HVdc TL: Geotechnical Risk Review

Background, Current Situation, Action Going Forward

30-Mar-2016

Boundless Energy

Prepared and presented to CCB by Maria Veitch and myself in support of PCN-XXX

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Purpose

- Provide an overview of the risk associated with uncertainty in geotechnical conditions for HVdc foundation installation
- Review risk mitigation measures and residual exposure
- Seek approval of PCN for $5M to support risk mitigation

Key Messages

Key Messages	Supporting Information
1 **Uncertain soil conditions challenge predictability** of foundations by type	• Risk mitigation plan • Design assumptions
2 **Uncertainty is leading to need to order supplemental material** to avoid risk of delay to contractor	• Actual vs. projected installations • Significant number of tower and foundation combinations challenge flexibility • Supplemental material orders under PT0308 • Anchor optimization
3 **Prudent steps required to ensure reliable designs in poor soil conditions**	• Geotechnical investigations • Macro-pile vs. deep rock foundation
4 **Alternate foundation techniques being implemented** to manage overall cost risk	• Micro-pile vs. H-Pile • Macro-pile vs. deep rock foundation
5 **Residual risk remains** that must be monitored	• Future risk mitigation activities

1 We have recognized the risk associated with uncertain geotechnical conditions and have designed mitigation measures to combat

Code	Title	Description (Cause)	Impact Summary (Effect)
OTLR029	Differing Geotechnical Conditions and Impact on Foundation Installation	IF as a result of geotechnical conditions differing from that contained in the desktop study.	THEN there is a risk of either: (1) the foundation designs for the HVdc line are unsuitable, and/or (2) the estimated quantities of pile increase, and/or (3) balance between rock and soil dramatically change, and/or (4) length of required guy anchor substantial increases, and/or (5) amount of import backfill increases beyond the pay items in the contract resulting in cost and potential schedule exposure due to increase in more difficult foundations or unavailability of supplemental material to support construction requirements.

1 Our design projections were based upon desktop geotech study which have inherent inaccuracy

- Design projections based upon Desktop Geotechnical Study[1] completed during engineering phase given the impracticalities and EA limitations of undertaking a geo program that would increase confidence
  - Desktop study based on available data
  - Structures foundation types identified along preliminary line route
- Result is 11 foundation types
- Material procurement was aligned with these projections, with the plan to check and "true-up" any shortfalls with Segment 5 order.

Foundation Projections

Self Supporting by Type	% of Total
Type 1 Grillage (100kPa)	33
Type 2 Deep Rock	18
Type 2I Intermediate Rock	18
Type 2s – Surface Rock	15
Type 2s-I Inter. Surface Rock	15
Type 3 – Pile	1

Guy Tower by Type	% of Total
Type 1A Grillage (250kPa)	28
Type 1 Grillage (100kPa)	5
Type 2 Rock	36
Type 2s – Surface Rock	30
Type 3 – Pile	1

(1) 350 HVdc Geotechnical Baseline Muskrat Falls to Soldiers Pond, document no. ILK-SN-CD-6200-GT-RP-0001-01

1 Variability further complicated by 11 tower types across the 1100 km line

- There are 11 tower types across the line
  - 5 guy towers (A1, A2, A3, A4, B1)
  - 6 self-support towers (B2, C1, C2, D1, D2, and E1)
- Significant combinations of towers and foundations exist
  - Each of the 5 guy towers could have 5 types of foundation
  - Each of the 6 self-support could have 6 types of foundations
- Failing an accurate prediction during design, material shortages could exist for any combination
- Offset risk by design and procurement of conversion kits as well as provisions with contract with Valard re timelines to confirm total quantities
- However practically, Project requires material flexibility to ensure program completion

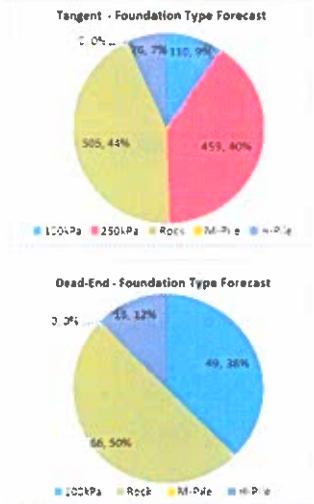
1 DG3 Material Estimate for did not adequately account for variability

- **Material estimates completed in 2011 did not take into account difference per Segment or Foundation Type over the entire HVdc line**
  - Segment 2 has a higher % of rock Segment 1
  - A4 tower type used in LRM inherently will have higher % of rock
- **Foundation material estimates and procurement was based upon total number of towers, with no contingent material for soil variability** from what was estimated in Desktop Geotechnical Study
- Original order was an estimate based on available information with the knowledge that subsequent orders would be required when more information was available
- Per the DG3 Basis of Estimate (p. 212 & 213):
  - *The quantities of steel towers are based on preliminary (40% complete engineering) tower spotting using PLS-CADD*
  - *The quantity and weight of each of the foundation types are based on the relative quantities and weights of the foundation types for each tower type.*

