPRP is solely based on a review of available data and on the concept and methods used by SLI and the client to assess stability issues at the North Spur. Therefore, the GPRP makes no representation regarding its accuracy and hereby disclaim any liability in connection therewith". This may be summarized as: "*Everything seems to be done according to the 'book', so it is OK*".

What is referred to here is in Geotechnical Engineering terminology denoted the **Limit Equilibrium Method** (LEM). This mathematical approach presumes full plasticity in the critical soil layer. However, this approach is not good enough any longer. Modern research in e.g. Sweden, Norway, Canada, Italy and Switzerland has shown that these old *early twentieth* century rules do **not apply** at all to extensive progressive landslide failure in slopes with *sensitive clay layers* or with what in Soil Mechanics is termed as *metastable* soil conditions. Recently, for instance, the Mount Polley Dam failure in British Columbia (2014) could not be predicted using the traditional LEM rules. Another example of an unpredicted forward progressive slope failure in Canada is the Saint Fabien slide in Québec, (2004) and there are dozens of progressive landslides in Scandinavia that were not possible to predict using traditional methods. However, to date there are methods available for predicting and forestalling progressive landslide events. Yet, the GPRP has, very oddly, not referred to the use of these, now well known, results of modern R&D - or to the fact that SNC Lavalin has not even presented any valid calculations at all based on progressive slope failure, proving that the North Spur will stay stable during impoundment.

According to the investigatory calculations made by the Dury and Bernander - based on soil properties as interpreted from data presented by SNC Lavalin - it has not been possible to confirm North Spur stability or even to establish a valid '*Factor of Safety*'.

Furthermore, when defining landslide hazard it is absolutely necessary to consider the slope gradient of the failure surface studied. The GPRP has not even objected to the fact that the analyses of *eastward* slide risk along the western part of the North Spur presented by SNC/Lavalin only relate to *horizontal* failure surfaces.

II: Jim Gordon does not endorse the safety

Jim Gordon does not any longer endorse the safety of the dam as he has written to you in a letter dated March 14, 2019.

III: Drainage

It is of course highly recommendable that monitoring ground water pressure is carried out in order to study frictional resistance, water flow and seepage etc.

However, failure in metastable soils is normally a fast and very sudden process. When occurring, it is normally far too late to act.

The *safest way* to prevent failure due to *liquefaction* in metastable soils is to drain the critical soil layer in such a way that it is no longer *fully water-saturated*. In the current state, this is probably the only way to establish a factual safety factor. This implies that deep pump wells, down to critical *metastable* soil layers, should be installed. This mitigating measure should be made prior to impoundment.

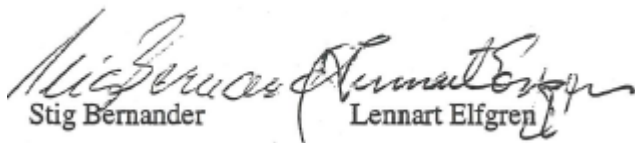
Conclusion

We recommend You to reconsider your decision.

We propose engaging a group of independent expert geotechnical engineers - in order to *investigate*, *identify*, and before impoundment, *drain* critical metastable soil layers in the western part of the North Spur – thus ensuring that disaster is truly forestalled.

World history is full of slope failures due to liquefaction in metastable ground layers below buildings, bridge piers, *earth dams* and concrete dam structures.

Yours Sincerely,



Stig Bernander Lennart Elfgren

Tekn Dr., Adjunct Professor Emeritus; Tekn. Dr., Senior Professor
Department of Civil, Environmental and Natural Resources Engineering,
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Links to reports and to video presentation:

Bernander-Elfgren (2018). *Dam Bank Stability in loosely layered silty sands and lean silty sandy clays. Comments on the risk of failure in the North Spur at Muskrat Falls in the Churchill River Valley, Labrador, Newfoundland*, 150 pp. <http://ltu.diva-portal.org/smash/get/diva2:1180147/FULLTEXT01.pdf>

