PART B
PLAN FOR THE EAST-WEST TIE LINE

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

6. Proposed Design

6.0 Overview

For the purpose of this application, EWT LP is proposing to develop a double circuit steel lattice tower line connecting Wawa TS, Marathon TS and Lakehead TS, with a single 1192 kcmil Grackle, ACSR conductor per phase.[1] This proposed design is based on the Board's Reference Option except with respect to the right-of-way, which EWT LP proposes to be 40 m rather than 50 m wide. In addition, for the purposes of this Application, EWT LP has adopted the X10 tower family proposed by Hydro One Networks Inc. ("HONI") in its June 4, 2010 study (the "HONI Study").[2] Further details of this Reference Option-based design (the "Reference-Based Design") are set out in Section 6.1.

EWT LP notes, however, that it is important not to commit to a certain design before the development work has even commenced. As discussed in Sections 7, 9 and 10 of this Application, this development process will take time but is fundamental to the successful completion of the design of the proposed East-West Tie project (the "Project"). Therefore, early in the development phase, EWT LP will test the key assumptions underlying the Reference-Based Design and undertake the studies necessary to determine whether a different design can be adopted at a lower cost (see Section 6.5.1 with respect to a potential savings of $116 million relative to the Reference-Based Design). At this stage, EWT LP has completed preliminary engineering work on the following technical design variations[3]:

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[1] In particular, a double circuit, 230 kV line between Wawa TS and Lakehead TS, connecting into Marathon TS, that is assumed to be placed alongside the existing double circuit lines W21/22M and M23/24L on an existing right-of-way that may require widening. The capacity requirement in thermal terms would exceed 466 MVA and 599 MVA (continuous and contingency, respectively) under the specific conditions.

[2] Project Definition Report AR 18379, Study Estimates for options, East-West Tie Expansion, Rev.0 June 4, 2010, HONI.

[3] Both the Board and the Minister of the Environment expect the transmitter to consider alternatives. See, for example, *Environmental Assessment Act*, section 6.1(2): "*Subject to subsection (3), the environmental assessment must consist of, … (d) an evaluation of the advantages and disadvantages to the environment of the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking …*". See also Chapter 1 of the Filing Requirements For Electricity Transmission and Distribution Applications, June 28, 2012 Ontario Energy Board: "*The applicant is expected to also compare the alternatives versus the preferred option along various risk factors….*".

- A variation of the Reference-Based Design that will first revisit the galloping criteria and adopt a unique tower design to provide the appropriate conductor spacing while still allowing for more cost-effective longer spans;
- A single circuit line variation that will connect to the same three stations as the Reference-Based Design;
- A variation of the single circuit design above that will use guyed cross-rope suspension type ("CRS") structures.

In accordance with the Board's filing requirements, this section covers the following:

- The Reference-Based Design, which is EWT LP's proposed design for the purposes of this Application (6.1);
- EWT LP's proposed line interconnection and switching arrangements (section 6.2);
- An officer's affidavit regarding the Project's compliance with standards (6.3);
- EWT LP's plans to study variations to the Reference-Based Design (6.4), including with respect to the key assumptions underlying the Reference-Based Design (6.4.2.1); EWT LP's methodology for undertaking the additional development work required to finalize the Reference-Based Design (6.4.2.2); and the Project design variations noted above (6.4.2.3);
- The benefits of EWT LP's design and development plan (6.5); and
- EWT LP's plans for the ownership and operation of the Project.

6.1 Summary Description of Reference-Based Design

For its Reference-Based Design, EWT LP has adopted the Board's Reference Option, except for the right-of-way width, which EWT LP proposes to be 40 m rather than 50 m. In addition, EWT LP believes the X10 tower family proposed in the HONI Study has a suitable head frame geometry to manage the galloping criteria but with limited span capability. EWT LP has therefore adopted this tower family for its Reference-Based Design (but also proposes to complete a detailed review of the galloping criteria post-designation as further explained in the description of "REF B" in Section 6.4.2.3).

The key parameters of the Reference-Based Design are as follows:

Proposed Design Parameter	Proposed Design Value	Value Matches that in the Reference Option?	Value Differs from that in the Reference Option?	Parameter Not Specified in the Reference Option?
Length of the proposed line	398 km			√
Number of circuits	2	√		
Voltage class	230kV nominal operating voltage	√		
Load carrying capacity, summer rating/summer emergency	466 MVA / 599 MVA	√ (ampacity is slightly greater than the specified minimums)		
Total load transfer capability of the East-West Tie Line	652 MW west	√		
Anticipated lifetime of the line	50 years	√		
Tower family	HONI X10			√
Number and spacing of towers	Approx. 1,475 towers @ 270 m spacing (average span is 90% of estimated design wind span of 300 m)			√

Proposed Design Parameter	Proposed Design Value	Value Matches that in the Reference Option?	Value Differs from that in the Reference Option?	Parameter Not Specified in the Reference Option?
Tower structure type	Free-standing lattice			√
Tower composition	Galvanized Steel	√		
Typical tower height	47 m			√
Overall tangent tower weight (average)	5,900 kg (estimated from X10 published values)			√
Wind Span, 0°	300 m			√
Average span length assumed	270 m (90% of design wind span)			√
RoW width requirement	40 m		√ (for the 300 m design span, 50 m is not necessary)	
Conductor type/size	2 circuits x 1-1192.5kcmil 54/19 Grackle ACSR	√		
Foundation	Concrete caisson or rock anchor or grillage depending on the ground conditions			√
Design assumptions	CSA C22.3-60826, compliance with OEB minimum technical requirements.	√		
Meteorological loadings	CSA Heavy Loading (minimum), plus judgment guided by CSA C22.3-60826, rime ice, unbalanced ice, regional data, local experience	√		

The parameters of the Reference-Based Design are further described in the December 17, 2012 Power Engineers report titled "Engineer's Report on the EWT Transmission Line OEB Reference Option", which is attached at Appendix 6A (the "Reference Option Report"). This Report was written in part to assist EWT LP in developing and evaluating criteria for the unspecified parameters of the Reference Option. It is also used as the basis for EWT LP's construction schedule and cost estimates for the Reference-Based Design, as discussed further in Parts 7 and 8 of this Application, respectively.

EWT LP is proposing the Reference-Based Design for the purpose of this Application and as a starting point for its development work. However, as discussed further in Section 6.4.2.1, EWT LP plans to test the key assumptions underlying the Reference Option during the development phase as part of the environmental assessment, consultation, land acquisition and ongoing technical design processes. In doing so, EWT LP will explore the variations to the Reference Option described in Section 6.4.2.3.

6.2 Line Interconnection and Switching

For the purposes of line interconnection and switching, EWT LP's proposed design is based on the Reference Option. This assumes interconnections for the Project located at Lakehead, Wawa and Marathon.

As discussed further in Section 6.4.2.2, EWT LP has developed a robust methodology for reevaluating its proposed design during the development phase. With respect to line switching and interconnection, EWT LP believes that development work may show that a more cost effective interconnection may be achieved by modifying how the new line interconnects at Marathon.

EWT LP also plans to evaluate whether there may be need for a new connection in the Nipigon area, and whether there is a need to interconnect the new line at Marathon at all. The Marathon TS is already supplied from two independent sources, Wawa TS and Lakehead TS. Therefore, the principal purpose of the Marathon interconnection is to reduce the reliability impact of single faults rather than to provide new supply capacity at Marathon itself. Given the relatively long distances in northern Ontario, a relatively low impact on reliability may be sufficient to offset the potentially significant cost of installing new switchgear at Marathon. This will need to be confirmed by detailed system studies.

6.3 Officer Undertaking re Compliance with Standards

EWT LP confirms that it will (i) design the Project to meet or exceed the existing NERC, NPCC and IESO reliability standards; and (ii) design the Project to meet or exceed the Board's Minimum Technical Requirements, as applicable, or where the design differs from the Minimum Technical Requirements, provide evidence as to the equivalence or superiority of the proposed alternative option when the applicable design is completed and at a time when the said evidence is required to be filed with the Board.

The undertaking required by Section 6.3 of the Board's Filing Requirements is attached at Appendix 6B.

6.4 Deviations from the Reference Option

6.4.1 Variations on the Reference Option for the Purposes of the Application

As discussed in Section 6.1, EWT LP's Reference-Based Design varies from the Reference Option only with respect to the right-of-way width. In addition, the Reference-Based Design uses certain parameter designs that are not specified in the Reference Option. For example, given that the Reference Option is silent on the tower design, EWT LP has adopted the X10 tower family for the purpose of the Reference-Based Design, given that it has a suitable head frame geometry to manage the galloping criteria, albeit with relatively shorter spans than optimal.

6.4.2 Plan to Revisit the Reference-Based Design During the Development Phase

6.4.2.1 Key Assumptions Underlying the Reference-Based Design

Historically, the first step in a transmission project has been to determine the technical design for the new line, assuming that the necessary right of way would be readily available regardless of the height of the towers, the span lengths, the width of the corridor and the location of the line. However, this approach has often proven not to be successful. Experienced developers now understand that the input from the environmental assessment, public consultations and First Nations and Métis consultation can significantly affect the line routing and design. Indeed a new line cannot be meaningfully designed in the absence of these critical inputs. Any transmitter that commits to a design, without first considering these fundamentals, risks serious delays in project development and construction to accommodate design and route changes. For example, a theoretical desktop design developed in the absence of environmental studies and consultation may have latent fatal flaws that prevent the Minister of the Environment from giving his or her approval to proceed. Any design, regardless of its theoretical technical excellence and cost-effectiveness, that is environmentally unacceptable to the Minister cannot legally be built. Moreover, such an approach is inconsistent with EWT LP's community-centric, local stakeholder sensitive approach to transmission development.

Because it is not yet informed by the environmental assessment and consultation processes, the Reference Option, although valuable as a framework for this Application, contains certain assumptions that must be revisited during the development phase. Any technical design for the Project at this stage will be subject to similar assumptions. Prudent developers must revisit these assumptions in the development phase, and cannot commit to certain technical design parameters before doing so. The following are some of the key assumptions that EWT LP plans to test as part of its early development work:

- EWT LP has assumed, based on the HONI Study, that the Reference Option can be met with an X10 tower family design. EWT LP plans to revisit this assumption during project development. In particular, although the X10 family has a suitable head frame geometry to manage the galloping criteria, it is likely too short and weak to accommodate the longer spans that are likely necessary to minimize the capital cost of the line. There may therefore be significant cost savings involved in revisiting the galloping criteria and reinforcing the X10 tower design to accommodate longer spans (see Section 6.4.2.3 below for further detail).

- The results of EWT LP's consultation process may also show that certain concerns may be mitigated by using different design specifications. Design assumptions that do not take into account the public preferences are rarely validated, especially where the developer has finalized its designs and routing in advance of public consultation. For example, the consultation process may show that stakeholders prefer taller, shorter, wider or narrower towers in a conventional structure, a "Y", delta, guyed "V", guyed cross rope suspension, 'H"-pole, some other tower configuration. EWT LP plans to incorporate feedback received during the consultation process into its final technical design.

- The Reference Option assumes a route for the Project along the existing East-West Tie line. However, that assumption is made without incorporating the results of the environmental assessment, the land acquisition work and the consultation program. Therefore, the route assumed in the Reference Option is necessarily preliminary. It does not, for example, reflect an assessment of the Project's potential impact on traditional First Nation and Métis land use. Legitimate concerns may yet be raised, including with respect to potential impacts on traditional lands, hunting and harvesting practices, and archaeological sites. As another example, the Reference Option route does not reflect a careful study of the sensitive environmental features in the Project area. That assessment may show that a deviation from the Reference Option route is necessary. Assumptions about the Project route that are made prior to the development phase are therefore subject to change.

- Significant data on the terrain and surficial geology of northern Ontario that will affect the choice of foundations (such as pile, pad and chimney, grillage or rock anchor) is available from the Ontario Geological Survey and the Ontario Department of Mines. This data allows for a preliminary assessment of suitable tower specifications. However, this data is not granular enough to allow for a rigorous assessment of the best tower design or of the best foundation at individual tower locations. Because the exact ground conditions will have a significant impact on the type and cost of foundations that will be suitable for the Project, any assumptions about those conditions that are made before the route has been established and field studies completed will be subject to change.

- Furthermore, although much of the Project area is on Crown Land, it would be inappropriate to assume that all land rights necessary for the Project are readily available. Certain private landowners may not want to grant land rights to the Project. Other land uses may also limit or preclude the construction of the Project in certain areas, or may make construction access more difficult and expensive. For example, newly created Provincial Parks and the new management practices for National Parks may preclude certain transmission activities in those areas. As another example, Crown land use polices may not allow, or may place restrictions on, development on Crown land. As discussed in Part 9, EWT LP has developed a comprehensive plan to acquire the necessary land rights for the Project. Those rights will help determine the Project route, which will then have to be considered in finalizing the technical design.

6.4.2.2 Methodology for Revisiting Underlying Assumptions

EWT LP has developed a comprehensive methodology for testing the underlying assumptions of the Reference Option. This methodology, which is tightly linked to EWT LP's development process, consists of three basic components:

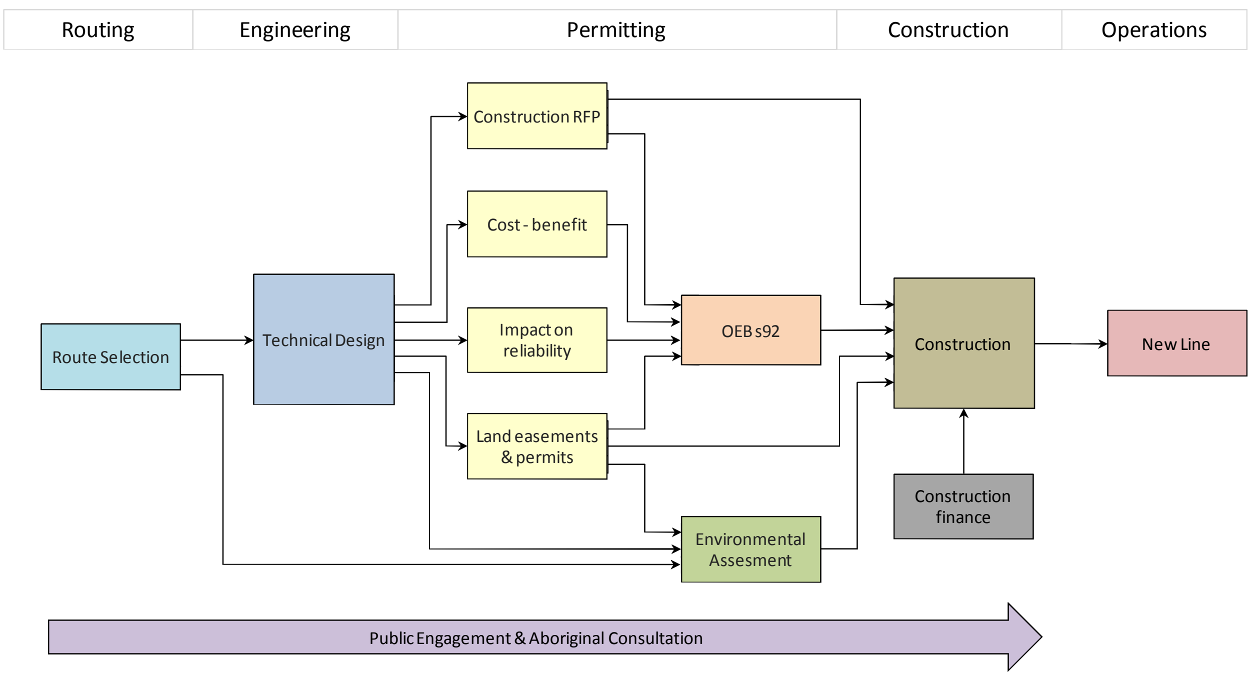
- Routing: As described in detail in Part 9 of this Application, the routing process will determine the terrain over which the line will run, which in turn will affect the technical design of the Project. Establishing a route requires consultation with the agencies, landowners and the public, and completing environmental and other studies to determine the preferred route for the new line. The preferred route takes in to account existing and traditional land use, including agriculture, housing, schools, historical and archaeological sites, sites of special scientific interest, conservation areas, provincial parks, First Nation Reserves, compliance with provincial and municipal land use policies, use of other utilities and utility corridors, crossings, visual intrusiveness and access both for construction and ongoing operations.

- Engineering: As described in detail in Appendix 6C to this Part, the bulk of the engineering work must be completed during the development phase. As discussed, this will require the re-evaluation of the Reference Option compared to EWT LP's alternative designs to determine the technical design that fits within the envelope determined through the routing process and that also meets the needs identified by the Ontario Power Authority with the lowest risk adjusted life time cost.

- Consultation and Permitting: As described in detail in Parts 9 and 10 of this Application, consultation with First Nations and Métis communities, the public and government agencies will also have a significant impact on the technical design of the line. For example, the permitting process will involve significant input from a variety of stakeholders that may affect where the line can be built and the features of the line, and therefore its technical design parameters.

A simplified version of EWT LP's development methodology is shown diagrammatically below.

<u>Figure 6.1: EWT LP's Development Methodology</u>



Although presented sequentially above, these aspects of EWT LP's development work will be done in parallel to save time to the extent practicable.

EWT LP believes that it is fundamentally important for a transmitter to have a methodology in place to reassess, during the development phase, any technical design proposed in the designation application.

6.4.2.3 Design Alternatives for Comparison to the Reference Option

In testing the assumptions of the Reference-Based Design, or any other design, a designated transmitter should have other alternative designs in mind to focus its development work. To this end, EWT LP has identified, in addition to the Reference-Based Design, one double circuit variation of the Reference-Based Design and two variations of a single circuit design that it will consider further in the development phase. These variations are as follows:

MODIFIED REFERENCE-BASED DESIGN ("REF B")

In the Reference Option Report, Power Engineers notes that although the Reference-Based Design is essentially compliant with the Board's minimum technical requirements, there are likely opportunities to vary the design to reduce costs to the benefit of ratepayers. Power Engineers identifies one negative driver on cost in particular -- the single loop galloping criteria -- as potentially overly conservative and recommends that it be reviewed.[4] This recommendation has led EWT LP to consider the Modified Reference-Based Design.

The galloping criteria is theoretically-oriented and may be of limited practical value in the Project area. Adhering to the galloping criteria will either require shorter spans that will increase capital costs (in part by increasing the number of required towers) or necessitate towers that are of a unique design and much larger than the X10 towers employed in the Reference-Based Design in order to sustain the longer spans. Furthermore, in its response dated December 4, 2012 to a transmitter's question, HONI noted, "Our records dating back to January 1990 show no forced outages relating to conductor galloping with respect to the existing East-West Tie lines. Data prior to January 1990 is not readily available. EWT LP is also not aware of any conductor damage due to galloping."

A critical task for the designated transmitter will therefore be to consider, in the absence of any legislative or regulatory requirements, the most technically appropriate and cost-effective galloping criteria for the Project taking in to account not only the specific topology and weather

[4] See Reference Option Report, page 5, Appendix 6A.

conditions expected to be experienced in the Project area over the life of the Project, but also the design and performance of the existing line, which as noted in Power Engineer's report does not meet the galloping criteria proposed in the Board's Reference Option.[5]

EWT LP's initial engineering indicates that the X10 tower family would still be too short and weak to accommodate the longer spans that are likely necessary to reducing the capital cost of the line.[6] EWT LP's preliminary studies indicate that the X10 towers could be reinforced to achieve these longer spans. The combination of a revised galloping criteria, a reinforced X10 tower design with the resulting longer span length and a narrower right-of-way are the differences between REF B and the Reference-Based Design. EWT LP will study REF B further in the development phase, particularly with respect to the appropriate galloping criteria and the methods for reinforcing the X10 towers.

SINGLE CIRCUIT DESIGN ("ALT A")

In this variation, instead of the double circuit line proposed in the Reference-Based Design and REF B, EWT LP would employ a single circuit line connecting the same three stations with lighter 795 kcmill Drake conductors but in a 2-bundle arrangement for the single circuit giving that circuit ample ampacity. The HONI Study considered and assumed the W1 tower family for this option, which EWT LP proposes to consider as well. In its August 18, 2011 Feasibility Study for Reinforcing the East-West Tie (the "IESO Study"),[7] the IESO looked at three alternatives, including two single circuit alternatives.[8] The IESO found that for a new single-circuit line, it would be necessary, immediately following a contingency or outage involving this new line, to re-prepare the system for the loss of one of the circuits on the remaining double-

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[5] See Reference Option Report, page 5, Appendix 6A.
[6] EWT LP notes that the existing East-West Tie line, which uses X7 towers, has 974 towers whereas the Reference-Based Design, which would use X10 towers, would have approximately 1,475 towers in order to accommodate the galloping criteria. The existing X7 tower family does not meet the applicable galloping criteria. Although the X7 towers do allow for longer spans, they can only accommodate a smaller conductor than that needed for the Project. To reduce visual intrusiveness, EWT LP notes that it would be preferable for the old and new East-West Ties to have similar span lengths in areas where the two lines will be adjacent.
[7] IESO, Feasibility Study: An Assessment of the Westward Transfer Capability of Various Options for Reinforcing the East-West Tie, August 18, 2011.
[8] In particular, single circuit conventional lattice towers each circuit with 2x1192.5 conductors and single circuit conventional lattice towers each circuit with 2x795 conductors.

circuit line. Although these control actions would comply with the IESO's criteria, the IESO found that a new double-circuit line would require no similar actions following the loss of either of the double-circuit lines or the loss of one circuit of one of the lines followed by the loss of one of the circuits of the companion line. The IESO therefore concluded solely on the basis of reliability that the installation of a new double-circuit line to reinforce the East-West Tie would represent the superior option.

In its December 17, 2012 report titled "Assessment of the Use of CRS Structures on HV/EHV Transmission Lines", which is attached at Appendix 6D (the "CRS Report"), Power Engineers further considered the electrical performance of EWT LP's single circuit alternative and concluded that it would have equivalent electrical performance to the single line options studied by the IESO. Power Engineers also indicated that steps can be taken to make a single circuit line more reliable than the design studied by the IESO for relatively small incremental costs. Doing so would reduce the likelihood of an outage on the new single circuit and mitigate, but not eliminate, the reliability difference between single circuit and double circuit alternatives in this regard. Steps to increase reliability on the single circuit line would include the use of longer insulators, the selected use of lightning arrestors on towers with higher than normal tower footing resistances and the addition of mechanical tower strength.[9] EWT LP therefore believes there is value in studying ALT A further in the development phase.

SINGLE CIRCUIT DESIGN WITH CRS ("ALT B")

This variation would consist of a single circuit tower line connecting the same three stations and using either 1192 kcmill Grackle or 795 kcmill Drake in a 2-bundle arrangement. Unlike ALT A, which uses the W1 tower family, ALT B would use guyed cross-rope suspension type ("CRS") structures. Transmission lines using CRS structures, though new to Ontario, have successfully been used elsewhere, including approximately 2,000 km of 735 kV line in northern Québec (le pylône à chaînette). See Appendix 6E for a diagram of 230 kV CRS structures.

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[9] See CRS Report, pp. 17-18, Appendix 6D.

EWT LP acknowledges that the OPA, in its Long Term Electricity Outlook,[10] concluded that the installation of a double circuit line to reinforce the East-West Tie would be preferable to a single circuit given the conclusions of the IESO Study on the single circuit performance in a contingency event. However, this assessment was based on the relative costs of the two options with the OPA finding that the cost savings of the single line option were not sufficient to justify the performance difference. EWT LP notes that this cost-benefit analysis would change significantly if a single line option were considered in combination with CRS structures. As noted in the CRS Report, CRS structures have a significantly lower construction cost when compared, for example, to the Reference-Based Design. Power Engineers also indicates that CRS has a long, proven track record and would be expected to perform well in northern Ontario based on its performance in northern Québec and elsewhere. Finally, EWT LP notes that the fully guyed CRS structures provide natural resistance to cascade failures. Therefore, EWT LP plans to study ALT B further in the development phase, especially to revisit the cost-benefit analysis of whether the cost savings associated with a single circuit CRS design justify the difference in performance in a contingency event.

For reference, a table outlining some of the key structure designs described above and their technical specifications is set out at Appendix 6F.

EWT LP has carefully selected these design variations based on preliminary engineering work. Much of this work has focused on the potential benefits of CRS structures, which are described in greater detail in the CRS Report. However, the remaining studies necessary to confirm the technical feasibility are outside the scope of this Application and instead will be completed during the development phase. As indicated in Section 6.5.1 of this Application, additional development work may prove that a single circuit CRS design can be offered at a lower cost to ratepayers. On the other hand, if studies conclude that a conventional self-supporting double circuit steel lattice is ultimately more cost effective than the innovative use of CRS structures, then EWT LP will undertake further studies to optimize the appropriate tower design recognizing

[10] OPA, Long Term Electricity Outlook for the Northwest and Context for the East-West Tie Expansion, June 30, 2011.

the advantage of minimizing the number of individual towers given the limited vehicular access for construction in this part of Ontario. The optimization studies will need to incorporate the results of the environmental assessment studies, information about land availability and the observations received during public and Aboriginal consultation activities.

6.5 Strengths of EWT LP's Design and Development Plan

EWT LP's proposed design and development plan have several key strengths. The primary strengths relate to EWT LP's plan to reassess the assumptions underlying the Reference-Based Design in relation to the REF B (i.e. Modified Reference-Based Design), ALT A (i.e. Single Circuit Design) and ALT B (i.e. Single Circuit Design with CRS) variations described in Section 6.4.2.3. EWT LP has chosen these alternatives carefully because each can offer considerable cost-savings and other benefits if the development phase determines them to be preferable to the Reference Option. These benefits are set out below.

6.5.1 Capital Costs

EWT LP has completed a preliminary estimate of the construction costs of the Reference-Based Design, REF B (assuming a unique tower design) and ALT B variations. These estimates are set out in the table below.

Table 6.1: Estimated Construction Costs of Project Design Variations

	Alternative	**Incremental Substation costs, $m**	**Line Costs, $m**	**AFUDC + Owner costs, $m**	**Total Cost, $m**
Ref.-Based Design	Double Circuit, X10 Towers	None	395[11]	32	427
REF B	Double Circuit, Reinforced X10 Towers	None	352	28	380
ALT A	Single Circuit, W1 Towers	~8	319	~25	352
ALT B	Single Circuit, CRS Structures	8	281[12]	22	311

[11] See Reference Option Report, p. 1, Appendix 6A.
[12] See CRS Report, p. 2, Appendix 6D.

A cost saving of approximately $116 million may be achievable by adopting a single circuit solution with CRS structures as used in ALT B compared to the Reference-Based Design, or approximately $70 million compared to the optimized double circuit design of Ref B. These cost savings are the result of a number of the CRS design features:

- The CRS structures would allow for longer spans, which would allow for fewer structures and fewer tower sites to be accessed. This leads to lower capital and O&M costs, and also less risk of damage to the environment.[13]
- The CRS structures are lighter than the X10 towers and the foundations are simpler. This reduces the cost of the towers, foundations, tower assembly and sundry fittings.
- The CRS structures also allow for a reduction in the Reference-Based Design right-of-way width by approximately 10% (with guying easements at the tower sites), which further reduces O&M costs relating to clearing activities.

The CRS savings can also include reduced need for reactive compensation to balance load flows between the new and existing lines based on its inherent close phase spacing relative to other structure options, whether single or double circuit.

6.5.2 Other Benefits of CRS

As discussed in Section 6.5.1, the primary benefit of CRS is reduced construction cost. There are other important benefits of the CRS structures:

- the CRS Report notes that the CRS structures offer significant environmental impact improvements, given their smaller footprint;[14]
- the structures are also easier to install, which also lowers the risk of schedule delays;
- because each tower is individually stayed, the line is naturally engineered to minimize the risk of cascade failure;

[13] A rational span target is on the 400m to 480 m range with longer spans used where the profile allows. This is the spanning limit of the existing East-West Tie line with its X7 tower family. However, the existing X7 tower is not suitable for the new East-West Tie because it will not carry a larger conductor and will not meet the Project's galloping criteria. In addition the X10 towers in the Reference-Based Design may not be the optimum tower choice because the tower has a span limit of only 300m to 330 m for the 1192 kcmil Grackle conductor suggested. This would lead to about 30% to 35% more structures on the line at a significantly higher cost.

[14] CRS Report, p. 11, Appendix 6D.

- the CRS structures are relatively maintenance free due to their simplicity and flexibility under load;[15]
- being a single circuit line with a horizontal rather than vertical conductor configuration, the towers are squatter and the line as a result is less visible from a distance. The visual impact is further lessened by the elegant use of wire guys in place of thick tower legs made of steel plate, which will potentially reduce the environmental impact of the Project and increase public acceptance; and
- the flat phase arrangement radically reduces the galloping flashover possibilities, allowing efficient, long spans without adopting large phase spacing.

CRS designs have been successfully deployed for years. As indicated in the CRS Report, CRS structures have a history of successful employment on four continents, including in both Canada and the U.S. in similar terrain and climate, for at least 30 years.[16] Power Engineers concludes that CRS is a viable structural choice for the Project if the single circuit option is acceptable.[17]

6.5.3 Voltage Class Flexibility

The Project's voltage is assumed as 230 kV given that this is the highest voltage in the area and the present operating voltage at the three connected stations. Notwithstanding that, the CRS single circuit designs can easily be dimensioned to allow for future conversion to 345 kV or 500 kV, the province's other high voltage, if such voltages become necessary at a future date. EWT LP's assessment is that a single circuit high capacity 230 kV line can be designed and constructed with a guyed tower family dimensioned for 345 kV or 500 kV operation at a cost equal to or lower than many types of 230 kV designs that are restricted to 230 kV operation. This feature of the CRS design variation therefore lays the groundwork for a very easy upgrade to a higher operating voltage at any time by an insulator change-out and addition of one phase set of conductors to convert the line to 3-bundle of the conductor choice. EWT LP notes that the first section (Hammer to Mississagi) of the transmission path between eastern and western Ontario from Sudbury to Thunder Bay was built for 500 kV operation but currently operations at

[15] CRS Report, p. 14, Appendix 6D.
[16] CRS Report, p. 1, Appendix 6D.
[17] CRS Report, p. 14, Appendix 6D.

230 kV, and that westward extension of the 500 kV system was considered in the first draft of the Integrated Power System Plan.[18]

[18] EB-2007-0707.

6.6 Ownership and Operation

EWT LP will own and operate the Project once it is in service.

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

Appendix 6A
Reference Option Report

December 17, 2012

EAST WEST TIE EXPANSION

Engineer's Report on the EWT Transmission Line OEB Reference Option

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POWER ENGINEERS

Engineer's Report on the EWT Transmission Line OEB Reference Option

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DATE	REVISED BY	REVISION	DOCUMENT NAME
11/15/12	P. Catchpole	A	Engineer's Report on the EWT Transmission Line OEB Reference Option-for review
11/20/12	P. Catchpole	B	Engineer's Report on the EWT Transmission Line OEB Reference Option-for review
12/12/12	P. Catchpole	C	Engineer's Report on the EWT Transmission Line OEB Reference Option-final
12/17/12	P. Catchpole	D	Engineer's Report on the EWT Transmission Line OEB Reference Option-final

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Executive Summary

POWER Engineers (POWER), as EWT LP's Engineer for the East-West Tie (EWT) transmission line project is very pleased to submit this report on the characteristics, cost estimate and construction schedule estimate for the Ontario Energy Board's EWT Reference Option. This report should be read in conjunction with our companion report describing a technical solution for the EWT project, a single circuit line with cross-rope suspension (CRS) structures. That solution offers considerable benefits on cost, structural and electrical integrity, environmental impact, and construction schedule risk mitigation. To understand that offering, it is necessary to understand this reference option for comparisons.

If the single circuit CRS alternative should find no acceptance during project development and EWT LP were to install what is essentially the 'Reference Option', then we believe that efforts to improve on the Reference Option's value to the OEB and ratepayers can take place and will likely prove fruitful.

The reference design option described herein is essentially compliant (capable of being compliant) with the minimum technical requirements for the reference option as provided in the OEB report of that title dated November 9, 2011. We do describe a concern for the negative impact on cost of one criterion – the single loop galloping requirement. This is discussed below.

The reference option leans on the conductor and structure solution offered in HONI's "Project Definition Report" dated June 4, 2010. Our conductor choice and structure family assumptions are the same. We believe that any adjustments that we might eventually make to these assumptions by way of the opportunity to perform the necessary, extensive studies will not adversely impact the statements of reference option cost estimate and schedule as discussed herein.

The report offers supporting information for the cost estimate and lists the few matters that put the cost estimate at the most risk. We offer a short description for managing that risk. Similarly, we offer a schedule with a described purpose of its nature and discuss the risk factors to the schedule and how these risks are managed.

The report offers a reference option cost estimate for the project of $395M noting that the cost of right-of-way and temporary land uses for construction are excluded in that value, as are substation renovation costs at Wawa TS, Marathon TS and Lakehead TS necessary to accept the new line. As noted above, we include a comparable cost estimate based on an adjustment to the single circuit galloping criteria from the project's technical requirements. That estimate for the project compares at $352 M – the $43 M difference between the two values represents the negative cost impact of the galloping criteria.

Ontario Power Authority (OPA) Need Statement

The OPA opines at the request of the OEB in Section 6 of their report dated June 30, 2011 that *expansion of the east-west tie is the preferred alternative (over internal generation expansion in the region) based on economic, flexibility, technical, operational and other considerations.* Further, *recommends that development work be initiated* and *proceeding with the project after development has been completed will depend on many factors including the capital cost of the E-W Tie and the extent of the (industrial and grid expansion) developments in the Northwest.*

The OPA opines further in section7.1 of the report that, *OPA has assumed that the proposed expanded E-W Tie would be a double-circuit 230 kV overhead transmission line… in conjunction with the existing tie is to provide total eastbound and westbound capabilities in the order of 650 MW…*

The OPA's assumed double-circuit, 230 kV arrangement is referred in the OEB filing request as the EWT project Reference Option. The OPA does acknowledge in section 7.1 of their report that *the OPA believes that the double-circuit 230 kV line is preferred, but other options could be proposed to the extent that they meet the other project scope criteria…*

This report discusses the Reference (Design) Option to the extent that its details are defined by the OEB Minimum Technical Requirements for the Reference Option of the E-W Tie Line, dated November 9, 2011.

Technical Requirements for the EWT LP Reference Option

The OEB Minimum Technical Requirements for the Reference Option specify performance requirements more so than dictate the means of achieving the performance. In other words, various line features such as conductor choice and tower configurations are not dictated but left to the developer to determine. The categories of the minimum requirements are listed and briefly discussed below. In each category, the choices made by EWT LP in order to develop a Reference Option-base design, schedule and cost estimate are described. We understand that EWT LP has adopted this Reference Option-based design, schedule and cost estimate for the purpose of its designation application understanding that post-designation development work may prove an alternative design to be more cost-effective or otherwise preferable. We also comment on the choices' compliance with the minimum technical specifications.

General Conditions

While the route for the new line is to be determined as part of the Development Plan, it is assumed for this report that the reference option is placed alongside the existing transmission line right-of-way (ROW) for the entire length. It is not reasonable to presume that, in practical terms the line will be exactly adjacent and on a shared cleared ROW 100% of the distance as various obstacles will interrupt such a notion. Rather, we assume that it is in proximity to the exiting line on its own cleared ROW but sufficiently close so as to share all existing access roads. This assumption supports the idea that a shared corridor may prove to be environmentally advantageous and shared access is cost effective.

Standards and Procedures

The Minimum Technical Requirements list 17 CSA Standards plus 9 additional ASCE, ASTM and other Guides or Standards. A full list of applicable and useful standards will be developed during the Development Plan period based on the choices for materials and methods. We do note that, for example, the CSA C22.3, No. 1 (now revision 2010 in lieu of the 2006 revision noted in the minimum requirements), CSA C22.3 No. 60826 and the ASCE Manual 74 all deal with the subject of loadings and strengths for conductors and support structures. They are not 100% compatible with each other in philosophy and methods. Essentially, CSA C22.3 60826 is designed to be used in lieu of CSA C22.3 No.1 on the subject of strengths and loadings but both can be honoured without significant cost to the project.

CSA C22.3 60826 tends to be non-specific with quantities for wind, ice, etc. but rather a guide on methodology. ASCE Manual 74 is a more comprehensive guide for specific quantities and load case management. Our experience with all of these documents will allow the engineering of a facility with top quality integrity against electrical and structural damage or failures.

Local experience is an invaluable source for design load data and we find merit in consideration of rime ice loads and unbalanced loads not specifically noted in the minimum requirements. Rime ice has caused tower collapse in this type of terrain in northern Quebec due to a lack of understanding the negative impact of otherwise cost-effective layout choices.

A less than stellar day for a Northern Ontario transmission line

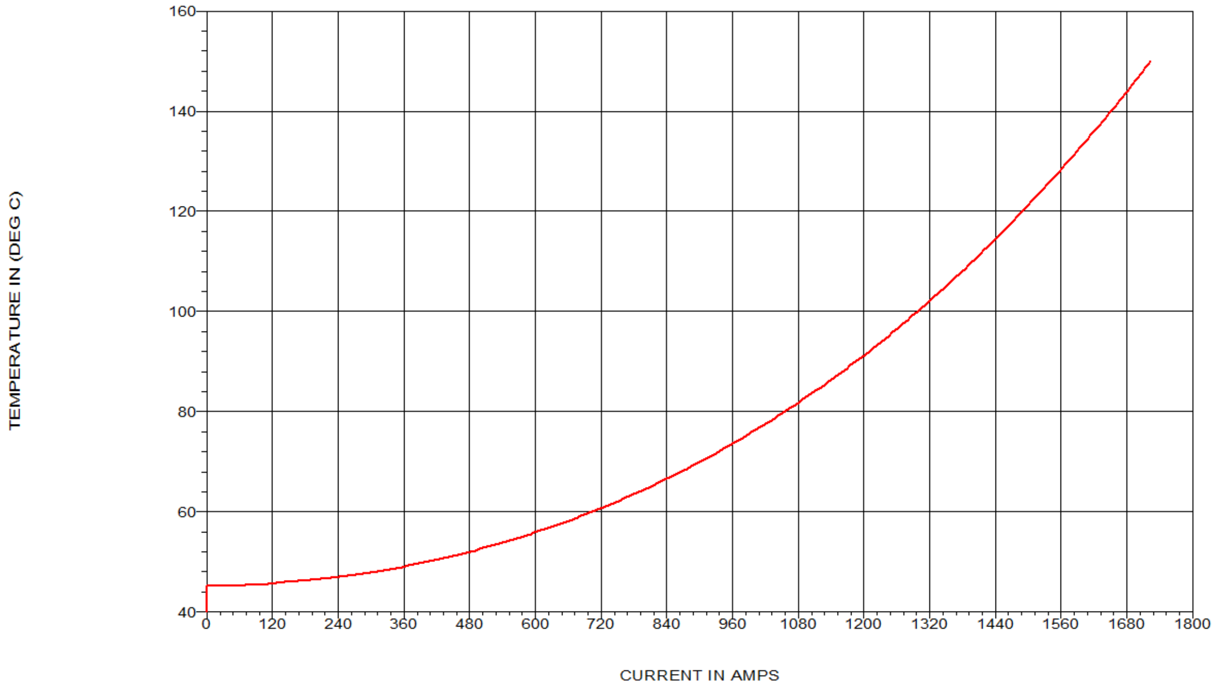
Conductor Selection

Conductor selection is to be made via a line optimization study that includes the impact of the choice on tower and foundation costs, span length choice, environmental (weather) load cases and material costs. The exercise includes cost of losses over an assumed 25 year period.

In our experience with NPV analysis, the relationship between the conductor choice and the NPV of the choice is that a range of conductor size, in terms of aluminum content in the order of ±25% causes a NPV change of only ±2-3%. In other words, the NPV of a project tends to be fairly insensitive to the conductor size choice and the exercise is more about making a decision on the balance between capital cost and lifetime operating cost. A larger conductor couples a higher capital cost with a lower operating cost with no meaningful impact on the facility's NPV. We suggest favouring the larger conductors from the reasonable range of choices because excess line losses equate to fuel wasted. With fossil fuels in the generation mix, this amounts to fossil fuels wasted.

For the Reference Design Option, we assume the already noted assumption on the minimum technical requirements of 1192.5 kcmil ACSR "Grackle" as a reasonable choice. From PLS-CADD, the graph below notes the conductor temperature: Amperes relationship for Grackle conductor compliant with the OEB minimum (summer) requirements. At 240 kV, 599 MVA equates to 1,440 A. The Grackle temperature calculates at 117°C, comfortably under the 127°C limit.

Other conductor choices could tweak the result in the project's favour but only marginally relative to this conductor choice so this was not done for report's exercise.



Insulator Selection

The minimum requirements ask for no problematic insulation criteria. For the reference design option we assume ceramic insulator strings. Ultimately, the choice will consider contractor and operator preferences and installed cost when comparing porcelain, toughened glass as a better performer than porcelain and silicon non-ceramic units.

We anticipate considerable challenges in developing cost-effective grounding of the line along much of its length. We will promote a higher insulator level than the minimum as a mechanism to reduce the lightning flashover rate on the line when high resistance ground is encountered. For the reference design, we assume 16 bells per suspension string.

Line Hardware Criteria

The minimum requirements ask for no problematic hardware criteria. Ultimately, hardware assembly parts will be selected for their articulating capacities to eliminate the binding of parts when unusual motions take place. They will also be selected to minimize wear when cyclical motions are expected. Neither of these concerns affects a basic estimation of cost and schedule for the reference design option.

Aeolian Vibration Control

Due to the author's participation on the CIGRE WG on Mechanical Characteristics of Conductors since 2004, the subject of mitigation of wire damage due to Aeolian Vibration is well understood by the EWT LP engineering team. The CSA C22.3 limits on conductor tension are no longer expressed in terms of %RTS limits; however the %RTS-based limits expressed in the minimum technical requirements are not problematic when developing this cursory reference design option.

Transmission Structure Design

The minimum technical requirements call for accommodation of single loop galloping based on CIGRE work done by Havard and Lilien. The published effort was CIGRE Technical Brochure 322, dated June 2007[1]. The vertical axis of the generated elliptical envelope is limited to 12 m implying a galloping case sag limit of about 9.5 m. This sag limits the structures' span limit to under 350 m (1,150 ft).

The X7 tower family is used on the existing circuits. That tower has only 5.5 m of vertical separation between phases of each circuit with the middle phase offset laterally 3.3 m. which will not meet the galloping criteria above because the 12 m galloping ellipses do not to fit with this X7 tower. This suggests that HONI chose their (from Ontario Hydro Standards) X10 tower family for their project solution based on this galloping and the live-line maintenance constraint. The X10 tower has a 7.7 m vertical separation coupled with the 3.3 m offset for an 8.3 meter separation. These tower dimensions are likely to require a span limit closer to 300 m.

The X10S (S denotes the suspension tower of the X10 tower family) tower has a span limit of only 183 m with a 3° line angle included when the intended 1843.2 kcmil ACSR conductor is used. If we estimate that the span limit is 270 ft without a line angle and ratio it upward for the smaller diameter Grackle conductor, the likely tower strength expressed as a span limit compliant is about 300 m. Therefore, the geometry and strength of the X10 family of towers supports a span limit of approximately 300 m.

We point out that the design span for the X7 family of towers now operating in the area for the existing EWT is 1,600 ft (488 m). If that line is performing well without undue galloping flashovers, the single loop criteria can be deemed excessively conservative and should be reviewed because short spans do not lead to a cost-effective and efficient design in rough and remote terrain as found on much of this project. The cost impact of the single loop galloping criterion is expressed by the comparable cost estimate in Appendix A for the 'long span' reference option. We understand EWT LP has proposed to revisit the galloping criteria as the basis for a Reference Option-based alternative that it plans to study further in the development phase.

For the reference option, we adopt the X10 tower family and use a span limit of 300 m. The alternative is to develop a new structure with very expansive headframe dimension in order to significantly increase the design span to a preferable value. However, given that this would require the engineering of a new tower design, it has not been considered for the purpose of this report. The 300 m design span will permit a ROW width well below 50 m so we adopt a ROW width for the reference option cost estimate of 40 m that is cleared to a lesser width when the spans allow. We understand EWT LP has adopted this right-of-way width for its Reference Option-based design.

The foundations for the self-supported X10 towers operate in tension, compression and shear. The subsurface conditions range from bare, hard rock to soft material of varied depth over rock. We assume a 50-50 combination of rock bolt footings with minimal concrete leveling pads to steel grillages where the soil depth permits. Ultimately, we would prefer micropile foundations but these are awkward and costly under self-supported latticed towers due to the magnitude and directions of forces applied and the tricky transition assembly between piles and tower legs. For this reference design option exercise, their consideration is not useful.

A small percentage of towers are expected to carry high loads such as for long spans over water coupled with soft and deep soil requiring costly pile foundations.

[1] This report's author, Catchpole has been a member of the Working Group, but not the Task Force that produced Technical Brochure 322 and has been present for Havard's and Lilien's CIGRE discussions on galloping since 2004.

T-Line Bonding and Grounding

The minimum requirements ask for no problematic bonding and grounding criteria. We anticipate the need for local ground grids at many towers when the local ground is high resistance. Experience in the area has led our engineering team to develop a process for iteratively developing/installing a grounding system at towers to meet the desired low resistance threshold when at all possible.

We have already mentioned above that tower insulation levels may be increased to reduce lightning flashover events in high resistance ground locations.

As-Built Documentation

All of the requested as-built line data is reasonable and routinely produced for projects. None of the requested information affects the reference design option cost estimate. The basis of the final engineered product will be a LiDAR survey offering the highest accuracy available in the industry.

Environmental Commitments & Legislation

The list of legislation and agencies presents no problems. Mitigation of their concerns is a key component on line engineering and construction methods. All can be accommodated with tested designs and work methods. We do question the mention of the Niagara Escarpment Commission as this project area seems well outside their region of concern.

EWT LP Reference Option Summary

The following brief list notes the essence of the line characteristics used for the Reference option scheduling and cost estimate which we understand EWT LP has adopted for the purpose of its designation application, recognizing that these characteristics are subject to change during the development stage. Items not mentioned imply compliance with the minimum technical requirements.