2 Desktop Projections were inaccurate

- **Segments 1 & 2 are indicating more grillage than rock**, in particular for tangent structures
  - Grillage: Plan = 33%; Forecast 49%
- **Quantity projections of 1% Pile not consistent with field conditions**, or Baseline Geotechnical Report wherein it stated that rock or grillage is expected to be used at 95% of locations, while the remaining 5% soft, sandy soil of significant depth where alternate foundation solutions (H-Pile, cribbing, etc.)

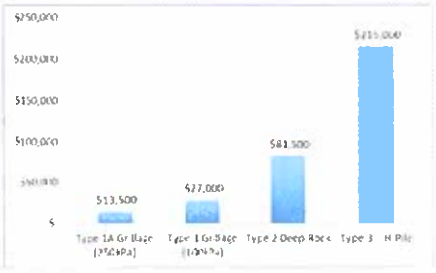
Installation Trends – Segments 1 & 2 (1)



(1) Data current as of 13-Mar-2016 as collected and interpreted by LCMC's Field Engineers

2 While uncertain soil conditions lead to variability in installation cost, contract with Valard "protects" LITP via a unit price structure

- Quantity used in contract reflects final as-designed structure staking list
- Unit price for grillage is more cost effective that rock
- Cost risk exist when "native" backfill not suitable for re-use
  - Requires borrowing and trucking backfill outside the tower box are
- Provisions for alternate foundation type exists (H-pile, caisson / crib), however are costly



Contract Unit Prices – Segments 1 & 2

Fast Fact
Foundation installation represents approximately 1/3 of total construction cost within Agreement CT0327-001 or $280M, while material supply is ~10% of installation cost.

2 Given order quantities were inaccuracy, spare material has been ordered to reduce risk of delay, however further orders expected

Package PT0308 – Tower Foundations	CO	PCN	Value ($M)
Original Commitment / Order	-	-	**20.2**
Change Orders			**16.1**
Addition of Surface Rock Foundation	001		0.3
Deep Rock Foundation Design Change	002	284	0.4
Unit Weight Increase for final tower design	0005	373	2.0
Pile Foundation Shoes – First Order	006	407	0.1
Quantity Changes due to Line Optimizations	005		(1.4)
Additional 10% of all Foundations	010	429	3.2
Extra S1&2 grillages	012	450	1.1
S1 to S4 Spares + Quantity Release for S5	021	541	10.2
Extra Pile Foundation Shoes		586	0.3
Extra Pile Foundation Shoes		TBD	
Total		-	**36.3**

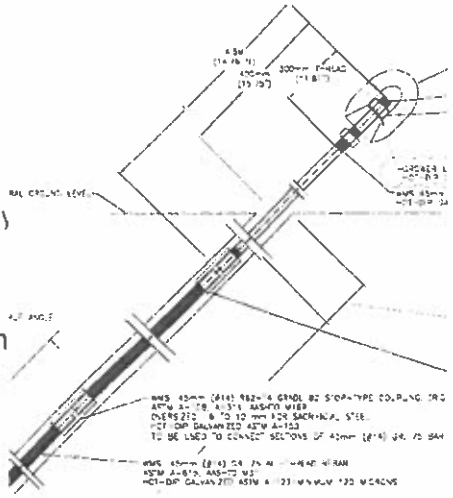
2 Meters of drilled guy anchors also influenced by inaccurate desktop projections

- Increased usage of grillage foundations directly correlates to increased depth of overburden and hence increased drilled guy anchor length prior to embedment in rock
- Forecasting 35% increase in material consumption
- Detailed optimization program underway in order to field verify required lengths to achieve design loads
- PCN-0452 approved in May 2015 $4M material and installation impact

Soil Type	Initial Calc. (%)	Initial Calc. (m)	Ordered (m)	Revised Calc. (%)	Revised Calc. (m)	Revised Calc. Incl. 5% Wastage (m)	[Revised Calc] – [Ordered] (m)
Dense Sand	18.1	15,802	16,029	0	0	0	-16,029
Dense Till	18.1	15,802	16,029	70	79,491	83,465	67,436
Weak Rock	63.8	55,700	56,502	30	34,067	35,771	-20,731
Sound Rock	0	0	0	0	0	0	0
Total	100	87,304	88,560	100	113,558	119,236	30,676

2 Site Instruction # 20 issued to Valard to reduce guy length by eliminating over-conservatism in design

- Reduces depth in soil by use of shorter top bar in NL where frost depth is less
  - Anchor bars re-worked to allow reduction in installation depth/cost by ~$1M (Ref PCN-0607)
- Reduces depth in rock with over burden by considering over burden weight to reduce required embedment in rock