Bernander-Elfgren (2018). *Response to and Comments on "Geotechnical Peer Review of Dr. S. Bernander's Reports and Analysis of the North Spur"*, 31 pp. <http://ltu.diva-portal.org/smash/get/diva2:1233686/FULLTEXT07.pdf>
Video presentation, 24 minutes, <https://www.youtube.com/watch?v=RXs5v0U275g>

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March 14th, 2019
Minister Siobhan Coady
Minister of Natural Resources
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Canada

Minister Coady

I am writing to correct a statement made in your letter to Dr. Elfgren and Dr. Bernander on March 12th, 2019. On the bottom of the first page and at the top of the second page there is the statement -

In addition, Mr. Jim Gordon, a retired hydropower consultant who previously voiced concerns about the stability of the North Spur in relation to your reports, subsequently withdrew that comment and endorsed publically the safety of the North Spur dam.

I suspect this endorsement is based on an article I wrote in 2016 titled "Is the North Spur safe?" It can be read at <http://muskratfalls.nalcorenergy.com/wp-content/uploads/2016/11/Jim-Gordon-North-Spur-Safety-Comments-October-2016.pdf>

Also a comment on the article can be read at - <https://www.cbc.ca/news/canada/newfoundland-labrador/north-spur-now-stable-engineer-1.3834734>

In the article there is the following statement at the beginning -

I have written several articles about my concerns regarding the safety of the North Spur dam, concluding in my last article that the dam was not safe. However, on undertaking a more detailed analysis of the NALCOR reports, I have changed my mind, and now believe the dam to be safe.

The article was written after I was assured by NALCOR that the design of the North Spur had been reviewed by HATCH, a large consulting company with extensive experience in dam design. Since I personally know the senior engineers in the HATCH geotechnical department, having worked with them on review boards, where I found that their judgement was sound, I believed the Spur dam to be safe.

About a month later, when I was talking to one of the HATCH geotechnical engineers on another project, I casually mentioned that they had approved the design of the North Spur dam. He then vociferously contradicted my comments, and advised that HATCH had never at any time reviewed the SNCL work on the Spur. Consequently I withdrew my support in a later blog.

It is unfortunate that NARCOR is still referring to my lapse of judgement. I should have checked the reference. My mistake.

I would like to refer you to my latest views on the North Spur expressed in the Uncle Gnarley blog published on Monday 2 July 2018. (Reference - <http://unclegnarley.blogspot.com/2018/07/jim-gordons-final-comments-on-north-spur.html> wherein there is an extensive analysis of the North Spur titled – (If too technical, jump to End of Quote on page 5).

THE NORTH SPUR – MY FINAL COMMENTS

At the end of the analysis there is the following statement – (pictures removed)

Start of quote -

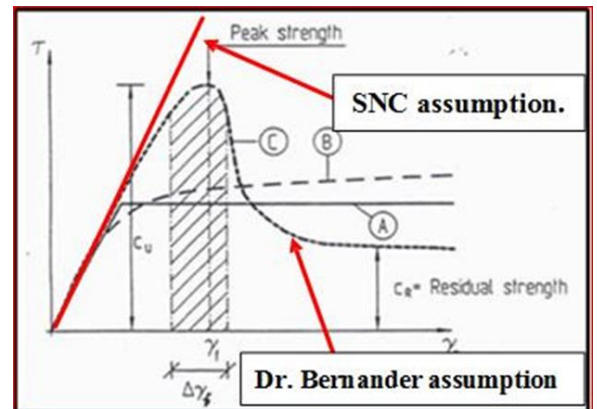
I still question whether the North Spur is safe, based on the lack of data and absence of geotechnical analysis in the GPRP report to support their conclusions. The report was prepared in three days, totally insufficient to assess the vast amount of geotechnical data on the Spur. This can be compared with the time required to investigate the Mount Polley dam failure, which occurred on August 4th, 2015, and the failure report was issued 5 months later on 30th January 2015.