Alignment:	generally within 0.5 km of the existing circuits to share access means
Conductor:	single 1192.5 kcmil ACSR “Grackle”
Tower Family:	HONI X10 with 300 m design wind span
Foundations:	50-50 rock bolt/steel grillage
ROW Width:	40 m

Reference Option Cost Estimate

The reference option cost estimate is developed on the spreadsheet, Figure 1 in Appendix A. The values in Figure 1 are explained below. The result of the cost estimate exercise shows a project cost, without substation work as $395 million for the reference option as described herein. We do point out that the cost of ROW purchase and temporary land needs for construction are not included in this estimate.

Some of the important construction costs are the most elusive and ultimately unpredictable with a degree of precision since contractors will factor in the presence and pressures of concurrent work when bidding time comes. The values offered herein came from the engineer’s own experiences and three respected and qualified transmission line contractors: Par Electric, Valard and Kiewit.

Appendix A also includes a cost estimate that assumes a revise, but still appropriate, single loop galloping criteria thus accessing the cost advantages of a long span design. That cost totals $352 M illustrating the negative impact of the single loop galloping criterion as being $43M.

Self-Supported, Double Circuit X10 Towers

The maximum sag for the design span of 300 m is 10 m. Coupled with a ground clearance of 8 m and insulators of 2.5 m, the bottom arms of the tower should be 20.5 m above grade. This requires the main body of the tower plus a 5 ft body panel as the average tower height for pricing. The Ontario Hydro data sheet for the tower declares a tower weight of [10,776+796+1420] 13,000 lbs (5,900 kg) for this combination of parts.

Recent design, fabrication and delivery prices on the last two years for large orders have been ranging from a reported $0.65/lb to $1.30/lb depending on the source country and the risk on quality willing to be taken by the purchaser. We understand that steel purchased at the low cost of $0.65/lb required field renovations that trended to final cost to closer to $1.00/lb. For our budget, we have used $1.10/lb or $2.42/kg.

The installation cost is provided one year ago by a respected and experienced contractor at $3.29/lb. With a 5% annual increase, we use $7.60/kg. Deadend towers are assumed to cost 4 times the unit rate of the suspension tower based on their much heavier weight and complexity.

Conductors, Ground Wire and OPGW

The Grackle ACSR is purchased for $1.50/lb or $7.53/meter. Six are required for the length of the line with a modest 4% overage. The ground wire is purchased at $1.50/m and the OPGW is priced at $6.00/m. Both use a 3% overage.

A current price from the respected and experienced contractor for conductor installation is $130,000/circuit-mile translating to $88,833/circuit-km. The ground wire and OPGW together are both installed for less than 1/3 that cost at $20,500/km.

Insulators and Hardware

Insulators and hardware are priced at $2,400 per tower ($400/phase) with Dead-end towers using 8 times the material (more complex assemblies) than suspension towers. The installation of the hardware and insulators is included in the tower erection and wire stringing unit rates.

Sundry and Closeout

Sundry and closeout costs are estimated as $2,000 /tower and $900,000 respectively.

Foundations

Tower foundations, whether steel grillages or rock bolt type are priced at 4/tower and $16,000 each.

Access Roads

We assume the need to construct and maintain 4 m wide access roads along 40% of the line length at a unit rate of $25,000/km

ROW Clearing

Clearing includes 75% of the line length at 30 m width at a unit cost of $8,000/Ha.

Environmental & Routing Support

The environmental, permitting and routing support is assumed as 1.9% of the labour + materials for the project.

Engineering

Engineering is assumed as 1.5% of the labour + materials for the project.

Construction Management & EWT LP Overheads

Construction Management, field services and EWT LP management and overheads are assumed as 12% of the labour + materials for the project.

Cost Risks & Risk Management

The costs presented are late 2012/early 2013 costs. Assume a 3% annual increase to represent the likely construction period of 2017-2018. Risks to the cost estimate's accuracy are:

1. The very limited detailed engineering work done to refine input values, particularly the assumption that the X10 tower is viable without change.
2. Lack of control over the eventual construction start time based on the usually unpredictability of the routing and permitting process.
3. Already noted volatility of labour costs since these are not entirely related to the work effort required by this project alone but to the presence of other projects competing for the materials, labour and equipment, and to the very nature of the contractual language relative to other project opportunities. This is by far, the highest risk item to the project cost.
4. Assumptions about production rates to meet a schedule since a faster paced schedule invites significant premium time rates for labour and more expensive equipment.

The ratio of material to labour for the capital cost estimate is about 1:5 making the labour cost the only component worthy of risk assessment. This cost estimate does not make any conscious choices to include or mitigate extreme issues related to the four points of risk above.

Construction Schedule

The construction schedule included as Appendix B was constructed on the premise that the start date is February 2, 2017 and the work is completed in mid November, 2018 – 21.5 months later. The objective was to understand what approach was necessary to complete the work in this time frame.

The key revelations from this timeframe goal are:

1. The latticed structures must be designed, tested and a fabrication contract signed before a contractor is signed up to do the work. The predecessor to signing the contractor and purchasing any materials or ROW and access rights is the receipt of the OEB s92 approval.
2. The period includes only one complete winter season midway through the period and most of another at the very early part of the work – useful for clearing wetter sections of the alignment. This does require close coordination with ROW and access purchases and agreements.
3. The work is conducted along the 420 km line by three concurrent activity sets. The entire line is broken into three sections: Wawa-Marathon at 170 km, Marathon-Nipigon at 140 km and Nipigon-Lakehead at 110 km. Each section is effectively a project unto itself with essentially parallel and concurrent work. This calls for a significant commitment of labour and equipment to the project and should be considered challenging.

Figure 3 in Appendix A is a collapsed view of the schedule easing the ability to recognize the basic sequence, durations and parallel nature of procurement, clearing, foundation installation, tower erection, stringing and station (TS) renovation work.

Any desire to shorten the schedule must recognize that the need for more labour or extending the workweek hours of a labour force carries a relatively high premium. The existence of added equipment can be costly since this will not be the only major project happening in this time frame.

We assume a single contractor for the work although that contractor may choose to supplement his forces with subcontracts at his risk. The contractor will procure all materials and consumables and equipment with the possible exception of the need for EWT LP to initiate the structure procurement including the cost of the detail engineering and any full scale testing.

For this estimate and for the schedule development, we have not accounted for the cost and schedule advantages that the use of heavy lift helicopters might offer. In fact, the use of helicopters is primarily a contractor decision driven by cost, schedule and access. There is a strong likelihood that heavy lift helicopters are an attractive option when the time comes and the structures, staging yards and access road plans will be organized accordingly.

Construction Schedule Risks & Risk Management

The risk to the schedule's start date is simply the ability to complete the routing and permitting work on a planned schedule. EWT LP has a comprehensive plan for that (development) work, which will include the ongoing engagement of Aboriginal communities, landowners, government agencies and others. However, the required review periods and the decision to grant a leave to construct are to some extent beyond the control of any transmitter.

The risks to the schedule's duration are a list of classic issues. The mitigation means are described with each as subset text:

1. When the summer and winter seasons sit in the 21 month timeframe – to the contractor's preferred advantage or not.
    a. Provide design features that trend to immune to seasonal installation
    b. Manage the work with an "as soon as possible" philosophy to maximize flexibility of work place latter in the schedule
2. Whether the winter season is easy or brutal
    a. a and b above
3. Summer and fall fire season risk – a dry season with events or not
    a. a and b above
4. Habitat and species rules, seasonal and pervasive
    a. a and b above
    b. design features that reduce the impact of construction methods and installed facilities on habitat and species
5. Availability of labour and major equipment when you most need it
    a. a and b above
    b. Planning and tracking via significant project management and construction management program
    c. Offering attractive contractual terms compared to competing contract opportunities
6. Major Supplier failures to deliver on time with viable product
    a. Procurement management plan as part of the construction management plan
    b. QA/QC program as part of the construction management plan
7. Failure of subcontractors to perform
    a. Construction management plan
8. Failure of timely ROW and access acquisitions
    a. Planning and tracking capabilities in the Project Management plan

Appendix A – Construction Cost Estimate

Figure 1 – Reference Option Cost Estimate

Figure 2 – Long Span Reference Option Cost Estimate

EWT Construction Cost Estimate														
Reference Design, 2ckt: 1-1192.5 ACSR			Ave. Span (m)	270	%DE	5%		270		7%	270		5%	
	$ x 1,000		**Wawa TS**	**Wawa-Marathon**			**Marathon TS**	**Marathon -Nipigon**			**Nipigon-Lakehead**			**Lakehead TS**
WBS	**Line Item**	**Unit**		**Qty**	**Unit $**	**Cost**		**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**	
LINE (Double Circuit 230 kV, X10)				168	km			148	km		82	km		
Purchases														
	ROW	Ha.												
2.1.4	Towers	kg		4,221,778	$2.42	$10,217		3,913,230	$2.42	$9,470	2,060,630	$2.42	$4,987	
2.5.4	Conductors	m		1,048,320	$7.53	$7,891		923,520	$7.53	$6,952	511,680	$7.53	$3,852	
2.5.4	OHGW & OPGW	m		173,040	$7.50	$1,298		152,440	$7.50	$1,143	84,460	$7.50	$633	
2.6.4	Insulation & Hardware	/twr		840	$2,400	$2,016		817	$2,400	$1,960	410	$2,400	$984	
2.7.4	Sundry	/twr		840	$2,000	$1,680		1	$2,000	$2	1	$2,000	$2	
Installations including consumables														
3.x.1	Access Roads (4 m wide)	km		100.8	$9,000	$907		88.8	$9,000	$799	49.2	$9,000	$443	
3.x.2	Clearing (30 m of 40 m ROW)	Ha.		378	$8,000	$3,024		333	$8,000	$2,664	185	$8,000	$1,476	
3.x.3	Yards @ 20 km	m^3		84,000	$50.00	$4,200		74,000	$50.00	$3,700	41,000	$50.00	$2,050	
4.1	Foundations (50% piers, 50% grillages)	m^3 & Ea.		2,489	$16,000	$39,822		2,193	$16,000	$35,081	1,215	$16,000	$19,437	
5.1	Tower (assembly, erection, dressed)	kg		4,221,778	$7.60	$32,085		3,913,230	$7.60	$29,740	2,060,630	$7.60	$15,661	
6.1	Conductors	ckt-km		336	$111,042	$37,310		296	$111,042	$32,868	164	$111,042	$18,211	
6.1	OHGW/OPGW	ckt-km		176.4	$20,500	$3,616		155.4	$20,500	$3,186	86.1	$20,500	$1,765	
8	Closeout	LS		1	$300,000	$300		1	$300,000	$300	1	$300,000	$300	
EPC COST	**$342,032,994**				**Totals:**	**$144,367**			**Totals:**	**$127,866**		**Totals:**	**$69,800**	
Eng Support	$5,198,902	1.5%	of EPC Cost											
Env. Support	$6,498,627	1.9%	of EPC Cost											
CM + Margin	$41,728,025	12%	of EPC Cost (10% + 20%)											
Total	**$395,458,548**													

Figure 1

EWT Construction Cost Estimate																				
Long Span Reference Design, 2ckt: 1-1192.5 ACSR					Ave. Span (m)	439	%DE	5%				439		7%	439		5%			
	$ x 1,000		Wawa TS			Wawa-Marathon			Marathon TS			Marathon -Nipigon			Nipigon-Lakehead			Lakehead TS		
WBS	**Line Item**	**Unit**	**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**
LINE (Double Circuit 230 kV, New Towers)						168	km					148	km		82	km				
Purchases																				
	ROW	Ha.																		
2.1.4	Towers	kg				3,915,027	$2.42	$9,474				3,628,898	$2.42	$8,782	1,910,906	$2.42	$4,624			
2.5.4	Conductors	m				1,048,320	$7.53	$7,891				923,520	$7.53	$6,952	511,680	$7.53	$3,852			
2.5.4	OHGW & OPGW	m				173,040	$7.50	$1,298				152,440	$7.50	$1,143	84,460	$7.50	$633			
2.6.4	Insulation & Hardware	/twr				516	$2,400	$1,239				502	$2,400	$1,205	252	$2,400	$605			
2.7.4	Sundry	/twr				516	$2,000	$1,033				1	$2,000	$2	1	$2,000	$2			
Installations including consumables																				
3.x.1	Access Roads (4 m wide)	km				100.8	$9,000	$907				88.8	$9,000	$799	49.2	$9,000	$443			
3.x.2	Clearing (40 m)	Ha.				504	$8,000	$4,032				444	$8,000	$3,552	246	$8,000	$1,968			
3.x.3	Yards @ 20 km	m^3				84,000	$50.00	$4,200				74,000	$50.00	$3,700	41,000	$50.00	$2,050			
4.1	Foundations (50% piers, 50% grillages)	m^3 & Ea.				1,530	$16,000	$24,481				1,348	$16,000	$21,566	747	$16,000	$11,949			
5.1	Tower (assembly, erection, dressed)	kg				3,915,027	$7.60	$29,754				3,628,898	$7.60	$27,579	1,910,906	$7.60	$14,523			
6.1	Conductors	ckt-km				336	$111,042	$37,310				296	$111,042	$32,868	164	$111,042	$18,211			
6.1	OHGW/OPGW	ckt-km				176.4	$20,500	$3,616				155.4	$20,500	$3,186	86.1	$20,500	$1,765			
8	Closeout	LS				1	$300,000	$300				1	$300,000	$300	1	$300,000	$300			
EPC COST	**$298,095,712**						**Totals:**	**$125,536**					**Totals:**	**$111,635**		**Totals:**	**$60,925**			
Eng Support	$5,365,723	1.8%	of EPC Cost																	
Env. Support	$6,558,106	2.2%	of EPC Cost																	
CM + Margin	$41,733,400	14%	of EPC Cost																	
Total	**$351,752,940**																			

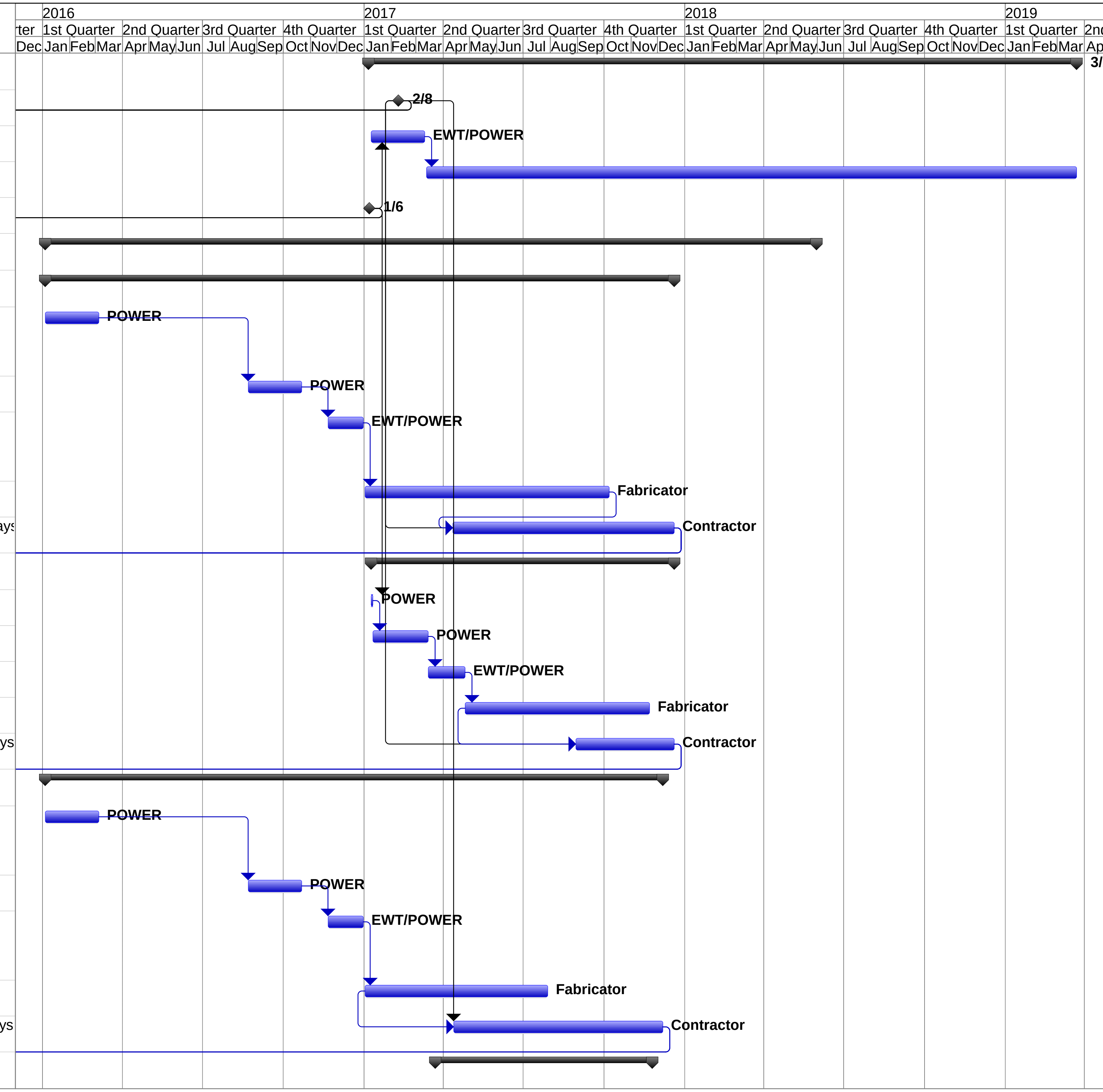
Figure 2

Appendix B – Construction Schedule

Figure 3 – Expanded Schedule

Figure 4 – Collapsed Schedule

ID		WBS	Task Name	Duration	Start	Finish	Predecessors
1		1	**CONSTRUCTION MANAGEMENT**	**576 days**	**Fri 1/6/17**	**Fri 3/22/19**	
2		1.1	Construction Contract Award (7.4.6)	1 day	Wed 2/8/17	Wed 2/8/17	
3		1.2	CM Staffing and Process Setup	45 days	Mon 1/9/17	Fri 3/10/17	5
4		1.3	CM	530 days	Mon 3/13/17	Fri 3/22/19	3
5		1.4	Design Approved (OEB s92 Decision)	1 day	Fri 1/6/17	Fri 1/6/17	
6		2	**PROCUREMENT**	**628 days**	**Mon 1/4/16**	**Wed 5/30/18**	
7		**2.1**	**Towers**	**512 days**	**Mon 1/4/16**	**Tue 12/19/17**	
8		2.1.1	Purchase Specification after task 5.4	45 days	Mon 1/4/16	Fri 3/4/16	
9		2.1.2	Bid	45 days	Mon 8/22/16	Fri 10/21/16	8
10		2.1.3	Select and Award (after OEB decision)	30 days	Mon 11/21/16	Fri 12/30/16	9
11		2.1.4	Fabricate and Supply	200 days	Mon 1/2/17	Fri 10/6/17	10
12		2.1.5	Receive and distribute	180 days	Wed 4/12/17	Tue 12/19/17	11FS-150 days,2SS+45 days
13		**2.2**	**Station Steel**	**247 days**	**Mon 1/9/17**	**Tue 12/19/17**	
14		2.2.1	Purchase Specification	2 days	Mon 1/9/17	Tue 1/10/17	5
15		2.2.2	Bid	45 days	Wed 1/11/17	Tue 3/14/17	14
16		2.2.3	Select and Award	30 days	Wed 3/15/17	Tue 4/25/17	15
17		2.2.4	Fabricate and Supply	150 days	Wed 4/26/17	Tue 11/21/17	16
18		2.2.5	Receive and distribute	80 days	Wed 8/30/17	Tue 12/19/17	17SS+90 days,2SS+40 days
19		**2.3**	**Major Station Equipment**	**503 days**	**Mon 1/4/16**	**Wed 12/6/17**	
20		2.3.1	Purchase Specification after task 5.4	45 days	Mon 1/4/16	Fri 3/4/16	
21		2.3.2	Bid	45 days	Mon 8/22/16	Fri 10/21/16	20
22		2.3.3	Select and Award (after OEB decision)	30 days	Mon 11/21/16	Fri 12/30/16	21
23		2.3.4	Fabricate and Supply	150 days	Mon 1/2/17	Fri 7/28/17	22
24		2.3.5	Receive and distribute	170 days	Thu 4/13/17	Wed 12/6/17	2FS+45 days,23SS+60 days
25		**2.4**	**Minor Station Equipment**	**177 days**	**Thu 3/23/17**	**Fri 11/24/17**	

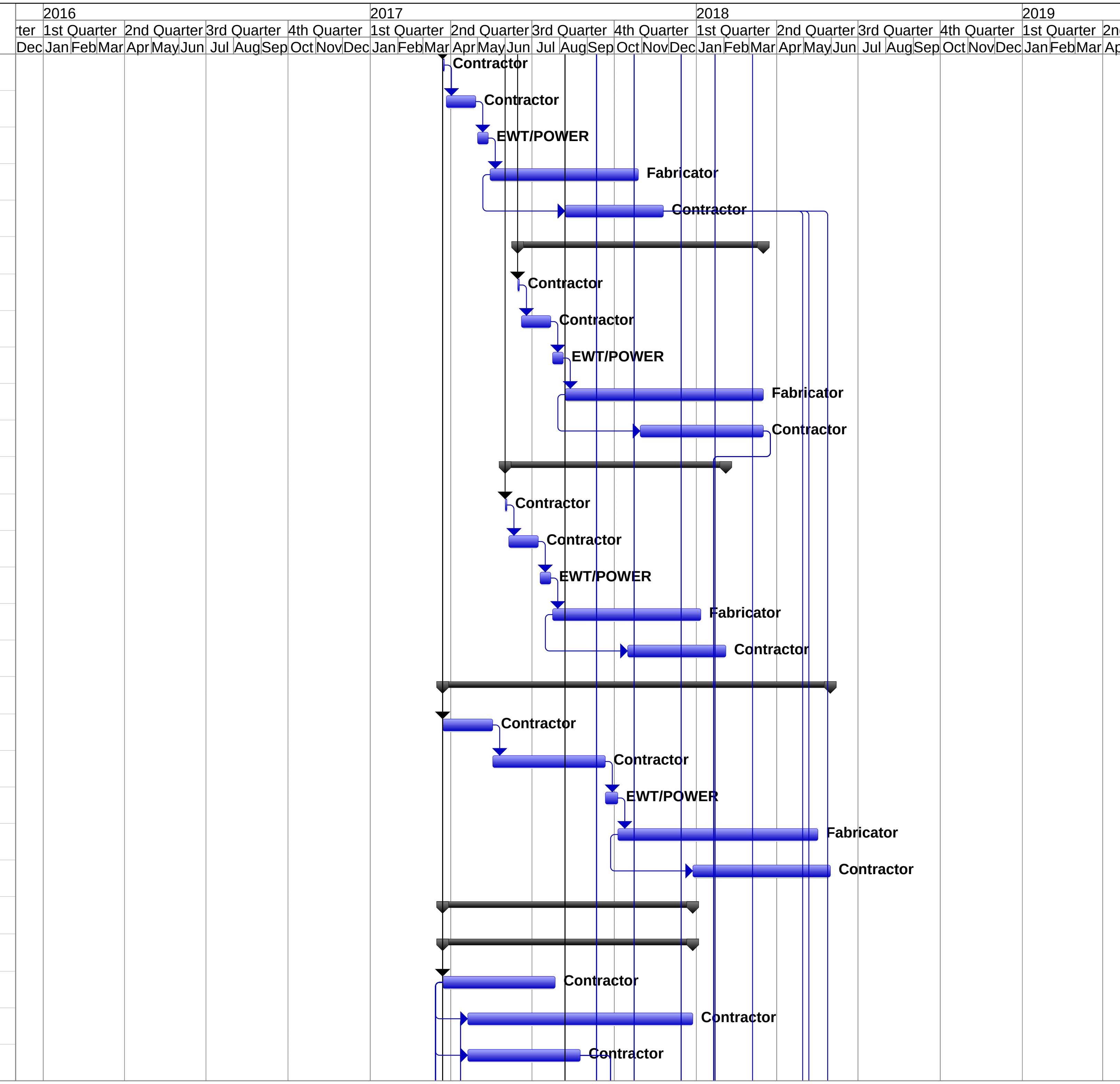


Project: EWT Construction Schedule V
Date: Mon 11/19/12

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
			Progress
			Deadline

Figure 3

ID		WBS	Task Name	Duration	Start	Finish	Predecessors
26		2.4.1	Purchase Specification	2 days	Thu 3/23/17	Fri 3/24/17	2FS+30 days
27		2.4.2	Bid	25 days	Mon 3/27/17	Fri 4/28/17	26
28		2.4.3	Select and Award	10 days	Mon 5/1/17	Fri 5/12/17	27
29		2.4.4	Fabricate and Supply	120 days	Mon 5/15/17	Fri 10/27/17	28
30		2.4.5	Receive and distribute	80 days	Mon 8/7/17	Fri 11/24/17	29SS+60 days
31		**2.5**	**Conductors and OHGW/OPGW**	**197 days**	**Thu 6/15/17**	**Fri 3/16/18**	
32		2.5.1	Purchase Specification	2 days	Thu 6/15/17	Fri 6/16/17	2FS+90 days
33		2.5.2	Bid	25 days	Mon 6/19/17	Fri 7/21/17	32
34		2.5.3	Select and Award	10 days	Mon 7/24/17	Fri 8/4/17	33
35		2.5.4	Fabricate and Supply	160 days	Mon 8/7/17	Fri 3/16/18	34
36		2.5.5	Receive and distribute	100 days	Mon 10/30/17	Fri 3/16/18	35SS+60 days
37		**2.6**	**Insulators and Hardware**	**177 days**	**Thu 6/1/17**	**Fri 2/2/18**	
38		2.6.1	Purchase Specification	2 days	Thu 6/1/17	Fri 6/2/17	2FS+80 days
39		2.6.2	Bid	25 days	Mon 6/5/17	Fri 7/7/17	38
40		2.6.3	Select and Award	10 days	Mon 7/10/17	Fri 7/21/17	39
41		2.6.4	Fabricate and Supply	120 days	Mon 7/24/17	Fri 1/5/18	40
42		2.6.5	Receive and distribute	80 days	Mon 10/16/17	Fri 2/2/18	41SS+60 days
43		**2.7**	**Sundry Items**	**310 days**	**Thu 3/23/17**	**Wed 5/30/18**	
44		2.7.1	Purchase Specification	40 days	Thu 3/23/17	Wed 5/17/17	2FS+30 days
45		2.7.2	Bid	90 days	Thu 5/18/17	Wed 9/20/17	44
46		2.7.3	Select and Award	10 days	Thu 9/21/17	Wed 10/4/17	45
47		2.7.4	Fabricate and Supply	160 days	Thu 10/5/17	Wed 5/16/18	46
48		2.7.5	Receive and distribute	110 days	Thu 12/28/17	Wed 5/30/18	47SS+60 days
49		**3**	**CLEARING, ROADS and YARDS**	**200 days**	**Thu 3/23/17**	**Wed 12/27/17**	
50		**3.1**	**Wawa-Marathon (180 km)**	**200 days**	**Thu 3/23/17**	**Wed 12/27/17**	
51		3.1.1	Access Roads	90 days	Thu 3/23/17	Wed 7/26/17	2FS+30 days
52		3.1.2	Clearing	180 days	Thu 4/20/17	Wed 12/27/17	51SS+20 days
53		3.1.3	Yards	90 days	Thu 4/20/17	Wed 8/23/17	51SS+20 days

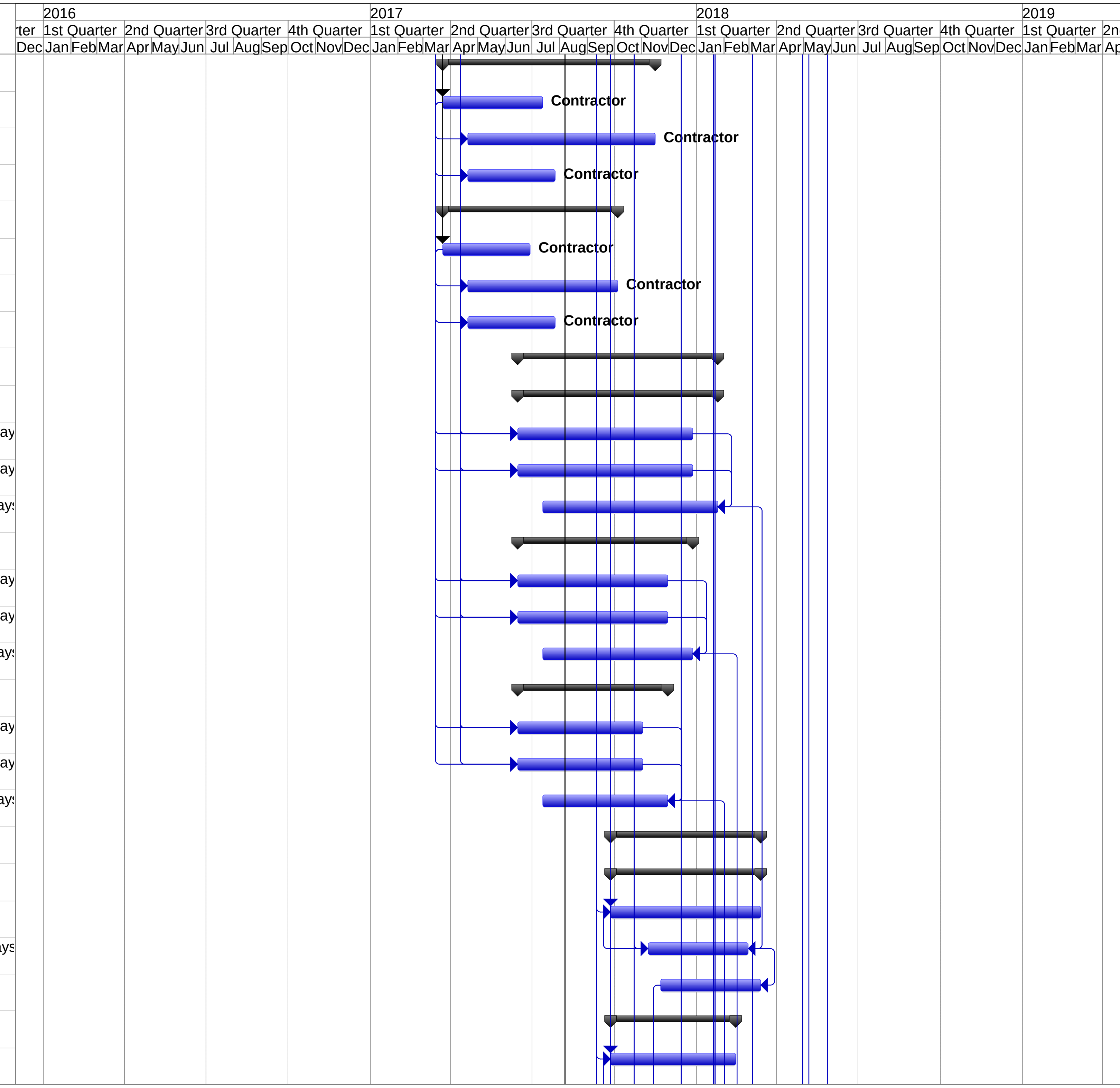


Project: EWT Construction Schedule V
Date: Mon 11/19/12

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Progress	
Split		External Tasks		Inactive Summary		Manual Summary		Deadline	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Figure 3

ID		WBS	Task Name	Duration	Start	Finish	Predecessors
54		**3.2**	**Marathon-Nipigon (140 km)**	**170 days**	**Thu 3/23/17**	**Wed 11/15/17**	
55		3.2.1	Access Roads	80 days	Thu 3/23/17	Wed 7/12/17	2FS+30 days
56		3.2.2	Clearing	150 days	Thu 4/20/17	Wed 11/15/17	51SS+20 days
57		3.2.3	Yards	70 days	Thu 4/20/17	Wed 7/26/17	51SS+20 days
58		**3.3**	**Nipigon-Lakehead (110 km)**	**140 days**	**Thu 3/23/17**	**Wed 10/4/17**	
59		3.3.1	Access Roads	70 days	Thu 3/23/17	Wed 6/28/17	2FS+30 days
60		3.3.2	Clearing	120 days	Thu 4/20/17	Wed 10/4/17	51SS+20 days
61		3.3.3	Yards	70 days	Thu 4/20/17	Wed 7/26/17	51SS+20 days
62		**4**	**FOUNDATIONS**	**160 days**	**Thu 6/15/17**	**Wed 1/24/18**	
63		**4.1**	**Wawa-Marathon (180 km)**	**160 days**	**Thu 6/15/17**	**Wed 1/24/18**	
64		4.1.1	Stub Angles in Piers	140 days	Thu 6/15/17	Wed 12/27/17	51SS+40 days,52SS+40 day
65		4.1.2	Guy Anchors	140 days	Thu 6/15/17	Wed 12/27/17	51SS+40 days,52SS+40 day
66		4.1.3	Acceptance	140 days	Thu 7/13/17	Wed 1/24/18	64FF+20 days,65FF+20 days
67		**4.2**	**Marathon-Nipigon (140 km)**	**140 days**	**Thu 6/15/17**	**Wed 12/27/17**	
68		4.2.1	Stub Angles in Piers	120 days	Thu 6/15/17	Wed 11/29/17	55SS+40 days,56SS+40 day
69		4.2.2	Guy Anchors	120 days	Thu 6/15/17	Wed 11/29/17	55SS+40 days,56SS+40 day
70		4.2.3	Acceptance	120 days	Thu 7/13/17	Wed 12/27/17	68FF+20 days,69FF+20 days
71		**4.3**	**Nipigon-Lakehead (110 km)**	**120 days**	**Thu 6/15/17**	**Wed 11/29/17**	
72		4.3.1	Stub Angles in Piers	100 days	Thu 6/15/17	Wed 11/1/17	59SS+40 days,60SS+40 day
73		4.3.2	Guy Anchors	100 days	Thu 6/15/17	Wed 11/1/17	59SS+40 days,60SS+40 day
74		4.3.3	Acceptance	100 days	Thu 7/13/17	Wed 11/29/17	72FF+20 days,73FF+20 days
75		**5**	**TOWERS**	**120 days**	**Wed 9/27/17**	**Tue 3/13/18**	
76		**5.1**	**Wawa-Marathon (180 km)**	**120 days**	**Wed 9/27/17**	**Tue 3/13/18**	
77		5.1.1	Assemble	120 days	Wed 9/27/17	Tue 3/13/18	12FS-60 days,53
78		5.1.2	Erect	80 days	Wed 11/8/17	Tue 2/27/18	66FF+20 days,12FS-30 days
79		5.1.3	Bolt up	80 days	Wed 11/22/17	Tue 3/13/18	78FF+10 days
80		**5.2**	**Marathon-Nipigon (140 km)**	**100 days**	**Wed 9/27/17**	**Tue 2/13/18**	
81		5.2.1	Assemble	100 days	Wed 9/27/17	Tue 2/13/18	12FS-60 days,53

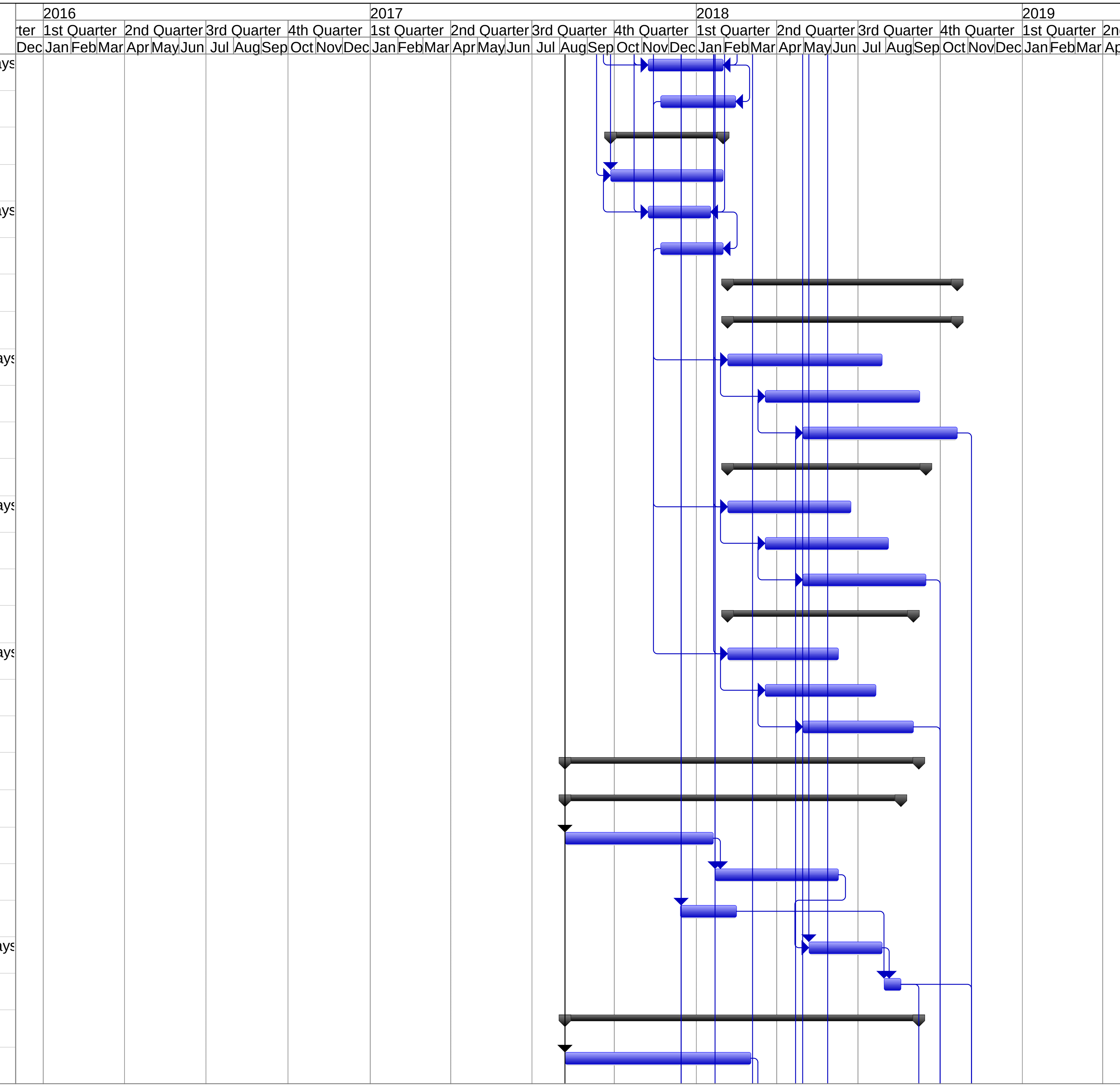


Project: EWT Construction Schedule V
Date: Mon 11/19/12

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Progress | Deadline

Figure 3

ID		WBS	Task Name	Duration	Start	Finish	Predecessors
82		5.2.2	Erect	60 days	Wed 11/8/17	Tue 1/30/18	12FS-30 days,70FF+20 days
83		5.2.3	Bolt up	60 days	Wed 11/22/17	Tue 2/13/18	82FF+10 days
84		**5.3**	**Nipigon-Lakehead (110 km)**	**90 days**	**Wed 9/27/17**	**Tue 1/30/18**	
85		5.3.1	Assemble	90 days	Wed 9/27/17	Tue 1/30/18	12FS-60 days,53
86		5.3.2	Erect	50 days	Wed 11/8/17	Tue 1/16/18	12FS-30 days,74FF+20 days
87		5.3.3	Bolt up	50 days	Wed 11/22/17	Tue 1/30/18	86FF+10 days
88		**6**	**CONDUCTORS, OHGW/OPGW**	**185 days**	**Mon 2/5/18**	**Fri 10/19/18**	
89		**6.1**	**Wawa-Marathon (180 km)**	**185 days**	**Mon 2/5/18**	**Fri 10/19/18**	
90		6.1.1	String	125 days	Mon 2/5/18	Fri 7/27/18	79SS+30 days,36FS-30 days
91		6.1.2	Clip in	125 days	Mon 3/19/18	Fri 9/7/18	90SS+30 days
92		6.1.3	Attachments	125 days	Mon 4/30/18	Fri 10/19/18	91SS+30 days
93		**6.2**	**Marathon-Nipigon (140 km)**	**160 days**	**Mon 2/5/18**	**Fri 9/14/18**	
94		6.2.1	String	100 days	Mon 2/5/18	Fri 6/22/18	36FS-30 days,83SS+30 days
95		6.2.2	Clip in	100 days	Mon 3/19/18	Fri 8/3/18	94SS+30 days
96		6.2.3	Attachments	100 days	Mon 4/30/18	Fri 9/14/18	95SS+30 days
97		**6.3**	**Nipigon-Lakehead (110 km)**	**150 days**	**Mon 2/5/18**	**Fri 8/31/18**	
98		6.3.1	String	90 days	Mon 2/5/18	Fri 6/8/18	36FS-30 days,87SS+30 days
99		6.3.2	Clip in	90 days	Mon 3/19/18	Fri 7/20/18	98SS+30 days
100		6.3.3	Attachments	90 days	Mon 4/30/18	Fri 8/31/18	99SS+30 days
101		**7**	**STATIONS**	**284 days**	**Mon 8/7/17**	**Thu 9/6/18**	
102		**7.1**	**Wawa TS**	**270 days**	**Mon 8/7/17**	**Fri 8/17/18**	
103		7.1.1	Site & Foundations	120 days	Mon 8/7/17	Fri 1/19/18	5FS+150 days
104		7.1.2	Structural Work	100 days	Mon 1/22/18	Fri 6/8/18	18FS+5 days,103
105		7.1.3	Large Equipment	45 days	Thu 12/14/17	Wed 2/14/18	24FS+5 days
106		7.1.4	Sundry	60 days	Mon 5/7/18	Fri 7/27/18	30FS+5 days,104FS-25 days
107		7.1.5	Testing	15 days	Mon 7/30/18	Fri 8/17/18	106,105
108		**7.2**	**Marathon TS**	**284 days**	**Mon 8/7/17**	**Thu 9/6/18**	
109		7.2.1	Site & Foundations	150 days	Mon 8/7/17	Fri 3/2/18	5FS+150 days

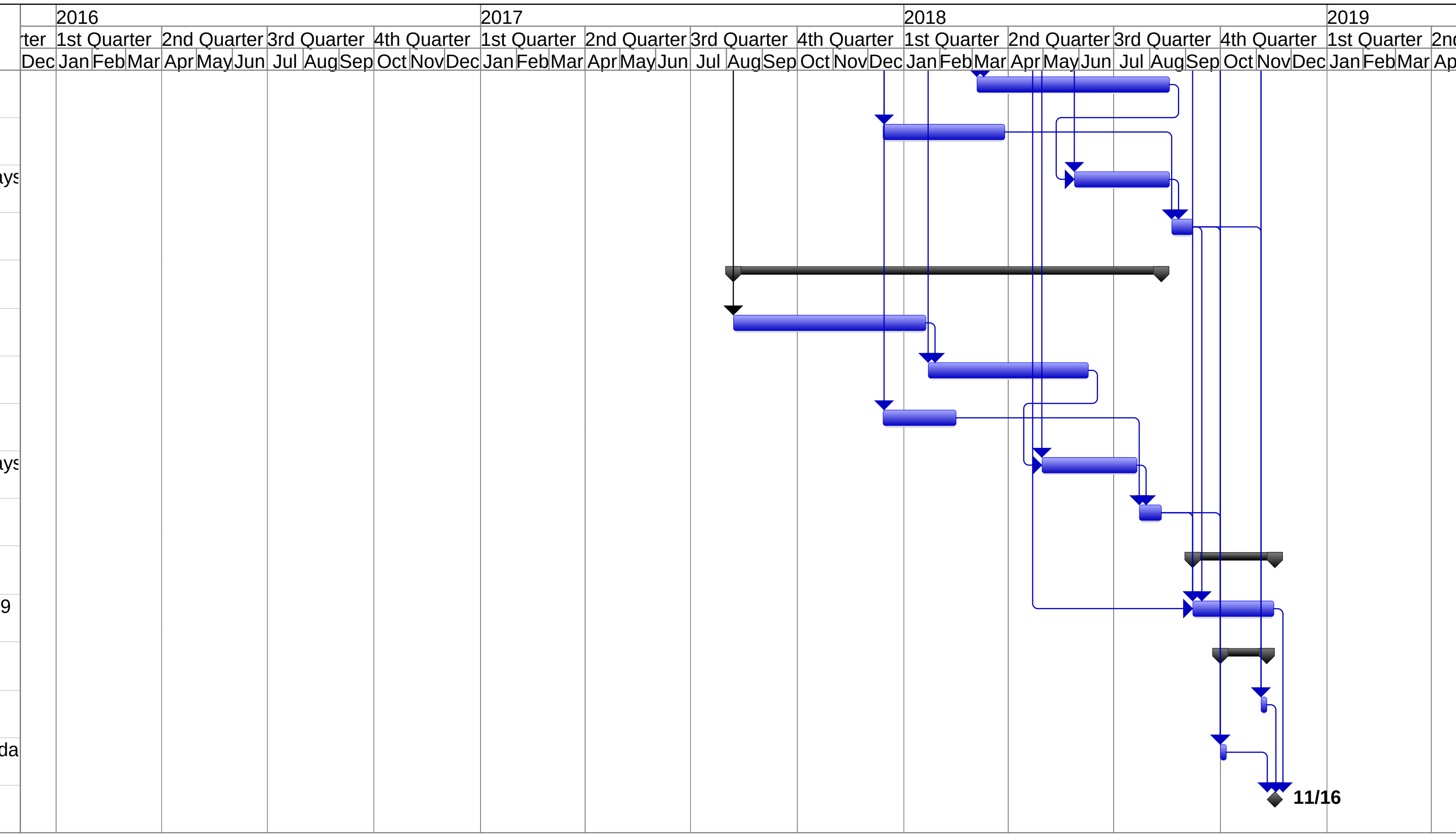


Project: EWT Construction Schedule V
Date: Mon 11/19/12

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Progress	
Split		External Tasks		Inactive Summary		Manual Summary		Deadline	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Figure 3