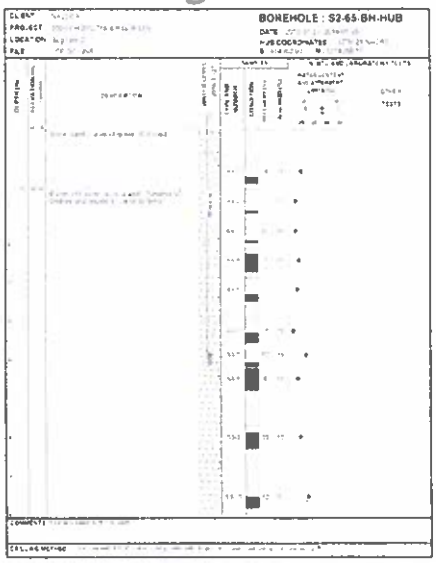
3 Geotechnical Data Collection initiated to reduce risk of contractor claiming differing site conditions for failed foundations

- Several installed grillage foundations in Segment 1 experienced settlement
  - S1-24, 54, 70, 86, 105 & 112
- Contractor positioning that settlement due to soils not suitable for grillage
- Geotechnical investigation to remove uncertainty and strengthen LCMC's position that settlement due to poor workmanship.
- Investigations have confirmed that sites are suitable for application of grillage foundations

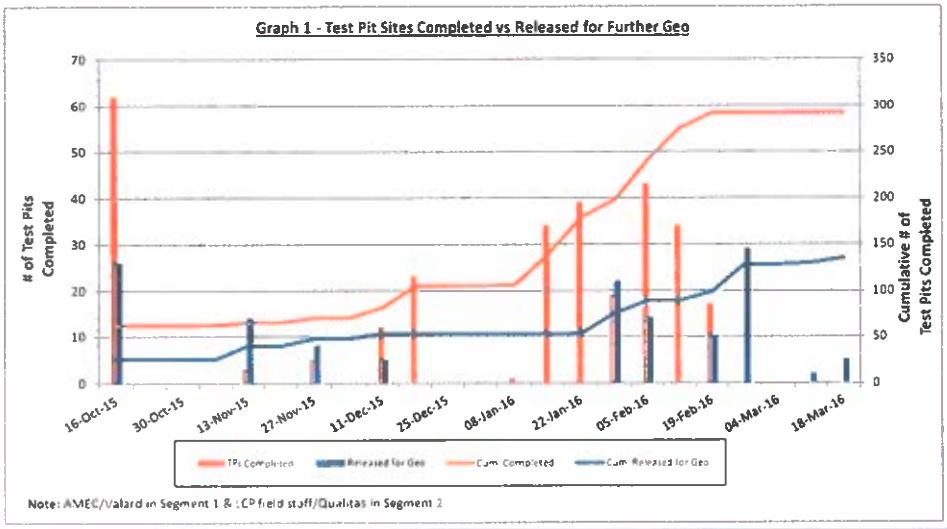
S1-70 Leg C, reclamation of grillage footing, saturated founding base and backfill

3 Geotechnical program for uncertain sites implemented to ensure reliable design

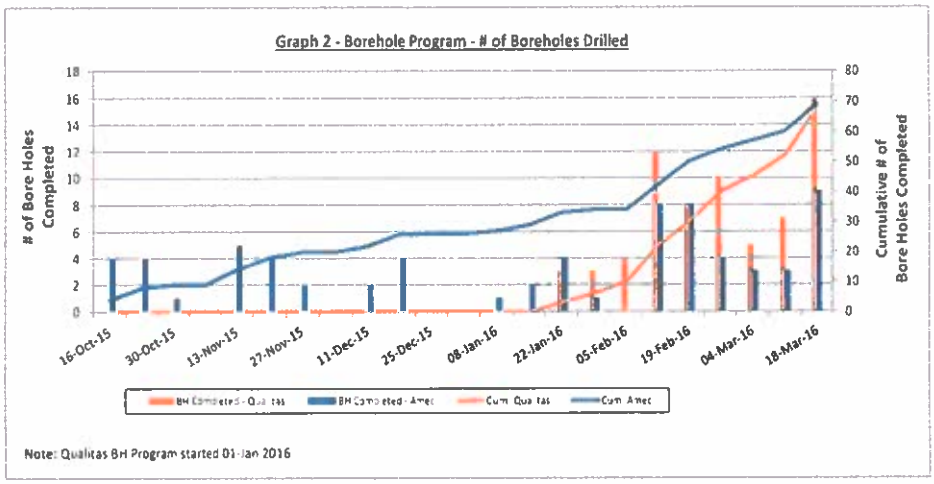
- LCMC agreed with Valard in August 2015 that in addition to failed site investigations, we would support geotechnical investigation where uncertainty exists to verify suitability of site for grillage
- PCN-0531 funded AMEC-Cartwright program to be managed by Valard ($275k)
- Decision made for LCMC to complete pre-foundation selection program for Segment 2 winter zone (S2 1 to 235) so as to reduce schedule risk for winter zone (PCN-0580 for $1M)