In particular, I would have preferred to have seen –

1. *The results of stress-strain tests on the soils. This is where Dr. Bernander and the consultant SNC depart in their expectation of the soil strength. SNC have assumed a linear relationship, whereas Dr. Bernander assumes a loss of strength at relatively low levels of strain, as shown in the following diagram extracted from his report ----->*

Such tests must have been undertaken. But results have not been divulged.

There is a reference to the strength reduction in the report as follows - Recent research in Norway (refs. (29) and (30)) recommends the use of the LEM approach in practice for the analysis of slope stability in sensitive and quick clays, with the addition of a correction factor, called $F_{softening}$, to account for the reduction of the clay shear strength after the peak shear strength has been reached, and to partially account for strain compatibility on the failure surface. (Report page 15)



The report then states - As an example of the effect of the mitigation measures for a slope on the Eastern side of the North Spur, the critical factor of safety was increased from 1.0 to 1.6. This is a 60% increase in the stability of the slopes, and within the reduction associated with $F_{softening}$ if one should use the results of some of the most recent researches.

However, there is no discussion on how the $F_{softening}$ factor was determined for the soils in the Spur. It has been assumed from other studies. Since the safety of the Spur is so critical, stress-strain test results should be available for the North Spur soils.

2. *Dr. Bernander has based his analysis on the lowest strength soils, whereas the GPRP has used the average soil strength, stating – Atterberg limits indicate that the clay has low to medium plasticity. Plasticity charts based on soil testing in 1979 and 2013 investigation are presented in Figure 6 for the Upper Clay and Lower Clay. For the Upper Clay, the plasticity index ranges between 3 and 22, with an average of 11. Only a few*

values are below 7 and most of them seem to be associated with a mixture of silty layers and clayey layers. (Report, page 10)

There has been no justification for this. What is the saying – the strength of a chain is equal to the strength of its weakest link. The soils in the Spur have been deposited in layers, with each layer having a different strength and characteristic. If there is a layer of weak soil, then the Spur will fail by sliding on that layer as occurred at Mount Polley in BC. The GPRP has not demonstrated that there is no such layer. The extent of soft and low-strength materials is unknown at this time. I would have preferred to see a three-dimensional computer model of the Spur showing the layer strength.

Picture removed.

Mount Polley dam in BC. The downstream slope failed on August 14th, 2014.

Report extract - (The) Independent Expert Engineering Investigation and Review Panel concluded that the dominant contribution to the failure resides in the design. The design did not take into account the complexity of the sub-glacial and pre-glacial geological environment associated with the Perimeter Embankment foundation. As a result, foundation investigations and associated site characterization failed to identify a continuous (soft) layer in the vicinity of the breach and to recognize that it was susceptible to undrained failure.

3. The GPRP concludes that the cut-off wall is a necessary component of the Spur safety enhancement. My experience with such walls is that they contain defects in the form of permeable windows caused by the permeable material falling off the vertical sides of the wall during the back-filling process. Impermeability can be seriously affected, and will not be known until the reservoir is filled.

Also, the GPRP rejects Dr. Bernander's description of a "gigantic force" applied to the wall, pointing out, correctly, that the location and height of the wall has been misinterpreted by Dr. Bernander. The GPRP report states –

In their analyses, Dury and Bernander assumed "a gigantic external force (locally on the (cut-off wall) COW)", assuming the water pressure resulting from impoundment on only one side of the COW, in addition to using incorrect geometry and incorrect location for the COW. Actually, the many piezometers installed in the North Spur show that the water pressure in the Spur will be acting on both sides of the COW (red triangle on Figure 13). If the calculation is performed for a COW at the actual location, the force on the wall will be much less than the force calculated by Dr. Bernander. (Page 21)

This statement is patently not correct and indicates a misunderstanding of the hydraulic forces exerted by the reservoir waters on the Spur. There has to be an impervious barrier to the headpond water within the Spur to avoid excessive seepage. It makes no difference to the hydraulic forces if the barrier is a cut-off wall constructed from the dam crest down to the impervious clay layer below the spur, as assumed by Dr. Bernander, or if the barrier is a short cut-off wall topped by an impervious blanket, as built at the upstream face of the Spur. Moreover, the impervious barrier can be located anywhere within the upstream half of the natural dam formed by the Spur.