ID		WBS	Task Name	Duration	Start	Finish	Predecessors
110		7.2.2	Structural Work	120 days	Mon 3/5/18	Fri 8/17/18	18FS+5 days,109
111		7.2.3	Large Equipment	75 days	Thu 12/14/17	Wed 3/28/18	24FS+5 days
112		7.2.4	Sundry	60 days	Mon 5/28/18	Fri 8/17/18	30FS+5 days,110FS-60 days
113		7.2.5	Testing	14 days	Mon 8/20/18	Thu 9/6/18	112,111
114		**7.3**	**Lakehead TS**	**265 days**	**Mon 8/7/17**	**Fri 8/10/18**	
115		7.3.1	Site & Foundations	120 days	Mon 8/7/17	Fri 1/19/18	5FS+150 days
116		7.3.2	Structural Work	100 days	Mon 1/22/18	Fri 6/8/18	18FS+5 days,115
117		7.3.3	Large Equipment	45 days	Thu 12/14/17	Wed 2/14/18	24FS+5 days
118		7.3.4	Sundry	60 days	Mon 4/30/18	Fri 7/20/18	30FS+5 days,116FS-30 days
119		7.3.5	Testing	15 days	Mon 7/23/18	Fri 8/10/18	118,117
120		**8**	**CLOSEOUT**	**51 days**	**Fri 9/7/18**	**Fri 11/16/18**	
121		8.1	Punch List	50 days	Fri 9/7/18	Thu 11/15/18	92SS+60 days,107,113,119
122		**8.2**	**Testing**	**30 days**	**Mon 10/1/18**	**Fri 11/9/18**	
123		8.2.1	Wawa-Marathon	5 days	Mon 11/5/18	Fri 11/9/18	92FS+10 days,107,113
124		8.2.2	Marathon-Lakehead	5 days	Mon 10/1/18	Fri 10/5/18	96FS+10 days,100FS+10 da
125		8.3	In Service	1 day	Fri 11/16/18	Fri 11/16/18	121,123,124

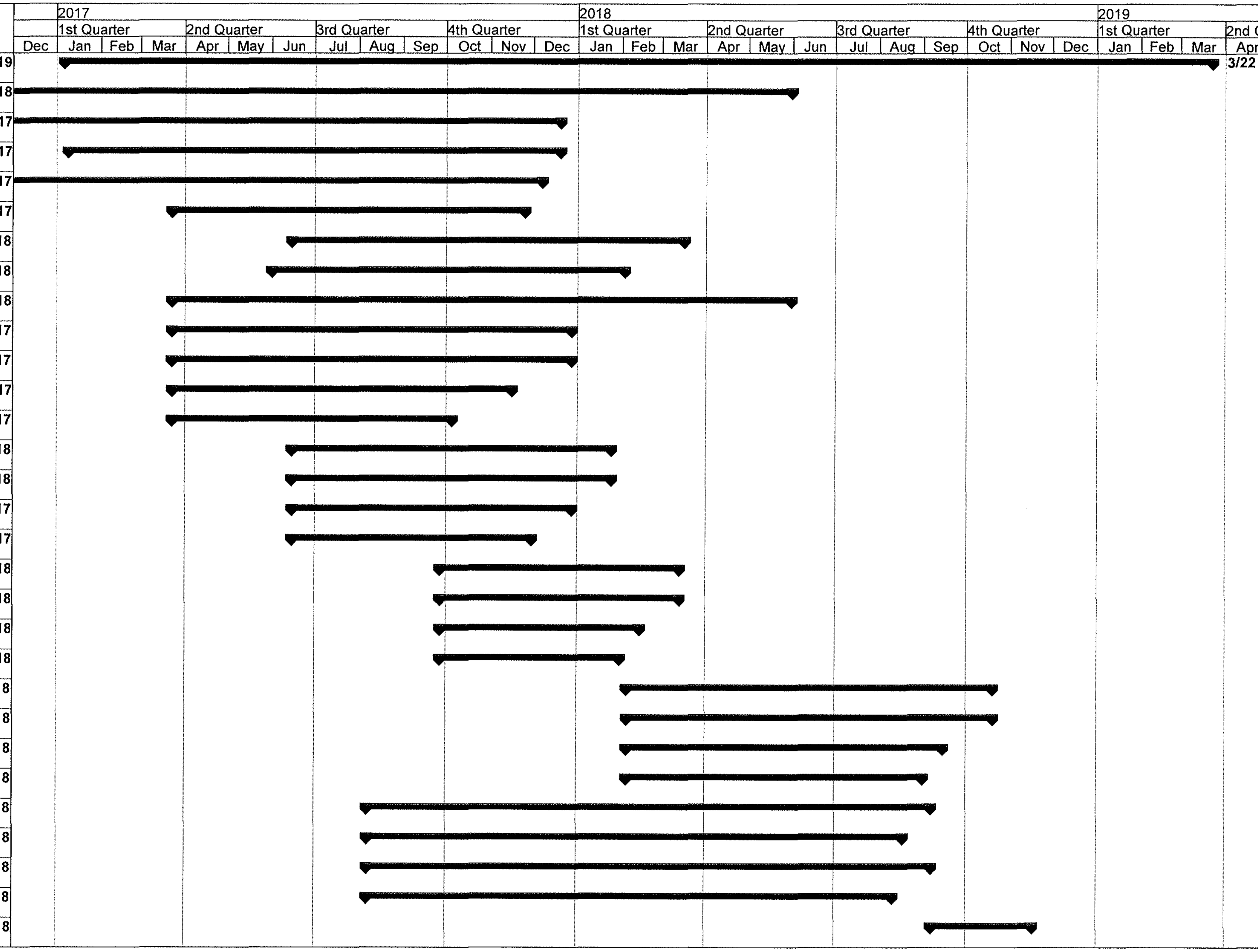


Project: EWT Construction Schedule V
Date: Mon 11/19/12

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
Progress	Deadline		

Figure 3

ID		WBS	Task Name	Duration	Start	Finish
1		1	CONSTRUCTION MANAGEMENT	576 days	Fri 1/6/17	Fri 3/22/19
6		2	PROCUREMENT	628 days	Mon 1/4/16	Wed 5/30/18
7		2.1	Towers	512 days	Mon 1/4/16	Tue 12/19/17
13		2.2	Station Steel	247 days	Mon 1/9/17	Tue 12/19/17
19		2.3	Major Station Equipment	503 days	Mon 1/4/16	Wed 12/6/17
25		2.4	Minor Station Equipment	177 days	Thu 3/23/17	Fri 11/24/17
31		2.5	Conductors and OHGW/OPGW	197 days	Thu 6/15/17	Fri 3/16/18
37		2.6	Insulators and Hardware	177 days	Thu 6/1/17	Fri 2/2/18
43		2.7	Sundry Items	310 days	Thu 3/23/17	Wed 5/30/18
49		3	CLEARING, ROADS and YARDS	200 days	Thu 3/23/17	Wed 12/27/17
50		3.1	Wawa-Marathon (180 km)	200 days	Thu 3/23/17	Wed 12/27/17
54		3.2	Marathon-Nipigon (140 km)	170 days	Thu 3/23/17	Wed 11/15/17
58		3.3	Nipigon-Lakehead (110 km)	140 days	Thu 3/23/17	Wed 10/4/17
62		4	FOUNDATIONS	160 days	Thu 6/15/17	Wed 1/24/18
63		4.1	Wawa-Marathon (180 km)	160 days	Thu 6/15/17	Wed 1/24/18
67		4.2	Marathon-Nipigon (140 km)	140 days	Thu 6/15/17	Wed 12/27/17
71		4.3	Nipigon-Lakehead (110 km)	120 days	Thu 6/15/17	Wed 11/29/17
75		5	TOWERS	120 days	Wed 9/27/17	Tue 3/13/18
76		5.1	Wawa-Marathon (180 km)	120 days	Wed 9/27/17	Tue 3/13/18
80		5.2	Marathon-Nipigon (140 km)	100 days	Wed 9/27/17	Tue 2/13/18
84		5.3	Nipigon-Lakehead (110 km)	90 days	Wed 9/27/17	Tue 1/30/18
88		6	CONDUCTORS, OHGW/OPGW	185 days	Mon 2/5/18	Fri 10/19/18
89		6.1	Wawa-Marathon (180 km)	185 days	Mon 2/5/18	Fri 10/19/18
93		6.2	Marathon-Nipigon (140 km)	160 days	Mon 2/5/18	Fri 9/14/18
97		6.3	Nipigon-Lakehead (110 km)	150 days	Mon 2/5/18	Fri 8/31/18
101		7	STATIONS	284 days	Mon 8/7/17	Thu 9/6/18
102		7.1	Wawa TS	270 days	Mon 8/7/17	Fri 8/17/18
108		7.2	Marathon TS	284 days	Mon 8/7/17	Thu 9/6/18
114		7.3	Lakehead TS	265 days	Mon 8/7/17	Fri 8/10/18
120		8	CLOSEOUT	51 days	Fri 9/7/18	Fri 11/16/18



Project: EWT Construction Schedule V
Date: Wed 11/14/12

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Progress	
Split		External Tasks		Inactive Summary		Manual Summary		Deadline	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Figure 4

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

Appendix 6B
Affidavit of Lloyd Andrew McPhee of EWT LP

EB-2011-0140

ONTARIO ENERGY BOARD

IN THE MATTER OF sections 70 and 78 of the *Ontario Energy Board Act, 1998*, S.O. 1998, c. 15, (Schedule B);

AND IN THE MATTER OF a Board-initiated proceeding to designate an electricity transmitter to undertake development work for a new electricity transmission line between Northeast and Northwest Ontario: the East-West Tie Line.

AFFIDAVIT OF LLOYD ANDREW MCPHEE

(sworn January 2, 2013)

AFFIDAVIT

I, LLOYD ANDREW MCPHEE, of the City of Sault Ste. Marie, in the Province of Ontario, MAKE OATH AND SAY:

1. I am the President of EWT LP, an entity licensed by the Ontario Energy Board (the "Board") to own and operate a transmission system. EWT LP's transmission license number is ET-2011-0350. EWT LP, a limited partnership formed under the laws of Ontario, will apply to be designated to develop the new East-West Tie Line (the "Project").

2. I have read the Board's Phase I Decision and Order dated July 12, 2012 (the "Phase I Decision") and the filing requirements for the East-West Tie Designation Process attached to the Phase I Decision as Appendix A. In particular, I have read Section 6.3 of the filing requirements which requires an affidavit from an officer of the licensed transmitter to confirm that:

   (a) "the line will be designed to meet or exceed the existing NERC, NPCC and IESO reliability standards"; and

   (b) "the line will be designed to meet or exceed the Board's Minimum Technical Requirements; or documentation of where the applicant seeks to differ from the Minimum Technical Requirements[1] and evidence as to the equivalence or superiority of the proposed alternative option."

3. I have also reviewed Section 6 of the evidence of EWT LP to be filed with EWT LP's application on January 4, 2013 and the related appendices.

[1] Ontario Energy Board, Minimum Technical Requirements for the Reference Option of the East-West Tie dated November 9, 2011.

4. I hereby confirm that EWT LP will (i) design the Project to meet or exceed the existing NERC, NPCC and IESO reliability standards; and (ii) design the Project to meet or exceed the Board's Minimum Technical Requirements, as applicable, and where the design differs from the Minimum Technical Requirements, provide evidence as to the equivalence or superiority of the proposed alternative option when the applicable design is completed and at a time when the said evidence is required to be filed with the Board.

5. I make this affidavit in support of EWT LP in the Board's proceeding to designate an electricity transmitter to undertake development work for a new East-West Tie Line.

SWORN BEFORE ME at the City of Toronto, in the Province of Ontario this 2nd day of January, 2013	
Commissioner for Taking Affidavits *(or as may be)*	LLOYD ANDREW MCPHEE

Frazer Keegan Maynard House,
a Commissioner, etc., Province of
Ontario, while a Student-at-Law.
Expires August 20, 2015.

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

Appendix 6C
Detailed Engineering Methodology for Refining the East-West Tie Line Design

Appendix 6C - Detailed Engineering and Design Methodology for Refining the East-West Tie Line Design

1. Design Activities

The design of the new East-West Tie has two basic components: (i) the electrical design of the line from a systems perspective that considers the impact of the new line on the quality, reliability and availability of electricity supplies; and (ii) the physical design of the line in terms of the mechanical and electrical elements of the towers, the foundations, the conductors, the insulators and the associated fittings.

EWT LP has assumed that Hydro One Networks Inc. will be responsible for the design and implementation of the protection and telecommunication systems for the new line given that the associated switchgear, instrument transformers, relays and SCADA equipment will be located in Hydro One Network Inc.'s existing facilities.

The purpose of the design activities is to determine the basic electrical parameters for the new line in terms of:

- Number of circuits
- Points of interconnection
- Operating voltage
- Capacity (normal / emergency)
- Availability / reliability
- Fault rating
- Electrical properties e.g. impedance, resistance (losses) etc.

The basic electrical parameters are used as the basis for generating alternative line configurations (including type of structure, structure materials, structure heights, structure spacing, right of widths, etc.) which are then evaluated in the joint routing and environmental assessment process.

Both the Ontario Power Authority and the Independent Electricity System Operator have previously completed basic design studies and concluded that the development of a new East-

West Tie transmission line is appropriate. EWT LP is mindful that the Independent Electricity System Operator's report was completed on August 18th 2011, some two years prior to when it expects a transmitter to be designated in order to develop the East-West Tie, and that the onus is on the transmitters to justify the need for the new line in its future application for leave to construct[1]. EWT LP therefore plans to work with the Ontario Power Authority and Independent System Operator to review and update their previous studies and confirm that the need for the new line still exists before incurring considerable development costs.

Power Engineers Inc. will perform the required system studies on EWT LP's behalf using the PSS/E™ suite of software programs developed by Siemens. This software is widely used throughout the transmission industry. The studies to be performed and the associated criteria are described by the Independent Electricity System Operator in a document titled *Ontario Resource and Transmission Assessment Criteria*[2]. The applicable North American Electric Reliability Corporation ("NERC") and North East Power Coordinating Council ("NPCC") standards and criteria are incorporated in to this document.

Power Engineers Inc. has a dedicated department of 40 staff members to perform power system studies for transmitters, distribution, generators and major industrial customers across North America. Power Engineers Inc. is familiar with NERC and NPCC standards, is a member of the Western Electricity Coordinating Council and participates in NPCC technical meetings.

EWT LP does not expect to encounter any specific issues in undertaking these routine studies. The Independent Electricity System Operator is understood to maintain a high quality model of Ontario's electric power system in an appropriate format, and the proposed new line does not incorporate any new technologies such as HVDC VSC that have not previously been used by Power Engineers Inc. and others both in Ontario and across North America.

After extensive study and public consultation, the Ontario Power Authority has eliminated generation and other non-transmission alternatives to the undertaking. Furthermore, the Ontario Power Authority has determined that a conventional alternating current overhead transmission

[1] Section 4.3, Filing Requirements for Electricity transmission and Distribution Applications, Ontario Energy Board, June 28, 2012

[2] Ontario Resource and Transmission Assessment Criteria, Issues 5.0 August 22, 2007, IESO

line is the preferred undertaking. Similarly, EWT LP, as an electricity transmitter eliminated three other transmission alternatives as described below after some consideration, and concluded that a conventional alternating current overhead line is the only cost effective and technically practical alternative for this undertaking. EWT LP therefore proposes to limit its consideration of Alternatives to the Undertaking to alternative designs of overhead transmission lines e.g. foundation designs, tower designs, tower heights, tower spacing, visual appearance etc.

The transmission alternatives that were dismissed are as follows:

- Conventional alternating current underground cables: This alternative can be eliminated on the basis of technical feasibility. High voltage alternating current underground cables are not technically feasible for a 400 km transmission line because the charging currents would exceed the thermal rating of the cable. The installation of reactive compensation to provide the charging current would be very expensive and would make the cable difficult to operate, especially as part of an integrated power system.

- HVDC underground cables: This alternative can be eliminated on the basis of cost. The use of high voltage direct current technology mitigates charging currents that prevents the use of underground cables. However, the cost of the converter stations required at either end of the cable to connect to the existing system, plus the cost of installing underground cables in a very rocky terrain, makes this option uneconomical. EWT LP estimates that an HVDC underground cable alternative would cost in the order of $1 billion compared to the Ontario Power Authority's estimate of $600m for a conventional overhead line.

- HVDC underwater cable across Lake Superior: This alternative can be eliminated on the basis of cost. Laying the cables across Lake Superior rather than on land reduces the length of the line by approximately 40 km and avoids the cost of digging through rock. However, the reduced installation cost is offset in part by the incremental cost of submarine cables as compared to terrestrial cables. In addition, this alternative gives rise to technical difficulties due to the challenge of laying cables in such a deep lake (in excess of 400m) and because only certain sized vessels are able to enter the St. Lawrence Seaway.

- HVDC overhead line: This alternative can be eliminated on the basis of cost. Although this overhead line would be cheaper than an equivalent overhead line of similar capacity (in part because there are only two rather than three conductors for HVDC operation) any potential savings is eliminated by the high cost of the converter stations required to connect the new line to the existing system. Also, while an HVDC line could technically provide superior operating performance and has been commercially available for over 50 years, in practice it would be difficult to implement because Ontario has very limited experience with its installation and operation.

2. <u>Engineering Activities</u>

The Board's filing guidelines for applications for leave to construct required the transmitter to demonstrate that it has evaluated alternative options and that the proposed alternative is on balance the best in terms of risk, cost, timeliness and technical performance.

EWT LP will perform the following studies:

- System studies to understand and quantify the impact of a project solution on the region's transmission network:
    - Power flow under normal and contingency conditions
    - Application of relevant prescriptive reliability rules under normal and contingency cases
    - Reactive power requirements under normal and contingency conditions (steady state only). May include fixed series capacitors, mechanically switched shunt reactors and capacitors, and SVCs or STATCOMs
- Transmission line studies to understand and quantify the impact of the transmission line design alternatives on the project's value:
    - Review of existing system outages and the impact of existing system performance on the new line design
    - Line impedance comparisons for different circuit and conductor/bundling configurations to provide input to system studies
- Preliminary lightning performance analysis to establish tower grounding and insulation requirements and to determine if design should include the option of using line surge arrestors in areas of very high soil resistivity
- The following station /connection studies to understand and quantify the impact of station interconnections and electrical option layouts on the project's value:
- Review of substation configurations for each of the alternatives considered
- Screening level cost estimates and impact upon reliability/maintainability of different configurations

The rationale for considering each alternative solution will be provided. As well, the relative benefits and weaknesses of each will be described and, where reasonably possible, quantified. An Alternative Solutions Report will be prepared to report on the preferred solution for the EWT project. The preferred alternative will be described in technical terms as much as available data allows. This description will include the nature and general 'look' of the design on the ground, its general impact on the surroundings, probable and possible construction methods, construction duration, and maintenance requirements, etc.

3. Engineering Studies

EWT LP will perform electrical studies work to design the line and support the EPC specification. These studies will establish minimum design parameters for the EPC specification. The studies to be performed are listed below.

- Transmission line design studies:
    - Insulation coordination including lightning performance, steady state power frequency performance, time domain analysis and statistical insulation performance to determine switching surge performance. The study will also include the impact of fault clearing on nearby lines if fixed series capacitors are to be installed. This study results in minimum shielding angles, minimum tower footing resistance, minimum insulator length and creepage distance, minimum clearances to tower, and minimum phase spacing to meet electrical performance requirements.
    - Minimum code clearances studies to determine minimum clearances to the structure, ground, and between phases required by applicable codes. It will include 5 mA calculations for ground clearance and minimum approach distances for live line maintenance based upon applicable codes.
    - Preliminary grounding design studies to establish tower grounding system design concepts and the practicality of achieving low enough tower footing resistances in expected soils. If this course of action is impractical, the study will include guidelines for the use of surge arrestors at towers to meet lightning performance criteria.
    - Optical ground wire (OPGW) and shield wire studies to establish minimum thermal (kA^2-sec) ratings for optical ground and economic loss analysis (NPV) studies to determine the economic benefit of insulating and sectionalizing the OPGW and shield wires. Number and specification of optical fibers will be included, along with the appropriate distance between regeneration stations. Mechanical and splicing details will be developed in other subtasks.
    - Economic conductor studies to establish the conductor/bundling that is predicted to provide the lowest total cost over the lifetime of the line. This will be based upon anticipated power flows on the line under normal system configuration. The analysis will consist of NPV calculations using screening level cost differences between alternatives and economic factors (study period, interest rates, cost of

energy, cost of demand, escalation rates) agreed upon with Brookfield and if appropriate, with other parties. As well, this will include selected sensitivity cases.

- EMF and audible noise calculation studies for the selected line design for predominant structure types and the most challenging situations, typically the most commonly used tangent structure at midspan.

- If required, perform pre-construction measurements of EMF (if existing lines are nearby) and post-construction measurements of EMF and RFI (radio frequency interference).

- If required, AC interference to determine voltages and currents coupled to nearby parallel linear facilities such as railroads or pipelines. It will be determined whether coupled voltage and current levels are high enough to determine mitigations to lower coupled voltages and currents to acceptable levels.

- Substation and reactive power compensation design studies:

  - If fixed series capacitors are required, develop basic electrical and environmental parameters for use in the EPC specification. This will include preliminary time domain calculations to establish series capacitor protective MOV ratings. IEEE and industry guide form specifications will be used to establish the parameters required. As well, it will include functional requirements and specific design requirements, including single line diagrams, for inclusion in the EPC specification. Lastly, it will include SSR (subsynchronous resonance) and any other studies needed to tune fixed series capacitor and/or generation performance in the EPC specification.

  - Prepare basic electrical and environmental parameters for fixed switched shunt reactors (if needed) and capacitors for inclusion in the EPC specification.

  - In costing its plan, EWT LP has assumed that the above studies will only be performed for the line alternative to be included in the EPC specification and that any substation work performed by EWT LP will follow existing Hydro One Network Inc. insulation and clearance standards. Circuit breaker TRV (transient recovery voltage) studies will be responsibility of EPC contractor.

4. <u>Remaining Design Work</u>

EWT LP will complete 80% of the design exercise for the new line between Wawa TS, Marathon TS and Lakehead TS. The engineering will stop short of selecting foundation types at each structure. A decision on foundation types will be left to the contractor during construction.

The following is the design work to be completed:

- Line Layout – The natural roughness of an alignment can direct the design to an efficient average span. Review the alignment for such roughness to recognize such guidance. Select design spans (wind and weight minimums and maximums) for all members of the desired structure family. Construct a set of structures in PLS-CADD for spotting the line. Target long spans to minimize sites requiring access. Use the environmental and land use mapping to identify exclusion and higher cost lengths of line. Complete the PLS-CADD design criteria file. Apply installed cost values to structures with supplemental values for high cost zones. Automatically spot the line and review clean up the computer's decisions. The structure design/spotting process may be iterative.

- Review the layout for compliance with anti-cascade measures and unbalanced tension creation near rising, long spans. Prepare to field review selected locations. Expect and identify locations that may require unique structure designs (long spans, tightly spaced proximities to other facilities).

- Electrical Design – Ensure that electrical clearance requirements are met with a safe buffer consistent with the accuracy of the input data for the design and expected construction accuracies. Ensure the insulation is adequate. Address the line's grounding capabilities for lightning and short circuit events. Ensure the outage rate is designed for the required minimum. Confirm that electric effects (EMF, corona and noises) are held to acceptable levels as per the criteria.

- Permitting & Landowner Constraints – Pay close attention to landowner requests and requirements that derive from the landowner negotiations. Ensure that the environmental mitigation requirements are met by the design and that construction requirements dictated by the design allow construction permitting compliance.

- ROW Design and Structure Spotting – Review the ROW width adequacy against the clearance and electrical criteria. Review the tower spotting with the short-listed contractors for their comments on access and constructability. This may require joint visits to the site to review critical locations.

- Materials and Structures – As the tower spotting approaches an accepted layout, develop the structure lists and material lists suitable for procurement, pricing and construction package use.

- Provide the detailed performance drawings for all structure types suitable for bidding, and detailed design by a selected vendor. Couple these drawings with the design, fabrication and supply specifications suitable for structure procurement. Expect world-wide interest and competition for fabricators' time from other major projects to coordinate the scheduling of his work.

- Foundations – develop a family of foundation types for the structures that can accommodate the wide range of expected soil conditions. Consider the attraction for foundation designs that are relatively immune to subsurface conditions (applicable regardless). Consider application with poor access, winter conditions, and short notice. Consider protection against corrosive soils. Set up the foundation family for use by the contractor to select a design on short notice during the construction period. Write the installation specification and design the foundations such that the contractor can successfully be responsible for the foundations strength by making material decisions in the field without needing to change his plan after commencing installation.

- Access Roads – In concert with structure spotting and foundation design development, review and fine tune as needed the access road plan for every tower site. Document the intended route to every tower complying with the environmental and landowner constraints. Design the width, turning radius, load capacity and slopes for access road commensurate with the expected and required equipment and material movements. Delineate the road design parameters for use by their construction contractor. Consider the cost-effective availability of road materials and the contractor's operating rules (single lane, closures, seasonal limits, etc.)

- Recognize the need for helicopter movement people, equipment and materials as access road constraints tighten or get expensive. Ensure that the design of structures and foundations can accommodate helicopter construction if such occurs. Include landing site design for helicopters at tower sites and staging yards accordingly.

- Construction Practices Criteria – review the overall design features of the installations and installation methods with the short-listed bidding contractors. Agree that the design is compliant with the contractor's practices and rules for construction and that they offer a cost effective solution for the project.

EWT LP expects, but has yet to confirm, that given the length of the line and the need for over 1,000 structures, it is likely going to be the most cost effective for ratepayers to develop a new family of towers or import and repurpose an existing modern family of towers from another jurisdiction.

EWT LP estimates that the detailed design of the line will take just over four months to complete. However this schedule is predicated on having finalised the route with stakeholders, First Nations and Métis communities, and land owners, and having completed an aerial LiDAR survey of the entire route which is budgeted to cost $250,000. Without having completed these steps, any proposed design for the East-West Tie submitted as part of an application for designation is merely conceptual and may not be realizable.

EWT LP will also negotiate an interconnection agreement with Hydro One Networks Inc. and, if necessary, Great Lakes Power Transmission LP, as set out in the Transmission System Code. The agreement will describe the facilities connecting the two transmission systems and set out the respective obligations of the parties in relation to:

- transmission system expansion and associated cost responsibilities;
- operational requirements and authorities;
- protections;
- emergency preparedness and emergency operations;
- outage co-ordination;
- forced outages;
- new or modified transmission facilities;
- the information to be exchanged between the parties;
- the protection of confidential information;
- a dispute resolution process that provides for the fair, timely and effective resolution of disputes and that sets out specific timelines for completion of the dispute resolution process; and
- such other provisions as may be required to enable a transmitter to comply with its obligations under the Transmission System Code relative to neighboring Ontario transmitters and to the reliability and integrity of its transmission system.

PART B
PLAN FOR THE EAST-WEST TIE LINE

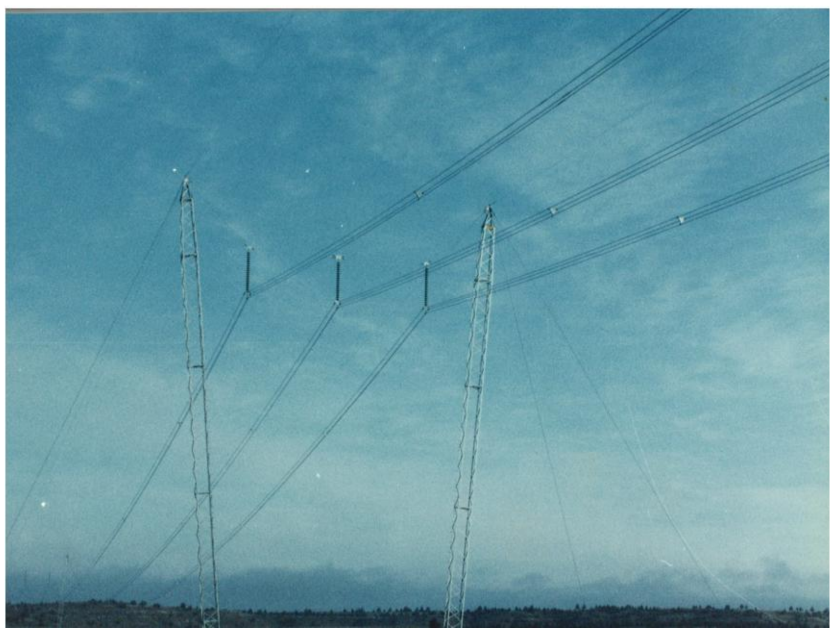
EXHIBIT 6
PROPOSED DESIGN

Appendix 6D
CRS Report

December 17, 2012

EAST WEST TIE EXPANSION

Assessment of the Use of CRS Structures on HV/EHV Transmission Lines



BPA: 500 kV CRS Towers in Oregon

PROJECT NUMBER:
121672
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POWER ENGINEERS

Assessment of the Use of CRS Structures on HV/EHV Transmission Lines

PREPARED FOR: *EWT LP*

PREPARED BY: *PETER CATCHPOLE*
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DATE	REVISED BY	REVISION	DOCUMENT NAME
11/20/12	P. Catchpole	A	Benefits and Concerns with the Use of CRS Structures on HV/EHV Transmission Lines – for review
12/12/12	P. Catchpole	B	Benefits and Concerns with the Use of CRS Structures on HV/EHV Transmission Lines – final
12/17/12	P. Catchpole	C	Benefits and Concerns with the Use of CRS Structures on HV/EHV Transmission Lines – final

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Executive Summary

POWER Engineers (POWER), as EWT LP's Engineer for the East-West Tie (EWT) transmission line project is very pleased to submit this report which assesses the use of the Cross-rope suspension (CRS) or Chainette tower type for the project. This structure type has a history of successful employment on four continents, including North America (both USA and Canada) going back more than 30 years. The "Chainette" or "Cross-rope" design that we suggest will lead to capital savings and structural integrity improvements for the facility for Ontario ratepayers in excess of any structural alternative available within the industry.

It also offers very large environmental impact improvements. We consider it to be our responsibility as engineers to describe these benefits to the OEB at this early stage in the project's development so they can consider pursuit of the idea and take advantage of the design's features and capabilities. The CRS design is a guyed tower and therefore limited practically to single circuit use. Part of our assessment for its use includes study of a single circuit solution to reveal its acceptability for the EWT project. We suggest that the cost savings with the CRS design option as a single circuit solution are large enough at more than $100M to warrant serious consideration.

Every study conducted by POWER over the last 20 years that compares structure types for HV or EHV transmission line application points to significant capital cost savings when a guyed tower type is compared to a self-supported type. The particular design we discuss offers large savings and also maximizes structural integrity improvements, visual and ground disturbance improvements.

It is essential to understand the concerns that typically come to mind when it comes to contemplating guyed transmission line structures. This report addresses and identifies mitigating factors for all of the concerns that we anticipate so that the selection of this guyed tower type can be made with full knowledge of its history and nature. We are confident that the tower type has no inherent features that should qualify it for dismissal from use on the EWT project. It is the opinion of POWER Engineers that these significant savings alone are grounds for exploring the choice in detail.

This report will describe our understanding of the benefits – the obviously positive attributes of a particular type of guyed tower. It will discuss the methods for dealing with the design's unique features, and it will discuss means of mitigating the typically recognized concerns with the design.

The primary feature of any guyed tower design is that it is most likely, and most rationally a single circuit design. Thus, the use of a CRS design requires that the EWT project use a single circuit solution in lieu of the presumed double circuit solution. Once a single circuit solution is deemed acceptable, we do not consider a guyed-V tower type or any other guyed tower option in this report, because all guyed tower options fall short of the CRS' benefits. Thus, our comparisons are to the Board's Reference Option design with the HONI X10 tower type. That reference design option is fully addressed in our companion report, "Engineer's Report on the EWT Transmission Line OEB Reference Option."

The Reference Design Option is a double circuit latticed tower based on the HONI (Ontario Hydro) X10 family. Our companion report, "Engineer's Report on the EWT Transmission Line OEB Reference Option" discusses a constraint applicable to any double circuit tower design. This constraint is the required single loop galloping requirement that forces either inordinately large vertical framing dimensions at the top of a double circuit tower or costly short design spans. Either way, this constraint results in the reference option having a significantly higher capital cost for potentially insufficient reliability gains viz-a-vis the single circuit CRS design.

Our intention with these two reports is to provide the Ontario Energy Board staff with enough information to make an informed choice for the EWT project. The topics in this report are gathered under three major headings:

- EWT LP Proposed Structure Type – CRS
    - CRS (Chainette) Single Circuit Option
    - Worldwide Experience with CRS Towers
    - Single Circuit Solution
- CRS Features Comparison & Concern Mitigations
    - Comparable Dimensions
    - Structural Weight
    - Structural Integrity
    - Foundations
    - CRS Tower Erection Methods
    - ROW Requirements
    - Installed Footprint & Working Space
    - Construction Disturbance
    - Avian Interaction
    - Visual Impact
    - Electrical Characteristics
    - Maintenance
    - Electrical Characteristics – Conductor Choice
- Application of the CRS Design in Northern Ontario
- Compliance with the EWT Minimum Technical Requirements
- System Impacts of a CRS Single Circuit
- EWT Construction Cost Estimate with Proposed CRS Option
    - Capital
    - Cost Comparison Summary
- Construction Schedule

The cost estimate for the CRS option is $281M compared to our estimate of $395M for the reference option. This $114M savings is in part due to the galloping constraint that does not impact the single circuit, CRS design but requires shorter spans or unique tower designs that increase the capital cost of the reference option. If the galloping constrain is relaxed, as discussed in the companion report, the reference option cost will drop considerably but will not come close to matching CRS option cost. We understand that EWT LP has proposed to consider the single circuit alternative in greater detail during the development phase.

To complete the cost advantage picture, we include a cost estimate for a single circuit, self-supported (unguyed) design option based on the HONI W1 tower family. The cost estimate for this option at $319M shows savings over double circuit options but more importantly, illustrates the value of guyed structures by being $38M more expensive than a guyed (CRS) design option. We understand that EWT LP has proposed to consider the single circuit alternative using W1 towers in greater detail during the development phase.

EWT LP Proposed Structure Type - CRS

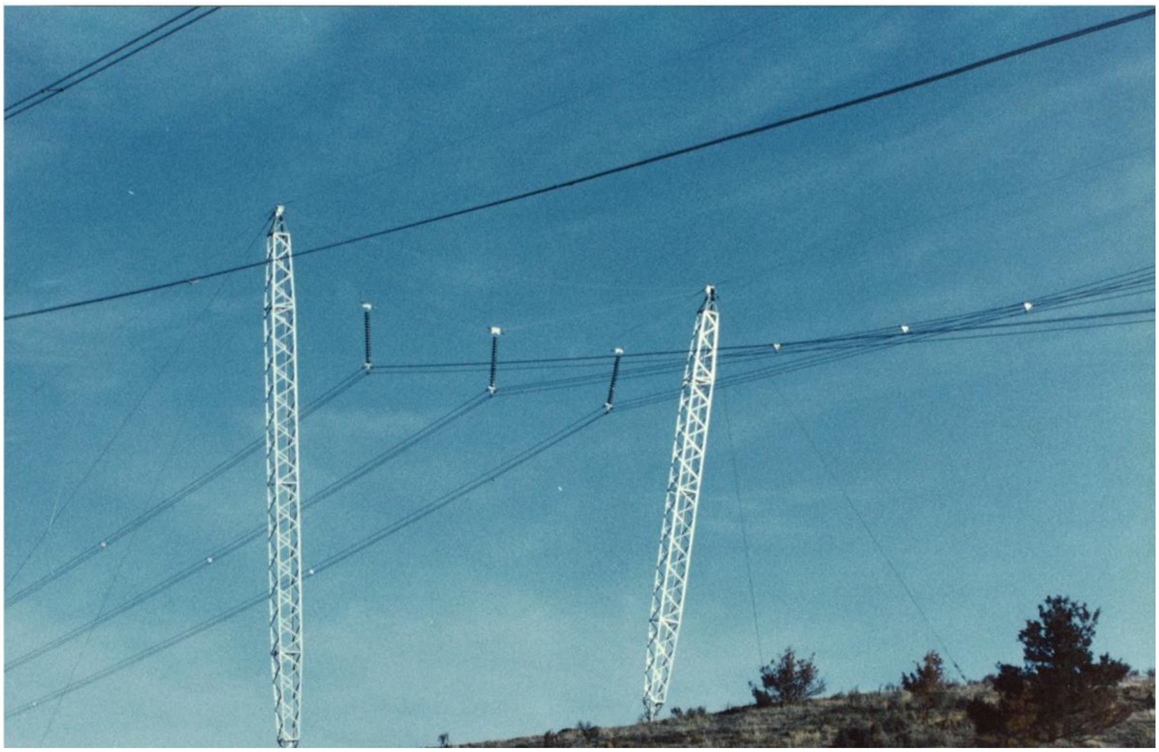
CRS (Chainette) Single Circuit Option

This report is aimed at describing the benefits of the CRS (Cross-Rope Suspension or Chainette) tower design for the EWT project. There are various guyed tower configurations within the industry but, as discussed below, the CRS maximizes all of the benefits that any guyed tower design trends towards. The photo of the BPA version below illustrates the style.

We understand that EWT LP has proposed to consider the CRS tower in the development of the EWT project because it provides a long list of well understood benefits for the project and the Ontario Ratepayers. These are discussed in detail below. The list of benefits falls under the following headings:

1. Construction cost reduction
2. Operating cost reduction
3. Low maintenance
4. Structural integrity improvement
5. Visual impact reduction
6. Minimal avian impact
7. Ground disturbance reduction for construction
8. Right-of-way width reduction
9. Supports sustainability goals

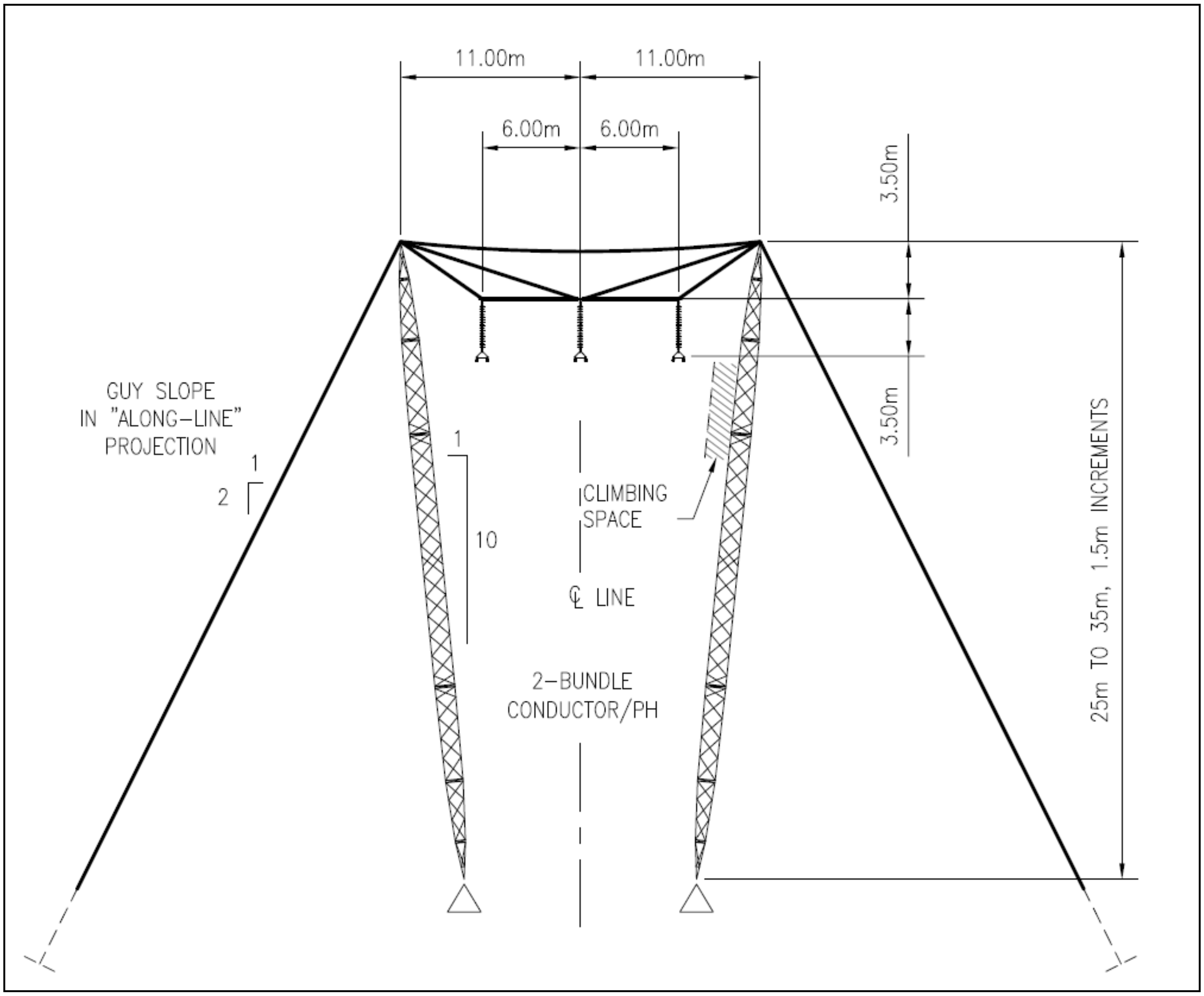
The CRS design, despite its long history of use on North America, often also raises concerns because it is still new to many people and despite the long list of tangible benefits. Once understood – as we will try to achieve in this report, the primary point of concern is maintenance methods. This concern is addressed in Ref 2.



BPA CRS Tower carrying a light angle

The genesis of the CRS structure is well described in Ref 3, a paper presented at the 2002 ASCE Transmission Line Design Conference held in Omaha, NE. The first application of the tower design was with Hydro Quebec in the 1970s as described in Ref 1. Hydro Quebec refers to the design as the Chainette (cable) tower. The CRS can be understood as a Guyed-V design with the latticed steel, truss bridge removed and replaced with a cable system to support the conductors. The two masts are separated from a common foundation in order to position all phases between the masts. The absence of the bridge is the source of the very light weight of the design and the absence of support steel of a tower body or mast as typically placed between two phases in other designs allows the much closer phase spacing for electrical advantage.

CRS towers are employed across the globe at voltages between 735 kV (Hydro Quebec) and 400 kV (ESKOM, South Africa). The proposal for the EWT project is to dimension the design for 230 kV; however, for a very small increase in cost, a 500 kV framing can be used opening the door for an easy transition of the facility to 500 kV in the distant future, if desired. The EWT 230 kV version of the design is shown in the figure below.



230 kV CRS Design for the EWT Project

Worldwide Experience with CRS Towers

The following organizations/countries have CRS structure transmission line installations at voltages ranging from 400 kV to 735 kV. We are not aware of any negative concerns from any of these organizations. We have spoken to BPA (Len Custer) and ESKOM (Rob Stephens). We know both men well and both express great satisfaction with their CRS installations.

- HQ, Quebec, Canada 1970s. 735 kV, 1250 miles. See Ref 1
- BPA, Oregon, USA 1980s, 500 kV 37 miles. See Ref 2
- Transener, Argentina 1998-1999 500 kV 800 miles. See Ref 3.
- ESKOM, South Africa 2000+ 400 kV several lines. See Ref 5.
- Sweden 1988 400 kV unknown distance. See Ref 3
- Brazil, 2001, 500 kV 1,600 miles. See Ref 4.

Reference 3 provides a description of the genesis of the tower design by its creator, Brian White of Canada. References 1 through 5 all provide detailed descriptions of some of the points made below regarding the CRS design features and characteristics when compared to alternative designs available to the various authors.

Senior design staff at POWER Engineers was involved in the CRS projects in Argentina and South Africa. We have considerable experience with CRS engineering.

Single Circuit Solution

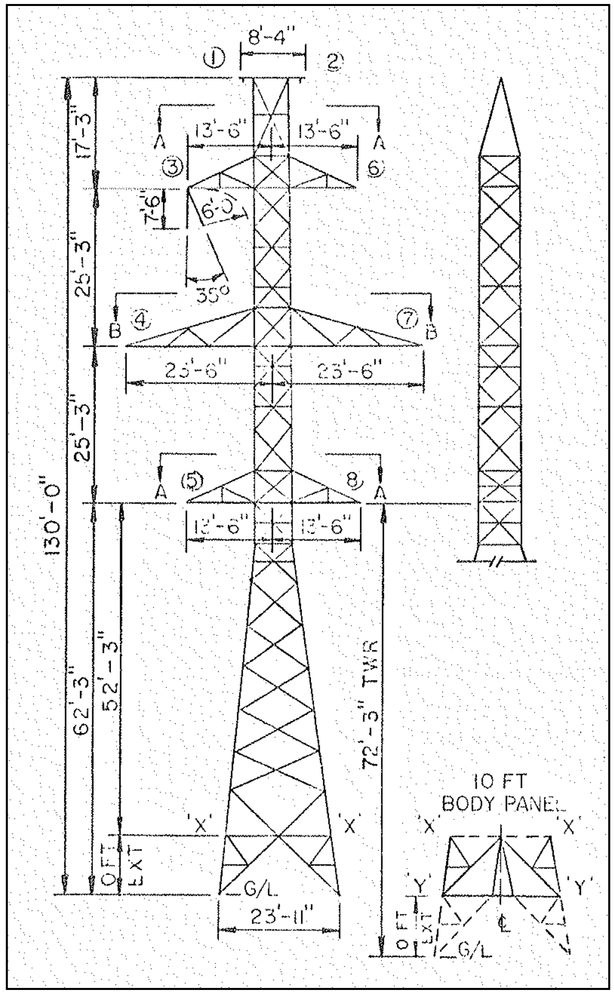
The primary reason for proposing the CRS tower design is cost savings. In unpopulated areas, the opportunity to use guyed tower designs becomes realistic. Numerous studies show that guyed transmission tower designs are less expensive to install than self-supported designs. The reason that guyed tower designs are less expensive to install is two-fold; 1) they are generally lighter in weight and installation costs are closely tied to the structures' weight and 2) foundations are simplified to a set of tension-only guy anchors and compression-only pins under the mast(s). The cost savings associated with these two points amplify as the line location becomes more remote (access costs rising) and the subsurface ground conditions become complex (Canadian Shield). The EWT project is a prime candidate for taking advantage of these cost savings with guyed structures.

However, all rational guyed structure designs for HV transmission lines are applicable only to single circuits. Therefore, EWT LP has reviewed to the extent possible in the time available and with the information available, the sensibility of a single circuit solution for the EWT project. This review and our opinion supporting the validity of the single circuit solution are presented in this report. This decision gives access to the best-in-the-business cost savings available with the CRS design.