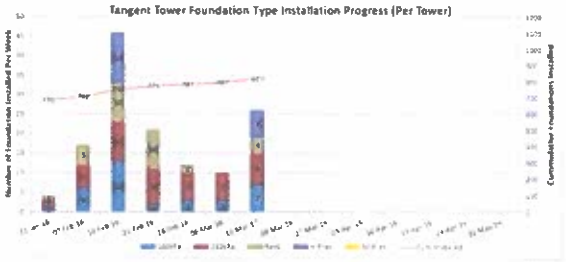
3 In total, ~300 sites have been test pit, while ~140 have been identified for geo borehole



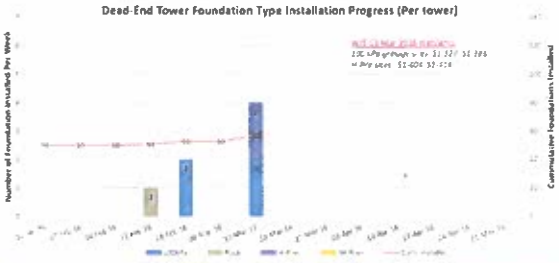
3 ~137 boreholes completed in Segments 1 & 2



3 Valard's installation progress steadily improving due in part to the benefits of geo program

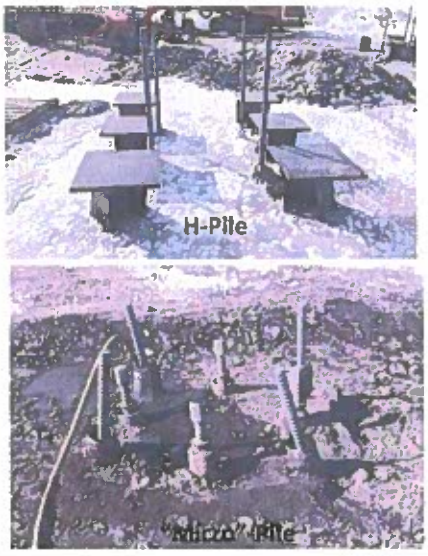


Segment 1 and 2 Tangent and Self-Supporting Tower Progress



4 Where grillage doesn't work, micro-pile being trial tested over H-Pile

- Currently forecasting approximately 90 locations that are unsuitable for grillage foundation
- H-Pile design available and field proven, but is costly
- Micro-pile concept viewed as more cost effective solution given the reduction in materials, large pile caps and extension welding
- LCMC approved Valard to undertake design in Q4-2015 at a cost of $150k, Initial field installation on T&M basis at S1-167 which was recently completed.
- Unit price proposal expected from Valard in the near term.



4 Alternate rock foundation design being explored in order to explore potential cost savings

- Current rock foundation is expensive, in particular for deep rock applications, requiring both significant excavation, rock leveling, and concreting
- Team currently with Valard to explore alternate design for rock depths up to 4m (i.e. Macro-Pile) currently being installed by LEG for Hydro Quebec. Design funded at $150k.

5 While decreasing as mitigation actions are implemented, residual risk will remain until the final foundation is installed

- On-going trend analysis are being completed based upon test pit, borehole and actual installation data
- Based upon current trend, we have sufficient foundation material, with the noted exception of pile caps. Cost exposure of $1M.
- Increased guy anchor consumption remains a risk
  - $1M for materials, plus $3M for installation
  - Site Instruction 20 recently issued to offset quantity exposure by decreasing anchor length 1.5 m per anchor in NL for soil and up to 3 m for rock with overburden
  - Anchor installation rates to be closely monitored
- Geotechnical investigation on Island may be needed
  - Assume 5% of 2,000 sites on the Island, cost exposure of $1 to $2M
- Stream diversions required when a structure is located in or near a stream course.
  - Implemented when a constraint makes a structure move impossible or the diversion is the less expensive option; cost exposure of ~ $100k

In Conclusion....

Risk has materialized; interim cost allowance required to facilitate mitigation

- Risk has been identified, while mitigation strategy and actions being implemented
- Cost risk exposure is manageable – $20 to $40 M
- Opportunities exist to offset cost exposure through design optimization (e.g. micro and macro piles, drilled guy anchors) and line routing optimization
- We are taking the steps require to ensure that the installed foundation meets the underway design criteria
- PCN will be tabled seeking $5M of LIL Contingency for implementation for implementation of risk mitigation measures