nalcor energy
LOWER CHURCHILL PROJECT

Lower Churchill Management Corporation
Lower Churchill Project Operations Office
350 Torbay Road, Suite 2
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January 12, 2015

Re: Letter from Dr. Serge Leroueil to the Lower Churchill Project in relation to the North Spur stabilization at Muskrat Falls

As noted by the Independent Engineer in its July site visit report for the Lower Churchill Project, geotechnical assessments and dynamic studies for the North Spur stabilization at Muskrat Falls were reviewed by Professor Idriss and Dr. Serge Leroueil. Professor Idriss is an internationally renowned expert of seismic hazard analyses and dynamic analyses of earthworks and civil structures. Dr. Leroueil is recognized for his expertise in dealing with sensitive soils, particularly the slopes of the St. Lawrence Valley in Quebec. With the involvement of these two experts, Nalcor can rest assured that analytical work of the North Spur has been done to a world class standard.

Dr. Leroueil is recognized for his expertise in dealing with sensitive soils, particularly the slopes of the St. Lawrence Valley in Quebec. Dr. Leroueil was engaged by the Lower Churchill Project to review and provide his expert opinion on the "Engineering Report - North Spur Stabilization Works - Dynamic Analysis Study - Phase 2." Prior to receiving this report, he was privy to the information in the report, including the appendices. The Lower Churchill Project has continued to engage Dr. Leroueil on the dynamic and progressive failure analysis and all documentation on this topic will be shared with him during this process.

Enclosed is Dr. Leroueil's letter to the Lower Churchill Project in relation to his review of geotechnical assessments and dynamic studies of the North Spur stabilization project as well as a follow up email in relation to his comments on the Engineering Report — North Spur Stabilization Works — Dynamic Analysis Study — Phase 2.

Please note, personal information has been removed.

Serge Leroueil

M. Régis Bouchard
Lead Geotechnical Engineer
Lower Churchill Project
SNC-Lavalin Inc.
350 Torbay Road, Suite 2
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August 24, 2014

Object : Comments on the Report "Engineering Report – North Spur Stabilization Works – Dynamic Analysis Study – Phase 2" dated xx-May-2014.

M. Bouchard,

At your request, I have examined the above mentioned report. As you know however, if I think I well know the behaviour of clays, sensitive clays in particular, my knowledge on the dynamic behaviour of soils and its analysis is rather limited. Moreover, I received the main report but not the appendices. So, I read the entire report but my comments should be seen in this context and are essentially limited to Section 2.

Section 2 is satisfactory to me. However, in relation with the field section 13 and its stability, I would add that the stabilization works increase the factor of safety from about 1.0 to about 1.6, which is very significant. Also, by doing that the maximum shear stresses in the soil mass have been significantly reduced, eliminating the possibility of progressive failure in the sensitive clays.

Also, in Page 7, I think it would be good to give the factors of safety obtained for the sections 4 and 9 for static conditions.

At the bottom of Page 17 and in relation with Figure 2.9, more information is needed on the location of the piezocones. Where is CPT-04 for being upstream and with an OCR of 5? Where is CPT-08 for having an almost constant OCR? What is the N_{kT} value considered?

The end of Section 2.3.3. has to be completed. Also, it is "remoulded undrained shear strength" rather than "residual undrained shear strength".

Reading the Sections on dynamic analyses, I have not found anything unsatisfactory but, as indicated earlier, I am not expert in this domain. The conclusions however look very interesting.

Reading the Sections on dynamic analyses, I have been frustrated not to find important figures that are in the appendices. It seems to me that the most important figures should be found in the main report. This latter should not be a presentation of the appendices and should stand by itself.

Minor comments:

- Tables 2.1 and 2.2: It is Plasticity index rather than Index of plasticity and Liquidity index rather than Index of liquidity.
- Page 35, l. 5: "Maximum shear wave velocity" is not a soil property.
- There are some references that are missing. In particular, concerning Figures 5.7 and 5.8, either the references should be added or a general reference should be in the title.
- Page 40 and possibly elsewhere, it should be "indices" rather than "indexes".
- Page 49, in the Section on "Limitations and Sensitivity", I have been surprised to read that "the granular material can be very sensitive to their saturation". This is true but I am not sure that this aspect has been considered in the analyses.

Yours sincerely.

[redacted] s.30(1)

Serge Leroueil, Ing. Ph.D.

[redacted] s.30(1)

Tel.: [redacted]

s.30(1)

From: [redacted]
Sent: 26 octobre 2014 06:01
To: Bouchard, Regis
Cc: Gagné, Bernard (Hydro); [redacted] s.30(1)
Subject: RE : North Spur Downhill progressive failure

Bonjour Régis,

Je ne t'ai pas oublié mais je partais pour 2 semaines de travail avec Luciano Picarelli à Naples, et ma vie s'est compliquée par le fait que mes bagages (avec mon transformateur d'ordi sont arrivés avec 3 jours de retard (Pas de méprise, le problème était à Toronto!).

Concernant le North Spur, mon opinion est la suivante:

- Il n'y a pas de méthodologie établie pour évaluer la stabilité contre une "downhill progressive failure". Bernander a proposé une méthodologie très artisanale, qui, à ma connaissance, n'a été utilisée que pour l'analyse de ruptures existantes, pour lesquelles les résultats étaient connus à l'avance. Ariane Locat a adapté la même méthode pour des "uphill progressive failures" qui a été utilisée pour comprendre deux étalements dans les argiles sensibles. À mon avis, commencer à faire des calculs c'est donner plein de prises et de questions.

- D'un autre côté, les méthodes d'analyse consistent à définir la contrainte de cisaillement initiale le long d'une surface de rupture potentielle, probablement à peu près horizontale et passant par le pied de talus dans notre cas. Cette contrainte de cisaillement est maximale à peu près sous la crête du talus. Si une perturbation vient augmenter en un endroit la contrainte de cisaillement jusqu'à la résistance au cisaillement du sol, alors la rupture progressive peut commencer, et éventuellement se poursuivre jusqu'à une rupture globale. Il y a deux choses importantes dans ce que je viens de dire:

1) La contrainte de cisaillement initiale. Si vous montrez que vous avez amélioré la stabilité du talus (F plus élevé), ça veut dire que vous avez diminué vos contraintes de cisaillement initiales et que vous vous éloignez de la résistance du sol.

2) Perturbation qui peut accroître localement la contrainte de cisaillement. Cette perturbation peut venir du bas ou du haut. Au Québec, la perturbation est le plus souvent une érosion ou une petite rupture en pied de talus. Mais, comme vous avez protégé votre pied de talus, vous avez enlevé la possibilité de perturbation en pied de talus. La perturbation peut aussi venir du haut, comme par du fonçage de pieux dans le cas de Surte étudié par Bernander. Et là, il faut montrer que vous avez pris toutes les précautions pour empêcher toute perturbation en pied de talus.

Si vous améliorez votre stabilité, donc diminuez la possibilité de rupture progressive par rapport à ce qu'elle était, et si vous empêchez toute perturbation, vous ne pouvez pas avoir rupture progressive. Je crois que c'est de cette manière qu'il faut aborder le problème.