To reinforce their theory about the forces acting on the cut-off wall, the GPRP has added a counterforce on the downstream face of the cut-off wall (Report Figure 13) equal to the pressure on the upstream face. If this was the case, then the cut-off wall and blanket would not be required.

What Dr. Bernander is describing is the concentration of the forces at the watertight barrier resulting in high compressive forces on the soil immediately downstream of the watertight barrier. Without the watertight barrier, the dam would be built with a homogeneous glacial till, as at Bay d'Espoir and Cat Arm, and the hydraulic forces would be dissipated throughout the dam, instead of being concentrated at the watertight barrier.

The effect of the force concentration has not been determined. It would have to be undertaken by a fine-mesh finite element analysis.

Picture removed.

Teton Dam failure due to excessive seepage on first filling. June 5th, 1976. This was the unexpected event which started the dam safety campaigns in North America.

4. The GPRP has assumed that the safety factors applicable to the Spur stability are those recommended by the Canadian Dam Association. As first mentioned by Phil Helwig, these safety factors were developed for dams constructed with known homogeneous materials such as rock, gravel, and silt, all within a determined size, placed and compacted under strict specification requirements, and tested throughout construction. On the other hand, the North Spur contains a mixture of sand, silt and clay, resting naturally, and not compacted, nor tested as in an engineered dam. The safety factor for such a natural dam should be higher. The GPRP has not demonstrated that the CDA factors can be applied to the Spur.

*Also, I would refer the GPRP to a paper (reference provided by Phil Helwig) authored by J. Michael Duncan, titled "Factors of safety and reliability in Geotechnical engineering" which demonstrates that using a simple factor of safety is insufficient, and that a reliability analysis is also required. (ASCE Geotechnical Journal, Oct. 1999. *1) A reliability analysis has not been undertaken by the GPRP.*

**1 Factors of Safety and Reliability in Geotechnical Engineering 1999 J Michael Duncan The Seventh-Spencer J Buchanan Lecture.*

So what can be concluded from all this? – is the North spur absolutely safe? The reservoir spillway has been designed to pass a 1/10,000 flood, and the Spur is able to withstand a 1/10,000 earthquake. But is the risk of a slope failure at the North Spur also assessed at 1/10,000? If not, then how risky is it? Nobody knows, since a reliability analysis has not been undertaken.

Recommendations:

The government of NL should appoint an eminent panel of geophysical experts, completely independent of Nalcor, to assess the scientific evidence and undertake all necessary additional research, and undertake a comprehensive review of the safety and stability of the North Spur. The Panel's work should include:

1. Giving Dr. Bernander and his associate Dr. Elfgren the opportunity to respond to the GPRP report, and include their comments therein.

2. Assessing the results of stress-strain tests on the various soils within the Spur, to demonstrate that the linear relationship and softening factors have been correctly determined and applied to the geotechnical calculations.

3. *Producing a three-dimensional computer model of the strength of the various soil layers within the spur, to demonstrate that there are no extensive layers having a strength below average strength, which could form a sliding plane.*

4. *Undertake a reliability analysis of the safety of the Spur.*

5. *Seeking precedents for the use of CDA dam safety factors in slope safety calculations in a natural dam.*

Given the recent revelations that Nalcor staff have been “marking-up” reports by the “Independent” Engineer, it is imperative that the chosen Panel is verified to be Independent of Nalcor. Only then will the residents downstream of the Spur — and those who are responsible for paying for the dam — feel that Government has done its utmost to ensure their safety and the safety of the Spur.

Jim Gordon. Hydropower consultant, retired.

End of quote.

This is certainly not an endorsement of the safety of the North Spur. On the contrary, the risk of a failure is still unknown. My view is (from first line in the Final Comments) *I still question whether the North Spur is safe, based on the lack of data and absence of geotechnical analysis in the GPRP report to support their conclusions.*

There are too many unresolved geotechnical issues for me to unequivocally endorse the current design. The unresolved issues are outlined in the four comments beginning on page 2.

