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Minister Siobhan Coady
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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

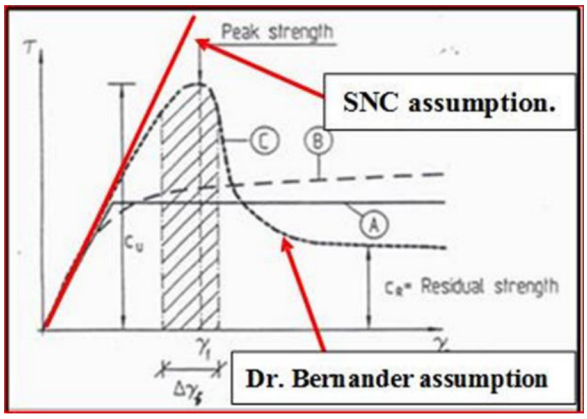
At the end of the analysis there is the following statement – (pictures removed)

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 is 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-train 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.muskratfallsinquiry.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.