CRS Features Comparison & Concern Mitigations

The CRS design is best understood when compared to alternatives. This section of the report compares the features of the CRS to the Board's reference option structure for the EWT project using the Ontario Hydro X10 family of towers. When useful, other tower designs are mentioned for context. Following sections of the report offer sustainability benefits of the CRS design and cost differences with the X10 designs. To understand the EWT LP reference option and to have a good understanding of values pulled from that option, please reference our companion report, "Engineer's Report on the EWT Transmission Line OEB Reference Option."

Comparable Dimensions



The OH X10S tower dimensions

The middle phases of the X10 tower are 47 ft apart and bottom phases attachment points are 68 ft below the top of the tower (shield wire positions). The phase spacing on the CRS is reduced to about 6 m (20 ft) with a flat arrangement, allowed by the absence of a steel mast between the phases. The out-to-out phase dimension of the CRS is 40 ft compared to 47 ft for the X10 design. This translates into narrower right-of-way purchasing and clearing requirements for the CRS tower for equal spans.

All three phases of the CRS attach 3.5 m (11.5 ft) below the top of the masts (shield wire positions at the top of the masts). The tower height of the CRS design that allows an equal span capability with a common conductor choice and design tension is 17 m (56.5 ft) shorter than the X10 design.

For example, a 98 ft CRS design has the equivalent span capability of the 155 ft X10 design. This offers a greatly reduced visual impact and eases construction access effort up the structure or it allows longer spans for a comparable height of tower. The more tightly spaced phases lower the circuit's impedance. These points are discussed in more detail below.

We note in the reference option report that the single loop galloping constraint imposed by the reference option's minimum technical requirements effectively renders all double tower designs like the X10 non-competitive on cost. In that report, we suggest a review of that single loop galloping criteria to dampen this handicap to the double circuit design. However, if it is found that there is some merit to the constraint and we point out that the CRS design accommodates the single loop galloping by the flat arrangement of phases. The presumed width of a galloping ellipse of 12 m in height is 40% of the height: ie 4.8 m. The space between the single loop galloping ellipses on the proposed CRS tower is 1 m. Thus, the flat phase configuration of the CRS towers presents no constraint to the design spans for the CRS design and allows retention of the single loop galloping requirement.

Structure Weight

We note in our companion report on the EWT Reference Option that employs the X10 tower with "Grackle" conductors and an estimated 300 m wind span design, our estimate of the weight of the 135 ft X10S tower is 5,900 kg (13,000 lbs).

The target design wind span for the CRS is 488 m (1,600 ft) comparable to the existing X7 towers. We anticipate a design sag for the conductors of 21 m. Considering ground clearance of 8.0 m and an insulator length of 2.5 m, the 'flat ground' CRS mast height to compare to the 135 ft, 5,900 kg X10 tower used at 90% of the design span (270 m) is 35 m (115 ft). The 35 m CRS tower weight estimate is 5,260 kg (11,600 lbs) employed on [90% of 488 m] 440 spans. The compared weight of structural support steel along the line becomes:

- 21,850 kg/km for the X10 reference option
- 11,950 kg/km for the proposed CRS design (54% of the reference design option)

This structural weight reduction to near half would be comparable against any type of four-legged, self-supported tower design. The fundamental reason for the reduction is the change to a guyed tower design. The CRS design maximizes the difference due to the replacement of the structure's bridge with a cable system. A cost estimate for a self-supported tower design based on the HONI W1 tower family was executed with comparable input. The basic difference between the two cost estimates (W1 vs. CRS) is based on the estimated W1 tower weights at 7,500 kg on 440 m spans (17,045 kg/km.).

TABLE 1	**CRS Weight Estimates (lbs)**						
	Mast Length (ft)						
	90	100	110	120	130	140	150
Component	Weights (mast, mast, cables)						
Mast	4,100	4,550	5010	5,030	5,920	6,380	6,830
Mast	4,100	4,550	5010	5,030	5,920	6,380	6,830
Cables and Guys	1,380	1,445	1,510	1,575	1,640	1,705	1,770
	9,580	10,545	11,530	11,635	13,480	14,465	15,430

Structural Integrity

The CRS design takes full advantage of three structural principles:

1. The most efficient structural member in tension is a cable
2. The most efficient structural member in compression is a latticed mast
3. The most expensive use of a structural member is in bending

The two masts of the CRS are pinned at the bottom end and supported by guys only at the top where the cables supporting the conductors are also attached and where the shield wires attach. All loads onto the two masts from the conductor system are only compression forces. There are no bending forces applied to the masts by any intact or unbalanced load cases. Only gravity, due to their slight inclined positions and wind blowing on the masts themselves are sources for bending loads in the masts. These bending loads are very modest compared to the compression loads. When the wind blows on the windward mast, it is put into more compression that the leeward mast and the force acts against the direction of the gravitational forces on the mast. This compensating of bending forces on the masts is one reason for the modest slope of the masts. There are no bending loads of significance in the tower design and all tension loads are taken by cables. The CRS structure is unique in the industry in the purity of employment of these three structural principles.

Each mast of the CRS is supported by six cables: two guys, an overhead shield wire each way, the cable tie between their tops, and the conductor suspension cable set. The loss of any one of these six cables can occur without risking the mast's collapse and in some cases without risking continuity of power delivery.

Most importantly, these fully supported masts that never need to resist large bending forces will tolerate the complete collapse of an adjacent tower or the loss of all tension in the wires spanning between towers without risk of collapse. The CRS design is inherently cascade failure resistant without risk of damage and at no added cost unlike any other tower design in the industry.

Self-supported tower designs adopt bending of the tower body/mast and arms from all load cases with transverse force, unbalanced vertical forces and longitudinal forces. One reason for the greater tower weight is the strength needed to resist these bending forces within the latticed structure by the use of long and strong bracing members throughout the tower. They are not inherently cascade resistant without added bracing weight and effectively subjecting the entire tower to a bending force resisted by bracing, not guy wires. Thus, their security against cascade failure is dependent on the strength and weight of the tower design and its modes of damage and such designs cannot be declared as cascade failure resistant without risk or without costs incurred to minimize risk.

Foundations

Self-supported tower designs such as the X10 use four foundations that are designed for compression, uplift and shear. For example, if there is a transverse load of 20 kips[1] applied 140 ft above grade and there are footings 35 ft apart supporting a 20 kip tower, the design uplift force is about 35 kips each. The coincident shear load is 5 kips per foundation.

The CRS design is supported on two pin foundations that are subjected to only compression and modest shear forces and with four guys that are obviously tension only. The comparable forces on the CRS design to the quick calculation above are about 20K of tension on each of two guys and compression only on the mast pin(s). Compression loads with very modest shear loads are resisted by relatively inexpensive foundation designs and tension only anchors are less expensive yet. Remember the principle that a bending load is the most expensive to resist. This is why drilled piers for tubular poles render a tubular pole solution the most expensive.

Micropile Foundations

Micropiles or Soil Anchors are comprised of a single steel rod grouted into a small diameter, drilled borehole. The strength of the micropile is developed by the bond between the grout and the steel rod and by the bond between the grout and the surrounding soil. The detailed means of installing them varies between vendors and with the soil type. The attraction to micropile foundations is that they can be installed in any soil type: from shallow or deep soft sands and clays to fractured or solid rock with the same equipment. The depth of the hole determines its holding power as a function of the soil strength. The installer effectively drills until it works. With other forms of foundations: steel

These four 38 mm, hollow core micropiles were installed 20 meters deep in glacial till in a State Park disturbing less than 0.2 m^3 of soil and tested to 30 tons of tension each.

[1] I kip = 1,000 lbs, approximately 4.4 kN

grillages, poured concrete piers or piling, the type and depth of soil determines the equipment that must be used. To assist in the decisions, geotechnical teams drill numerous boreholes along the alignment to improve the odds of getting the right equipment and materials to each tower site. This great expense is avoided with the "one solution fits all" nature of micropiles.

A micropile foundation in compression and shear requires a cluster of micropiles battered in all directions and attached to a pile cap that transitions the loads to the legs of the structure. The clusters of piles under each leg of an X10 type of tower are likely to be comprised of about 6 micropiles. The cluster of piles under the two more modestly and simply loaded CRS masts is likely to be comprised of three micropile units. Each tension anchor for the four guy wires of the CRS design require a single micropile that can be set with less attention to accurate positioning. Thus, the comparable use of micropiles is about 20 to 24 accurately placed units for the self-supported designs and 10 less accurately placed units for the CRS design a cost and time savings of better than 50% on material and labour. The choice of any other type of foundation under a self-supported tower design is much more costly for the equipment reason noted and comparatively massive material transport to all tower sites.

The final advantage of a CRS foundation set is that each component: two compression units under the masts and the four guy anchors can be set to a much looser tolerance than the four stub angles/anchor bolt piers of a self supported tower must be set. The setting tolerances for the CRS foundation components are about ±0.3 m in all directions before any structural or clearance problems occur. When a contractor understands this, significant cost savings on foundations installation are available.

CRS Tower Erection Methods

Table 1 above notes that the weight of each mast of the CRS design ranges from about 4,600 lbs to 7,500 lbs, dressed with the two guy cables. This means that the masts can be erected with cranes or helicopters with this capacity by one lift each. The cable system between the masts weights about 400 lbs and is installed thereafter from the ground. This compares to the transporting and lifting crane or helicopter requirements of the self-supported X10 design at 2 times the weight of the CRS/km.

Helicopter transport and erection of the X10 tower designs is most probable with S-64 Skycrane, rated capacity 20,000 lbs, with 1 lift onto preset stubs. By comparison, helicopter transport and erection of the CRS towers is possible with K-MAX at 6,000 lb rated capacity, Vertol or S-61 machines, rated capacity 9,000 lbs, with 2 lifts. The cost differences of the helicopter or mobile crane requirements can be significant. If helicopter erection is shown to be attractive due to lack of cost-effective access roads, the CRS tower design can be designed to helicopter capacity.

The structural components of the CRS masts are near universal in that comparatively few unique pieces are needed to create the entire structure or different lengths of mast. Factory fabrication and field assembly are greatly simplified. Their light weight and relatively compact shape makes them very compatible with staging yard assembly by yard crews, rather than the more expensive on-site crews. Very tall CRS masts may be assembled in 2 sections in a main yard and transported to the site for joining and erection. Transport can be by medium size helicopter or modest flatbed truck. The reduced impact on access road load limits needs is significant.

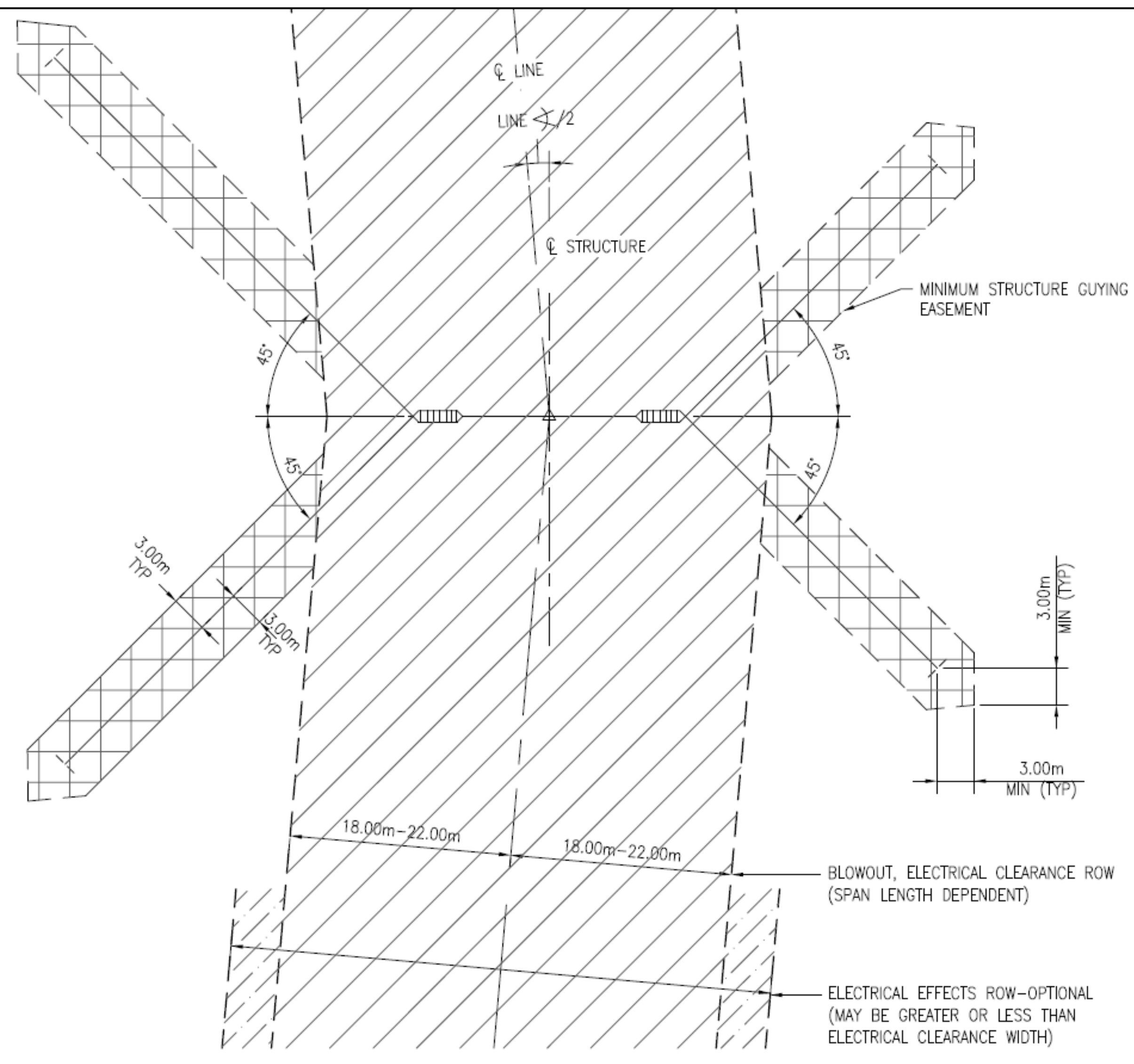
ROW Requirements

A common view of guyed structures, especially of the CRS is its greater ROW width requirement. A rough calculation shows that the conductor blowout criteria for the ROW require a width in the range of 37 m to 40 m for the target design wind span of 488 m. We suggest that it is possible to adopt a two-part or two-tiered ROW definition that, if adopted will save considerable land expense compared to the long-standing notion that guyed towers require greater ROW width. That definition is:

The Electrical Easement: a continuous strip of ground centered on the center phase of the circuit of a width defined by blowout, clearance requirements and noise or EMF criteria with the usual constraints placed on land use by the presence of the electrical conductors above.

The Support Structure Easement: patches of ground at each structure dimensioned to accommodate construction and maintenance of the structure. In the EWT project's case, this is a rectangular patch of ground that encompasses an area defined by the four anchor points OR– discrete strips of ground from the structure masts out to each anchor sufficient to allow installation and inspection access. This is the view taken of guying easements for distribution lines.

This two-tiered easement definition with the strip easements to anchors option is displayed in the figure below. This two-tiered definition of ROW is applicable to any structure type. When the structures are deemed to need only anchor access strips for their installation and maintenance, the land acquisition needs compare well to the land requirements with unguyed structure types.



EASEMENT REQUIREMENTS – PLAN VIEW

ROW Width	Span	Structure Area	Electrical ROW	Total Area/mile
Tiered, long span	440 m	4x6x24 m	40 m	4.13 ha/km
	(0.13 ha is attributable to the structures' guying footprint)			

This ROW needs expressed on a per-km basis is approximate but shows that a two tiered view leads to considerable acquisition savings over conventional single-tier ROW. It suggests that guyed structures do not require significantly more ROW.

We further suggest that clearing be defined for each of the two easement categories with unique clearing rules. These are:

Electrical Easement Clearance Rules:

1. Clear cut and maintain clear cut ONLY for access road maintenance, helicopter pad access and within 3.0 meters of structure foundations
2. Limit growth height to better than 3.00 meters vertical and 8.00 meters horizontal separation from electrical conductors. Clearing need and re-growth cycles are species dependent.
3. Remove all large trees (diameter criteria being species specific) that can fall onto conductors or structures.

Support Structure (Guying) Easement Clearance Rules:

4. Remove vegetation ONLY as needed to install the anchors
5. Cut vegetation ONLY to maintain 1.0 meter separation to guy wires
6. Remove all large trees (>0.25 m diameter at 1.0 m above grade) that can fall onto guy cables.

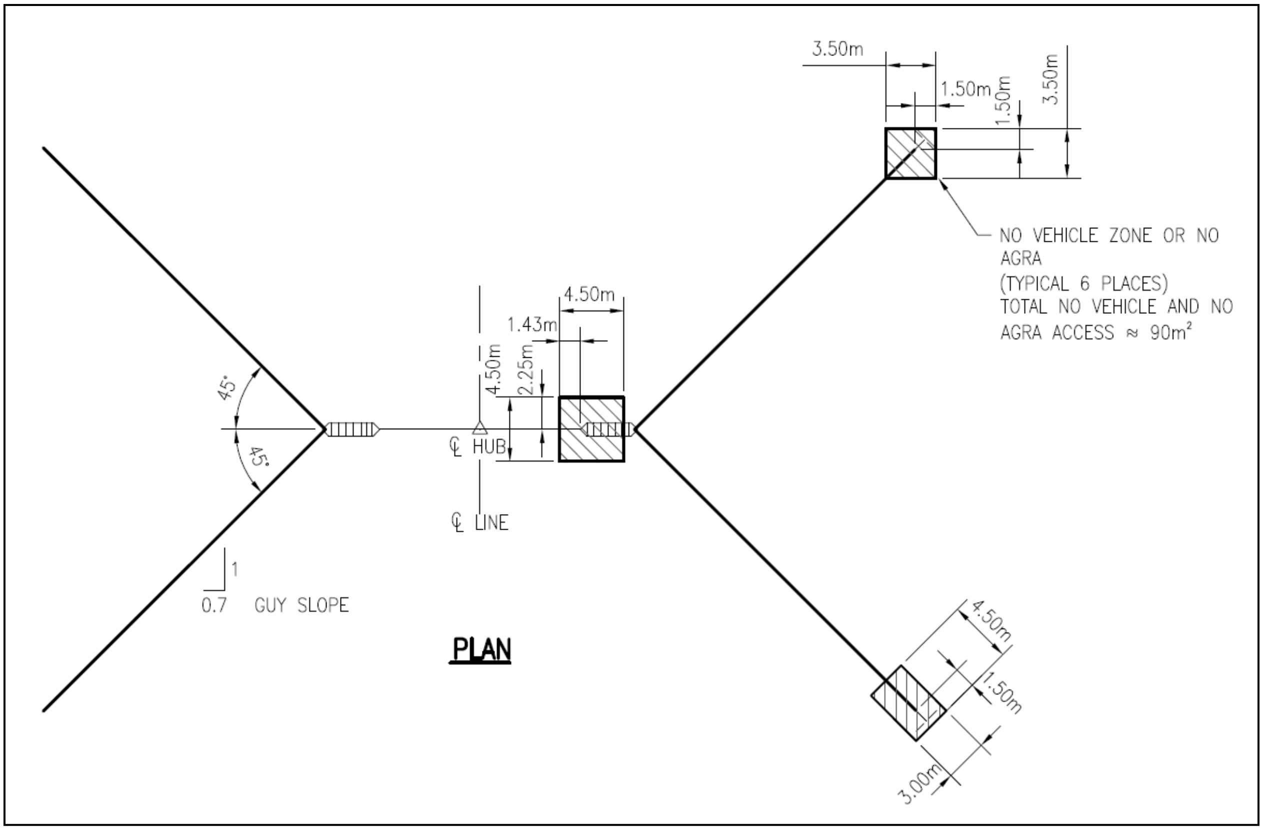
These rules amount to appropriately selective ROW maintenance clearing and will save maintenance costs and leave a ROW that is more environmentally acceptable in the public's view without risk to the line's operation. The long design span target of 488 m means that fewer structures ever need attention and that a higher percentage of the conductors are high enough above grade to allow rule 2 to leave considerable quantities of vegetation to grow on the ROW compared to a shorter span design.

Installed Footprint & Working Space

The figure below illustrates the plan view layout of a CRS structure. The mast tip separation is 22 m and the typical guy slope is 1H : 1.41V. The effective slope across the ROW or along line is 1H:2V. The distance from centerline of the line to guy anchorages increases as the slope of the ground falls away.

The image above is a portion of Drawing CR-1 provided in Appendix A. Drawing CR-1 illustrates the actual final product ground surface area occupation of the CRS structure. Although guyed structures are seen to occupy a large land area, certain land uses can be exercised without restriction within that large area. The actual land occupation includes about 20 m^2 at each mast and 13.5 m^2 at each anchor for a total occupation of about 94 m^2. The interior of a self-supported 135 ft X10S tower removes about 80 m^2 of land from most usage with its footprint. For grazing or wilderness land, the area taken out of service by the CRS is equal to that taken out of service by a self-supported tower.

The working space is a bit constrained by the four widely spaced guy wires. However, the CRS structure requires that cranes reach 17 m lower to access the structure tops. The smaller, lighter cranes required for the CRS installation and maintenance can better navigate the spatially constrained sites.



Construction Disturbance

We have described above the net area requirement as equal between tower types. In detail, there are differences. The typical foundations for the self-supported designs are four concrete piers approximately 1.0 m in diameter and 4 m to 10 m deep. The volume of concrete that must be poured on site and the volume of earth that is excavated and must be disposed of are approximately 12 m^3 to 55 m^3 per tower (up to 140 tons and 110 tons of material respectively). Foundations for the CRS masts are typically micropiles (about 3 under each mast and four tension anchors) or can be precast concrete units. The materials for 10 micropiles 40 ft long and 8 inches in diameter are 4 m^3 of grout and soil displaced (10 tons and 8 tons respectively per site) The effort of and size of equipment causing the disturbances to move less than 10% of the materials onto an off-site compared to the self-supported tower options are considerably less.

The size and weight of equipment to erect CRS structures that weight 1/2 the weight of the self-supported tower option per lift and occupy much less ground area before being stood up will cause significantly less disturbance to the site. In addition, the much lighter towers can attract a higher percentage of helicopter erection removing some disturbing activities from the sites entirely. Lighter helicopters with fewer flights will do less aerial wind-blown debris damage.

The surface area of an X10 tower laid on the ground is about [40 ft x 150 ft] 6,000 sf. The laid down area of two 120 ft masts set 10 ft apart is [20 ft x 120 ft] 2,400 sf. This allows significantly smaller fly, assembly and storage yard requirements for the CRS design.

Avian Interaction

There are three areas of interest with respect to avian interaction with HV and EHV transmission lines: exposure to collisions with spans of wires, with the structures, and with perching on the structures by raptors for hunting.

The spans of wires between towers are considered to offer exposure points for bird collisions. Each horizontal plane of wires offers two exposure points, one from each approach side to the line. The double circuit towers such as the X10 tower have three levels of conductors and one level of OHGW for a total of eight avian collision exposure points. The CRS spans have all conductors in the same plane and have both shield sires in a single plane above for a total of four exposure points. This is a 50% reduction in exposure relative to the double circuit design. In addition, the top exposure points of the OHGW layer are up to 17 m lower in altitude, as described above for equal spans.

At the 2012 APLIC Workshop in Casper, WY, we asked if there was data to suggest that birds collide with structures and if the experts could explain the source of a “no guys” rule promoted by some jurisdictions. There seems to be no data suggesting that birds collide with structures reinforced by the fact that most birds found under power lines are found in the spans, not at the structures. The lack of dead birds found on the ground at structures suggests that structures are not the issue. The source of the “no guys” rule seems to be tall, lighted, guyed communication masts. These very tall masts seem to attracted the birds, perhaps with the night lights and they get tangled in the large array of guys supporting the very tall masts. We would suggest that the guy wires of shorter, unlit transmission line structures cannot be included in this category of guying.

There is an assumption that birds of prey will use transmission line structures in flat terrain for hunting perches and that they hunt avian prey that we may choose to protect. The reaction to this assumption is that perching of raptors is often discouraged by the design features of the structures. At 500 kV for example, the ON-Line project in Nevada has chosen to use a tubular cross-arm and legs of a Guyed-V tower design in large measure to make perching more difficult that it appears to be on latticed steel tower bridges. The CRS design has only a wire system at its tower tops and no structural beam of any sort – tubular or latticed for perching. To the degree that the raptor perching assumption is valid, the CRS design offers the most perchless structural shape possible. The problem is further mitigated by the fact that raptor droppings show that they are hunting rodents, not other birds.

Visual Impact

It is noted above that the CRS designs are about 90% the weight of the X10 designs for duty of the project. It is reasonable to quantify visual impact by the amount of material in the air and it is reasonable to estimate that the weight of the towers is uniformly distributed top to bottom. If we allow that the bottom 17 m of a tower lies beneath the average horizon, and the average height of the X10 tower line is 41 m, then the visual exposure is of [5900*(41-17)/41] 3,450 kg of steel per tower above the horizon. The preferred CRS tower is 35 m tall, exposing 18 m of its height above the horizon. The exposed weight is [18/35*5300] 2,725 kg per tower.

On a ‘per km’ basis, the comparative visual impact based on exposed tonnage of tower steel is 12,800 kg/km for the X10 tower type and 6,200 kg/km for the CRS design due to its longer spans. While this is a crude way to quantify the visual impact, it does suggest that the CRS design cuts the line’s visual impact in half compared to a double circuit design.

Maintenance

The inspection and maintenance methods to be employed with CRS designs are common issues of concern. Three references [1: Part 4; 2 and 3] address the subject. The concern lies with access to the phases from positions on the tower and therefore from the cable system assuming bucket truck access is not viable. Maintenance of CRS towers is considered easy by these long-time owners. The suggested 6 m phase spacing allows the approximately 1.1 m OSHA clearance access from buckets and on the masts past the phases for live line access.

As with any tower design, the details of the climbing and maintenance procedures must be developed. The precedence with the CRS design is well established. Len Custer, BPA tells us that BPA is very happy with the CRS towers and that they are quite maintenance-free due to their simplicity and flexibility under load. South Africa is developing live line procedures for their installations. We strongly suggest that the obviously significant benefits on the described range of subjects, particularly cost should give rise to serious consideration for developing satisfactory maintenance practices and procedures for the CRS.

Electrical Characteristics – Conductor Choice

The reference option offered by EWT assumes the use of single 1192.5 kcmil ACSR “Grackle” conductors on each of the two new circuits. For this single circuit option, we are assuming 2-bundle 795 kcmil ASCR “Drake” conductors per phase. The compliant summer and winter ratings are 1,225 A (976 MVA) and 1,400 A (1,115 MVA) respectively at 128°C. This more than ample capacity means that we could revert back to the larger, single 1192 Grackle choice but we like the 2-bundle Drake as it can set the stage for a future 4-bundle 500 kV circuit without removing the conductors OR the 2-bundle Drake line can simply run cooler with a maximum emergency temperature of under 80°C. To revert this design option to a single Grackle per phase would offer a savings of near $25M not expressed in the option’s cost estimate.

We are also attracted to the small diameter conductor because it ships on longer reels allowing stringing setup locations to be further apart leading to lower installation cost than heavy, fat conductors provide. This gives better control over relatively volatile installation costs.

Application of the CRS Design in Northern Ontario

POWER Engineers’ transmission line engineering staff has worldwide experience with all manner of line design, transmission structure types, construction methods, environments, etc. including leadership participation in the CRS installations in Argentina and South Africa. We also have been working in Northern Ontario since the 1970s. There is no doubt that the CRS design is a viable and valuable structural choice for the EWT project provided the single circuit option is acceptable to the OEB and IESO.

We have noted above that guyed structures of any type show increased cost and schedule benefits to a project as the access to the ROW becomes more complicated and costly due to ruggedness and remoteness and as the subsurface conditions become highly variable and unpredictable. This is based on the comparatively lighter weight and simpler foundations. The CRS design maximizes the benefits of light weight and the installation methods permitted for the foundation and anchors installations makes their installation costs very low. The characteristics of the entire length of the EWT project set the stage for accessing these cost savings and the other benefits discussed above.

Compliance with the EWT Minimum Technical Requirements

The OEB document of that title dated November, 9, 2011 is applicable to the reference option by title. Much of the criteria are sensible and transferable to a single circuit CRS design option. A single distinction between the two solutions is that we would increase the clearance to ground for the CRS design since the effectively very long longitudinal insulator swing length will allow excessive sag during unbalanced ice conditions compared to a standard insulator suspended from a rigid tower arm.

System Impacts of a CRS Single Circuit

POWER has reviewed the IESO report entitled "Feasibility Study – An Assessment of the Westward Transfer Capability of Various Options for Reinforcing the East-West Tie", IESO_REP_0748 Version 1.0 dated 18 August 2011 (IESO Report). The IESO Report is a well prepared and clearly documented investigation of two alternatives specifically 1) a 230 kV double circuit line using single 1192.5 kcmil ACSR conductors and 2) a single circuit 230 kV line with a bundle of two 795 kcm ACSR subconductors or two 1192.5 kcmil subconductors. The single circuit option was not exhaustively investigated, but its basic electrical performance was characterized in sufficient detail to perform some cursory analysis comparing the two alternatives as well as identifying in concept some additional measures to optimize performance of a single circuit option.

On page 7 of the Report, it was concluded that *". . .With the East-West Tie reinforced with a new single circuit line, it would therefore be necessary, immediately following a contingency or outage involving this new line, to re-prepare the system for the loss of one of the circuits on the remaining double circuit line. ...All of these control actions would comply with the IESO's criteria."*

Read in its entirety, this means that a new single circuit line could be used, but would require more corrective actions to be taken should the new single circuit line be out of service for either forced or planned outages. The report goes on to conclude on page 7 that *"For the One-plus-One contingency condition, the installation of a new double-circuit line to reinforce the East-West Tie would therefore represent the superior option."* Note that this conclusion was drawn irrespective of cost.

The OPA in its report entitled "Long Term Electricity Outlook for the Northwest and Context for the East-West Tie Expansion" dated June 30, 2011 states on page 20/21, Section 7.1 *that " . . . A single-circuit 230 kV line would likely have a similar cost to a double-circuit 230 kV line, but would have reduced operability during planned and forced outages. Therefore, the OPA believes that the double-circuit 230 kV line is preferred, but other options could be proposed . . . ."*

These two documents conclude that for similar cost, a double circuit line would be preferable, but do not preclude the use of a single circuit option.

POWER has compared the electrical characteristics (specifically series impedance and shunt capacitance expressed as susceptance) which affect electrical power flow and reactive power compensation requirements for a representative conventional four legged lattice tower *single* circuit design and a cross rope suspension (CRS) tower design. Results of the comparison are summarized in the following table.

Table 2 – Electrical Characteristics of a Single Circuit 230 kV Line Using Conventional Lattice and CRS Structures

Tower Type	GMD (m) (3)	Series Impedance (4)		Susceptance (4) (5)
		R_1 (Ω/km) (7)	X_1 (Ω/km) (6)	B_1 (μS/km)
Lattice (1)	10.57	.036	.376	4.41
CRS (2)	7.56	.036	.349	4.71

Table Notes:

1. OH Type W1S 230 kV tower used as example of single circuit tower with history of use in Ontario.
2. CRS example tower geometry developed by POWER. See drawing CR-1, Appendix A.
3. Geometric mean distance (GMD) is an equivalent conductor spacing obtained by taking the cube root of d_{12} x d_{23} x d_{31} where d_{12} is the distance between phase 1 and phase 2 and so on. A smaller GMD results in a lower series reactance (X_1) which in turn results in less voltage drop and less need for

4. reactive power compensation (series capacitors, mechanically switched shunt capacitors, and static VAR systems).
5. Positive sequence impedances and susceptances calculated using two 795 kcmil Drake ACSR subconductors in a vertical bundle with a 45.7 cm (18 in) sub-conductor spacing.
6. Susceptance is a parameter which defines the amount of capacitance the line will contribute. The higher the susceptance the more shunt capacitance the line contributes and the less capacitive reactive power compensation will be required.
7. A lower series reactance (X_1) results in less voltage drop and less need for reactive power compensation (series capacitors, mechanically switched shunt capacitors, and static VAR systems).
8. Resistance is predominantly a function of the number and type of conductors. Lower resistance results in lower electrical losses (higher efficiency energy transmission).

This comparison illustrates that the electrical characteristics for a CRS tower design can be made comparable, and even more desirable (approximately 7% lower reactance in this example) than for a more conventional four legged single circuit lattice tower design. This occurs because the CRS structure does not have grounded steel structural surfaces between phase conductors, allowing phases to be placed as close together as possible without violating electrical or mechanical minimum clearances, thereby reducing the GMD between phases.

The type of towers studied in the IESO Report are not specifically stated, but given the discussion involving relative costs of double circuit vs. single circuit options it is assumed that conventional lattice towers were used in the analysis.

From an electrical performance perspective the CRS tower design will perform as well or better than a conventional lattice tower design. Consequently the single circuit analyses in the IESO study will be applicable, although likely to somewhat understate the electrical performance of a CRS tower design.

The CRS tower provides a significantly lower cost alternative than a conventional double circuit lattice tower so based upon conclusions noted in the IESO Report and the OPA Report warrants further consideration. Our cost estimates suggest a capital cost saving with use of the CRS tower vs. a double circuit reference option of $114M with the single loop galloping criteria in place and $71M with it removed from the technical requirements – a significant opportunity to lower the cost of the project to the ratepayers.

A number of specific opportunities to mitigate or eliminate issues raised in the IESO Report follow. Please note that this discussion is not intended to be negative criticism of the IESO Report, rather it is a listing of additional studies work which will more fully evaluate single circuit line performance and allow for a more comprehensive comparison of single circuit and double circuit line options.

1) Higher impedance of the single circuit option is discussed in Section 2.2 beginning on page 5 of the IESO report. The use of fixed series capacitors on both the Wawa Marathon line section and the Marathon to Lakehead line sections could resolve or at a minimum mitigate this concern.
    a. Outages of both circuits of the existing double circuit line
        i. By selection of the level of series compensation the amount shunt compensation (both dynamic and fixed switched) needed in this contingency can likely be reduced to even less than required for a double circuit line.
        ii. Similarly, the concern for upgrading the current carrying capacity of the existing 115 kV circuits T1M, A1B & A5A to allow 105 C long term emergency rating of 690 A would be able to be mitigated and possibly eliminated by series compensating the Marathon to Lakehead line segment. The 230 kV single circuit

line could be tuned to carry more or less current depending upon the level of series compensation.

2) Transmission system losses are discussed in Section 2.3 beginning on page 7 of the IESO Report.
   a. Active (real) power losses are predominantly a function of the conductor resistance and the current flowing through the conductors. Both of these factors can be managed with either a single or a double circuit option.
      i. The number and size of conductors is a design variable. Economic conductor selection studies will reveal which conductor/bundle arrangements result in the lowest projected overall lifetime costs. Economic conductor selection studies should be undertaken regardless of the option chosen. The conductor/bundle selection on the single circuit option can be designed to manage losses to whatever level is shown to be preferred.
      ii. As noted earlier, selection of series compensation levels on a 230 kV single circuit line will determine how current is shared between existing and the new single circuit 230 kV line. Analysis of system performance for different levels of series compensation and conductor/bundle configurations for the new circuit should be performed. The overall lifetime costs of operating the tie, including both existing and new circuits, could then be evaluated and a decision regarding the conductor/bundle configuration and series compensation levels of the new lines chosen to minimize overall operating costs for the EW Tie, including the existing double circuit line. The issue of how power is shared with existing 115 kV lines for a double circuit outage of the existing line should be considered concurrently. This opportunity to manage the system losses was acknowledged in Section 2.3, page 9 of the IESO Report.
3) Planning Criteria
   a. An outage of a new single circuit 230 kV line would be equivalent to the loss of both circuits of a new 230 kV double circuit line. A structure failure on either a single circuit or a double circuit line would have the same effect. However an outage affecting only one circuit of the new double circuit line would require less stringent steps to re-prepare the system for the next contingency. A CRS single circuit line is more structurally reliable than any self-supported tower design. This reduces the likelihood of an outage on the new single circuit to lower than that of a double circuit, self-supported design and mitigates, but not eliminates, this difference between single circuit and double circuit alternatives in this regard. Steps to increase reliability on the single circuit line include:
      i. Use of longer insulators. The probability of insulation flashover for lightning and switching transient events and is determined by the intersection of the statistical distributions for insulation strength and voltage stress. A modest increase in insulator length, for example the addition of one or two insulator units, can dramatically decrease the likelihood of flashover. At 230 kV lightning will be the predominant source of insulator flashovers. The impact of additional insulation can be quantified during the design process to allow designing to specific reliability targets. The CRS tower geometry makes adding additional insulation length less costly than for a conventional lattice tower. The masts will need to be marginally increased in length and if necessary, they can be placed

farther apart to provide additional horizontal clearance. Steel weight changes only marginally and the structure foundations and guying remain almost unchanged.

ii. Selected use of lightning arrestors on towers with higher than normal tower footing resistances. Tower footing resistance and insulation length are the two predominant design parameters that determine the probability of insulation flashover due to lightning strikes. It is anticipated that for a number of the tower locations, rock will be near the surface making it difficult to obtain low enough tower footing resistances to keep the probability of lightning flashover within acceptable levels. The addition of metal oxide varistor (MOV) surge arrestors or lightning arrestors on towers with higher than desired tower footing resistances will all but eliminate the possibility of an insulation flashover for lightning strikes to the tower. Lightning arrestors that are specifically designed for attaching to conductors at transmission line towers are readily available and a proven product.

iii. Additional mechanical strength. Similar to the reliability gains provided by adding additional insulation length, very modest increases in tower strength provide significant increases in the return period for storms that can be withstood without damage.

In summary, our assessment of the impact on the system's nature and operation by the use of a single circuit design as described herein is very modest when weighted against the capital cost savings to the ratepayers that the design offers and the subject is therefore in integral part of the EWT LP development plan proposal.

EWT Construction Cost Estimate with Proposed CRS Option

Capital

The basis for the cost savings of the CRS structure are provided here. Some of the key cost components are described. Minor differences between these CRS option costs and the reference option costs are buried in the quantity and unit rate details and do not globally impact the fundamental cost difference. As noted above, we include a comparable cost estimate for a representative self-supported (unguyed) tower design to highlight the cost impact of using guyed structures on a project such as this.

Assumed Usage

The CRS structure is considered to be compatible with virtually all of the land use and terrain along any likely route between Wawa TS and Lakehead TS. Throughout this report, we are assuming that 100% of the structures on the line can be CRS designs. Corner structures can be guyed mast sets or self-supported strain towers. Alignment corners greater than about 8° will use such towers.

Purchase Cost Savings

The present cost of purchasing latticed towers in large quantities ranges from about $0.90/lb for Indian steel, $1.05 for Turkish steel and $1.30 for North American steel with information suggesting that some projects are serviced at 0.65/lb from India. We know of a recent 500 kV project that purchased tower steel at about $0.65/lb but the required field fixes have done much to undo the savings on that project.

The self-supported towers have some heavier members that drive the "per lb" costs down but they also have a very wide array of pieces to drive the unit cost up. By comparison, the CRS tower is comprised of lighter pieces and much fewer numbers of pieces, enhancing mass production. For this report, we assume a purchase price of $1.00/lb for either tower type.

Installation Cost Savings

POWER asked PAR Electric to provide comparative installation cost estimates for the two design options. POWER provided the tower arrangements, weights and foundation volumes. The costs to handle and install can be expressed in $/lb units at $3.29/lb for the self-supported family towers and $3.16/lb for the CRS towers.

Foundation Cost Savings

PAR's work included foundation installation costs. They were asked to assume four concrete piers for the delta towers at 10.25 cy each and guy anchor micropiles at 40 ft deep each. The cost per tower (four legs, four foundations for the X10 type of tower was $64,000 ($16,000/leg). The cost for the micropile type mast supports and guy anchors for the CRS tower was $30,000 – less than 50% of the X10 tower type cost.

Clearing Costs

The longer design spans permitted by the CRS design allow larger blowout dimensions and the ROW width is assumed at 40m – equal to that suggested for the reference option but with all 40 m cleared.

Cost Comparison Summary

The cost estimate developed for the reference option are described in the companion report, "Engineer's Report on the EWT Transmission Line OEB Reference Option" is $395M. The comparable cost estimate provided herein for the single circuit, CRS design option is $281M – better than $100M less based on the merits of the structure choice. Although not expected to be the case, the cost calculations can be in significant error and still support the suggestion that the CRS design option deserves serious consideration as a choice that presents considerable cost savings.

Cost item	Unit	CRS	Ref	CRS less by…	Reason for delta
Towers	kg	$13,855	$24,673	$10,818	Much less steel to buy
Conductors	m	$13,441	$18,695	$5,254	Smaller conductors
OHGW & OPGW	m	$3,075	$3,075	$0	No change
Insulation & Hardware	/tower	$2,287	$4,960	$2,673	3 phases, not 6, few towers
Sundry	/tower	$1,037	$1,684	$647	Per tower, fewer sites
Access Roads (4 m wide)	km	$3,980	$3,980	$0	No Change
Clearing (30 m or 40 m of 40 m ROW)	Ha.	$9,552	$7,164	-$2,388	Longer spans, wider clearing
Yards @ 20 km spacing	m^3	$9,950	$9,950	$0	No Change
Foundations (50% piers, 50% grillages)	m^3 & Ea.	$27,186	$94,341	$67,155	MUCH simpler, fewer towers
Tower (assembly, erection, dressed)	kg	$41,793	$77,486	$35,693	Fewer, lighter towers
Conductors	ckt-km	$91,381	$88,389	-$2,992	2-bundle, 1 circuit
OHGW/OPGW	ckt-km	$8,567	$8,567	$0	No Change
Closeout	LS	$900	$900	$0	No Change

The table above reveals the sources of the capital cost savings with the CRS ($ x 1,000). The blue cells are material purchases and the green cells are installation costs. As described above in the generically applicable narrative, the vast majority of the savings relate to the labour savings due to the reduced weight and number of structures and the comparative simplicity of the CRS foundations.

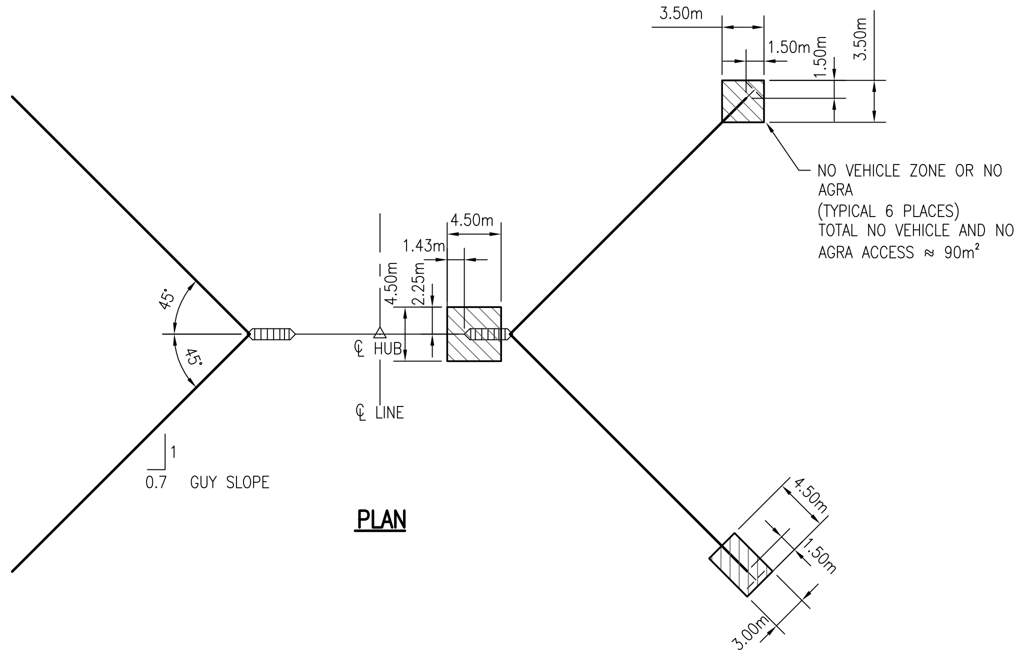
Construction Schedule

The CRS design option has features that will adjust the duration of selected construction tasks compared to the reference option. For example, the lesser tonnage and simpler steel components of the CRS designs will shorten the steel supply duration. The longer spans lead to fewer tower sites and much simplified foundations shortening that the foundation installation time a great deal. Yet, if we stay with the 2-bundle conductor system, the stringing time is lengthened some modest amount. In the overall, the CRS option will shorten the project's construction schedule or more likely lower the challenging workforce requirement. In other words, the CRS option will lower the risk of a schedule overrun.