The dam safety is a geotechnically very complex issue and revolves around the use of 2 different equations used to assess the stability. Both equations include factors for soil strength and so forth. Both were tested and benchmarked on the near vertical scarps left by previous landslides, where the soil parameters were adjusted to indicate a factor of safety of 1.0 equal to slope being on the verge of failure.

The equations were then used to determine the slope of the dam sides required to achieve a dam stability safety factor which is within the guidelines issued by the Canadian Dam Association.

The main issue is the relationship between soil deformation and stress outlined in the first comment, the stress-strain relationship.

To elaborate – imagine an ordinary spring fish scale, rated at 10Kg. This will provide a reasonably accurate measure of the weight of a fish up to the limit of 10kg. The spring extension remains proportional to the weight.

Assume now that the limit on spring extension stop is removed, and that a fish of about 25kg was being weighed. The weight will result in uncoiling of the spring to the extent that it will not return to the zero position on removing the fish. In this case the spring extension has exceeded to proportional limit, and the spring uncoils.

The assumption by Dr. Bernander is that the stress on the soil induced by the horizontal force of the water in the reservoir will exceed the proportional limit, based on his knowledge of similar soils, as shown in the diagram on page 2.

The assumption by SNCL is that the stress on the soil induced by the water in the reservoir will remain within the proportional limit based on their interpretation of the soil geotechnical data, also as shown in the diagram on page 2.

From these assumptions two different formulae have been developed to predict calculated slope safety factors.

Unfortunately the formula used by Dr. Bernander predicts an unstable slope, whereas the formula used by SNCL and the GPRP indicates a stable dam for the slopes currently built.

Which equation is correct remains to be determined.

It must be remembered that the North Spur dam is unique. It is the first dam in the world containing sensitive clay and even pockets of quick clay within the dam structure, and is resting on a foundation of sensitive clay. There is no precedent. All precedents provided by SNCL were found to be small dykes with a height less than one-quarter of the Spur height, with very flat side slopes.

The issue could be resolved by publishing the results of stress-strain tests. This has not been done, leading to the suspicion that no such tests were undertaken.

It should be noted that both Dr. Stig Bernander and Dr. Lennart Elfgren have also recommended undertaking stress-strain tests as mentioned in their report titled “Response to and Comments on Geotechnical Peer Review of Dr. S. Bernander’s Reports and Analysis of the North Spur”, dated July 2018. Page 6 of the report includes the following statement in the Abstract –

(2) The stress/strain deformation properties of the porous soils in the North Spur have not been made available. Only strength properties, related to fully drained conditions, have been given. How stresses relate to simultaneous deformations under undrained (or partially undrained) conditions have not been defined in any way. Such relationships are crucially essential for any up-to-date analysis of slope stability.

Copied from reference - <https://www.muskatfallsinquiry.ca/files/P-00434.pdf>

Since the dam is unique, containing sensitive clay, resting on a sensitive clay foundation, it is absolutely inconceivable that from a dam safety standpoint, no stress-strain tests have been undertaken. It is clearly apparent that neither NALCOR, nor SNCL nor the GPRP understand the importance of stress-strain tests required to determine the safety of a dam.

And note that only one test is insufficient. Each type of soil within the North Spur will require at least 3 tests, resulting in about 12 to 15 tests, or more if there is a wide variability in the test results.

I would strongly suggest that NALCOR be requested by some entity to undertake stress-strain tests before the reservoir is filled. If a failure occurs, I just hope that the instrumentation installed in the dam will be adequate to provide sufficient warning time to both start remedial measures and alert the downstream residents.



James L. Gordon.



Government of Newfoundland and Labrador
Department of Natural Resources
Office of the Minister

MAR 12 2019

Dr. Lennart Elfgren, Senior Professor
Dr. Stig Bernander, Adjunct Professor Emeritus
Department of Civil, Environmental and Natural Resources Engineering
Lulea University of Technology
SE 97187
Lulea, Sweden

Dear Dr. Elfgren and Dr. Bernander:

RE: Investigation of the Safety of the North Spur

Thank you for your letter discussing studies related to the stability of the North Spur.