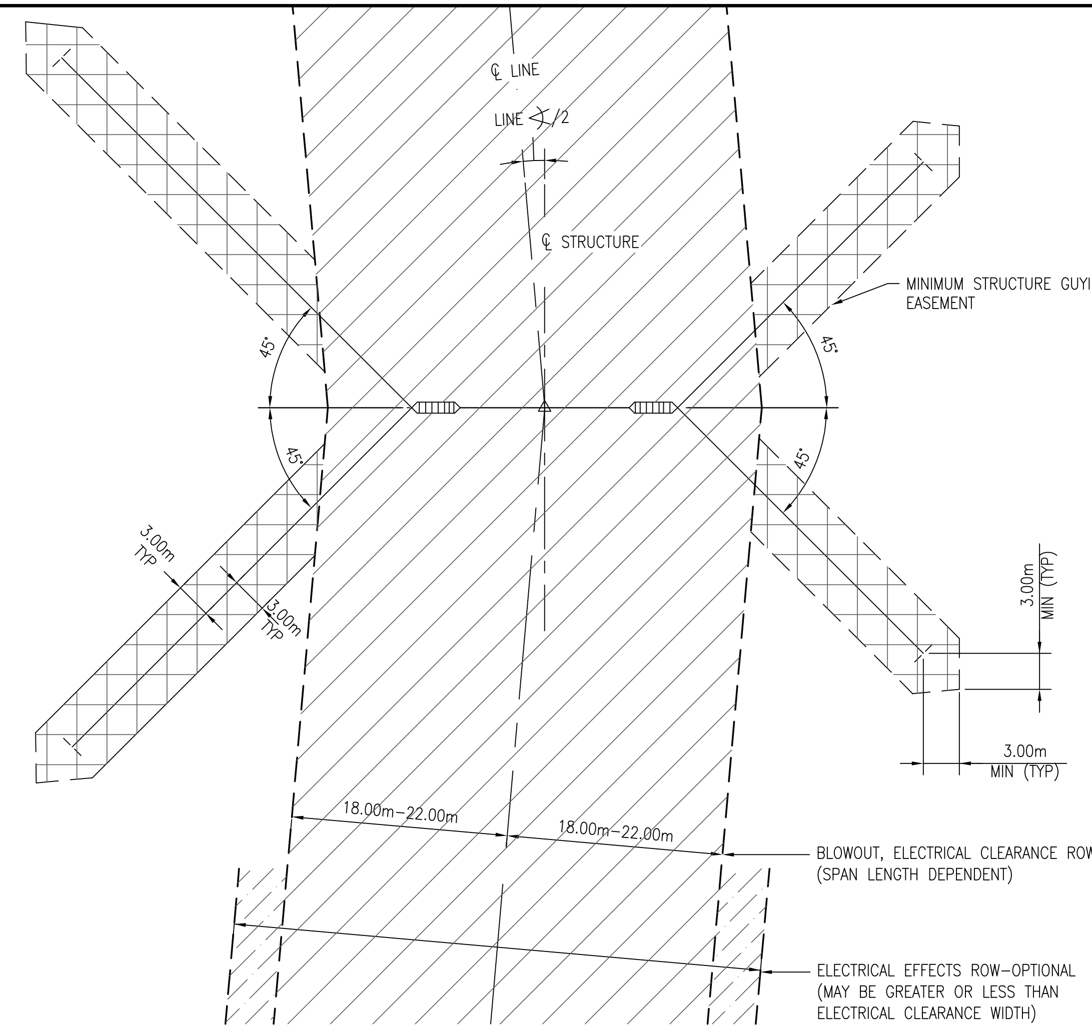
We have not expressed these differences with a new, CRS option schedule. We refer to the reference option schedule but recognize the lower risk to its overall duration.

Appendix A - Drawings

Drawing FIGURE 4.5-1 230 kV CRS Structure General Features



PLAN



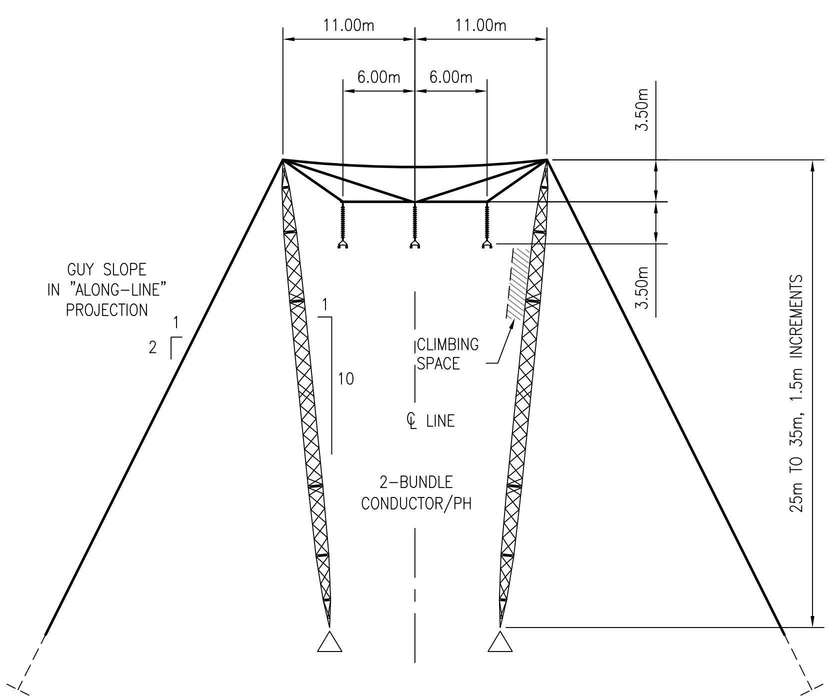
EASEMENT REQUIREMENTS – PLAN VIEW

CLEARING TYPE 1: ROW

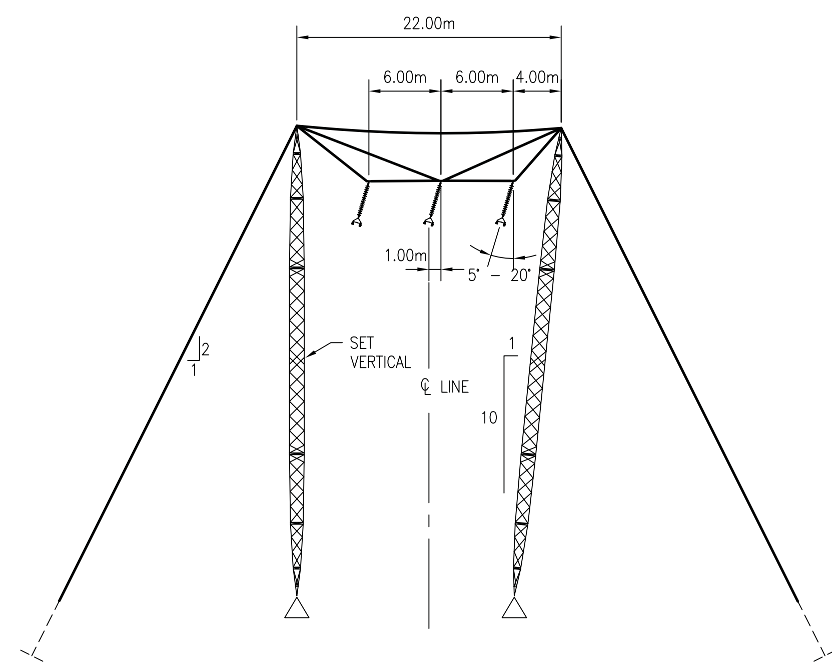
1. CLEAR CUT AND MAINTAIN CLEAR CUT ONLY FOR: ACCESS ROAD MTCE, HELICOPTER PAD ACCESS AND WITHIN 3.00m OF STRUCTURE FOUNDATIONS.
2. LIMIT GROWTH HEIGHT TO GREATER THAN 3.00m. VERTICAL AND 8.00m HORIZONTAL SEPARATION FROM ELECTRICAL CONDUCTORS.
3. IN VICINITY, REMOVE LARGE TREES THAT CAN FALL ONTO CONDUCTORS OR STRUCTURES.

CLEARING TYPE 2: GUYING EASEMENT

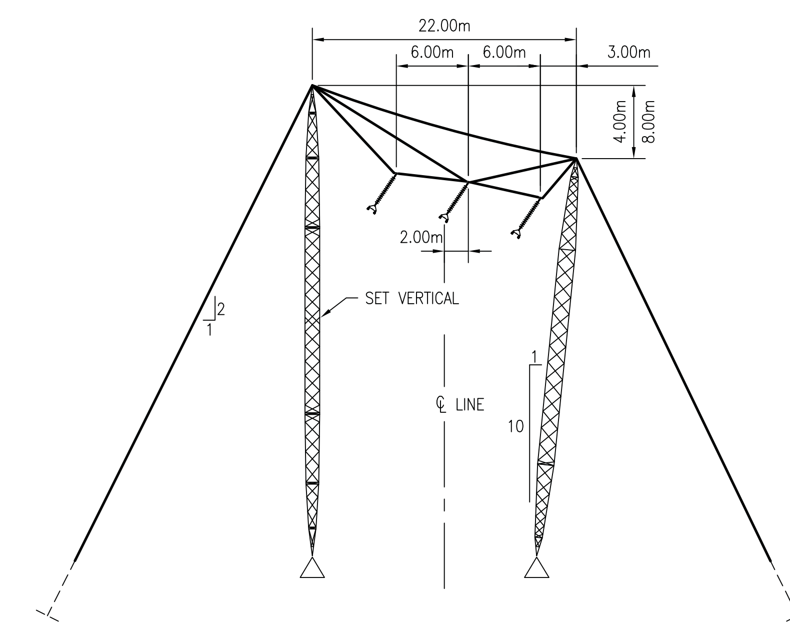
1. REMOVE VEGETATION ONLY AS REQUIRED TO INSTALL ANCHORS.
2. CUT VEGETATION ONLY TO MAINTAIN 1.00m SEPARATION TO GUY WIRES.
3. IN VICINITY, CUT ONLY LARGE TREES (>0.25m DIAMETER) THAT CAN FALL ON GUY WIRES.



ELEVATION



LIGHT ANGLE STRUCTURE – ELEVATION



MEDIUM ANGLE STRUCTURE – ELEVATION

Figure_4.5–1.dwg

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REV	REVISIONS	DATE	DRN	DSGN	CKD	APPD
A	ISSUED FOR PROPOSAL	**/**/**	JLQ	PC	PC	*

REFERENCE DRAWINGS

DSGN	*	*
DRN	*	*
CKD	*	*
SCALE:	NTS	

FOR 22x34 DWG ONLY

POWER ENGINEERS

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230 kV CROSS ROPE STRUCTURE GENERAL FEATURES

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JOB NUMBER 121672

REV A

DRAWING NUMBER FIGURE 4.5–1

Appendix B – CRS Option Cost Estimate

Construction Cost Estimate – CRS Structure Option

Construction Cost Estimate – W1 Tower Option

EWT CRS Construction Cost Estimate																				
1 ckt: 2-795 ACSR			Ave. Span (m)			439	%DE	5%				439		7%	439		5%			
	$ x 1,000		Wawa TS			Wawa-Marathon			Marathon TS			Marathon -Nipigon			Nipigon-Lakehead			Lakehead TS		
WBS	**Line Item**					**Qty**	**Unit $**	**Cost**				**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**			
LINE Single Circuit 230 kV, CRS		**Unit**				168	km					148	km		82	km				
Purchases																				
	ROW	Ha.																		
2.1.4	Towers	kg				2,313,825	$2.42	$5,599				2,144,719	$2.42	$5,190	1,266,781	$2.42	$3,066			
2.5.4	Conductors	m				1,048,320	$5.41	$5,674				923,520	$5.41	$4,998	511,680	$5.41	$2,769			
2.5.4	OHGW & OPGW	m				173,040	$7.50	$1,298				152,440	$7.50	$1,143	84,460	$7.50	$633			
2.6.4	Insulation & Hardware	/twr				516	$1,800	$930				502	$1,800	$904	252	$1,800	$454			
2.7.4	Sundry	/twr				516	$2,000	$1,033				1	$2,000	$2	1	$2,000	$2			
Installations including consumables																				
3.x.1	Access Roads (4 m wide)	km				67.2	$25,000	$1,680				59.2	$25,000	$1,480	32.8	$25,000	$820			
3.x.2	Clearing (40 m of 40 m ROW)	Ha.				504	$8,000	$4,032				444	$8,000	$3,552	246	$8,000	$1,968			
3.x.3	Yards @ 20 km	m^3				84,000	$50.00	$4,200				74,000	$50.00	$3,700	41,000	$50.00	$2,050			
4.1	Foundations (50% piers, 50% grillages)	m^3 & Ea.				1,530	$7,500	$11,475				1,348	$7,500	$10,109	747	$7,500	$5,601			
5.1	Tower (assembly, erection, dressed)	kg				2,313,825	$7.30	$16,890				2,144,719	$7.30	$15,656	1,266,781	$7.30	$9,247			
6.1	Conductors	ckt-km				336	$114,800	$38,573				296	$114,800	$33,981	164	$114,800	$18,827			
6.1	OHGW/OPGW	ckt-km				176.4	$20,500	$3,616				155.4	$20,500	$3,186	86.1	$20,500	$1,765			
8	Closeout	LS				1	$300,000	$300				1	$300,000	$300	1	$300,000	$300			
EPC COST	**$227,002,527**						**Totals:**	**$95,299**					**Totals:**	**$84,201**		**Totals:**	**$47,502**			
Eng Support	$5,221,058	2.3%	of EPC Cost																	
Env. Support	$6,583,073	2.9%	of EPC Cost																	
CM + Margin	$41,995,467	19%	of EPC Cost (10% + 20%)																	
Total	**$280,802,126**																			

Figure 1

WBS	Line Item	Unit				Qty	Unit $	Cost				Qty	Unit $	Cost	Qty	Unit $	Cost			
EWT Construction Cost Estimate																				
1 Ckt: 2 -795 ACSR				Ave. Span (m)		439	%DE	5%				439		7%	439		5%			
	$ x 1,000		**Wawa TS**				**Wawa-Marathon**		**Marathon TS**				**Marathon -Nipigon**			**Nipigon-Lakehead**		**Lakehead TS**		
WBS	**Line Item**	**Unit**				**Qty**	**Unit $**	**Cost**				**Qty**	**Unit $**	**Cost**	**Qty**	**Unit $**	**Cost**			
	LINE Single Ciruit 230 kV, W1					168	km					148	km		82	km				
Purchases																				
	ROW	Ha.																		
2.1.4	Towers	kg				3,299,180	$2.42	$7,984				3,058,060	$2.42	$7,401	1,610,314	$2.42	$3,897			
2.5.4	Conductors	m				1,048,320	$5.41	$5,674				923,520	$5.41	$4,998	511,680	$5.41	$2,769			
2.5.4	OHGW & OPGW	m				173,040	$7.50	$1,298				152,440	$7.50	$1,143	84,460	$7.50	$633			
2.6.4	Insulation & Hardware	/twr				516	$1,800	$930				502	$1,800	$904	252	$1,800	$454			
2.7.4	Sundry	/twr				516	$2,000	$1,033				1	$2,000	$2	1	$2,000	$2			
Installations including consumables																				
3.x.1	Access Roads (4 m wide)	km				100.8	$25,000	$2,520				88.8	$25,000	$2,220	49.2	$25,000	$1,230			
3.x.2	Clearing (40 m of 40 m ROW)	Ha.				591	$8,000	$4,724				520	$8,000	$4,162	288	$8,000	$2,306			
3.x.3	Yards @ 20 km	m^3				84,000	$50.00	$4,200				74,000	$50.00	$3,700	41,000	$50.00	$2,050			
4.1	Foundations (50% piers, 50% grillages)	m^3 & Ea.				2,295	$7,500	$17,213				2,022	$7,500	$15,164	1,120	$7,500	$8,402			
5.1	Tower (assembly, erection, dressed)	kg				3,299,180	$7.30	$24,084				3,058,060	$7.30	$22,324	1,610,314	$7.30	$11,755			
6.1	Conductors	ckt-km				336	$114,800	$38,573				296	$114,800	$33,981	164	$114,800	$18,827			
6.1	OHGW/OPGW	ckt-km				176.4	$20,500	$3,616				155.4	$20,500	$3,186	86.1	$20,500	$1,765			
8	Closeout	LS				1	$300,000	$300				1	$300,000	$300	1	$300,000	$300			
EPC COST	**$266,021,944**						**Totals:**	**$112,148**					**Totals:**	**$99,484**		**Totals:**	**$54,390**			
Eng Support	$5,320,439	2.0%	of EPC Cost + $2.5M																	
Env. Support	$6,650,549	2.5%	of EPC Cost + $35M																	
CM + Margin	$41,233,401	15.5%	of EPC Cost (10% + 20%)																	
Total	**$319,226,333**																			

Figure 2

Appendix C References

1 "Validation of a Chainette Tower for a 735 kV Line", CIGRE 1978 Session, Hydro Quebec.
2 "New Hot-stick Procedure Developed by BPA", T&D Magazine, April 1986, BPA
3 "Electrical Transmission in a New Age", ASCE Conference 2002, Behncke, White
4 "Special Hardware for Gross-Rope Cable, CIGRE 2009, SA Regional Conference, Brazil
5 "Optimal Line Designs", CIGRE 2011 Session, ESKOM, Pages 32-42.

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1978 Session — August 30 - September 7

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VALIDATION OF A CHAINETTE TOWER FOR A 735 kV LINE

by

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SUMMARY

A tower consisting of two guyed masts supporting a flexible crossarm formed of steel cables is planned for use on future 735 kV lines on the Hydro-Quebec network. The application of this concept called "chainette tower" at this high tension level and under the loading conditions to be met, called for a detailed study in order to establish the layout of the structure, followed by a thorough validation program.

This Paper first describes the design of the chainette tower and then the validation program. The program was intended to examine the mechanical behaviour of the system, explore and develop appropriate construction and maintenance techniques and to evaluate the economic gain that would be realized. Computer analyses, experiments on reduced scale models as well as the construction and full scale testing of a section of line were used to meet these objectives.

The validation program leads to the conclusion that the chainette tower is technically sound, advantageous for construction and maintenance, and also more economical than conventional towers.

Chaînette, Tower, Ultra high voltage, Validation.

REPORT

1. INTRODUCTION

The very large investment program in the James Bay Transmission network warranted an overall re-evaluation of existing 735 kV tower designs. Time available before the start of construction, as well as economic considerations led to plan the first lines with the proven guyed V – shaped tower. However, preliminary studies indicated that the chaînette tower promised to be an even more interesting alternative for the remaining lines [Ref. 1].

A brief review of existing guyed towers revealed that, for extra-high voltages, 50 per cent of the weight of steel of the tower is in its crossarm and that, as voltages increase, much heavier crossarms have to be installed at much greater heights. For instance, at 230 kV, the crossarm weighing only one ton has to be installed at 25 meters, while at 315 kV, a two ton crossarm has to be installed at 35 meters and at 735 kV, a five ton crossarm has to be installed at 45 meters. For extra-high voltages, this makes the raising of guyed towers very difficult and costly.

It became apparent then, that extrapolating tower designs that are efficient at lower voltages, into extra-high voltages, would not necessarily produce the most economical solution.

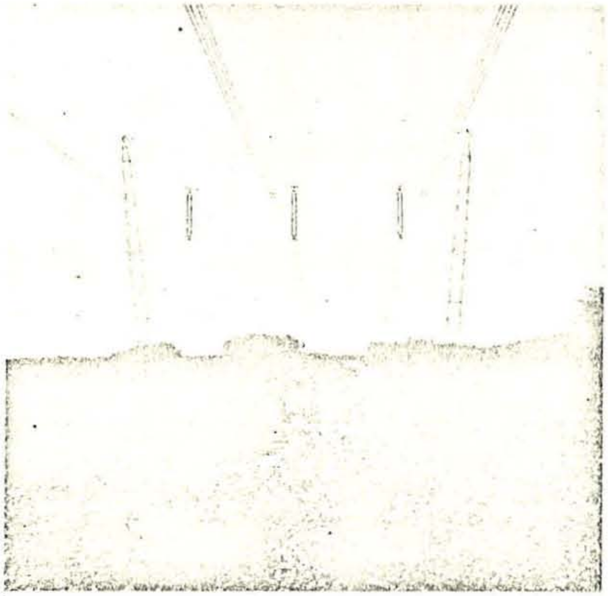

Figure 1 – Experimental 735 kV line with chaînette towers.

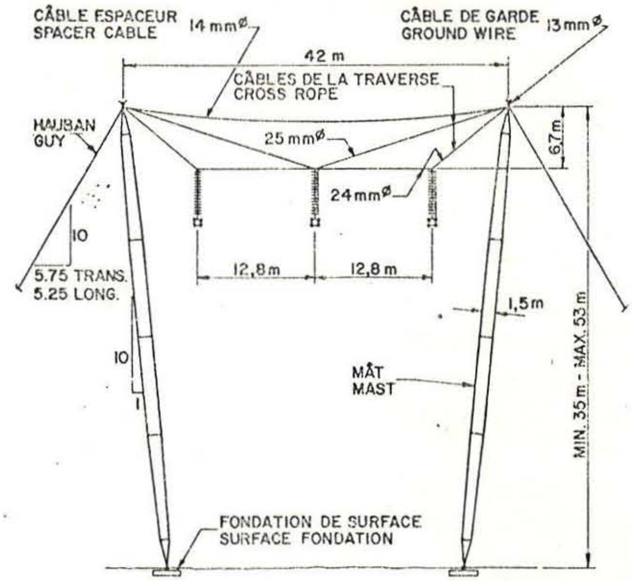

Figure 2 – General layout of chaînette tower

Resultant studies led Hydro-Quebec to the chaînette tower (Figs 1, 2). The concept consists of a steel wire cable system that suspends the three phases between two masts which are anchored on the outside by guys from their top to the ground. For large phase spacings, this design makes very efficient use of structural materials, specializing the role of each member into tension and compression members. The weight of steel for the crossarm of a 735 kV is reduced to only 10 percent of the total weight, and the total weight is reduced by about 40 percent compared with the guyed V – tower.

Furthermore, as the weight of each element is relatively low, this type of tower is highly suitable for helicopter erection. The mast can be assembled at a site where the working conditions are favourable and the complete masts can be flown to the tower site. Such mass production techniques are especially desirable when climate, topography and remoteness create difficult construction conditions. In addition, tower erection by conventional methods is simplified. Since there is no heavy crossarm in the tower, the structure can easily be raised from ground level by the use of only one gin pole and a medium size tractor.

A review of this design during a symposium at Hydro-Quebec in October 1973 [Ref. 2] brought up questions, in particular with regard to the stringing and sagging of the lines supported by this structure and also their dynamic behaviour. At the beginning of 1974, Hydro-Quebec committed itself to an elaborate construction and validation program to determine the advantages and disadvantages of the chaînette tower, to solve technical difficulties inherent to the design, and to evaluate the possible economic benefits.

In order to evaluate the construction and the maintenance aspects and to carry out full scale testing, a 4 km experimental line was constructed some 100 km north-east of Montreal (Figs. 1. 3). The site of the line comprising 11 towers of which 9 were chaînette towers, was selected so that topography and soils were representative of a variety of conditions.

Previous to the full scale testing, the concept was analysed first by means of computer programs and then by means of a model of the line at a scale of 1/50.

2. DESIGN

The chaînette tower can be thought of as consisting of two tripods between which the three phases are suspended on a slack cable system. Each tripod has one compression member, the mast, and two tension members, the guys. The ground wires are attached to the top of each mast. A spacer cable is installed between the top of the mast to simplify tower erection. It becomes slack after the weight of the conductors is applied on the structure and has no structural value ; however, it facilitates access to the phases during construction and maintenance operations.

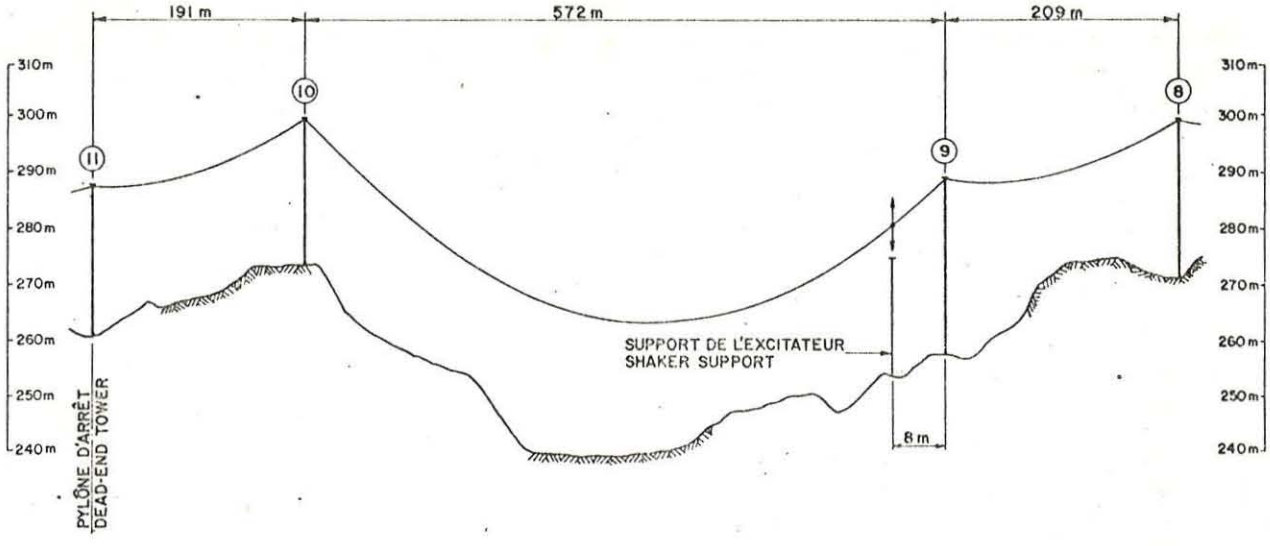

Figure 3 – Partial profile of the experimental line.

2.1. Design Criteria – The tower is designed to support a three-phase line each phase of which comprises 4 conductors of 35 mm in diameter. The ground wires have a diameter of 13 mm. Weights and wind spans are limited to 520 m and the ratio of wind to weight span is limited to 1.2. The maximum ice load corresponds to an accumulation of 32 mm in radial thickness. Design wind pressure is 0.8 kPa on the cables and 1.8 kPa on the masts. 800 Pa 1800 Pa

All members of the cross-rope suspension system must be maintained under tension at all times in order to avoid impact loads on the hardware. This became a design criteria in the shaping of the cross-rope of the towers. It was also an acceptance criterion in the analysis of the tower under a conductor galloping condition. These did not prove to be particularly restraining.

2.2. Tower description – The outline and main dimensions of the chaînette tower are shown in Figure 2. Each mast weights only 3 700 kg at maximum height.

The arrangement at the top of the mast is shown on Figure 4. The cable attachments are compressed types and the ground wire is locked in a permanent pulley by means of a preformed grip. Temporary outriggers are added for the stringing of the ground wire by helicopter.

Guy anchors consist of a grouted steel rod in either overburden or rock.

A chaînette tower can be used for angles up to 5°. The elements used are then identical to those of the suspension tower. However, the top of the inside mast is 3 meters higher than the outside one. The chaînette assembly is slightly modified in order that the three phases be maintained level.

2.3. Foundations – Due to the flexibility of the cross-rope assembly, the structure is practically insensitive to foundation movements. For example, a 15 cm upward movement of one foundation will cause only a 3 percent increase in stress levels in the guys and a 5 percent increase in the masts. The tower is also insensitive to movements of foundations in transversal and longitudinal directions.

A study of the geometrical changes in the structure shows that the electrical clearances are not greatly affected by foundation movements. In the case of a simultaneous 15 cm settlement under the two foundations, the clearance of the external phase to the mast is reduced by only 3.5 percent while the insulator string is vertical and by 5 percent at an extreme swing position of 19°. The clearance to ground of the central phase is reduced by only 70 cm.

Similar behaviour is produced if creep in guys or slipping of anchors is experienced. Therefore, the electrical clearances and stress levels remain acceptable. It will not be necessary then to adjust the guy tensions as on most guyed towers, particularly during the first years, to remedy the effects of creep in guys or foundation movements.

Insensitivity of the tower to settlement or uplift makes it possible to use surface foundations (Fig. 5) installed at a depth not exceeding one meter, even in regions (like the James Bay area) where frost reaches 3 meters. Excavation is then reduced to a minimum. In the case of overburden, the foundation consists of a steel grillage with H beams which sits on a 25 cm pad of compacted granular material. In the case of surface rock, the foundation consists of a grouted deformed bar topped with a steel plate. For both these types of foundation, a spherical plate is added to insure a perfect hinge of the lower end of the mast.

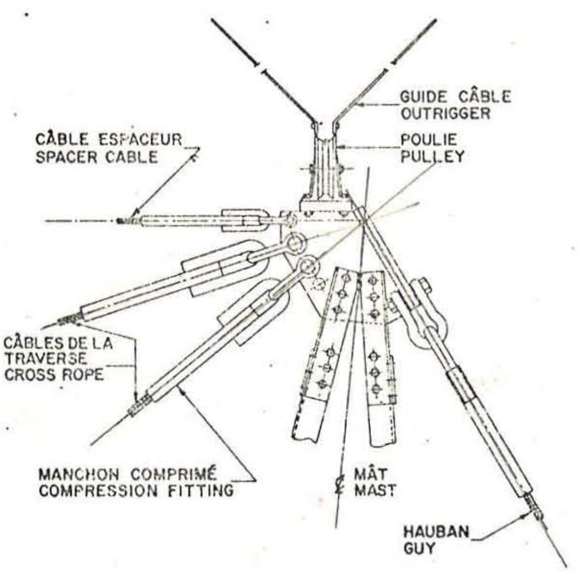

Figure 4 – Hardware at the top of the mast

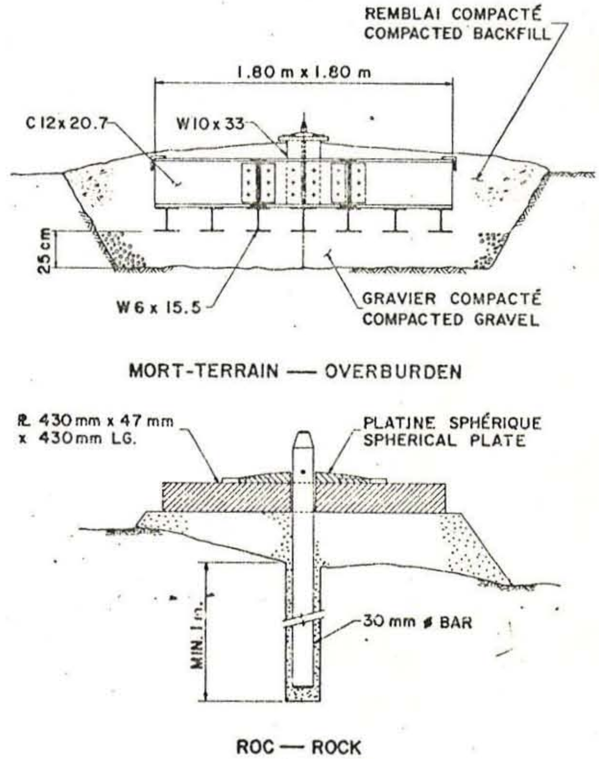

Figure 5 – Surface foundations

Just like the tripod of a surveyor, the structure easily adapts itself to local topographical conditions. For this reason, the construction tolerances on the foundations can be very generous : an error of 30 cm in the horizontal positioning and 75 cm in the vertical are accepted. Analysis demonstrated that the stress levels are not affected by more than 2 percent.

2.4. Weight comparison – The previously mentioned structural efficiency of the concept is significantly reflected in the total weight of the tower. The Table below showing the evolution of 735 kV towers designed by Hydro-Quebec, illustrates this point :

– Self-supporting Tower (1965)	65 tons/km
– Self-supporting Tower (1974)	42 tons/km
– Guyed-V Towers (1976)	31 tons/km
– Chaînette Tower	19 tons/km

3. MECHANICAL STUDIES AND TESTING

Investigating the mechanical characteristics of a line supported on chaînette towers was a major preoccupation of the validation program. Of the static aspects, most unknowns were related to the structural flexibility of the design that is, to its capability of experiencing large displacements particularly in the longitudinal direction. In addition to this highly non linear static behaviour, dynamic aspects were also of interest : responsiveness to conductor galloping, in particular, was an unknown to be clarified. On the other hand, the use of cables requiring many pieces of hardware gave concern as to the possibility of mechanical failure ; thus, study of tower behaviour under mechanical failures was naturally included among the investigations undertaken in order to achieve a sound tower design.

3.1. Static Loads – Two aspects of the behaviour under static loads appeared problematic at the beginning of the studies. The first comes from the fact that the layout of the structure is not determined for a zero load condition, but has to be defined under an "everyday" load case, because large displacements take place between these stages. The analysis of the tower under other loading conditions must then take into account the true initial length of the elements, that is without elastic elongation. The other problematic aspect concerns the evaluation of longitudinal loads on the tower : important displacements occur in the chaînette under unbalanced forces transmitted by the conductors ; this force-displacement relationship being non linear, it is necessary to develop an iterative computer routine capable of simulating the static behaviour of a complete line. The calculation process takes into account non-linearities caused by both the behaviour of the chaînette tower and that of the suspended cables.

As with any tower designed for the Hydro-Quebec network, a chaînette tower was submitted to static testing under ultimate design loads : among these, an unbalanced icing condition was investigated and also a maximum ice load for which the test was pursued until failure. The study of the test results did permit confirmation of the analytical predictions and improvement of the design of the masts.

In order to validate the mathematical model for the analysis of a complete line, one external phase was loaded with weights to simulate an unbalanced ice loading condition. The 572 meters span between towers 9 and 10 (Fig. 3) was loaded with 12 weights of 860 kg each, distributed along the span to simulate a 25 mm radial ice cover on each of the 4 conductors of that phase. The analytical predictions for displacements and forces in the elements were in close agreement with the experimental results.

3.2. Dynamic loads – The study of the dynamic behaviour of the chaînette tower was focused on the phenomenon of full-span galloping initiated by wind action on an iced conductor. This is the only vibration phenomenon that produces important loads on the tower due to the large movements involved.

Studies were accomplished by mean of a structural analysis program : the program determines the natural vibration frequencies of the system (Fig. 6) and calculates dynamic stresses associated with each vibration mode in each of the elements of the line including those of the towers. A similar analysis was performed to simulate infinitely rigid towers for comparison purposes. The results were compared with the theoretical work of Simpson [Ref. 3] and with Japanese experimental results [Ref. 4].

A reduced scale model constructed at 1/50 of the true dimensions was used to verify the frequencies determined analytically. The design of the various elements of this model was done according to dynamic similitude principles so that forces were reproduced 1/2500 those of the real line ; the frequencies obtained on the model were $\sqrt{50}$ times those of the real system. The cables were simulated by bead-chains and elasticity of the guys was taken into account by fixing the chains to cantilevered metal strips (Fig. 7).

The analytical and laboratory research was followed by full-scale testing in the span between towers 9 and 10 (Fig. 3) of the experimental line. A galloping motion corresponding to each of the first three modes of vibration was obtained by mechanical excitation in order to confirm the predicted frequencies and to examine the behaviour of the line. The analytical and experimental studies related to galloping are presented in further detail in the Appendix.

Ice shedding was also simulated on the experimental line by suddenly releasing the weights attached along a span to represent the ice loading. In one of the cases, release of a simulated 25 mm radial icing on each of the 4 conductors in a phase was performed. These tests confirmed analytical predictions of the fundamental mode vibration frequency.

Results of the analytical, laboratory and full-scale work compared fairly well and proved that the expected dynamic stresses in a chaînette tower line are lower than those of a rigid tower system. Full-scale tests revealed that dynamic behaviour is satisfactory.

3.3. Mechanical failures – On account of the extensive use of hardware and because these components are more exposed to mechanical deficiency than laminated steel members due to the fabrication process, a certain number of mechanical failures had to be investigated in order to ascertain the reliability of the chaînette tower : studies were mainly oriented towards failures in guys and in cables from the cross-rope assembly.

figs6/7

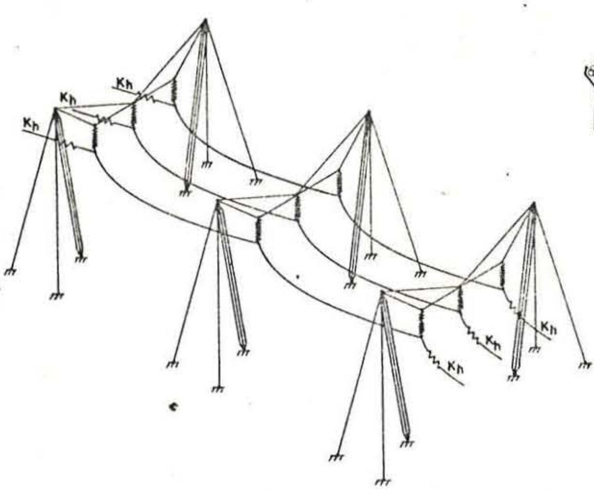

Figure 6 – Mathematical model for the dynamic analysis

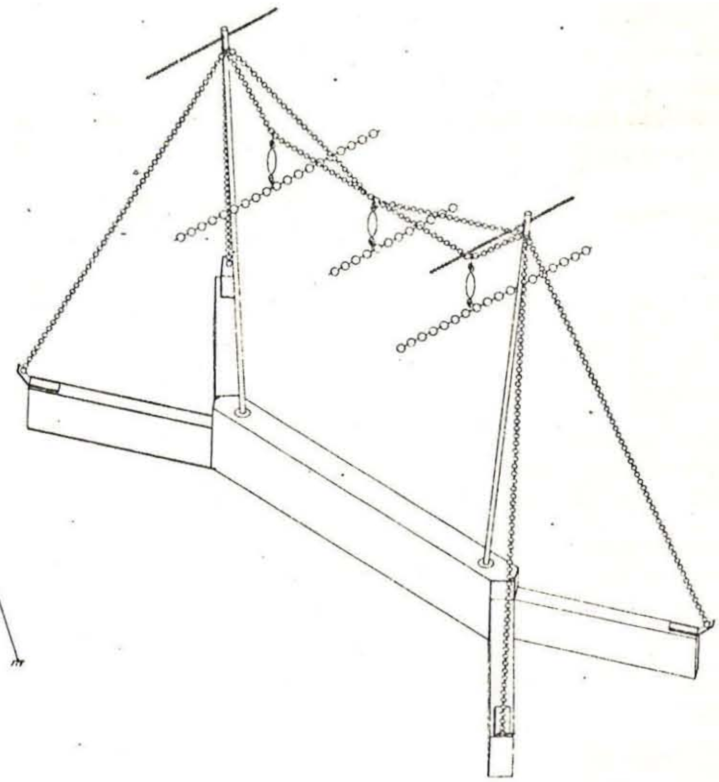

Figure 7 – Reduced-scale model

Tests were first performed on the reduced-scale model since this method of experimentation makes it possible to simulate a large number of cases for each desired method of dynamic excitation.

3.3.1. Broken guy – The first type of disturbance to be studied was the case of a broken guy. The reduced-scale model indicated the predominantly important role of the overhead ground wire which becomes severely stressed when maintaining the affected mast in longitudinal equilibrium. The impact factors related to the behaviour of the ground wire were evaluated using the mathematical model of a complete line ; these impact factors along with the results of computerized static analyses made it possible to estimate the maximum dynamic response of the system under any specific condition, with or without an ice loading in the conductors. These predictions were checked by full-scale tests on tower 10 of the experimental line (Fig. 3) by slowly releasing a guy in the side of tower 11 and of tower 9 : in this last case, the release of the guy was also executed suddenly. Results of static and dynamic analyses proved to be very satisfactory.

Principal parameters involved in the response of the ground wire for guy breakage under everyday loads are the weight-span on the affected tower and the length of the span adjacent to the broken guy. Ground wire tension increases with an increase of the former parameter and with a decrease of the latter.

The failure of a guy also produces an overload in the remaining guy. However, analysis indicates that its tension does not exceed its ultimate design load even for ice loadings up to 10 mm thick on the conductors.

During the full-scale dynamic release, it was noticed that the system reacted smoothly. Oscillations of the affected mast were almost completely damped out after 4 cycles : the return of travelling waves induced in the conductor phases continued to disturb the system slightly for about a minute. Once the system was stabilized, it was established that the tip of the mast had experienced a displacement of 3.7 meters transverse to the line and one of 4.8 meters parallel to the line : electrical clearances were sufficient for the network to be operated even with a broken guy on a tower.

Model testing and computer-aided calculations thus permitted a good understanding and analysis of guy breakage : as a result of these studies a new ground wire was chosen for future lines. Full-scale tests on the experimental line confirmed the exactness of the calculation method and indicated a satisfactory dynamic behaviour.

3.3.2. Cross-rope assembly breakage – Apart from guy breakage, the most important types of mechanical failures that could affect the chaînette tower are those that could take place in members of the cross-rope assembly. For studying these situations, only reduced-scale tests were conducted by cutting off superior and inferior cables of the system. Simulated ice loading on the conductors was included for some of the tests.

Breaking the superior cable did not produce any major distortion in the tower layout and maximum impact load produced in the lower cable did not exceed 80 percent of the nominal cable resistance even with a simulated 32 mm ice cover on the conductors. On the other hand, breakage of the lower cable between the external phase and mast was followed by a very violent swing of the released phase ; however, tensions induced in the upper cable for the tests did not exceed 82 percent of its capacity.

Failure of the lower cable between two phases was not studied ; in fact, such a defect may cause important damage, if not complete collapse, to one of the masts. Therefore, special attention must be given to fabrication quality controls in order to reduce the risk of such failure.

3.3.3. Other mechanical failures – Other tests were conducted on the reduced-scale model and on the full-scale line in order to study some other behaviour aspects of a line on chaînette towers : one such aspect is conductor breakage. According to experimental results, the release of a phase taking place under everyday loads should not cause any damage to the towers. Only the insulators must, in some cases, sustain impact loads greater than their maximum static design load : however, it has been found after reference to other studies [Ref. 5] on the phenomenon, that the momentary overload is much less than that induced in conventional towers. Therefore, as far as conductor breakage is concerned, the chaînette tower is preferable to other types of towers.

4. CONSTRUCTION AND MAINTENANCE

Suitable construction methods for the new chaînette tower were developed under the validation program during the construction of the experimental line.

As indicated earlier, it has been noted that the use of surface foundations allowed reduction of the necessary excavation to a minimum and the speeding up of the construction of the footings.

All the masts were pre-assembled in a yard located at an end of the line before starting erection. The masts were assembled in two sections using mass production techniques and brought together afterwards at the place provided for storage ; these operations proved to be very easy since the design of the masts is simple and all parts can be handled without any special equipment. The guys were all pre-fabricated in the yard, their lengths being determined after measuring the exact location of the anchors relative to the mast footing. The guys were then attached to the masts. A temporary guy, required to maintain the mast upright before the spacer cable (Fig. 2) is installed, was also attached to each of the masts. The spacer cable was fixed to one of the two masts of each tower. The cables of the cross-rope suspension system were pre-cut since their length is pre-determined and the dead-end fittings were shop-compressed.

All the towers of the experimental line were erected by helicopter in order to assess the efficiency of this method. A Sikorski S-61L with a lifting capacity of 3 900 kg was used ; the suspension hook was held about 15 meters under the helicopter by a steel cable and the pilot was in constant radio-contact with the ground signalmen during all operations. The helicopter picked up a complete mast by its upper end, and transported it to the site of the tower. Then the helicopter laid down the foot of the mast on the ground to eliminate any rotational movement and lifted it again to lower it onto the footing base with the help of the ground team. The guys were than attached to the anchors in order to maintain the mast in equilibrium, the helicopter released the sling and the operation resumed with the next mast. The spacer cable, already attached to one of the masts, was installed at the top of the second mast by means of the winch on a caterpillar tractor ; afterwards the temporary guys were removed and the permanent guys were adjusted and pre-tensioned.

In addition to helicopter erection, other construction methods were tried out : a tower prototype which was to be used for the static loading tests was erected by means of conventional equipment. One method, which was repeated several times, used a 30 meter gin pole to erect the 53 meter tower masts. The mast was hung from above its center of gravity and lifted vertically ; then its lower end was directed onto the footing. This method appeared to be very efficient.

The cross-rope suspension system, including insulators and travellers, was completely assembled at the site of each tower. It was hoisted by means of the winches of two caterpillar tractors and connected to the tower.

The stringing of the ground-wires was done by helicopter. A horizontal axis reel allowed the helicopter to lay down the ground-wire into a V-shaped outrigger at the top of each mast. Sagging and attachment of the ground-wires to the dead-end towers were done using normal methods.

Stringing under tension and sagging the bundle of 4 conductors were also done conventionally. Clamping did not involve any problem of differential longitudinal displacement of the attachment points of the conductors. A sliding ladder suspended from the spacer cable and provided with a safety cable allowed the linemen to easily reach the attachment points of the conductors. Several methods of live-line maintenance performed on towers of the experimental line, suggested some minor improvements in the design of tower details. With regard to maintenance, it has been noted that the chaînette tower offers interesting advantages. The smaller number of insulator strings resulting from the use of three I-shaped suspension assemblies and the reduction of the total number of components simplify maintenance operations. A sliding ladder or seat with a few pulleys and ropes are sufficient to ensure access to the insulators and conductors on each phase (Fig. 9).

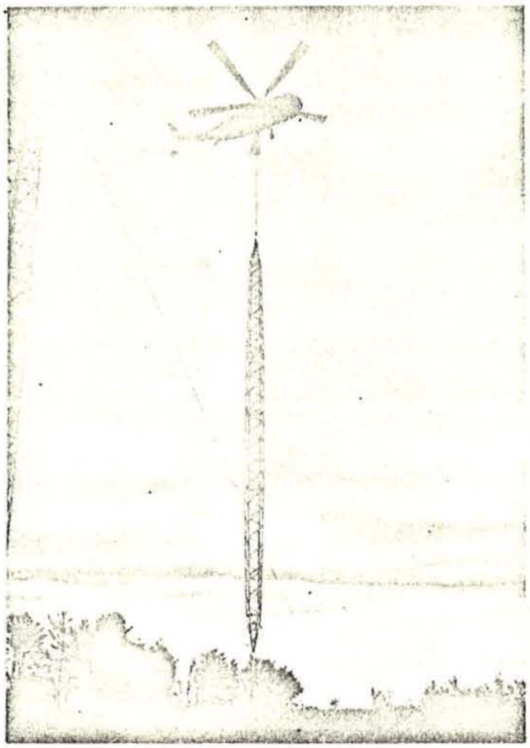

Figure 8 – Erection by helicopter

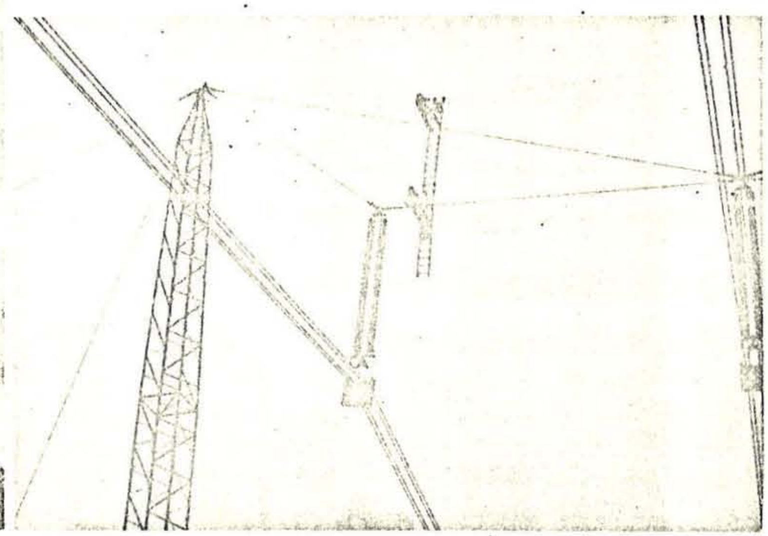

Figure 9 – Access to the cross-ropes.