Our Government is committed to ensuring the safety of dams in the Province in order to protect all Newfoundlanders and Labradorians. Nalcor Energy's stated goal has been to ensure the stability of the North Spur as well as keeping the lines of communication open with stakeholders as well as the general public. The North Spur, including data, groundwater and soil properties have been studied by multiple geoscience and geotechnical engineers since 1965; and Nalcor Energy and SNC Lavalin (SNC) have regularly reviewed the engineering work and have engaged third-party experts to complete external validation. Independent reviews have validated the extensive field investigations that support the engineering design. The design solution has been addressed in numerous engineering studies and the geotechnical conditions are well documented. In regards to stabilization, geotechnical engineers undertook the engineering design with third-party experts verifying the outcomes. The stabilization work on the North Spur began in 2015 and was completed in August 2017. In order to provide information about the work completed on the North Spur and hear the concerns of residents, Nalcor Energy held independent public sessions in Upper Lake Melville, Labrador, in January, 2017. A list of Nalcor actions and studies on the North Spur is posted at www.musktratfalls.nalcorenergy.com and then select "Newsroom," then "Reports."

As with many projects, there are sometimes varying perspectives and all must be scrutinized to determine if there is merit in the information presented. Nalcor assembled a group of individuals with extensive knowledge and research on landslides and the behaviour of sensitive clays under a Geotechnical Peer Review Panel ("GPRP"). The panel's February 2, 2018 report entitled, "Geotechnical Peer Review of Dr. S. Bernander's Reports and Analysis of the North Spur" concluded on page 5 that, "The GPRP examined the engineering documentation available for the North Spur and concludes that the overall approach, concepts and methods used for checking the stability and integrity of the North Spur follow the current standards and state of the art practice." In addition, Mr. Jim Gordon, a retired hydropower consultant who previously voiced concerns about the stability of the North Spur in relation to



your reports, subsequently withdrew that comment and endorsed publically the safety of the North Spur dam. Furthermore, Natural Resources Canada requested an Independent Engineer (IE) review and comment on the reports. In January 2018 the IE presented its comments summarizing that the current overall design, review, and due diligence process for the North Spur was consistent with what was expected for a major hydroelectric project.

Nalcor has designed and constructed the Muskrat Falls facility to Canadian standards of dam safety and construction. The structures at Muskrat Falls are subject to regular inspection; have sensors and other instrumentation to provide advance notice of potential issues; and are monitored on an ongoing basis. Nalcor reports the generation facility is being monitored to meet the Dam Safety Guidelines, as outlined by the Canadian Dam Association (CDA), and includes bi-weekly and monthly inspections, as well as ongoing monitoring and daily analysis of instrumentation.

According to the CDA guidelines, the responsible dam engineer or decision-maker must assess and interpret the information provided in the guidelines, identify any considerations not addressed by those documents, take into account advances in understanding and determine the appropriate dam safety requirements for specific situations. For further information, please visit the CDA at www.cda.ca.

There is also an established and active Dam Safety Program for the Muskrat Falls Project developed by the SNC Engineering team. Nalcor advises that this program includes detailed inspections, monitoring and analysis for the entire life of the Muskrat Falls facilities and is focused on structure movement; water pressure; water flow and seepage; slope; foundation and joint movement; temperature; and seismic acceleration. Instrumentation installed on the dam and structures at the Muskrat Falls site are connected to data loggers to ensure that data can be collected and monitored. There is also ongoing monitoring and analysis of the instrumentation that will continue when the project moves from the construction to operational phase in the coming years.