5. ECONOMIC BENEFITS

Since the assessment of the economic advantage of the chaînette tower is an integral part of the validation program, a study was undertaken in order to compare the costs of a line on chaînette towers with those of a line on guyed-V towers.

The savings in direct cost of the towers were calculated by excluding the fixed costs (right-of-way, conductor, ground-wire, etc.) from the total. Minimum savings amount to 13.3 percent as shown in Table 1.

Therefore we notice a significant economy regarding purchase of materials, as well as assembly and erection. The light weight of the masts, the more generous tolerances in construction of foundations, the easy assembly due to the reduced number of different members, and the I configuration of the insulator strings, are among the factors tending to reduce construction costs.

Table 1

Economic comparison of the towers and estimate of minimum savings

	Guyed-V Tower	Chainette Tower	Minimum Savings
Purchase of materials	49.1 %	42.8 %	+6.3 %
Shipping, storing, distribution	10.0 %	8.4 %	+1.6 %
Foundations and anchors	17.9 %	19.9 %	−2.0 %
Assembly and erection	23.0 %	15.6 %	+7.4 %
	100.0 %	86.7 %	13.3 %

Note : All costs are given as a percentage of the cost of a V tower.

It must be pointed out that the only negative economic aspect of the chaînette tower concerns the foundations. The cost of guy anchors being the same for both types of towers, it is the need to build two footings rather than only one for the guyed-V tower that makes the latter more advantageous in this regard. However, the calculations have taken into account the use of conventional footings buried at a depth of 2.5 m rather than surface foundations like those on the experimental line.

Furthermore, the validation program allowed the identification of several possible improvements in the design. Adopting the chaînette tower will probably involve a decrease in the total construction time. The possibility of erecting the tower by helicopter is also very advantageous in remote areas, or in the case of a very tight schedule, for example in the event of a collapse. Chaînette tower erection experience on a real line section should also lead to further improvements in the construction techniques. It is therefore obvious that the calculated gain represents the lower limit of the possible savings.

6. SUMMARY AND CONCLUSIONS

The chaînette tower presented here is a technically sound concept. Many important advantages result from its inherent flexibility. In the case of mechanical breakage, damage should be more limited for this tower design than for a more rigid tower and it should be possible, in some cases, to temporarily operate the damaged line. The tower's flexibility should also reduce the risk of progressive line collapse (cascade) in disastrous circumstances. Its insensitivity to foundation or anchor movements cuts down maintenance costs and eventually would make the use of surface foundations economically advantageous.

The chaînette tower can be easily erected by means of a conventional method or by helicopter. This latter alternative offers a considerable advantage, especially in cases of collapse occurring in remote areas. Construction and live-line maintenance are easier for the chaînette tower than for the guyed-V tower or the self supporting tower, due to its simple structure, the reduced number of the components and its light weight.

Substantial cost benefits will result from the use of the chaînette tower on an important part of the James Bay 735 kV network. It may be suggested that more substantial savings would be realized if this concept were used in areas where the ice load is of less importance ; the weight reduction, which would probably be more sensitive than for other tower types due to the high structural efficiency of each element, could possibly result in more important savings regarding purchase of materials, shipping and erection.

It must be recognized that the chaînette tower occupies a rather large area at its base ; its use may therefore appear less attractive for inhabited regions. In remote areas, like the James Bay territory, the increased surface requirement does not present any disadvantage ; the reduced visual impact of the structure makes its use interesting in scenic areas. Except at the location of the towers, clearing of the right-of-way can be less than for other types of lines : indeed, the absence of structural elements between phases could allow reduction of phase spacing and, therefore, width of clearing.

The validation program has clearly established that construction, operation and maintenance of chaînette towers on a 735 kV transmission line are not only feasible but also offer advantages over alternatives.

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APPENDIX

STUDY OF PHASE GALLOPING OF A CHAINETTE TOWERS LINE

1. Introduction – Among the vibration phenomena which may affect a transmission line, one can distinguish three particular types: aeolian vibration, subspan vibration and conductor galloping. From the standpoint of the designer, galloping is singled out for further study because it features movements of great amplitude that induce considerable stresses in the tower.

The vibrations of a catenary represent a large displacement non-linear phenomenon, the exact mathematical solution of which cannot be conveniently formulated : only in some special cases of shallow catenaries [Ref. 3], approximate solutions are available. Furthermore, to make this analysis even more complicated, there are static couplings between adjacent spans.

2. Formulation of the Problem – A linear solution is sought. The following basic assumptions and design criteria are considered :

1) The galloping is occurring while the ice surface on the conductors is 1290 mm^2 (9.3 mm radial ice thickness), which corresponds to the most probable occurrence during the fifty year period for which it is designed.

2) The maximum galloping amplitude for a vibration of the phase in the fundamental mode is 6 meters. The maximum amplitudes in the second and third modes are of $6/2^2$ (or 1.5 meters) and $6/3^2$ (or 0.67 meter) respectively.

3) At rest, each structural member of the chaînette tower is under static load originated from the self-weight of the line. The assumed design criterion is that dynamic loads should never cancel out the initial loads in the cables, under the previously mentioned galloping amplitudes, in such a manner to avoid impact on the hardware.

4) Galloping usually occurs on a line covered with ice under heavy wind, when the ice cover on the conductors produces a shape which causes aerodynamic instability. Since the lift and drag forces strongly depend on the shape of the icy conductor section, an assessment of aerodynamic forces is practically impossible. To circumvent this dilemma, aerodynamic considerations are abandoned and only free vibration of the system is considered, independently of driving forces. A simple normal mode analysis is performed. The dynamic stresses in the towers for unit deflection of each characteristic mode are computed. The influence of the adjacent spans is represented by springs (Fig. 6) the stiffnesses of which are function of the physical and geometrical properties of the line [Ref. 6].

3. Linear Analysis – To study the problem, a theoretical perturbation method presented by Simpson [Ref. 3] and a numerical analysis by the normal mode method using a computer program were applied. Both these methods assumed linear behavior of the system. However, one can question the validity of a linear solution under large displacements (about 6 meters for the first mode). To answer this objection, Simpson's method was used in order to predict the frequencies corresponding to the first four vibration modes of the Japanese experimental lines [Ref. 4]. The recorded results which applied to 310 meters spans at galloping amplitudes of 5.2 meters are very well matched by the theoretical calculations, thus providing experimental evidence to justify the linearization.

4. Model for the Computer Analysis – A two span model (Fig. 6) with both ends fixed is first employed. Normal mode method and Simpson's method yield identical results (0.41 Hz) for the fundamental frequency of a 365 meters two span system, without ice load. Assuming a 1290 mm^2 ice cover, the computer method and Simpson's method give 0.350 Hz and 0.357 Hz respectively : all in all, there is close agreement.

In computer modelling, both two and four span models were developed. To represent realistic end conditions, static coupling between adjacent spans is simulated by a horizontal elastic support with a spring constant k_h. For fixed end, k_h is equal to infinity. All structural members of the chaînette tower are simulated by rods characterized only by axial stiffness. Each phase is considered as a chain, the links of which are also rods with only axial stiffness. The connections between links are provided with vertical springs to simulate the bending stiffness of the cable resulting from its tension T. The stiffness of these springs is defined as :

$$K = \frac{T}{\ell}$$

where ℓ is the length of each link. This length is chosen through vibration considerations : in the simulation of a continuous system by a series of finite elements, Duncan [Ref. 7] shows that approximately 13 elements per complete wavelength are required to ensure errors in frequency of less than 1 percent. As this investigation is concerned with the first three modes each span length is divided into forty links. The bundle of 4 conductors forming each phase is replaced by an equivalent single conductor in the model. Two different span lengths of 365 meters and 520 meters are considered in the study.

For the two span analytical model, spring constant k_h of 1,790, 3,570 and 10,700 kg/m corresponding to adding approximately eleven, six and two additional spans respectively, have been used in the analysis.

As the stiffness increases, the natural vibration frequencies and the dynamic loads in the structural members [Ref. 6] increase also. However in all cases considered, dynamic loads do not cancel out the initial static tensions in the cables, which satisfies the design criteria. Therefore the design is considered safe. If the spring constant k_h increases from 10,700 kg/m to infinity (completely fixed ends), the dynamic response involves slackening in the cables : the design becomes unsafe. A model composed of two unequal spans was also analysed : the influence of offsetting span lengths appears to have practically no influence on dynamic loads and natural frequencies. So far, the movements of conductors and insulators are limited only to the vertical plane. In reality, the sway of the insulators can also take place in the transverse plane perpendicular to the conductor. When the displacements in both directions are permitted, the dynamic loads and the natural frequencies decrease ; however, the decrease does not exceed 2 percent.

One advantage of the numerical computerized method over the theoretical method is that many spans can be added to the basic model to simulate more precisely the influence of adjacent spans. As a final step in this analytical study, a four span model was developed ; the results compare favourably with those obtained from the two span model ; however, it must be noted that offsetting span lengths produces an important decrease of the dynamic loads though it does not decrease the natural frequencies.

It must be mentioned that an analysis has been done on a line model where the towers were replaced by extremely rigid supports. In this case, the dynamic loads in the insulator strings appeared to be higher than those obtained with the model for chaînette towers ; therefore, it can be stated that the galloping phenomenon causes less dynamic load in a chaînette tower than in a more rigid tower.

To sum up, the chaînette tower line can safely withstand a 6 meters gallop amplitude under 1,290 mm^2 of ice. For equal loading conditions, the dynamic loads induced on a chaînette tower are lower than those sustained by conventional towers because the former are more flexible.

5. Experimental Studies — Prior to experimental studies on the full scale line, a 1/50 scale model was developed and tested. Its design was based on the principles of dynamic similitude. This scale model allowed the reproduction of a variety of geometric conditions and it was therefore possible to confirm theoretical predictions [Ref. 8].

Then, tests on the full scale experimental line were conducted. Experimentation was done on the 572 meters span between tower 9 and 10 (Fig. 3) : a shaker located about 8 meters from tower 9 was used to induce vibration in one of the phases.

The purpose of the experiment was to verify the analytical findings concerning the resonance frequencies and the dynamic loads for one, two and three loop galloping modes of 6 meters, 1.5 meters and 0.67 meter amplitudes respectively.

One-loop oscillations were produced by several means. One of them was to pull a rope fastened to the phase at midspan. Another was to drop simultaneously a series of weights which were suspended along the span. A third method was to pull the line down by means of a bulldozer and suddenly release it. All member stresses, frequencies and logarithmic decay were obtained from continuous graphic recordings.

Calculations by the computerized normal mode method yield frequency values of 0.130 Hz, 0.133 Hz and 0.136 Hz for one-loop mode while the experimental data give 0.126 Hz (deviation ± 0.001). When guys are attached to the suspension clamp to prevent longitudinal movement, the experimental natural frequencies increase to 0.157 Hz (deviation ± 0.04). In all cases, the gallop amplitude ranges from 6 to 17 meters while the displacement of the suspension clamp at the bottom of the insulator string ranges from ± 0.6 to ± 1.4 meters. The apparent logarithmic decay varies from 8 percent to 67 percent, this deviation resulting from travelling waves adding to the induced standing wave : therefore the logarithmic decay data is given as recorded. The dynamic loads never exceed 37 percent of the normal static loads, even for the most severe gallop amplitude.

All two and three loop modes were excited by the shaker. Two signals, the first corresponding to the force, the second to the displacement of the shaker lever are transmitted to an oscilloscope and represented on the y and x axis. At resonance, an ellipse shows up on the screen of the oscilloscope with its major axis nearly horizontal and its minor axis nearly vertical ; the driving arm of the shaker is then decoupled and continuous recording of stresses and displacements is done on a plotter.

The calculations yield frequencies of 0.215 Hz and 0.216 Hz for two-loop modes with the insulator string being free to sway. The mean experimental value is 0.215 Hz (deviation ± 0.004). As the longitudinal movement of the insulator is practically insignificant, the vibration frequency is not affected whether the suspension clamp is restrained or not, by additional guys. All the experimental results for resonance frequencies are in very close agreement with the theoretical ones. However, there are some discrepancies between experimental and theoretical dynamic loads : even so, the dynamic loads are still well below normal static loads. The logarithmic decay ranges from 4 percent to 7 percent.

The three-loop vibration mode is excited by means of the shaker but requires a flexible coupling to the phase because of considerable longitudinal motion. Therefore, boundary conditions have an effect on resonance frequencies : the value of 0.305 Hz is obtained when insulator strings are free and 0.323 Hz (deviation ± 0.002) when insulator strings are restrained. The theoretical results corresponding to the first case are of 0.326 Hz and thus agree fairly well with the experimental values. The logarithmic decay ranges from 5 percent to 8 percent and the deviations concerning dynamic loads do not exceed 40 percent.

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Session de 1978

IMPRIMERIE LOUIS JEAN – 05002 GAP

New hot-stick procedure developed by BPA

Cross-rope "Chenette" towers require special procedure for hot-sticking

By Donald P. Ellsworth, Chief, Transmission Line Maintenance, Bonneville Power Administration

In 1982, the Bonneville Power Administration (BPA) constructed 157 miles of 500-kV line from the vicinity of Moro, OR, to Summer Lake in south central Oregon. The line is part of the Northwest-Southwest Intertie between Oregon and California. The design of this line includes about 35 miles of "cross rope" or "Chenette" type towers (Fig. 1). The average height of these structures is approximately 110 ft. The conductor is made up of three-bundle (Bunting) ACSR 1.192 kcmil. Bunting weighs 1.34 lb per ft. The average span is approximately 1300 ft and the average vertical load is about 5200 lb.

BPA's branch of transmission-line maintenance in Vancouver, WA, developed methods to perform live-line maintenance on these towers. Since the procedure would involve linemen being supported on the cross ropes, we conducted tests to ensure the mechanical integrity of the poured zinc fittings in our laboratories. The tests included high current through the connections to ensure they would be stable under fault conditions. BPA's laboratory subjected the end fittings to 1300 A for 4.3 minutes. Cross-rope strands were glowing bright orange and the end fittings remained solid. The tests documented performance of the fittings and were useful in reassuring linemen of the structure capability.

In addition, we further assured that we could suspend men and apply external loads to the cross-rope assembly by applying concepts contained in a *T&D* article published November, 1978, by Winston S. Acton of BPA, *Computer aids weights-on-line solutions*. We applied safety grips at the point of attachment of the construction guy to give an extra margin of safety (Fig. 2).

The next step in developing our procedures was tool development. A 5-ft bar, with a wheel on each end, was developed by A.E. Borter and Hayes Conaty of BPA. This bar was used to support a ladder on the uppermost guy that ties the top of each

Fig. 3. A step platform was attached to the bottom of the ladder.

mast together. This upper guy is referenced as the "construction" guy. Using this method, we position a man at the center insulator-suspension point on the cross rope. A step platform was attached to the bottom of the ladder to give the lineman a "porch" to work from (Fig. 3).

An additional ladder was positioned on the lower cross rope at the level of insulator attachment, equidistant between the phases, which are 26 ft apart. A 16-ft hot stick was attached to the center phase and secured to the ladder in a saddle clamp (Fig.4). This hot stick maintained a clearance of 13 ft from the ladder to an energized phase.

To remove the center vertical string of insulators, we proceeded as follows: A saddle tool was placed over the center insulator-attachment bracket to support the lift sticks with

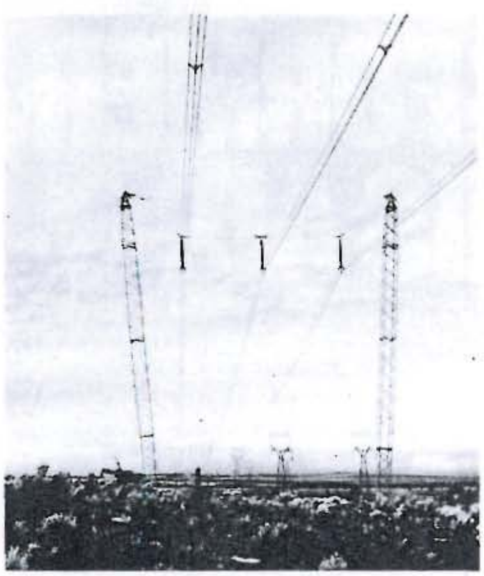

Fig. 1. BPA 500-kV line has 35 mi of "Chenette" towers.

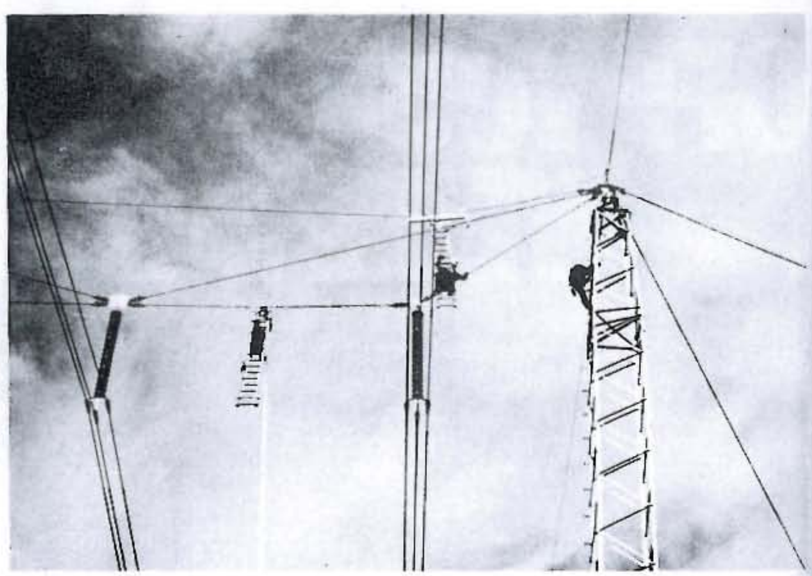

Fig. 2. Safety grips were applied at the point of attachment of the construction guy.

Fig. 4. A 16-ft hot stick was attached to the center phase and secured to the ladder.

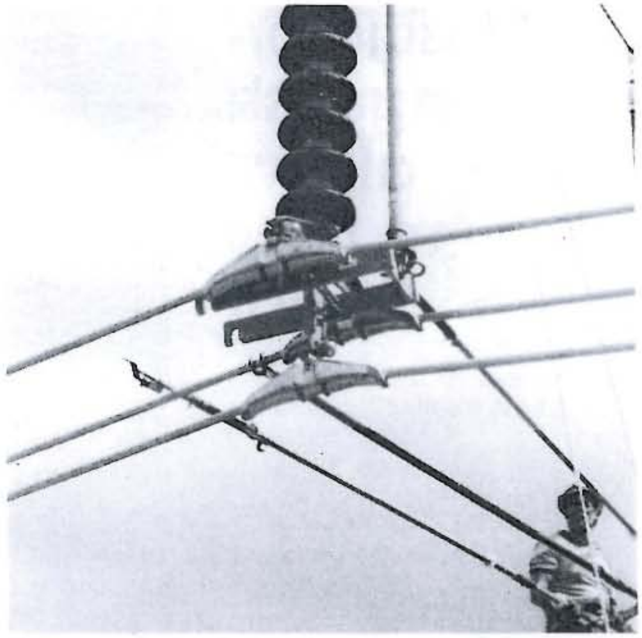

Fig. 5. Saddle tool was placed over the center insulator-attachment bracket to support lift sticks.

corresponding jack screws with rachet handles (Fig. 5). A lift stick with the hot-end attachment was installed on the conductor-support bracket, and a second lift stick was attached to the bottom bracket and hooked to the rachet handle. The strain on the insulators was then transferred to the lift sticks by operating the rachet handle to pick the conductor. Two men on the ladder supported by the lower cross rope separated the ball/socket insulator connection with hot sticks (Fig. 6). A large "pig tail" stick was attached at the third insulator down and a strain on the tool by means of the handline slacked the "Y" ball at the top insulator support bracket. Replacing the insulator string then became routine as it followed the reverse sequence (Fig. 7). To our knowledge this is the first hot-line maintenance performed on this type of tower in the Northwest. BPA's Redmond district line crew, supervised by Stan Peterson, performed the work. T&D

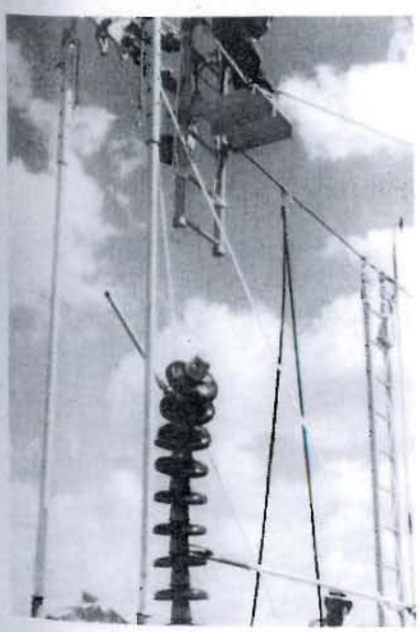

Fig. 6. Two men on ladder supported by the lower cross rope separated the ball/socket insulator connection.

Fig. 7. Replacing the insulator string followed the reverse sequence.

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POWER ENGINEERS
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THE CROSS ROPE SUSPENSION STRUCTURE

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Introduction

This paper describes the design, construction and operation of a guyed suspension tower used in extra high-voltage (EHV) transmission lines, known as the Cross Rope Suspension (CRS) structure. The CRS concept, whereby conductor phases are suspended from a transverse spanning wire rope instead of from rigid crossarms, is a line structure like no other, as different from square-based rigid latticed towers, Guyed-Vs, H-frames and the rest as a jet plane is from a propeller-driven one, or as an aluminum overhead conductor is from a copper one. With a design based on simplicity, flexibility and strength, and utilizing the two most efficient elements of structural engineering, namely a wire rope in tension and a lattice mast in compression, it comes close to being a truly optimum structure.

The CRS structural concept has been utilized in difficult and remote areas and across valleys in North America and, as a tower system, in long transmission systems in Canada, South Africa and Argentina. A compact variation of the CRS tower has been used in Europe, taking advantage of its low visual impact, narrow Right of Way and marginally improved electric and magnetic field characteristics.

In spite of such strong credentials, including its all-important low impact on the environment and very low cost to strength benefits, designers, utilities and the public are still reluctant or hesitant, or simply decline, to consider the CRS tower in new or existing projects. This may possibly be due to poor understanding of the strength of this design and its behavior, and unfounded reservations that its somewhat larger base area would sterilize more arable land. In the event that inaction is the result of lack of information about this unusual structure, this paper is presented to compile in one place many of the qualities and advantages of the CRS tower, a few perceived disadvantages and a brief review of major applications.

Brief History of the Cross Rope Suspension (CRS) Concept and Tower System

One of the first transmission line applications of the Cross Rope concept occurred in 1955 when a massive avalanche damaged five towers of the Kemano-Kitimat 315 kV lines in a valley in British Columbia. This is a very rugged mountainous area with difficult problems of finding any, let alone safe, tower locations, combined with the potential of extreme winds and ice loads, in the order of 60 N/m (4 lb/ft), in the most exposed sections.

Designers quickly realized that there where no really safe locations in the valley due to the magnitude of the avalanche threat and, to avoid relocation of the lines, a radical solution was thus implemented: Two 77 mm (3 in) steel cables spanning 1.2 km (0.75 mi) across the valley would suspend the 6 phases of 58 mm (2.3 in) conductors well above the avalanche threats that would pass below, see Figure 1. This Cross Rope suspension arrangement has supported, to this day, the nearly 2 km (1.2 mi) long, 6-conductor section of lines with no significant incidents, White (1956).

Figure 1

With the exception of relatively short low voltage cross suspension spans built in Hawaii, and a recently uncovered application with short cross spans in a narrow gorge in Russia, the CRS concept remained dormant for almost 20 years. During that period, the structural efficiency of wires and lattice masts and crossarms found application in the Guyed-Portal structure, used in relatively flat terrain in northern Europe, and the Guyed-V tower, used in more difficult terrain in North America, White (1960). Guyed-V towers became a preferred suspension structure for EHV lines but their limitations became apparent with their use at the 735/765 kV level. As line voltage increases, towers become top heavy as the crossarm width increases almost directly with voltage while height increases more slowly.

The cumbersome weight of a 735/765 kV class Guyed-V tower requires complex arrangements and heavy mobile cranes and access for erection, as seen in Figure 2, and the tower itself exceeds the capacity of almost all helicopters. This was the scenario confronted by line designers in the early 1970s when the 735kV James Bay project of Hydro-Quebec was under study, Lecomte (1980). In addition to construction difficulties in remote areas, a tower failure from whatever cause could become a major problem of access for repair if the sometimes very long access roads were not immediately available. It is difficult to maintain long bush roads throughout the year where some of these lines were soon to be built and when the only access was really over frozen swamps and muskeg in the winter, a springtime accident could be costly.

Figure 2

Figure 3

A different tower type or construction method was therefore desired for the James Bay system as all conventional tower systems carried severe handicaps of construction or maintenance or both. A cross rope support system suspended between the tops of two guyed masts was proposed as an appropriate tower or support system by White (1973), and although the project schedule did not permit their use on the first two James Bay lines, they were installed on the next three lines totaling approximately 2000 km (1250 mi) in length, Souchereau (1978)**.** The new tower type was called the Cross Rope Suspension, or Chainette in Quebec, Figure 3.

The initial concept was derived from the single rope concept of the system used in the mountains of British Columbia, but fear of galloping resulted in a proposal for a 6-part suspension system. The triangulated suspension system will prevent oscillatory vertical forces at one support point from being transmitted to other phase support points.

Figure 4

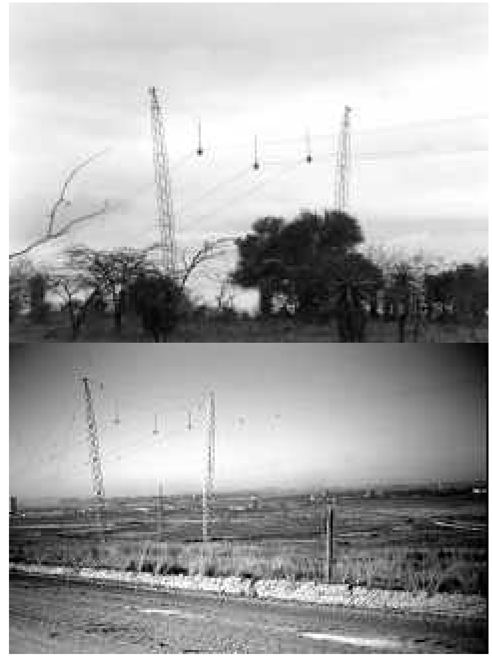


Figure 5

A test line verified the advantages of construction and operation of this new support system and especially the advantages and ease of use of small helicopters for transport and erection of the components, while a special test verified the value of the 6-part cross rope system in avoiding potential galloping resonance of the system.

CRS usage and development continued as the Bonneville Power Administration (BPA) constructed a 60 km (37 mi) stretch of 500 kV CRS lines in Oregon in 1982, with a 6-part system necessary for the icing areas of the Pacific Northwest, Ellsworth (1986). In Sweden, on the other hand, Vattenfall developed a compact version of the CRS tower for their 420 kV national grid, Gidlund (1988). The Swedish CRS tower design, shown in Figure 4, is based on a Guyed-V structure where two V-string insulators for the outer phases and an extended I-string assembly for the middle phase, all supported from a cable and post system between the guyed masts, replace the steel crossarm.

The next significant line project using CRS structures took place in the early 1990s in South Africa. Eskom, the South African power utility, developed the adaptation of the CRS technology for the South African conditions, initially at a voltage of 400 kV. The standard Eskom CRS tower is of very simple construction, shown in Figure 5, consisting of two guyed masts connected by a spacer cable and a single cross-rope, Behncke (1994). The absence of an icing threat enabled this first large-scale use of the single cross rope system whereby the conductor phases are suspended from the cross-rope by inverted suspension clamps, and each clamp is kept in place by two compression sleeves.

Recently Transener, the Argentine high-voltage transmission operator, has completed the 4th Line Project, a 1300 km (800 mi) long 500 kV transmission line supported by CRS structures, Lezaola (2001). The Transener CRS structure design is similar to the Eskom model, but with longer masts, reflecting the higher voltage and quite long span construction.

Main Design Characteristics

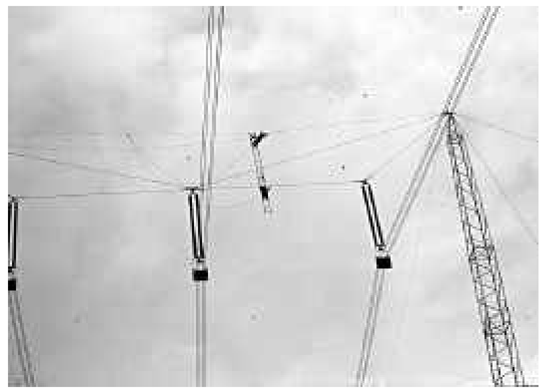
As described above, the CRS tower used in EHV lines is made of two guyed masts connected by a spacer or construction cable and the main cross rope, the latter being a single cable or a 6-part cable arrangement from which the phases are suspended. The masts use common-end tapered pieces with various combinations of extensions that allow the height of the tower to be adjusted, as well as to locate structures on steep side slopes by using unequal mast lengths. Mast slopes are usually set at 1/10 because vertical masts do not appear attractive and the 1/10 slope makes it easy to spot the footings. The shield wires are attached at the tops of the masts and thus carried above and outside of the outer phases. This negative shielding angle offers the best lightning protection possible.

The design loads of wind and/or ice on wires and the wind load acting directly on the masts are very easily traced through the cross wire and mast components and down through the guys to the anchors and footings. The masts act as beam-columns under biaxial bending, and a manual second-order analysis, e.g., using the secant equation, Chen (1987) would yield acceptable results without the need for more complex modeling.

The cross rope assembly will distort with transverse conductor wind loads, which directs attention to the cross rope sag/span ratio. A very low sag/span ratio imposes high continual loads in all components due to conductor weight span supported by the cross rope, and thus high everyday tensions in the suspension wires and guys that may induce vibration. Excessive sag of the cross rope, on the other hand, will reduce component tensions under vertical conductor loadings, thus requiring slightly taller masts, a minor issue. However, if the sag is too great, the cross rope system will become sloppy and distort too much under transverse wind on conductors, creating clearance problems that require that the masts have to be moved further apart. Usual practice is a sag/span ratio of 1/5 or 1/6. Elastic distortions due to load changes in different sections of the cross rope assembly will be found to be negligible compared to the geometric distortions.

The lack of steel members between phases permits reduced phase spacing. This effective compaction can be very valuable on long lines as the increase in surge impedance load (SIL) and reduction in series compensation, partially compensated for by increased but less costly static vars, can produce savings approaching the purchase cost of the steel masts themselves, Lezaola (2001). However, the phase compaction is limited by gradient effects such a RI, AN, corona losses and mid-span spacing. The 7 m (23 ft) phase spacing used on the 4th Line Project in Argentina respects the gradient conditions and spacing for wind motions. In areas with frequent icing and strong associated winds producing large-amplitude galloping, however, the subject of phase spacing would require further study.

Figure 6



Fabrication, Construction and Tolerances

The only critical dimension for erection is the spacing between the tops of the masts, which is controlled by the pre-cut length of the spacer cable. With this distance and the known height of each tower, the elevation of the guy anchors and mast footings can be surveyed and the guy lengths can be calculated. The guys can be pre-cut and end-fitted with allowance for insertion of a tension device, such as a turnbuckle or U-bolt, at only one of the guys. Thus, the construction process is as indicated below:

- The masts are assembled at each tower site or at a remote camp if helicopters are used.
- One mast with its guys is erected first, the guys are attached to the anchors and the mast is held with a temporary rope to the opposite footing.
- The second mast with its guys and the spacer cable is erected, the spacer cable is connected to the first mast and the guys are attached to the anchors.
- The temporary rope is removed and the adjustable guy takes up the slack until the spacer cable is tight. At this point the structure is approximately plumb.

- The cross rope system with attached insulators, stringing blocks, clamps and pilot lines can then be raised with no more concern about the guy tensions or plumbing of the structure or any other control.
- Stringing, regulating and clamping-in is as for any other line, working from ladders rolling on the spacer cable, see Figure 6, instead of fixed ladders that have to be moved in stages from support points on a crossarm, (Ellsworth 1986).

Because of its great flexibility (no rigid connection points), the CRS structure is very insensitive to what would normally be unacceptable construction errors when working with most other types of line structures. Thus the tolerances on setting of footings and anchors and precision of erection can be moderate as errors in the order of 0.3 m (1.0 ft) or so are of no structural consequence. Minor self-adjustment of the cross rope and negligible tilting of the masts will absorb any errors. The only critical dimension is the correct spacing of the mast tops, which is ensured by the pre-cut and fitted spacer or construction cable.

The guys are automatically pre-tensioned when the conductors are raised and attached to the suspension cross rope, and the every-day tensions in the wire components and guys are set by the weight span supported plus the effect of any line angle carried.

Before concern is raised about the precision needed to cut and end fit (shop applied compression fittings suggested) the spacer cable, the cross rope cable(s) and the guys, the usually specified tolerance is about ± 5cm (± 2 in), a not unreasonable task. Even a ± 10 cm (4 in) error in the cross rope, or in any of the guys, will result in a difference in sag at mid cross rope of no more than about ± 10cm (± 4 in), well within usual buffers for survey errors.

Advantages of CRS Towers

The CRS structure is simple, flexible and strong, and some of its salient advantages with respect to traditional transmission towers are listed below:

- Exceptionally high strength/weight ratio, consisting as it does of only two latticed masts and some wire rope elements while its steel weight is about 50 percent of the weight of a 500 kV Guyed-V structure of comparable capacity.
- The low cost of materials is more than equaled by the rapidity and low cost of tower assembly and erection, with single crane crews erecting dozens of pre-assembled masts in a day. Pre-cut and fitted guys eliminate all the usual problems of plumbing structures and tensioning guys.
- All CRS structures are almost automatically anti-cascade structures, the extra relaxation afforded by the depth of the CRS suspension added to the normal insulator string length significantly reduces the residual static (RSL) load,

while these longitudinal loads applied by the insulator strings to the cross rope are transmitted directly to the strongly guyed points of the tops of the masts.

- Calculations and field tests have verified that, with the assistance of the shield wires, the CRS tower can sustain the loss of one guy, still retaining 55-60 percent of its design transverse capacity, Souchereau (1978). Under this situation, the clearance from live phase to mast may be sufficient to remain in operation, a possible problem for identifying and locating failures in remote areas.
- The strength of the CRS tower can be increased significantly by simply using larger steel cables, and the central sections of the masts can be reinforced, thus increasing the chances to sustain direct impacts from moderate high intensity winds (HIW), such as tornadoes, at no more than 2-3 percent of the total cost of the structure.
- The masts plus incremental extensions can adjust to irregular terrain and, when used with specially fitted cross ropes, can create angle suspension towers for line deviations up to about 12-15 degrees.
- The CRS structures get the highest environmental rating for use in rural settings as they practically disappear from view at 0.5 km (0.3 mi), the only visible evidence of a line can be the sun shining on the wires. The actual impact on the terrain will be of two small compression footings for the masts and four guy anchors; the spacing between the bases being large enough to allow passage of normal farm equipment, thus with no dead space as found with typical 4-leg lattice towers where only weeds can grow between the corner legs.
- If one or more structures are destroyed by a tornado, macro- or micro-burst or any other casual event, such an errant crop duster, the damage will most likely be confined to the masts, with all wire components immediately reusable. Repairs should be made as quickly as new masts can be brought to the site. In fact, the CRS design has been adopted by some utilities for emergency replacement structures, an indication of its versatility and ease of construction.
- The CRS is simple in design and construction with all assembly work, except for a few wire rope connections, done on the ground, which saves costly time and reduces the risk of accidents. The masts are light, e.g., 2 tons each approximately for a 500 kV line, resulting in easy erection with winch and gin pole, or ‘A’ frame, or by small mobile cranes, or relatively small helicopters.
- Maintenance procedures follow those used for construction with access to the insulator strings directly from the masts for the outer phases or from ladders that roll out on the spacer cable for the center phase, as shown in Figure 6.

Some Disadvantages

The space required for the installation of a CRS structure will be somewhat larger than that for a Guyed-V, but the reduced spacing between phases of the CRS will result in a narrower right of way (ROW) between the structures. The inter-phase spacing on the 500 kV line built in Argentina with CRS structures, Lezaola (2001), is 7 m (23 ft) as compared to the 12.7 m (42 ft) required on the Alicura 500 kV Guyed-V line built in the 1980s for the same conditions, Behncke (1984). The 13 m (43 ft) reduction in ROW width on a span of about 500 m (1650 ft) will more than compensate for the small-added area at each structure site.

The subject of access to the insulator strings and conductor support points for construction and maintenance operations is of valid concern to line designers and field personnel considering the use of the CRS structure for the first time. However, experience from the very first trials at Hydro-Quebec through to the projects at Bonneville Power to South Africa and Argentina has shown that the line crews can readily adapt methods and equipment to suit the structure, with the dominant new component being the use of ladders with rollers to run on the spacer or construction rope.

One major utility that left the problems to the line crews to work out found that, after suitable adjustments, the crews could clip-in 4 phases in the usual time for 3 phases. The efficiency resulted from being able to roll quickly across the structure from phase to phase, without having to climb up and reposition the ladder and miscellaneous equipment at another point on the crossarm.

The authors know of no other perceived or real disadvantages but would welcome all comments, problems and ideas as they wish to complete their understanding of this interesting structure.

Conclusion

The CRS transmission structure, of simple design and flexible but strong construction, has been extensively tested and has been now in service in several countries at voltages from 400 to 765 kV. Its qualities of line compaction and low visual impact make the CRS tower an ideal solution for sensitive environmental areas. Finally, and contrary to the common perception, use of the CRS tower is beneficial to farmers, as the distances between the masts and between the masts and the guys are sufficient to allow normal farming activities, with minimum loss of arable land.

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SPECIAL HARDWARE FOR CROSS-ROPE CABLE

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SUMMARY

During those last years, engineers of the industry have being developing studies about new technologies for Extra High Voltage Transmission Line, in order to enhance competitiveness by finding better economical solutions. In other hand, more and more the technical requirements have being improved to attend more restrictive criteria of security and maintenance.

That study has shown that the use of Cross-Rope structure, for in lines of 500 kV and above, results in a substantial overall cost reduction of the project.

This paper summarizes the entire process of the development of special hardware for the Cross-Rope cable, including researches and the final laboratory and field tests.

KEYWORDS
Transmission Lines, Towers, Cross-Rope, Hardware

INTRODUCTION

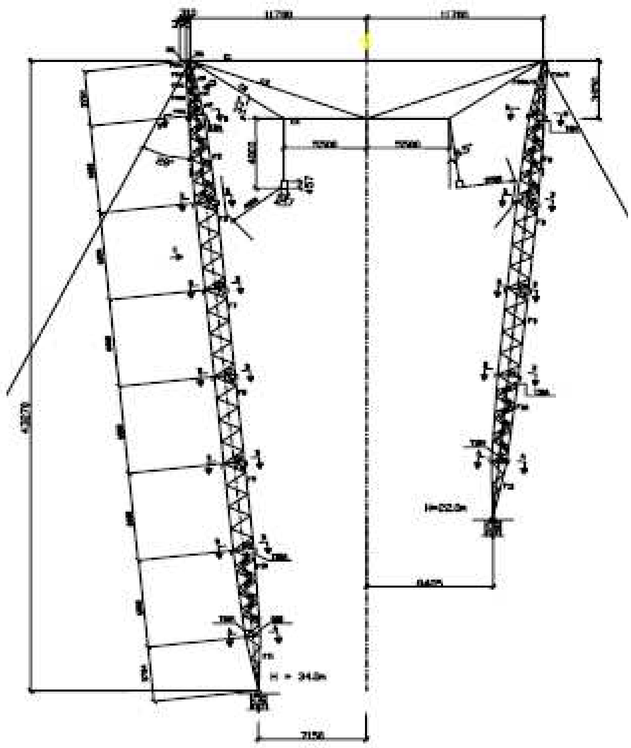
Most of the transmission lines in the north of Brazil, in the rainforest area, are located in and uninhabited areas, with very flat terrain and exposed to moderate wind activity. A careful study is required for those lines, to assure that the environment requirements are fulfilled. Among several different designs for suspension towers, Cross-Rope was chosen due the low visual impact and it's economical and safety performance.

In the process of selecting the final design, two solutions for the basic configuration of suspension towers were study: Trapeze model (Chainette) and the new version CCRS (Compact Cross Rope Suspension) (pictures #1 and #2). In both cases, finite element based mechanical software was used, as a first approach for the loading diagram, followed by prototype testing. The CCRS version was chosen by it's versatility and low cost, and was adopted in those projects.

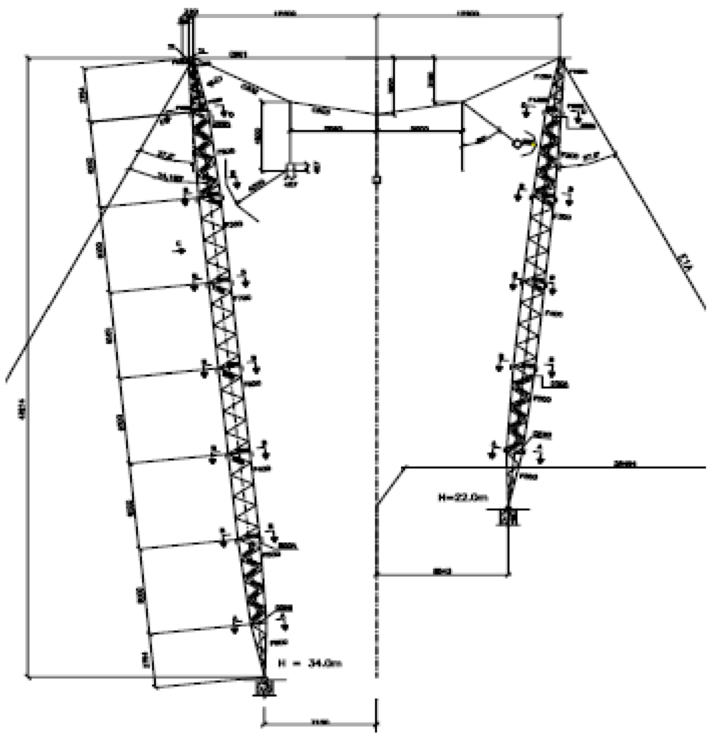
The design concept adopted for the development of the Cross-Rope Hardware was based on the principle of helical attachment devices, which avoids the tensile concentration, as well as reduces the risk of misapplication, providing long-term life expectation in service expectation in service.

1– Historic

This concept of towers has being used in several countries for many years, with different design and line voltages. In Brazil, the first project was built in northwest area, in 2001. A 500 kV Single Circuit Transmission Line, with approximately 2,000 Km was built using Cross-Rope suspension towers.



Picture. #1 – Chainette)



Picture. #2 – Cross-Rope

2 General Conception of the Structure Compact Cross Rope

2.1- Electrical Performance

The electrical aspects of the electrical performance of the hardware are not the object of this paper, however, as an informative purpose, it was shown the main electrical parameters for this first project in Brazil, in 2001.

2.1.1 – Basic Electrical Parameters

The following parameters were considered to define the electrical requirements for the Cross-Rope Suspension Tower in this project:

- Line Potency : 1,200 MW
- Line Voltage : 500 kV
- Conductors : 954 MCM – 45/7 Rail
- Bundle = 4 x 0,457m
- Phase Configuration Horizontal
- Phase Distance = 5,5m from the axis of the bundle.

Based on those parameters, the suspension Cross-Rope tower was designed.

2.1.2 – Electrical Requirements:

The electrical characteristics of the suspension string were defined based on the follow electrical requirements of the line:

- ✓ Number of insulator per string: leakage distance 25,4mm/kV rms;
- ✓ Electrical Field: Maximum one meter from the ground, at the boarder of cross area of 5kV/m, and at the line axis = maximum of 15 kV/m;
- ✓ Distance conductor-ground = minimum 10m;
- ✓ Free Corona Visual; at 500kV x 1.15 phase to phase
- ✓ Radio Interference - signal-noise in the limit of cross area = 24dB / 50% of the time;
- ✓ Audible Noise - Maximum in the limit of the cross area 58dBA for thin rain;
- ✓ Magnetic field - Maximum in the limit of the cross area 83µT;
- ✓ Performance for Atmospheric Impulse - Maximum - one turned off per 100km per year. Without right discharge for the dominant shape of the maximum operating voltage. Wind with periods of return of 50 years;

2.1.3 – Main Electrical Characteristics

Considering the over voltage values and the expected performance for transmission line the following minimum distances were calculated for phase-to-ground and phase-to-phase clearances:

- Phase Ground: 3,70m from the bundle center or 4,02m of the external conductor;
- Phase to Phase: 5,48m between the bundle center or 5,02m between the external conductors.

TABLE 1 – Electrical Characteristics

Characteristics	Values
Number of Insulators	22 x 16.000 kgf 26 x 12.000 kgf – Jumper
Electrical field in the limit of cross range	1,2 kV/m
Minimum distance conductor to ground	10m
Conductor surface maximum gradient	17,85 kV/cm
Radio Interference	42 dB
Additive noise in the limit of cross range	55 dBA
Magnetic Field in the limit of cross range	3,2 µT
Magnetic Surge Performance	1,0 Deslig./100km. Year
Cross Range	60 m
SIL (MW, 500 kV)	Around 1.200 MW

2.2 – Mechanical Aspects

Table two demonstrates the wind pressure values calculated according to IEC 826 for new lines at the Northwest of Brazil, where the wind is more intense than in Amazon area. These values consider that the transmission lines are in uninhabited areas, with regular terrain, no obstacle (category B), for medium span of 450m.

The wind basic velocity (V_0), defined as being the velocity of gust of wind (3s) that occurs in 10m over the ground level, in open and plane terrain, with few obstacles. Data from Brazil Air Force in a period between 8 and 25 years ago.

TABLE 2 – Mechanical Characteristics

Element	Parameter	Values
Basic Data	Wind basic velocity – V_0 (Gust 3s, 10m, rug. B, T=50 years) (C1=1,02; C2=0,51)	32,13 m/s
	Yearly medium velocity- Vmd (10 min, 10 m, rug. B)	13,66 m/s
	Wind variation – CV	20,87%
	Ground rugosity (predominant)	B
	Return period for data limit	50 years
	Return period for last limit	250 years
	Velocity V_R for data limit	23,12 m/s
	Velocity V_R for last limit	27,63 m/s
	Dynamic Pressure qo for T=50 years	32,77 daN/m^2
	Dynamic Pressure qo for T=250 years	46,80 daN/m^2
	Medium span (Vm)	450 m
Ground Wire	Project wind – Vp for last limit	39,87 m/s
	Wind pressure Pv for data limit	68,19 daN/m^2
	Wind pressure Pv for last limit	97,40 daN/m^2
	High intensity wind	23,05 m/s
	Pressure of the high intensity pressure	32,54 daN/m^2
Conductor	Project wind – Vp for last limit	38,73 m/s
	Wind pressure Pv for data limit	64,36 daN/m^2
	Wind pressure Pv for last limit	91,93 daN/m^2
	High intensity wind	23,05 m/s
	Pressure of high intensity wind	32,54 daN/m^2
Towers	Project of wind velocity (10 m)	38,68 m/s
	Project wind pressure, height function H	$91{,}6832*(H/10)^{0{,}149}$daN/$m^2$
	High intensity of the wind	46,10 m/s
	Pressure of high intensity wind	130,14 daN/m^2

It was considered the hypothesis of small front high intensity winds, as happens in tornadoes. By the lack of data recorded, the following assumptions were considered.:

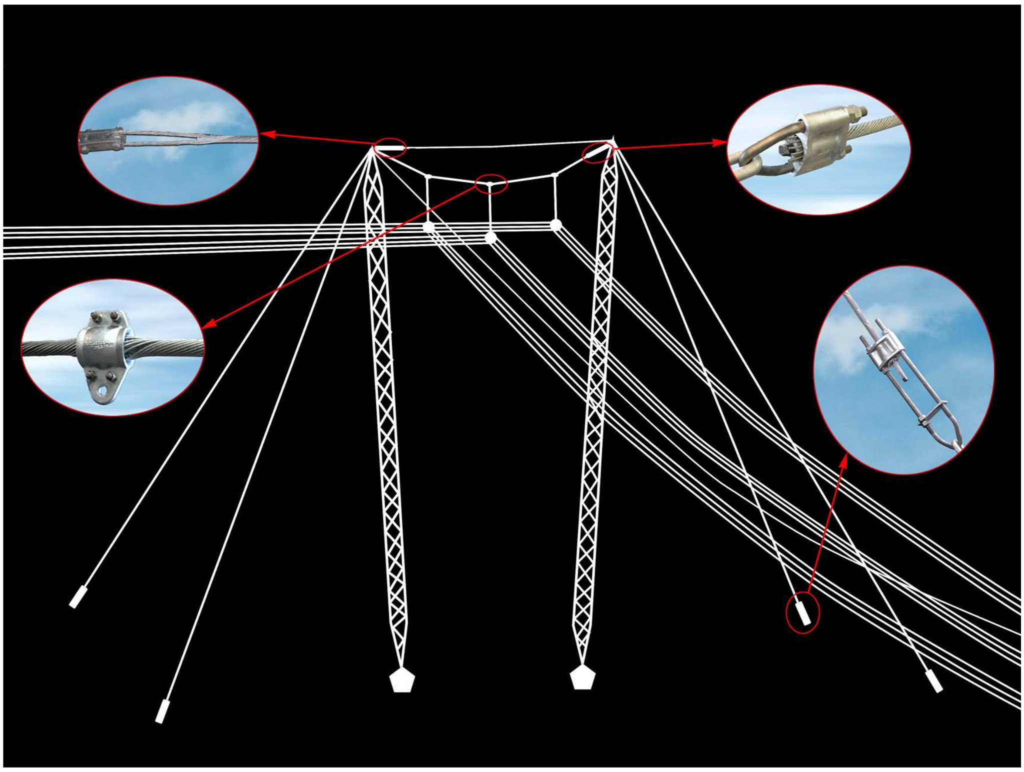
- ✓ To estimate the high intensity of the wind velocity it was used the wind basic velocity in gust from the available data, with the return period of 250 years, plus 20%.
- ✓ To calculate the wind pressure in the cable, due to their dimension, this velocity of high intensity was reduced in 50%.

2.3 - Structural Aspects

The Suspension Stay Structure Cross-Rope was projected for a wind span of 450m, span weight of 600m and deflection of 0°.

The project consists in two masters, separated in the base and interconnected in the top by the auxiliary steel cable and the Cross Rope, which is used for support the three phases, as shown in picture #3 below.

The auxiliary cable, besides being necessary to maintain the distance between two masters during the assembly operation, it's also fundamental for the maintenance of the suspension strings. It supports the electrician in the case of insulator string maintenance.



Picture #3 – Detail of Cross-Rope Tower Accessories

The typical components of a 500 kV single circuit Cross-Rope tower are:

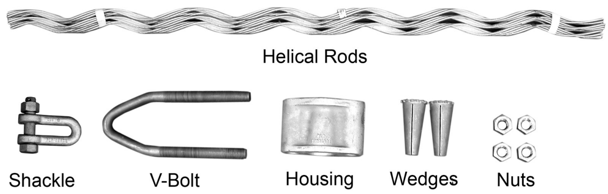
a. Two foundations for the masters;
b. Four foundations for the Guy;
c. Two masters;
d. Four Guy cable – 7/8" – 40,000 daN;
e. Four set of Guy Dead End Hardware – VARI-GRIP™
a. One set of auxiliary cable with:
    i. Two Dead End Hardware – BIG-GRIP™;
f. One set Cross Rope with:
    i. Two Dead End Hardware - VARI-GRIP™
    ii. Three Insulator String Connection Clamp - GAP

3 Hardware for the Cross-Rope & Auxiliary Cables

3.1 – Cross-Rope Dead End Assembly

The Cross-Rope Cable is connected to the two masters through a helical/wedge type clamp Vari - Grip^{TM}, as shown in the picture # 4 below.

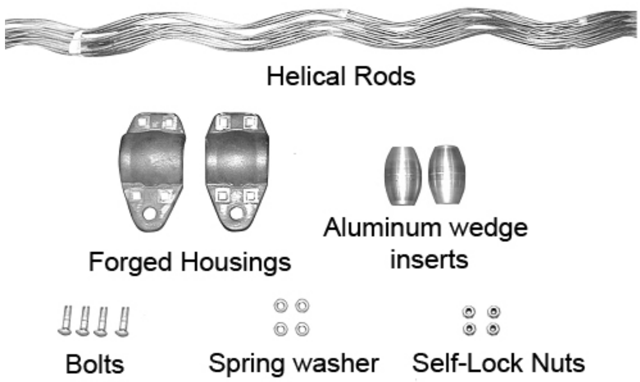
This concept of hardware minimizes the concentration of stress at the Cross-Rope cable, as well as eliminates the misapplication issues, typical of bolted and compression type hardware.



Picture. # 4 – Vari Grip^{TM} Components

To connect the suspension string, it was developed a helical clamp – GAP , based on the concept of the Armor Grip Suspension Clamp, extensively used to support aluminum conductors in suspension string all over the world.

The GAP concept, as in the Vari - Grip^{TM}, is also based on the helical/wedge cable retention, as shown in picture # 5 below.



Picture # 5 – GAP Components

3.2 – Dimensioning the components

Auxiliary Cable Dead End Hardware – BIG-GRIP^{TM}: The auxiliary cable is practically unloaded during the entire TL life, besides during the structure assembly or in eventual maintenance.
For the calculation of the hardware, it was considered basically the following requirements:

- Cable Slippage Load : > 100% of the auxiliary cable ultimate load;
- Components Breakage Load: > 100% of the auxiliary cable ultimate load
- Vibration Withstand : 100 millions of cycle x 0.5 cable diameter of amplitude and 30 Hz of frequency

Guy Cable Dead End Hardware – VARI-GRIP™: The requirements for the dead-end hardware assembly of guy cables, is already part of most of utility specifications for guyed towers. The basic requirements for this project were:

- Cable Slippage Load : > 100% of the guy cable ultimate load;
- Components Breakage Load: > 100% of the guy cable ultimate load
- Vibration Withstand : 100 millions of cycle x 0.5 cable diameter of amplitude and 30 Hz of frequency
- Cyclic Load : > 12,000 cycles with load varying from 10% to 40% of the guy cable breaking load.

Cross-Rope Dead End Hardware – VARI-GRIP™: Since the project was adapted from the existing Guy Cable Dead End Hardware, it was adopted the same requirements, as per below:

- Cable Slippage Load : > 100% of the Cross-Rope cable ultimate load;
- Components Breakage Load: > 100% of the Cross-Rope cable ultimate load
- Vibration Withstand : 100 millions of cycle x 0.5 cable diameter of amplitude and 30 Hz of frequency
- Cyclic Load : > 12,000 cycles with load varying from 10% to 40% of the Cross-Rope cable breaking load.

Insulator String Connection Clamp - GAP: The concept applied at the GAD's development was based in the distribution of the stress, from the vertical load of the suspension string to the Cross Rope cable. The same concept has being successfully used, during decades, at the Armor Grip Suspension Clamp, to support the aluminum conductor to the suspension strings.

The cable retention is obtained by the conjunction of two principles:

- Wedge – The two parts aluminum inserts are retained in to the steel forged housing, by the wedge concept.
- Helical – The helical rods, distributes the stress over the cable, from the wedge retention, over a large area, minimizing the effects of high stress in to the cable wires.

The housing is the most critical component, since the project has the target the minimize the bending moment to the cable at the attachment point, as well as the string length in order to do not affect the minimum electrical distances.

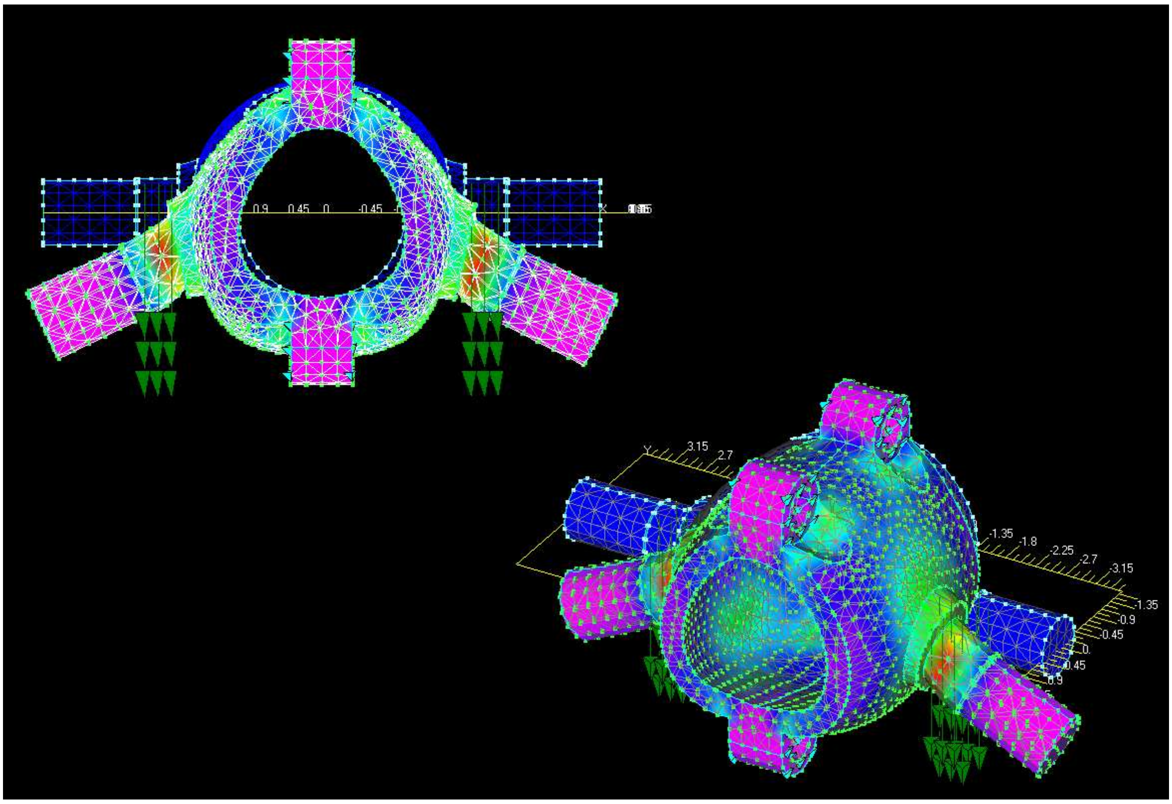
An economical and technical viability study was conducted, to define the geometry, dimensions, material and process, in order to meet the project requirements.

Two alternatives were evaluated:

a) string articulation point aligned with the Cross Rope Cable axis;
b) the articulation point was dislocated in order to reduce the orthogonal bending moment at the housing

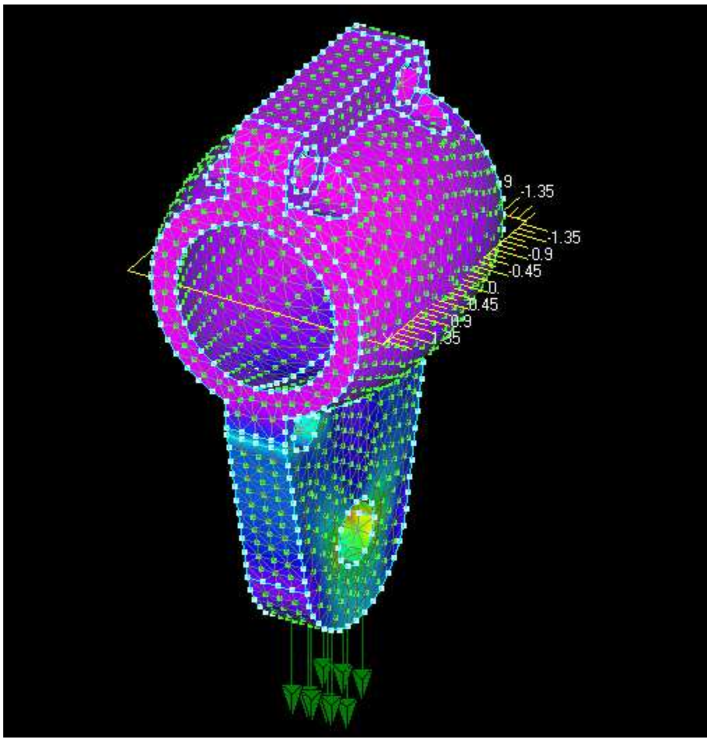
The option A presented high stress caused by the flexural moment, inherent to the project concept. See picture # 6. The undesirable consequence would be the nucleation of a fatigue process, followed by the product rupture in short/medium term.

The solution would be an excessive increase of material and consequent cost increase, since by the chosen forged process, additional machining operation would be necessary to get the final dimensions.



Picture # 6 – GAP – Housing Option – A – Stress Concentration

The option B give us a better result in terms of stress concentration from both tensile and shearing loads, see picture #6, as well as to represent better design to be forged.



Picture # 7 – GAP – Housing Option – A – Stress Concentration

3.3 – Prototype Testing Program

Besides the regular tensile/deformation and slippage tests, the projects involved the following prototype test, to reproduce the field condition it's being foreseeing for the product, during the operational life:

a. Overall Assembly Tensile
b. Cyclic Load
c. Vibration

3.3.1 Tensile Test

As a first step the overal assembly was submitted to a tensile load of 60% of the respective cable breaking load by one minute .

The load was then relieved to zero and the sample was visually inspected. Then the load was increased up to 100% of the respective cable breaking load, and was maintened for one minute.
The sample was considered approved, since no rupture or cable slipping was noticed.]

3.3.2 Cyclic Load Test

This test followed the parameters below:

a) Minimum Load	10% of the cable breaking load;
b) Maximum Load	40% of the cable breaking load
c) Frequency	8 a 10 cycles per minute;
d) Duration	12.000 cycles.

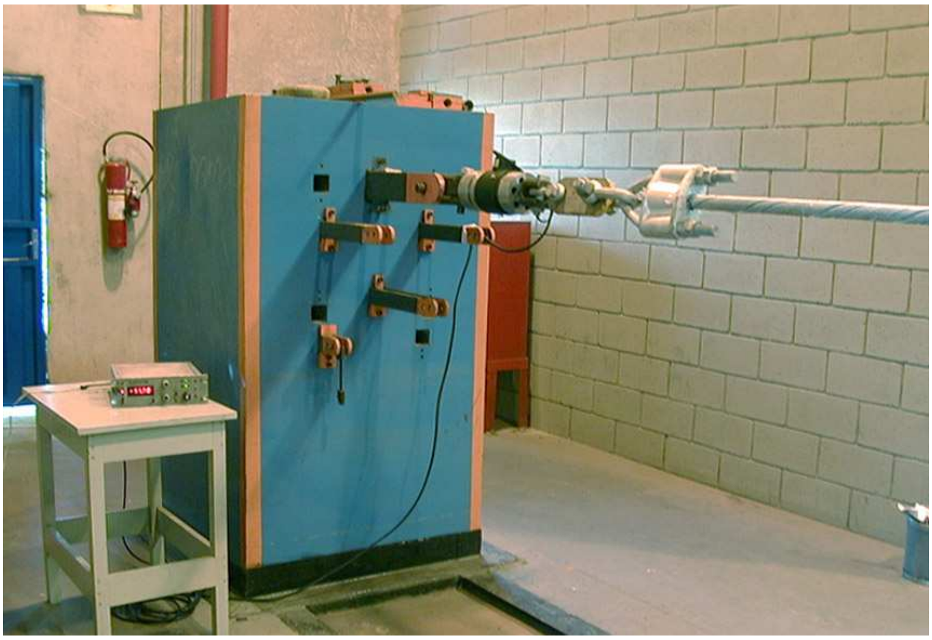
After 12.000 cycles the assembly was tensioned up to 100% of the cable breaking load and maintained for one minute without sliding and rupture of any component.

3.3.3 Vibration Test

This test followed the parameters as follows:

a) Applied Load	20% of the cable rupture load;
b) Frequency (f)	from 10 Hz to 50 Hz;
c) Amplitude peak to peak (Y)	Yf ≈150 mm/s;
d) Duration	10^7 cycles.

Picture # 7 shows a general view of the test span.



Picture # 8 – General view of vibration test of Cross-Rope Accessories

3.3.4 Test Results

The accessories were tested several times during the development process, and as routine test for several contracts with **satisfactory** results.

3.5 – Tower Loading – Prototype Test.

The picture # 9 below showed the first prototype test of a 500 kV Cross-Rope tower used in Brazil. The prototype withstands all specified loads, accomplishing with all requirements for the approval.

Picture # 9– 1st. 500 kV Cross-Rope Tower tested in Brazil.

3.6 – Field Tower Assembly

One of the most valuable advantages of Cross-Rope towers, refers to it’s labor reduced lifting in the field.
The picture # 10 below gives us a general overview of how practical is the lifting of a 500 kV Cross-Rope Tower.

Picture # 10 – General overview of a 500 kV Cross- Rope tower field assembly

3.6 – Maintenance and Repair

After several projects built, in different environment in both Brazil and Argentina, solutions and practices were developed to allow the maintenance of all parts of the Cross-Rope, including the more sensitive components, like the assembly to connect the Cross-Rope cable to the tower. The following pictures show same examples of maintenance work done.

Picture # 11 – General overview Maintenance of a Cross-Rope tower

4.0 – Conclusion

- The Cross-Rope tower is a very competitive solution, for 500 kV Transmission Lines in areas with low density and flat terrain, as we have in North and Northwest of Brazil;
- Several tests and field installation approve the design and concept of the tower and the hardware.
- Maintenance and repair are already under developed and approved.
- New solutions of hardware are in course, using this concept.

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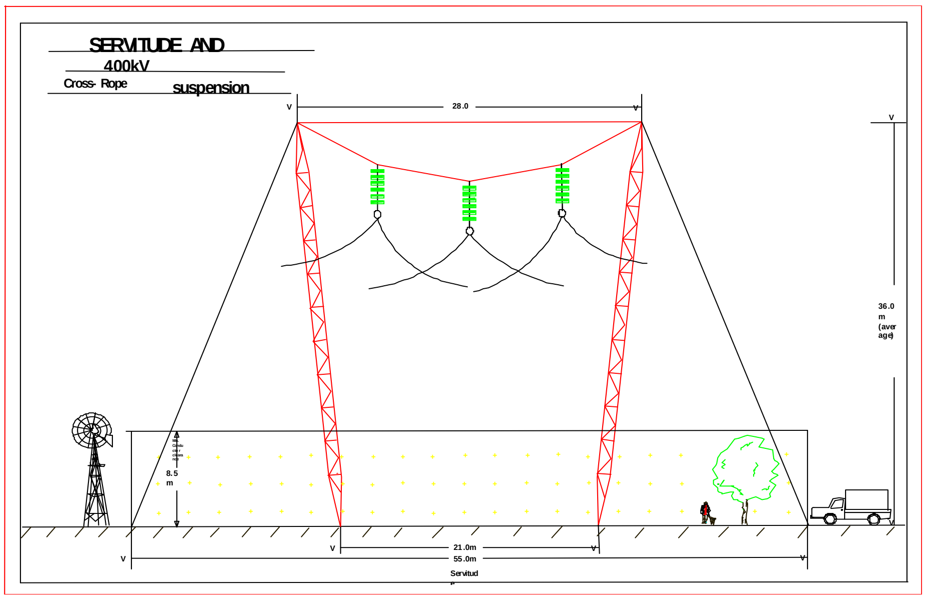
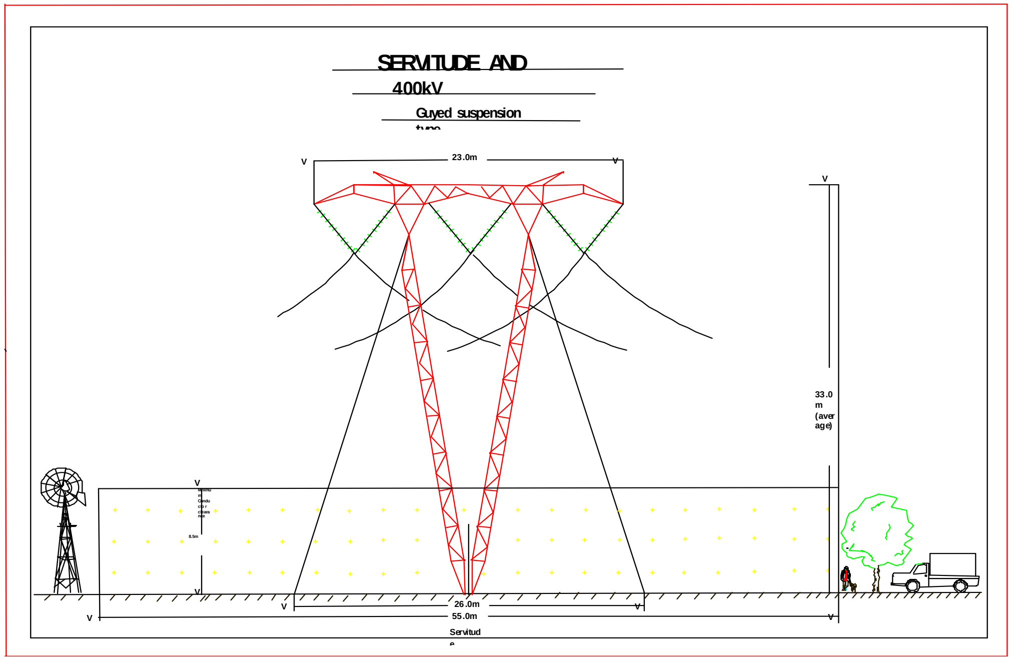
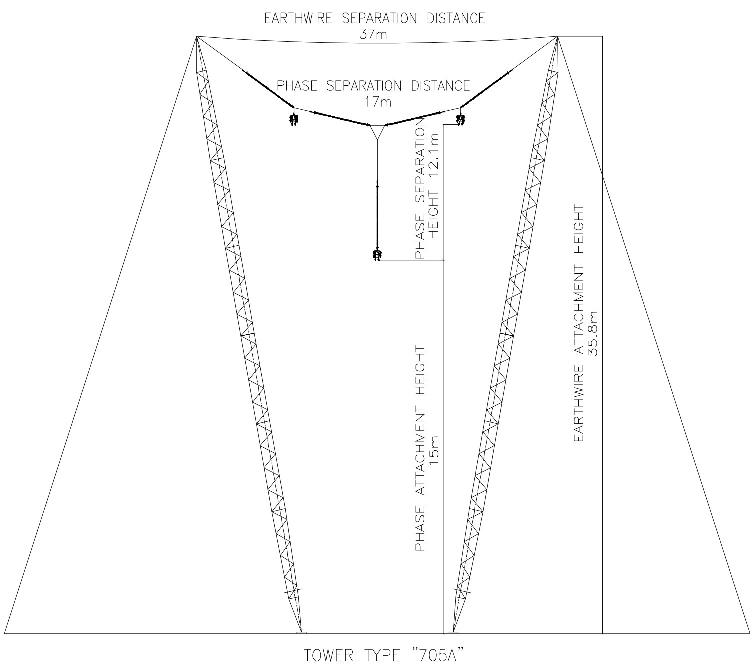
TOWER SELECTION

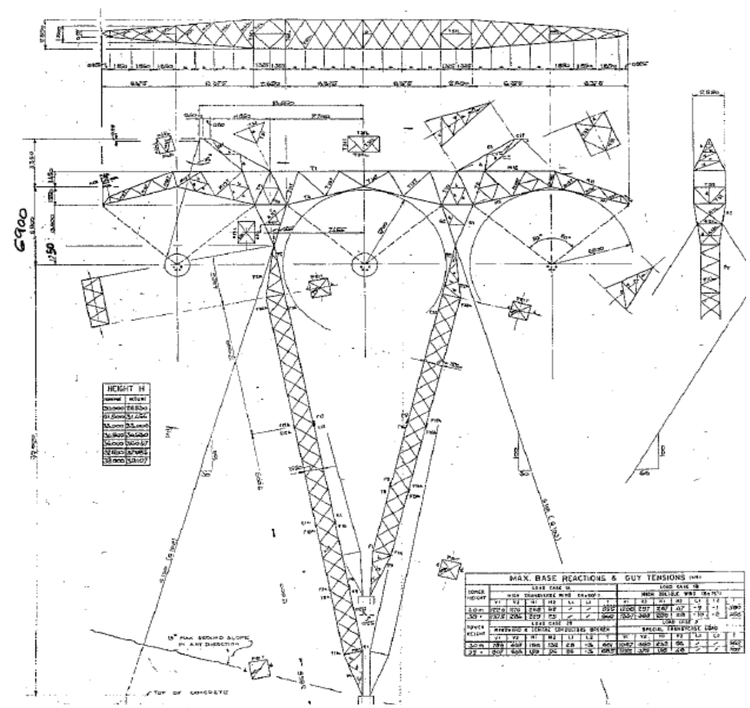




Tower development

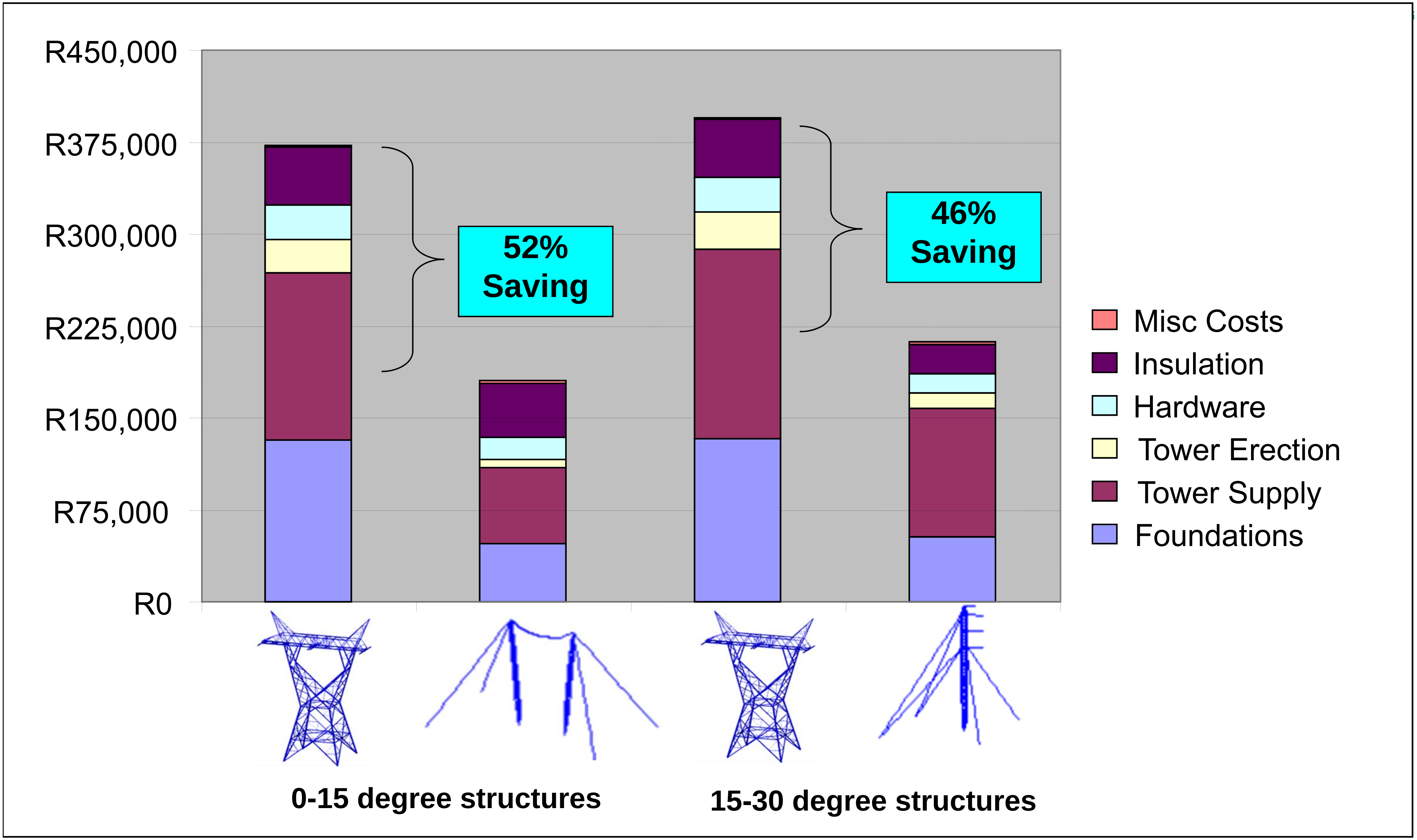


Proposed CRS 6% saving on line cost



Existing guyed V

Cost Savings



Performance comparison

Fault Classifications in the last 5 years

Fault Types	Droerivier - Hydra No1 400kV	Droerivier - Hydra No2 400kV	Droerivier - Hydra No3 400kV	Athene - Pegasus No1 400kV	Athene - Pegasus No2 400kV	Alpha - Beta 1 765kV	Alpha - Beta 2 765kV
Birds	13	14		2			1
Fire					2		2
Lightning	2	6		1	2	10	6
Other				1			
Pollution							
Tree							
Unclassified		1					
Equipment Failure			2				
Wind				2			
Unknown	3	2		3	1	1	
Vandalism				2			
Total	**18**	**23**	**2**	**11**	**5**	**11**	**9**

Improved performance can give

0.05-0.1faults/100km/annum

705A tower at NETFA

EXAMPLE LINE

- .Quad “Zebra” guyed Vee tower
- .Triple “Bunting” conductor guyed Vee tower
- .Quad “Bunting” cross rope suspension (CRS) tower with a phase spacing of 6,5m.
- .Quad “Rail” conductor with a CRS tower with a 6,5m phase spacing.
- .Triple “Bittern” conductor with a CRS tower with a 6,5m phase spacing.
- .Quad “Boblink” conductor with a CRS tower with a 6,5m phase spacing.
- .Triple “Bersfort” conductor with a CRS tower with a 8,2m phase spacing.

ATI SCORES

CASE	AL AREA mm^2	DESCRIPTION	K_1 (LCC)	K_2 (CI/MVA_{th})	K_3 (CI/MVA_{sil})
1	1715	4XZEB V	103,53 [3,30]	28,13 [3,07]	7,43 [3,19]
2	1817	3XBUNT V	84,4 [6,25]	19.48 [5,20]	6,31 [5,38]
3	2423	4XBUNT CRS 6.5m	88,36 [5,64]	13.27 [6,73]	7,02 [3,96]
4	1935	4XRAIL CRS 6.5m	87,76 [5,73]	14.32 [6,47]	5,94 [6,12]
5	1933	3xBIT CRS 6.5m	82,91 [6,48]	17.86 [5,60]	6,31 [5,38]
6	2901	4Xbob CRS 6.5m	93,33 [4,87]	17.04 [5,80	8,06 [1,88]
7	2059	3xBers CRS 8.2m	80,41 [6,81]	16.23 [6,00]	6,30 [5,40]

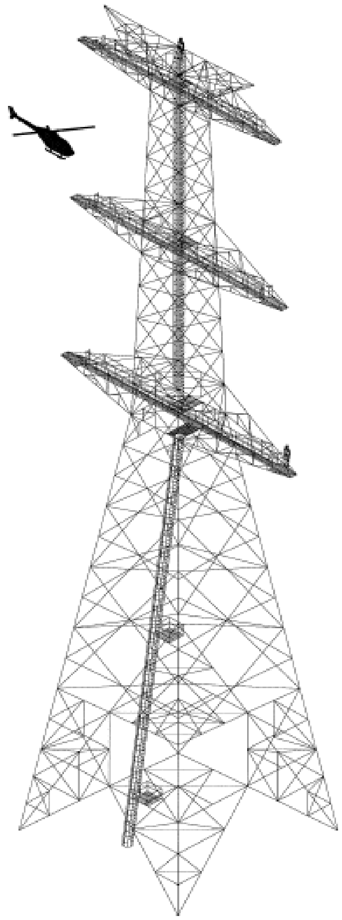
ATI WEIGHTING

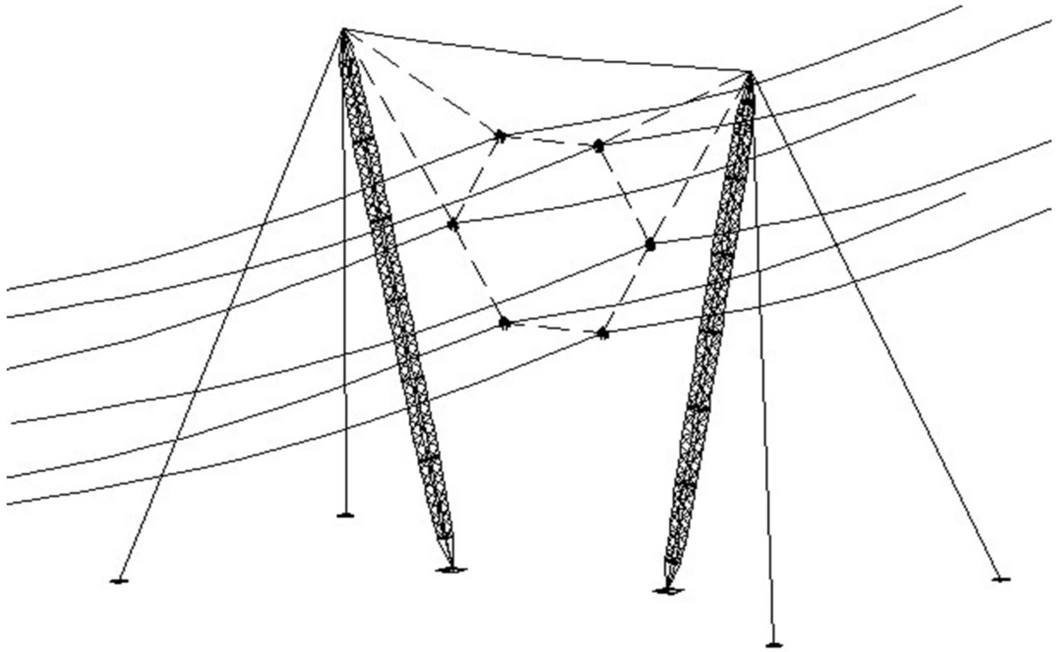
CASE	$W_1;W_2;W_3$	$W_1;W_2;W_3$	$W_1;W_2;W_3$	$W_1;W_2;W_3$
	0,8;0,1;0,1	0,6;0,2;0,2	0,4;0,3;0,3	0,2;0,4;0,4
1	2,82 [7]	2,89 [7]	2,96 [7]	3,03 [7]
2	5,80 [3]	5,67 [4]	5,55 [4]	5,42 [4]
3	5,23 [5]	5,18 [5]	5,14 [5]	5,09 [5]
4	5,56 [4]	5,74 [3]	5,93 [2]	6,11 [1]
5	6,04 [2]	5,90 [2]	5,77 [3]	5,63 [3]
6	4,33 [6]	4,21 [6]	4,08 [6]	3,96 [6]
7	6,42 [1]	6,24 [1]	6,06 [1]	5,88 [2]

FINDINGS/BENEFITS

- Tower, foundation, hardware, electrical designers work together with planners (iterative process)
- Indicator very sensitive and detects errors rapidly
- Line optimisation is possible looking at overall line design.
- Reliability is assumed constant for options
- Cost system is critical
- Most aspects of the line design are taken into account

Double Circuit developments

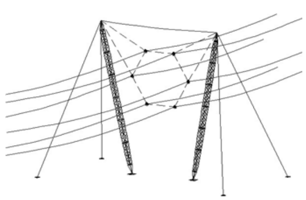




Comparison self supporting vs CRS

Bulk power transfer capacity	5,000 MW
Max tower height (Self Support)	77,5 m
Max tower height (Cross Rope)	53,2 m
Performance (Faults / 100 km / year)	< 0,3
Visually acceptable	Yes
Efficient land use	57 %
Conductor Bundle	8 x Bersfort
Max Altitude (AMSL)	1,650 m
Country wide application	Yes

Self Support Tower (Figure 3a)	
Electric field (max)	9,7 kV /m
Audible Noise	43,5 dBA
Radio Interference	48,3 dBμV/m
Magnetic Field (@ 523 A)	3,9 μT
SIL	2,581 MW



Cross Rope Tower (Figure 3b)	
Electric field (max)	10 kV/m
Audible Noise	49,8 dBA
Radio Interference	56,3 dBμV/m
Magnetic Field (@ 523 A)	4,3 μT
SIL	2,904 MW

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

Appendix 6E
230 kV CRS Structure Diagram

Figure_4.5–1.dwg

REV	REVISIONS	DATE	DRN	DSGN	CKD	APPD	REFERENCE DRAWINGS
A	ISSUED FOR PROPOSAL	**/**/**	JLQ	PC	PC	*	

DSGN	*	*
DRN	*	*
CKD	*	*
SCALE:	NTS	

FOR 22x34 DWG ONLY

POWER ENGINEERS

***

230 kV CROSS ROPE STRUCTURE GENERAL FEATURES

***
***

JOB NUMBER	REV
121672	A

DRAWING NUMBER
FIGURE 4.5–1

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 6
PROPOSED DESIGN

Appendix 6F
Key Features of Structure Design Variations

Appendix 6F - Key Features of Structure Design Variations

EWT Structure Comparisons Figure 3, sheet 1

8/13/2012

Tower X7 **Conductor** 2 x 1-795

Basic Tower

Heights:	Overall	Body	Leg Ext.	Low AP
	140	140	0	87
Weights:	11480	11480	0	

	Spans (ft)	Spans (m)
Wind, 0°	1600	488
Wind, 3°	1100	335
Weight	2200	671
Span Usage:	80%	
Tons/km	19.9	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	48	14.6
GMD as 1 ckt	TBD	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	76.2	23.2
Factor:	0.335	
Blowout:	28.5	8.7
Edge Distance:	15	4.6
ROW Width:	135.1	41.2

Tower X10 **Conductor** 2 x 1-1192

Basic Tower

Heights:	Overall	Body	Leg Ext.	Low AP
	155	130	25	87.3
Weights:	15156	10776	4380	

	Spans (ft)	Spans (m)
Wind, 0°	1075	328
Wind, 3°	716	218
Weight	1275	388
Span Usage:	80%	
Tons/km	28.9	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	47	14.3
GMD as 1 ckt	TBD	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	34.6	10.5
Factor:	0.335	
Blowout:	14.6	4.4
Edge Distance:	15	4.6
ROW Width:	106.2	32.4

Tower W1 **Conductor** 1 x 2-1192

Basic Tower

Heights:	Overall	Body	Leg Ext.	Low AP
	122	122	0	87
Weights:	11920	11920	0	

	Spans (ft)	Spans (m)
Wind, 0°	1600	488
Wind, 3°	1100	335
Weight	2200	671
Span Usage:	80%	
Tons/km	19.7	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	48	14.6
GMD as 1 ckt	34.62	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	76.2	23.2
Factor:	0.335	
Blowout:	28.5	8.7
Edge Distance:	15	4.6
ROW Width:	135.1	41.2

Tower CRS **Conductor** 1 x 2-1192

Basic Tower

Heights:	Masts	Cables	N/A	Low AP
	100	12		88
Weights:	8644	1806	0	

	Spans (ft)	Spans (m)	
Wind, 0°	1600	488	
Wind, 3°	1100	335	
Weight	2200	671	
Span Usage:	80%	grillages	
Tons/km	12	incl.	39%

Phase spacing (Δ)	ft	m	Better than W1 by:
Hor. O/O	39.5	12	
GMD (230kV)	24.25		30%

ROW Width Requirement			
C (max):	4200	1280	
Max Sag:	76.2	23.2	
Factor:	0.335		
Blowout:	25.5	7.8	
Edge Distance:	15	4.6	
ROW Width:	121	36.9	10%

HONI Structure Comparisons at 500kV Figure 3, sheet 2

8/13/2012

Tower CRS **Conductor** 1 x 2-1192

Basic Tower

Heights:	Masts +	Cables	NA	Low AP
	100	12	0	88
Weights:	8644	1806	0	

	Spans (ft)	Spans (m)
Wind, 0°	1600	488
Wind, 3°	1100	335
Weight	2200	671
Span Usage:	80%	
Tons/km	12	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	39.5	12
GMD as 1 ckt	32.75	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	76.2	23.2
Factor:	0.335	
Blowout:	29.7	9.1
Edge Distance:	20	6.1
ROW Width:	151.4	46.2

Tower Z2 **Conductor** 1 x 4-583

Basic Tower

Heights:	Overall		NA	Low AP
	122			99
Weights:	11612	1355		

	Spans (ft)	Spans (m)
Wind, 0°	1650	503
Wind, 3°	1200	366
Weight	1900	579
Span Usage:	80%	
Tons/km	15.3	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	80	24.4
GMD as 1 ckt	50.4	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	81	24.7
Factor:	0.335	
Blowout:	31.3	9.5
Edge Distance:	20	6.1
ROW Width:	182.7	55.7

Tower Z11 **Conductor** 1 x 4-583

Basic Tower

Heights:	Overall	Body	Leg Ext.	Low AP
	127	122	5	86
Weights:	10257	16505	0	

	Spans (ft)	Spans (m)
Wind, 0°	1050	320
Wind, 3°	1020	311
Weight	1300	396
Span Usage:	80%	
Tons/km	16.4	grillages incl.

Phase spacing (Δ)	ft	m
Hor. O/O	42	12.8
GMD as 1 ckt	41.8	

ROW Width Requirement		
C (max):	4200	1280
Max Sag:	31.3	9.6
Factor:	0.335	
Blowout:	14.7	4.5
Edge Distance:	20	6.1
ROW Width:	111.4	33.9

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 7
SCHEDULE

7. Schedule

7.0 Overview

EWT LP acknowledges that the primary objective of the Ontario Energy Board (the "Board") in the present proceeding is to select the most qualified transmitter to "develop, and to bring a leave to construct application for, the East-West Tie line."[1] To this end, EWT LP has prepared a schedule for the proposed East-West Tie Line (the "Project") that will minimize the time required to develop the Project without sacrificing the comprehensiveness of EWT LP's consultation plans or technical and environmental studies. This is a fine balance, and one that EWT LP has struck appropriately. Pursuing speed in the development phase at all costs will result in a lengthier and costlier construction phase, particularly if the early consultation and technical and environmental studies prove deficient, causing a key approval to be overturned or creating delays to accommodate additional consultation or studies. In contrast, by taking a relatively conservative approach to scheduling, one that takes into account all of the tasks reasonably necessary to develop the Project, EWT LP is able to:

- provide the Board and ratepayers with transparent and comprehensive timelines and cost estimates;
- minimize the risk that unanticipated events will increase the Project schedule or budget; and
- increase the likelihood that external events that affect scheduling assumptions will generally be favorable and allow EWT LP to complete the Project sooner than anticipated.

In effect, EWT LP's approach to scheduling ensures that ratepayers will not have to bear the risk of a poorly developed or overly aggressive schedule. It ensures that the appropriate balance is struck between effectiveness and efficiency -- a balance that will ultimately provide the largest cost-savings for the ratepayers.

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[1]Phase 1 Decision and Order (July 12, 2012) EB-2011-0140, p. 3.

In accordance with the Board's filing requirements, this Section includes the following:

- A project execution chart with major development and construction milestones (7.1);
- EWT LP's timeline for the development phase (7.2), including a detailed development schedule (7.2.1), development milestones (7.2.2), proposed reporting requirements (7.2.3), proposed consequences for failing to meet milestones (7.2.4) and risk mitigation strategies (7.2.5);
- EWT LP's timeline for the construction phase (7.3), including a preliminary construction schedule (7.3.1), proposed reporting requirements (7.3.2), proposed consequences for failing to meet milestones (7.3.3) and risk mitigation strategies (7.3.4);
- EWT LP's partners' relevant experience in completing other projects on schedule (7.4); and
- Opportunities to accelerate the Project schedule (7.5), including a description of EWT LP's conservative approach to scheduling (7.5.1) and its opportunities to accelerate the development and construction phases (7.5.2 and 7.5.3, respectively).

7.1 Project Execution Chart

EWT LP, through its partners, has extensive familiarity with the routing, design, permitting and land acquisition processes in Ontario, and extensive knowledge of the Project area. Drawing on that experience, EWT LP has determined that the development of the Project to the point of filing an application for leave to construct will take approximately 32 months from the date on which EWT LP is designated by the Board.[2] This timeline is based on a number of assumptions that are described more fully in Section 7.5.1; as development work progresses, if these assumptions prove to be overly conservative, it may be possible to accelerate EWT LP's development work so that a leave to construct application can be filed within 23 months of designation.