The Government of Newfoundland and Labrador also has its own provincial dam safety program to oversee the safe management of all dams in the province including dams at Muskrat Falls. This program also applies to all stages of a dam's life cycle (design, construction, operation and decommissioning) and manages the risks associated with dams to public safety, infrastructure and the environment. It follows the formal process set out by the CDA which requires that a construction permit be issued that includes terms and conditions which place the responsibility on the owners to do periodic reviews. This also includes a requirement to develop a maintenance and surveillance manual as well as an emergency preparedness plan, which are both reviewed every five years. Furthermore, the Water Resources Management Division of the Department of Municipal Affairs and Environment (MAE) receives weekly construction reports from Nalcor and has quarterly face-to-face meetings for status updates of the project. There are also annual on-site inspections done by dam safety program government agency personnel. All of these reviews are done under the purview of best practices as provided by the CDA. MAE retains all records to ensure that owners are following the stringent guidelines as outlined by the



CDA. In addition, MAE helps to provide and facilitate dam safety training opportunities for dam owners in the province. For further information please visit the MAE website at www.mae.gov.nl.ca and proceed to *Environment – Water Resources – Dam Safety Program*.

I appreciate the work that you both have done in researching the stability of the North Spur. While I recognize your recommendation for an independent committee of experts, as previously mentioned, numerous industry experts have already been engaged at various stages to review and scrutinize the stabilization design as well as reports that questioned the stabilization work completed on the North Spur.

I want to thank you for offering your views on the stability of the North Spur.

Sincerely,

A handwritten signature in blue ink, appearing to read "Siobhan Coady".

SIOBHAN COADY, MHA
St. John's West
Minister



Luleå, October 2nd, 2018

Hon. Siobhan Coady, Minister, Department of Natural Resources
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Dear Hon. Siobhan Coady,

Investigation of the Safety of the North Spur

During the last couple of years, Dr. Stig Bernander has studied the stability of the North Spur and found that there is a risk for a dam breach and for part of the Spur sliding into the Lower Churchill River 70 m deep pool downstream of Muskrat Falls. The results of his studies have been brought to the attention of Nalcor/Lavalin, who recognized it was significant enough to warrant a peer review. Subsequently Muskrat Falls Corporation appointed a Geotechnical Peer Review Panel, GPRP, to scrutinize his work.

The review panel, however, did not make use of any recent R&D methods, as Dr. Bernander had advised. Instead it only re-examined the old data and methods provided by Nalcor/Lavalin, which not even considered basic geotechnical principles regarding deformations and inclinations. Methods, based on recent R&D, which are now available, are vital for a proper calculation of the risk of the dam's failure. In the failure of the Mount Polley Dam in BC in 2014, it was for instance found that the traditional methods were not able to predict the failure.

Using up-to-date methods, data from reports by Nalcor/Lavalin and probable deformation properties of the varying strain softening soils in the North Spur, indicate a conceivable risk for a progressive downwards failure along inclined sliding surfaces into the river downstream of the Muskrat Falls.

We recommend you to appoint an independent committee of experts to investigate this problem before impoundment and – if necessary – to propose appropriate mitigation measures to prevent a dam failure. The costs for such an investigation will be minor compared to the catastrophe a dam failure would give.

We include links to two of our reports and to a video presentation. They summarize our concerns and our criticism of the Geotechnical Peer Review Panel Report.

Sincerely yours,

Two handwritten signatures in black ink. The signature on the left is 'Stig Bernander' and the one on the right is 'Lennart Elfgren'. Below each signature is the printed name of the respective person.

Stig Bernander Lennart Elfgren

Tekn Dr., Adjunct Professor Emeritus; Tekn. Dr., Senior Professor
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Links to reports and to video presentation:

Bernander-Elfgren (2018). *Dam Bank Stability in loosely layered silty sands and lean silty sandy clays. Comments on the risk of failure in the North Spur at Muskrat Falls in the Churchill River Valley, Labrador, Newfoundland*, 150 pp. <http://ltu.diva-portal.org/smash/get/diva2:1180147/FULLTEXT01.pdf>

Bernander-Elfgren (2018). *Response to and Comments on "Geotechnical Peer Review of Dr. S. Bernander's Reports and Analysis of the North Spur"*, 31 pp. <http://ltu.diva-portal.org/smash/get/diva2:1233686/FULLTEXT06.pdf>
Video presentation, 24 minutes, <https://www.youtube.com/watch?v=RXs5v0U275g>