EWT LP also estimates that Project construction could be readily completed within 22 months from the date the construction contract is executed. A shorter construction program could be designed if required to provide an earlier in-service date, although this would likely increase cost and risk to ratepayers. The construction timeline is described more fully in Section 7.3 below.

Together, EWT LP's development and construction schedules, and the intervening period during which the leave to construct application would be heard and the construction contract negotiated, would conservatively result in an in-service date of November 2018 (assuming designation on August 1, 2013).[3] If the development assumptions prove to be overly conservative, the in-service date may be advanced to as early as February 2018. The diagram below sets out EWT LP's overall Project schedule and shows the key milestones during the development phase (assuming designation on August 1, 2013).

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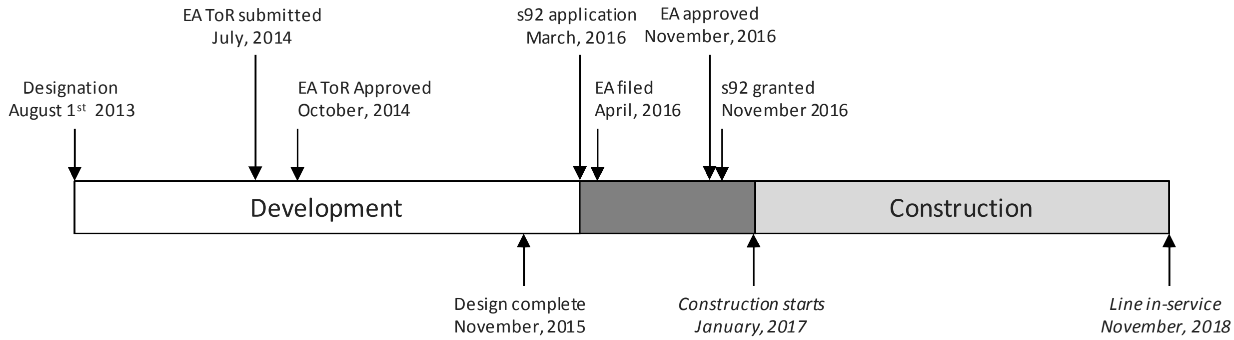
[2] To the point that all consultation and technical and environmental studies completed, to the extent necessary to file a leave to construct application.

[3] Although the province's Long Term Energy Plan and the OPA's Long Term Electricity Outlook for the Northwest offer an earlier target completion date, these plans forecast a completion date without considering the length of the designation proceeding. Adjusting those target dates forward relative to the time that has passed since those plans were prepared results in a target completion date that would be slightly later than the one EWT LP is proposing here. This is discussed more fully in Section 7.3 below.

Figure 7.1: Project Schedule and Milestones



As discussed further in Section 7.5.1, this development schedule is relatively conservative. It is based on a thorough review of the regulatory requirements and development challenges that are likely to face the Project, particularly in the environmental assessment and consultation process. To assist in its scheduling and budgeting estimates, EWT LP also has prepared (i) a detailed workflow for the Project on the 32 month development schedule (see Appendix 7A); (ii) a detailed workflow for the Project on the accelerated 23 month development schedule (see Appendix 7B); and (iii) a detailed Gantt chart showing EWT LP's preliminary Project development schedule, which breaks the Project into approximately 360 individual tasks and subtasks (see Appendix 7C). EWT LP believes that this level of scheduling detail is necessary to ensure that the designated transmitter can anticipate and appropriately mitigate all events that could have a material impact on the Project schedule. This degree of preparation also allows EWT LP to take advantage of any opportunities to accelerate the schedule that present themselves during the development and construction phases. Those opportunities are described in greater detail in Sections 7.5 below.

Note that any changes to the assumed designation date will not necessarily result in a day-for-day modification to the schedule above due to seasonal factors in the environmental assessment plan.

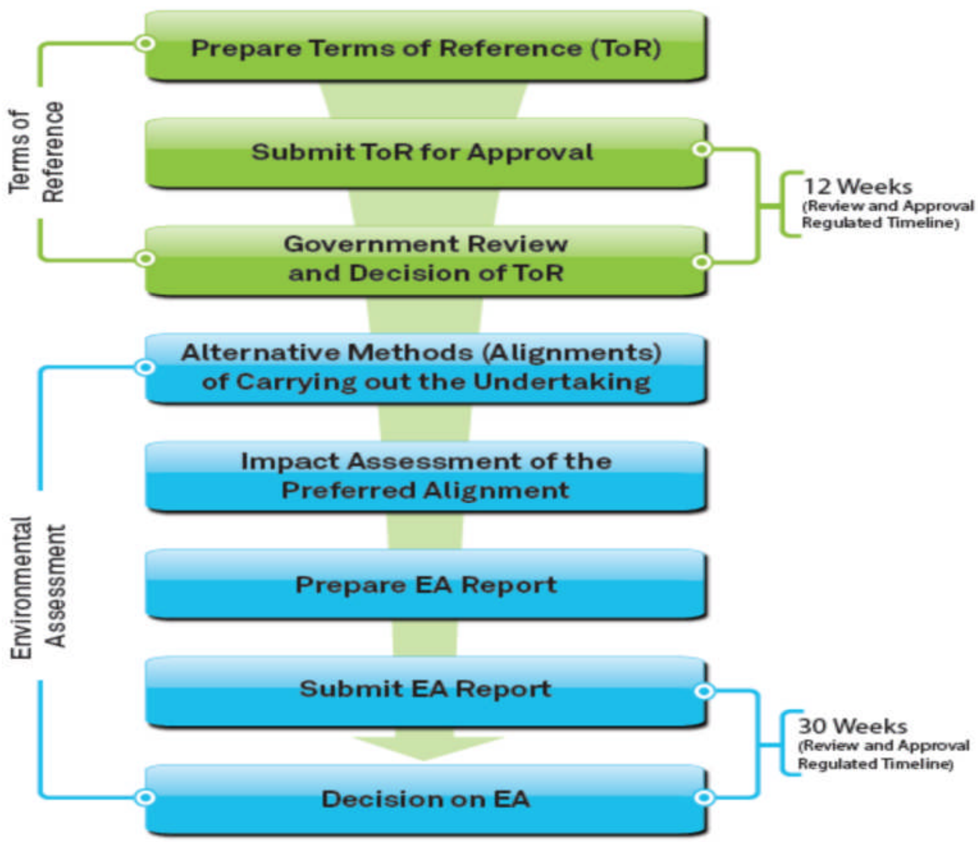
7.2 Development Phase

EWT LP believes that 32 months, from the date of designation, is a credible period for efficiently and effectively completing the development work necessary to submit a leave to construct application for the Project. As mentioned above, if the conservative assumptions underlying this timeline change as the development work progresses, it may be possible to file a leave to construct application within 23 months of designation.

As discussed further in Section 7.5.1, many of these assumptions relate to the critical path in the Project schedule, and in the development schedules of all major transmission lines in Ontario: the individual environmental assessment process under the *Environmental Assessment Act* (the "EA Act"). This process has to be completed to establish the route, basic physical design and method of construction. Certain timelines in this process are prescribed by regulation and outside the control of the proponent. For example, Ontario Regulation 616/98 prescribes certain timelines for public notice and comment, and specifies timelines within which the Minister of the Environment must, subject to certain exceptions, issue a decision on the terms of reference (12 weeks) and environmental assessment review (30 weeks). While the environmental assessment is ongoing, EWT LP will also be completing other aspects of its development work, such as the examination of the technical alternatives to the Reference Option discussed in Section 6.5.1 of this Application.

The following diagram provides an overview of the individual environmental assessment process under the EA Act, as well as some of the timelines that are beyond the proponent's control.

Figure 7.2: Overview of Individual Environmental Assessment Process under the EA Act



As they relate to EWT LP's Project schedule, the key steps in the environmental assessment process are as follows:

- At the outset, the transmitter must consult with stakeholders to determine the appropriate terms of reference for the environmental approval. Once approved by the Minister of the Environment (the "Minister"), the terms of reference will outline the environmental issues that the proponent must consider as part of the environmental assessment. Although there is no statutory timeline for completing consultation, the consultation has to be sufficient to explain the Project to all potentially interested stakeholders and solicit their views as to the scope of the assessment and potential alternatives to the proposed Project design. Stakeholders expect and the EA Act requires the designated transmitter to consider a range of alternative designs and construction methods. Some transmitters may consider their preferred alternative to be the 'obvious' choice and therefore attempt to assess an unduly narrow range of alternatives during the terms of reference phase. However, as a result of its pre-development work, EWT LP believes that there are credible alternatives that will need to be discussed with stakeholders in preparing the terms of reference (see Section 6.4.2.2 for further information on those alternatives). Given the range of credible alternatives, the number of potentially interested stakeholders and the schedules of those stakeholders (e.g. certain municipal councils only meet monthly), EWT LP believes that the studies and consultation required to complete the preparation of the terms of reference, including two sets of open houses, will take eleven months from designation. Time spent in soliciting feedback on the terms of reference will help ensure that the Minister is able to approve them in an expeditious fashion. It also helps ensure that the remainder of the environmental assessment will be guided by an outline that has been vetted by all interested stakeholders. It is much more efficient to complete an environmental assessment process using robust terms of reference that reflect a Project design endorsed by key stakeholders than to forge ahead with a plan based on poorly considered alternatives, only to have stakeholders raise concerns with those alternatives at a later date.

- The draft terms of reference for the environmental assessment are submitted to the Ministry of the Environment ("MOE") for review and approval. The regulations under the EA Act state that the government's review and approval of the terms of reference should take no more than 12 weeks (3 months), although they also give the Director of the MOE's Environmental Assessment and Approvals Branch ("EAAB") the ability to extend the deadline for completing this review if the Minister believes there is a compelling reason to do so (e.g., if the reason is unusual, unexpected, or urgent).[4]

- After the terms of reference are approved, the transmitter must complete the environmental studies identified therein. These studies are typically undertaken in coordination with the detailed engineering and construction design of the line. The studies involve field work to verify and complement secondary source data. The field work has to be undertaken over a period of no shorter than one year (i.e., one complete ecological cycle) so that the environmental impact of the line and its construction can be studied in each of the four seasons. There are also certain seasonal limitations to the studies. For example, certain breeding habitats can only properly be studied in the relevant breeding season. Certain impacts to birds can only be properly assessed during key migration seasons. As a result, the minimum study period will be 12 months. To compress the development schedule, EWT LP has planned for certain of its field studies to start before the Minister has approved the terms of reference. EWT LP believes that this risk is acceptable given that it has planned for a second, less extensive set of field studies

[4] Section 7(3) of the EA Act.

for summer 2015 to capture any missing data. With the completion of the field studies, other studies and two further sets of public open houses, EWT LP plans to finalize the Project route by June 2015.

- With the final Project route established, EWT LP plans to complete a detailed route survey using LiDAR (including establishing the survey ground control for eventual Project construction, flights and data processing) during summer 2015. This will provide the necessary survey information to complete the detailed design of the Project and preparation of a successful application for leave to construct for submission March 2016. This application will be based on the final route of the line and will also benefit from detailed public input from the environmental assessment which is due to be filed with the Minister the same month.

EWT LP believes that it is inappropriate at this stage to assume a more aggressive environmental assessment timeline the following reasons:

- the terms of reference can only be prepared, submitted and approved when sufficient detailed development work including routing has been completed to adequately describe the Project, and after sufficient public consultation has been completed to confirm the range of routing alternatives and satisfy the requirements of the *Environmental Assessment Act*;

- the environmental assessment can only be substantially completed after the terms of reference have been approved, and public consultation has been undertaken;

- the detailed Project design can only be completed once the route has been substantially finalized, and this requires the environmental assessment to have been substantially completed; and

- the application for leave to construct can only be prepared and submitted once the detailed Project design has been completed.

Aggressive assumptions about the timeline for completing any of these steps, if proven wrong, can create cascading delays through each subsequent step. A commitment to an unreasonably expedited timeline will therefore increase the risk that Project delays will occur after the designation phase at the expense of ratepayers or result in a failed prudency review by the Board.

That said, if exemptions from or changes to the environmental regulations allow Project development to be completed in a shorter time, EWT LP will amend its Project plan and schedule accordingly to pass any benefits to ratepayers. As described in Section 7.5.1, changes to EWT LP's assumptions about the environmental assessment process may also allow EWT LP to accelerate development work, which could also reduce development costs to the benefit of ratepayers.

It is also worth stressing that EWT LP's development plan does not contemplate EWT LP sitting idle while it awaits a decision on the terms of reference or any other aspect of the environmental assessment process. Rather, EWT LP will complete the environmental assessment simultaneously with the rest of its development work. For example, as mentioned above, EWT LP plans to study technical variations to the Reference Option in the development phase while the environmental assessment is ongoing. One of these variations, a single line design that uses cross-rope suspension ("CRS") type structures, will be a particular focus of EWT LP's development work. As indicated in Section 6.5.1 of this Application, a cost saving of approximately $116 million may be achievable by adopting a single circuit solution with CRS structures compared to a Reference Option-based design. In this way, EWT LP plans to maximize the time available in its development schedule with a view to achieving benefits to ratepayers.

7.2.1 Development Schedule

A detailed Gantt chart showing EWT LP's Project development plan is included in Appendix 7C of this filing. This Gantt chart is based on EWT LP's relatively conservative assumptions for a 32 month development phase. It provides a comprehensive view of EWT LP's plan showing how the primary tasks have been broken into sub-tasks and how the individual tasks have been carefully coordinated to minimize the overall Project duration. EWT LP believes that this is the minimum level of detail required in a Project development plan, to identify the development activities that need to be completed and thus the skills, resources and costs required to implement the plan. Without this level of detail, there is a serious risk that the resulting project schedule will lack credibility.

7.2.2 Development Milestones

EWT LP's detailed Gantt chart contains the development milestones for the Project. They are reproduced below, and for convenience broken into the six principal categories of activities: routing and design, environmental assessment, leave to construct, land rights acquisition, procurement and public consultation. Altogether there are 23 milestones that will be used internally to measure the progress of the Project against the schedule, to identify variances and to evaluate opportunities to amend the plan to meet or advance the target completion date as necessary.

Of the 23 internal milestones, there are three key events during the development phase that act as important performance milestones. Two of these events -- the submission of the terms of reference for an environmental assessment, and the approval of the terms of reference -- relate to the environmental assessment process. The other event, the application to the Board for leave to construct, is associated with the Board's processes. All three events are subject to public notification and provide suitable performance milestones against which EWT LP can demonstrate satisfactory progress of development activities.

The proposed performance milestones and their respective dates are therefore:

Milestone	Approximate Date
Submission of the terms of reference for the environmental assessment	July 2014
Approval of the terms of reference for the environmental assessment	October 2014
Submission of an application to the Board for leave to construct	March 2016

As mentioned above, if EWT LP's development assumptions prove to be too conservative, it may be possible to accelerate EWT LP's development work and to advance these milestone dates as well. In addition to these three milestones, EWT LP believes that the Minister will approve the environmental assessment, and the Board will issue the leave to construct, in November 2016. These dates are useful for planning purposes, but not for performance milestones because the development work necessary for filing the leave to construct application will be completed, and because the date of issuance of these approvals is at the discretion of the Minister and Board, respectively.

Given that the first of these three milestones occurs approximately twelve months after designation, EWT LP also intends to adhere to more detailed internal management objectives, which will occur on average every six weeks, to demonstrate that EWT LP is continuing to make satisfactory progress. These are tabulated below by principal activity, the three performance milestones being highlighted in yellow.

Table 7.1: Development Schedule

Date		Routing and design	Environmental assessment	Leave to construct	Land Rights Acquisition	Procurement	Public Consultation
2013	Aug-2013	Designation BY OEB					Meetings with key stakeholders
	Oct-2013		Identify project rational and alternatives				
	Nov-2013	Initial high-level design	Desktop studies				
	Nov-2013				First meeting with major land owners		
2014	Jan-2014						1st open houses
	Feb-2014	Alternative corridors identified					
	Feb-2014	Preliminary design complete					
	Apr-2015					Issue RFQ	
	May-2014						2nd open houses
	Jun-2014	Preferred route identified		HONI CCA, ISEO SIA, other studies			
	Jul-2014		EA Terms of Reference Submitted to EAAB				
	Aug-2014					Qualify construction contractors	
	Oct-2014	Alternative alignments identified					
	Oct-2014	Detailed engineering	EA Terms of Reference approved				
	Nov-2014		Field & environmental studies				3rd open houses
	May-2015						4th open houses
	Jun-2015	Preferred alignment selected					
	Nov-2015	Detailed line design complete					
	Nov-2015				Prepare offers for land rights acquisition		
	Dec-2015					RFP issued	
2016	Jan-2016						5th open houses
	Feb-2016					RFP responses received	
	Mar-2016			OEB s92 application submitted			
	Apr-2016		EA submitted	Hearing			
	Oct-2016				Complete land rights acquisition		
	Nov-2016		Provincial EA Approved				
	Nov-2016			OEB s92 application approved			
2017	Feb-2017					Construction contract executed	

7.2.3 Reporting Requirements

EWT LP has proposed reporting requirements during the development phase that will help the Board:

- ensure that EWT LP is moving forward with the work on the Project in a timely manner;
- facilitate the early identification of circumstances which may delay the Project schedule; and
- provide transparency regarding the costs that are intended to be recovered from ratepayers.

EWT LP proposes to report to the Board both at set intervals and on an exception basis. In considering the appropriate frequency, a balance has to be set between overly frequent reporting, where no opportunity exists for meaningful progress since the previous report, and under-reporting, which does not provide the Board with an opportunity to consider actions necessary to ensure the transmitter keeps the Project on target. EWT LP therefore proposes to report formally to the Board every six months, which it believes strikes an appropriate balance between keeping the Board informed and ensuring administrative efficiency (which contributes to the efficiency of the overall Project).

With the reporting frequency set to every sixth month -- i.e., every February and August assuming that EWT LP is designated on or around August 1, 2013 -- EWT LP expects to submit five formal progress reports to the Board during the development phase of the Project (assuming EWT LP's development assumptions are accurate). EWT LP believes that this is sufficient to meet the three objectives noted above. EWT LP will provide additional reports to the Board if events occur between scheduled reporting dates that have or are likely to have a material effect on the Project schedule or budget. This is what is meant by the reference above to exception basis reporting.

In each report, EWT LP proposes to provide the following information:

- An update on the status of the Project;
- A report of any significant issues since the last report, including the resolution of any significant risk to the Project;
- A progress report measured against the development phase internal management milestones noted above;
- A summary of actual and accrued expenditures against budget with a high level analysis of any variance and a forecast of the cost to complete;
- A forecast of progress for the next six months;
- A summary of any new significant risks that have arisen and the plan to mitigate them; and
- Any changes in the development plan proposed to ensure the Project is delivered on time and to budget.

EWT LP will also, as necessary, provide information about the following issues:

- **An update on the technical design of the line** – EWT LP believes this is important because any significant design changes could have a material impact on the construction and operating costs and therefore whether the continuation of development work is in the public interest.
- **The level of public support for or opposition to the new line** – EWT LP believes this is important because it affects the risk that permits and thus the completion of the line will be delayed. It also affects the duration and complexity of any subsequent application for the Board's leave to construct.
- **EWT LP's progress discharging any delegated procedural aspects of the Crown's duty to consult with First Nations and Métis communities** – EWT LP believes it is important for the Board to have this information because the honour of the Crown requires there to have been meaningful consultation before any action is taken that may affect actual or potential Aboriginal rights, and because permitting may be vulnerable to challenge if the duty has not been properly discharged.
- **The status of public consultation** – Even though EWT LP through its partners has a strong presence in northern Ontario, and has experience both in developing projects and being consulted on projects in the area, issues relating to public consultation may arise that cause the Project schedule to change. For example,

poor weather could delay key public consultation events. EWT LP may need to postpone the open houses scheduled for January 2014 and January 2016 if the weather makes travel unsafe for the public or EWT LP's staff. Conversely, it may be possible to identify and address all stakeholder concerns early in the development process, allowing the overall development program to be shortened.

7.2.4 Consequences for Failure to Meet Milestones and Reporting Requirements

In its Phase 1 Decision and Order, the Board was "of the view that the severity of the consequences should be proportional to the severity of the breach, and take into account the designated transmitter's mitigation efforts. In determining how to address any failure the Board will consider:

- the nature and severity of the failure
- the specific circumstances related to the failure
- the consequences of the failure
- the designated transmitter's proposal to address the failure.[5]

The Board also noted that its "policy indicates that the loss of designation and the inability to recover development costs are two potential consequences of failure."

EWT LP believes that the Board's decision sets out the appropriate considerations if EWT LP were to fail to meet a performance milestone or reporting requirement, and that the ultimate consequence be left to the discretion of the Board.

Of course, EWT LP believes that it is important for the Board to impose any consequences only after due process has been followed and after EWT LP has had the opportunity to present its evidence at the time of any alleged failure. In particular, if a milestone were missed, EWT LP believes it is important for the Board to consider why it was missed. A milestone that was missed despite the fact that the designated transmitter had a comprehensive and detailed plan which it diligently executed using skilled and experienced staff and contractors is very different

[5] Page 16, Board Decision and Order on Phase 1 (EB-2011-0140)

than a failure resulting from unfamiliarity with the process in Ontario or erroneous assumptions as to the nature and difficulty of working in the remote and rugged terrain in northern Ontario. EWT LP believes that it is important for the designated transmitter to have the opportunity to demonstrate prudency and the cause of the failure -- in effect, to have the Board factor the transmitter's due diligence into any potential consequences.

Finally, EWT LP believes that the loss of designation and consequential risk of loss of all incurred development costs is so severe that it is only warranted for the most egregious failures. For example, for repeated failures to meet milestones or the loss of access to the financial capacity and technical capability necessary to complete development and construction of the Project. As described in Sections 7.2 and 7.5.1, EWT LP does not expect to trigger such a consequence given the level of thought and detail that has gone into its Project schedule and the conservative assumptions underlying it. In addition, as described in Section 7.2.3, EWT LP has outlined detailed reporting requirements that will ensure that the Board has up-to-date knowledge of any issues that may arise and EWT LP's plans to mitigate them. As a result, the Board will be able to have confidence that proactive steps are being taken before any serious issue could transpire.

7.2.5 Development Schedule Risks and Associated Mitigation Measures

The key risk to the development schedule is the designated transmitter's ability to work through the regulatory approval process required to obtain finalized Project route siting. The time taken to secure a route for a new line can quickly over-run the initial schedule. For example, some might consider the route for HONI's recent and successful Bruce to Milton project to have been obvious -- i.e. the widening of the existing right of way to provide space for a new 500 kV double circuit transmission line. However, it still took over four years for the final route to be confirmed through the issuance of all regulatory permits.[6] EWT LP knows from this project and

[6] On September 27, 2006, the Minister of Energy informed the Standing Committee on Estimates that Hydro One had done some preliminary analysis of what needed to be done to reinforce the transmission system to the Bruce. On March 15, 2011, the Board issued its decision and order (EB-2010-0023) allowing for the expropriation of land

others, including the Brookfield Utility Group's experience with Wind Energy Transmission Texas LLC, that the selection of the preferred route for any transmission project requires the careful reconciliation of a multitude of issues.

The key event in the development phase is finalizing the detailed technical design of the line on its substantially final routing. This event represents the completion of all the public consultation and environmental studies needed to identify the preferred location and design for the line and its construction. Subsequent events including land acquisition, completion of the environmental assessment, preparation of an application for leave to construct and completion of the technical specifications for engaging the construction contractor, though important, are all dependent on the achievement of this critical internal management milestone. EWT LP believes that reaching this internal milestone is most likely to be delayed by issues arising during public consultation for the routing of the new line and that effective consultation with the public and First Nations and Métis communities is therefore the highest priority activity.

This and other key risks to the Project development schedule and their mitigation have been identified in the table below. Key risks to the Project construction schedule, Project development budget and Project construction budget are tabled in Sections 7.3.4, 8.5 and 8.9, respectively.

Table 7.2: Development Schedule Risks and Mitigation Measures

Risk	Probability	Severity	Mitigation
Issue of permits across Crown land (including national parks, provincial parks, MNR buffer zones) is delayed or denied	Very likely	Major	EWT LP will meet with the MNR and appropriate parks and land use agencies at the earliest opportunity to understand their potential issues and to ensure those issues are properly considered during the environmental assessment and technical design of the line,

rights. On May 10, 2011, the Minister of Natural Resources directed the Niagara Escarpment Commission to issue a development permit for the project.

Risk	Probability	Severity	Mitigation
			including its construction. EWT LP will actively consider routes that avoid parks and MNR buffer zones, where any additional cost of the alternative route is justified given the balance of lower environmental impact, permitting delays and the need to expropriate land.
Issue of permits, approval of environmental assessment, granting of leave to construct are delayed due to a failure of the Crown to consult fully with Aboriginal people	Somewhat likely	Major	EWT LP has prepared a comprehensive Aboriginal consultation plan (Section 10) and will work with the Crown and Aboriginal people to ensure that the appropriate consultation activities have been properly undertaken.
Expropriation of private land required	Somewhat likely	Major	EWT LP will meet with landowners at the earliest opportunity to understand the availability of suitable land for the new line. EWT LP will, in consultation with property owners and municipalities, develop a set of Land Acquisition Compensation Principles, which are fair to both ratepayers and landowners, and apply these in an attempt to reach voluntary agreements with property owners. If this is not viable, despite good faith and consistent efforts, the legislated expropriation process will be relied upon. EWT LP will attempt to avoid potential routes that would require the expropriation of multiple properties
Development is delayed because environmental approvals are not forthcoming.	Somewhat likely	Major	There are no absolute deadlines for carrying out an environmental assessment, and even those defined

Risk	Probability	Severity	Mitigation
			in Ontario Regulation 616/98 relating to ToR review and approval (12 weeks) and EA review and approval (30 weeks) are subject to certain exceptions. For example, the Director of the Ministry's EAAB has the authority to extend the deadline for completing the Ministry review of the EA if he or she feels that there is a compelling reason (i.e., if the reason is unusual, unexpected, or urgent) (see subsection 7(3) of the EA Act). EWT LP will initiate and maintain an on-going close working relationship with the assigned MOE EAAB Project Officer - proposing bi-weekly conference calls between the key Project Team members and Project Officer. EWT LP will also initiate and maintain an on-going relationship with the key ministries involved in the EA (such as the MOE, MNR and Ministry of Tourism, Culture and Sport) - proposing face-to-face meetings with these key ministries on a quarterly basis to ensure any potential issues from their perspectives are discussed and resolved prior to ToR and EA submission.
Development is delayed or abandoned due to opposition	Somewhat likely	Major	EWT LP has included a program for comprehensive public and Aboriginal engagement in its plan based on its unique knowledge of the key local communities and stakeholders and the extensive

Risk	**Probability**	**Severity**	**Mitigation**
			experience of its consultants. EWT LP has allowed for five rounds of public and Aboriginal consultation in 12 different locations (for a total of 60 public meetings), which it believes to be sufficient. A sixth round would add approximately 9 weeks to the Project schedule. Having strong connections in northern Ontario, EWT LP also has a good understanding of the local issues. EWT LP will report to the Board on the level of public and Aboriginal support for the Project after EWT LP has completed initial public consultation.
Development is delayed due to the activities of Aboriginal communities or individuals	Somewhat likely	Major	See the mitigation measures relating to issues of concern for Aboriginal communities set out in Table 10.1.1 in Section 10 of this Application.
EA ToR are rejected because EA is too 'focused' and does not consider a wide enough range of Project alternatives or alternative methods	Somewhat likely	Major	EWT LP plans to reduce the range of alternatives by undertaking desk top studies and consulting widely prior to submitting the EA ToR. EWT LP will 'focus' the Project to reduce the cost to ratepayers of completing the environmental assessment but will only eliminate alternatives as justified by the available evidence.
Public opposition to the line due to EMF issues	Somewhat likely	Major	EWT LP will provide information about EMF in the first and subsequent open houses. EWT LP will route the line to avoid areas that have historically proven sensitive to EMF (such as proximity to schools and

Risk	Probability	Severity	Mitigation
			nurseries).
Development is delayed due to Project management errors or omissions	Not very likely	Major	EWT LP is familiar with managing complex projects involving multiple stakeholders over long durations. EWT LP has engaged a highly experienced owner's engineer to undertake procedural activities including Project task tracking, risk tracking etc. and highly experienced land rights acquisition, public consultation and environmental specialists
Issue of permits across Crown land (other than parks etc.) is delayed or denied other than parks and MNR buffer zones	Not very likely	Major	EWT LP will meet with MNR at the earliest opportunity to understand the issues and ensure they are properly considered during the environmental assessment and technical design of the line, including its construction. EWT LP will determine the preferred route and design for the line in accordance with relevant provincial land use policies and good industry practice.
Development delayed by poor weather, limited site access	Very likely	Moderate	EWT LP is very familiar with the rugged terrain and inclement weather along the northern shores of Lake Superior. EWT LP has factored in reasonable additional time to allow for poor weather, long travel times and restricted access.
The Minister can, and has, approved a ToR with amendments, which are unannounced to both the proponent and the assigned MOE EAAB Project Officer until the Notice of Approval is issued. As a result, the	Somewhat likely	Moderate	EWT LP will work with MOE EAAB Project Officer to ensure that any issues that may require amendments have been adequately considered and documented in the ToR

Risk	Probability	Severity	Mitigation
amendments and how they are to be applied during the subsequent EA have to be interpreted by both the proponent and the assigned MOE EAAB Project Officer, which takes time to come to a mutual understanding.			
The review agencies commenting on the ToR and EA can, and often have, provided conflicting views on similar subject areas that cause unnecessary delays as they need to be interpreted, discussed, and resolved between ministries and even departments within a single ministry.	Somewhat likely	Moderate	Initiate and maintain an on-going relationship with the key ministries involved in the EA (such as the MOE, MNR and Ministry of Tourism, Culture and Sport). EWT LP is proposing face-to-face meetings with these key ministries on a quarterly basis to ensure any potential issues from their perspectives are discussed and resolved prior to ToR and EA submission. Initiate and maintain an on-going relationship with other review agencies and interested public members through a government review team by holding meetings with each of them as part of each of the 5 proposed consultation rounds. Identify areas of conflicting opinion and attempt to resolve prior to submission.
Participants may provide comments in order to delay the approval process -- the Ministry requires a proponent to consider them and respond to the "objector".	Somewhat likely	Moderate	Minimize the risk of late issues/concerns during the government review period by (a) engaging the public early, and continuing regular, responsive, meaningful and open communication throughout the life of the Project; (b) ensuring that documented responses are

Risk	Probability	Severity	Mitigation
			provided to every issue raised.
Minister rejects EA ToR due to inadequate consultation	Somewhat likely	Moderate	EWT LP has prepared and will execute a comprehensive and detailed consultation plan that exceeds the requirements of the MOE's Code of Practice.
Field studies etc. are delayed due to land access (most likely with respect to private land)	Somewhat likely	Moderate	Although EWT LP may apply to the Board for authority to enter land for the purposes of making surveys etc., this is a relatively time consuming process. EWT LP therefore intends to work directly with potentially affected landowners (primarily private parties) to obtain access for field studies and will provide appropriate compensation.
Development is delayed by unavailability of key stakeholders for meetings	Somewhat likely	Moderate	A company with roots in northern Ontario, EWT LP knows many of the key stakeholders. EWT LP plans to consult with key stakeholders at the start of the Project to confirm how they wish to participate in the development and permitting process. EWT LP will plan stakeholder meetings in advance, recognizing that meetings can often be delayed by poor travel conditions. EWT LP will maximize the use of its partner Bamkushwada LP to help arrange meetings with key stakeholders.
Development is delayed because IESO is unable to provide input to system studies in a reasonable amount of time or rejects EWT LP's engineering studies	Not very likely	Moderate	EWT LP intends to undertake the majority of the studies in accordance with the scope of studies developed by the IESO. EWT LP has engaged a highly experienced owner's engineer to perform these studies with advice from its partners. EWT LP will

Risk	Probability	Severity	Mitigation
			work closely with IESO staff to ensure its proposed alternatives are consistent with Ontario electric reliability standards and do not require re-engineering.
Development is delayed due to the unavailability of resources	Not very likely	Moderate	EWT LP has engaged three major international professional service firms to provide the specialist resources necessary to complete the development and construction of the Project. These companies have the capacity to simultaneously undertake multiple projects.
Board designates EWT in Fall 2013 or later	---	Moderate	The environmental field work is programmed to start in April 2014 assuming designation is on August 1, 2013. If designation is delayed, then EWT LP may not be able to complete summer fieldwork, which provides some of the richest ecological data, until summer 2015. This could delay the overall development program by up to six months.
Delays completing the environmental assessment due to excessive feedback from stakeholders	Somewhat likely	Low	EWT LP encourages public feedback on its proposals. EWT LP will post the environmental assessment in sections as it becomes available to ensure that the public is able to provide input at their earliest convenience. This shortens the duration compared to posting the final document when complete.
Delay due to unavailability or difficulty collecting data for desktop studies	Somewhat likely	Low	EWT LP is using environmental and land specialists based in Ontario who are familiar with the availability of data and already have much of the necessary data

Risk	Probability	Severity	Mitigation
			on record. The availability of other essential data has been confirmed as part of the preparation of this Application

7.3 Construction Phase

EWT LP has prepared an indicative schedule for the construction phase of the Project, assuming the line being built is based on the Board's reference option (see the description of the Reference-Based Design in Section 6.1). EWT LP has estimated that this construction phase, from the date the construction contract is executed, will take approximately 22 months. This timeline will allow for the procurement of materials, the construction of access tracks, the clearance of the right of way, the construction of foundations, the erection of towers, the stringing of the conductor and the commissioning of the line. This will require careful coordination with construction activities being undertaken by Hydro One Networks Inc. ("HONI") to allow for the connection of the new line and its integration into the provincial transmission system. A shorter construction program is possible although it may increase the cost and risk to ratepayers. The final construction schedule will depend on a cost-benefit analysis that weighs the benefits of bringing the new line into service at an earlier date against the risks and costs of doing so.

Based on this schedule, and assuming that the Board designates EWT LP on August 1, 2013 and issues its leave to construct decision in November 2016, the line will be in service in November 2018.[7]

The construction schedule is necessarily less detailed than the development schedule above. As discussed in Section 7.2, the development schedule is meant to be an accurate forecast of the expected duration of EWT LP's development work and a schedule to which EWT LP expects to be held. The construction schedule, however, is an estimated timeline and depends on a number of assumptions that cannot be resolved before the development phase is complete. Key issues to be resolved include the design of the line, the route of the line, and the method of construction.

[7] As mentioned above, if the assumptions underlying the development phase prove to be overly conservative, this date could be advanced to as early as March 2018.

The province's Long-Term Energy Plan published in November 2010 estimated a target completion date of 2016-2017, and the OPA's Long Term Electricity Outlook for the Northwest and Context for the East-West Tie Expansion published in June 2011 estimated a target completion date of 2017. However, these estimates made certain high level assumptions, and neither were based on the detailed consideration that has gone into EWT LP's schedule. Moreover, both estimates were prepared before the length of the current designation proceeding was known. If the province and the OPA's target completion dates were adjusted to account for the time that has passed since the respective reports were published, the new target date would likely be slightly later than EWT LP's proposed in-service date of November 2018.

If there is determined to be a need to accelerate this in-service date, EWT LP maintains that a balance must be struck between achieving speed in the development and construction phases and ensuring health and safety; the completion of comprehensive consultation, technical and environmental studies; and construction work. EWT LP believes it may be possible to accelerate the in-service date, but this would require considerably more construction resources -- for example, to allow construction to proceed simultaneously at multiple locations -- at a cost to the ratepayers. At this time, it is also unclear whether those construction resources would be available at the necessary time. Even if they were, increasing the number of work locations creates coordination challenges that can increase the risk of Project cost and scheduling overruns. There are also regulatory limits to how far the in-service date can be accelerated: EWT LP notes that construction activities of any type, including clearing the vegetation, generally cannot start until the environmental assessment has been approved.

7.3.1 Preliminary Construction Schedule

A detailed Gantt chart showing EWT LP's preliminary line construction schedule is included in Appendix B of the report titled "East West Tie Expansion Engineer's Report on the EWT Transmission Line OEB Reference Option" (see Appendix 6A). The schedule is based on the construction of the Reference-Based Design (see Section 6.1) and the reference route; as discussed in Section 6.5.2.2, a change in the Project design to use CRS transmission structures could significantly expedite the schedule. At this stage, the estimated construction schedule is based on a prudent and reasonable compromise between construction cost, schedule and risk. As indicated above, however, EWT LP expects there to be opportunities to compress the construction schedule when, after the development phase, the design and location of, and the need for, the Project are finalized.

For the purpose of this schedule, EWT LP has made the following key assumptions:

- The environmental assessment and leave to construct are approved in November 2016.
- A competitive procurement process has been run to select the most cost effective qualified construction contractor or construction consortium.
- The construction contract is executed after the Board has granted leave to construct and the Minister of the Environment has granted approval under the *Environmental Assessment Act*. This provides opportunity for EWT LP to negotiate from a position of commercial strength any minor amendments to the technical specification or contract commercial terms necessary to incorporate any permit conditions.
- EWT LP has completed approximately 80% of the detailed engineering for the new line during the development phase of the Project leaving the remaining 20% to be completed by the construction contractor. This remaining engineering would relate to the foundations, fittings and other related equipment, and be completed in accordance with criteria specified by EWT LP.
- The construction contractor is responsible for material procurement -- e.g. towers, conductor, fittings etc. -- and for arranging their delivery to site.
- The construction contractor is responsible for clearing the right of way and for establishing suitable construction yards, access roads and other similar facilities along the Project route.
- The construction contractor is responsible for acquiring all minor permits necessary for line construction.
- The construction contract is a fixed price contract with commercial terms developed to incentivize the safe and timely completion of the Project.

- Project construction is not delayed by work at HONI's switchyards or on any other transmission facilities in the Project area.

- Neither the Board nor the Minister of the Environment has imposed any unusual conditions as to the construction of the Project (e.g., requiring that construction only be undertaken in certain months or on certain days).

- The line is constructed in three separate segments with construction occurring simultaneously in all three segments -- i.e., the construction contractor has sufficient resources to provide three teams each responsible for constructing approximately 140 km of line.

- The construction contractor provides a reasonable buffer between each construction activity – clearance, foundations, tower erection, stringing – to minimize the risk of delays.

- EWT LP completes its development work and acquires land access rights through normal commercial negotiations.

Based on these assumptions, EWT LP estimates the line can be constructed in 22 months and will be in-service in November 2018.[8]

Assuming that schedule, the preliminary performance objectives for the construction phase are provided below:

Objectives	**Completion date**
Construction contract executed	Feb 2017
Materials delivered	Dec 2017
Rights of way cleared	Dec 2017
Foundations poured	Jan 2018
Towers erected	Mar 2018
Conductor stringing complete	Oct 2018
Commissioning complete / commercial operations	Nov 2018

[8] As mentioned above, if the assumptions underlying the development phase prove to be overly conservative, this date could be advanced to as early as March 2018.

Of these objectives, the two that will form milestones for the construction phase will be (i) the date the foundations start to be poured and (ii) the date the commissioning is complete.

7.3.1.1 EWT Preferred Construction Approach

EWT LP has made certain assumptions, described in Section 7.3.1, about how it proposes to undertake construction. Some elaboration is worthwhile here. EWT LP has decided that ratepayers would be best served by engaging the construction contractor through a competitive procurement process. EWT LP does not believe that engaging a sole source construction contractor in advance of the designation process or immediately after designation would provide better value to ratepayers.

EWT LP therefore believes that a fully competitive procurement process, with multiple experienced bidders bidding against a detailed and comprehensive technical specification and well defined commercial terms, is likely to provide ratepayers with the best value for money. EWT LP has selected a hybrid EPC procurement process in which EWT LP will complete most but not all the detailed engineering for the new line – approximately 80% -- and then engage a construction contractor to complete the final design, procure the materials and complete erection. The final remaining 20% of the engineering work will involve the foundations, fittings and similar equipment and will be performed to criteria specified by EWT LP.

The contractor will be engaged through a fully competitive two-part (RFQ/RFP) procurement process. The RFQ (request for qualifications) process will be run early in the process so that qualified contractors who are selected to make firm bids to construct the Project are also available to provide advice about the construction of the Project to EWT LP during the development phase. This will help reduce the risk that the Project permitted is subsequently found to be difficult or expensive to build. It also allows for the quick engagement of the construction contractor once the environmental assessment has been approved and the Board has granted leave to construct. EWT LP has scheduled the RFP process so that the bid prices are received prior to EWT LP's submission of its application for leave to construct to the Board.

The Board will therefore have better information available when determining whether construction of the Project is in the public interest.

7.3.2 Reporting Requirements

As described in Section 7.2.3 above, EWT LP has proposed reporting requirements during the construction phase that will help the Board:

- ensure that EWT LP is moving forward with the work on the Project in a timely manner;
- facilitate the early identification of circumstances which may delay the Project schedule; and
- provide transparency regarding the costs that are intended to be recovered from ratepayers.

EWT LP proposes to report to the Board both at set intervals and on an exception basis. In considering the appropriate frequency, a balance has to be set between overly frequent reporting, where no opportunity exists for meaningful progress since the previous report, and under-reporting, which does not provide the Board an opportunity to consider actions necessary to ensure the transmitter keeps the Project on target. EWT LP therefore proposes to report formally to the Board every six months, which it believes strikes an appropriate balance between keeping the Board informed and ensuring administrative efficiency (which contributes to the efficiency of the overall Project).

With the reporting frequency set to every six months -- i.e., every February and August assuming that EWT LP is designated on or around August 1, 2013 -- EWT LP expects to submit four formal progress reports to the Board during the construction phase of the Project. EWT LP believes that this is sufficient to meet the three objectives noted above. EWT LP will provide additional reports to the Board if events occur between scheduled reporting dates that have or are likely to have a material effect on the Project schedule or budget. This is what is meant by the reference above to exception basis reporting.

In each report, EWT LP proposes to provide the following information:

- An update on the status of the Project;
- A report on any significant issues that have arisen since the last report and the resolution of any significant risk to the Project;
- A progress report measured against the construction milestones noted below;
- A summary of actual and accrued expenditures against budget with a high level analysis of any variance and a forecast of the cost to complete;
- A forecast of progress for the next six months;
- A summary of any new significant risks that have arisen and the plan to mitigate them;
- Any changes in the construction plan proposed to ensure the Project is delivered on time and to budget; and
- Any changes to the expected in-service date.

EWT LP will also as necessary provide additional information about the following issues:

- Consistent with the Board's decision and order in the Bruce to Milton Section 92 application,[9] EWT LP will maintain a log of all complaints related to construction that have been received. The log shall record the person making the complaint, the times of all complaints received, the substance of each complaint, the actions taken in response, and the reasons underlying such actions. EWT LP will attach a copy of the log to its report.

7.3.3 Consequences for Failure to Meet Milestones and Reporting Requirements

EWT LP expects that the major milestone and reporting requirements will be confirmed in the terms and conditions of the Board's leave to construct approval. If any of these conditions are

[9] EB-2007-0050.

not satisfied, EWT LP would expect the Board to initiate a proceeding that would allow the designated transmitter to show cause for such a failure. EWT LP believes that it would be inappropriate to make determinations on the issue in the absence of the evidence about the actual design, construction and future operation of the Project. This information will not become available until the designated transmitter has completed detailed development work. For example, the conditions of the environmental assessment approval may require the designated transmitter to employ a rarely used construction technique to avoid environmental damage, and this technique materially increases the risk that tower erection will be delayed. However these conditions will not be known until development is complete.

7.3.4 Major Construction Schedule Risks and Associated Mitigation Measures

The following major construction risks and their mitigation have been identified based on the nature of the Project and the difficulty of the terrain.

Table 7.3: Construction Schedule Risks and Mitigation Measures

Risk	Probability	Severity	Mitigation
Construction is delayed by protests	Somewhat likely	Major	EWT LP has planned for a comprehensive program of consultation during the development of the new line to identify and, where appropriate, accommodate concerns with its Project. If in spite of this consultation, protests could endanger construction workers, EWT LP will suspend construction activities until the provincial authorities including the police can guarantee the safety of its workers and contractors.
Injuries to workers and the public during construction	Somewhat likely	Major	EWT LP is very concerned about the safety of the public and workers during the construction phase. The construction industry

Risk	Probability	Severity	Mitigation
			is one of the most dangerous industries in Canada[10]. The construction contractor's safety program will be pre-qualified and must meet or exceed Brookfield's safe work management system. EWT LP will employ on-site safety monitors during the construction program to ensure that the construction contractor deploys a safe system of work. If the construction contractor fails to employ a safe system of work, then EWT LP will suspend construction activities until the required remedial activities have been completed regardless of any consequential delay to the construction program, which will be at the contractor's risk.
Materials delivered are to the wrong standard / wrong materials are delivered to site	Not likely	Major	EWT LP plans at this time for the construction contractor to be responsible for procuring all materials required for the construction of the Project. The risk of procuring the wrong materials or materials to the wrong standard is therefore transferred to the construction contractor. However EWT LP believes it is not satisfactory to take a hands-off approach. Instead EWT LP will employ procurement specialists to review the construction contractor's procurement plan; engineers to review the construction contractor's technical specifications for key materials;

[10] Association of Workers' Compensation Boards of Canada

Risk	**Probability**	**Severity**	**Mitigation**
			and inspectors to inspect the quality of work in the construction contractor's suppliers' factories. EWT LP will also employ specialist engineers to inspect the materials as they are delivered to the Project area and prior to erection.
Construction is delayed by poor weather	Highly likely	Moderate	EWT LP through its partners has recent experience building transmission lines and generating facilities in this part of Ontario. EWT LP understands that poor weather can delay construction. EWT LP will work with the construction contractor to ensure the construction plan accounts for the possibility of poor weather conditions to the extent practicable. As set out in Section 8, EWT LP's preference is to enter into a fixed price contract with the construction contractor for the construction of the Project, which helps ensure that any exposure to ratepayers as a result of cost over-runs caused by poor weather will be mitigated.
Timely access to enter land is not available	Somewhat likely	Moderate	EWT LP plans to work with landowners from the start of the route selection process to identify a route where access for construction and maintenance will be available. EWT LP has engaged Altus Group Inc., a land specialist, to work with landowners to secure access to the land for development and construction.
Unplanned / unauthorized	Somewhat	Moderate	EWT LP will monitor

Risk	**Probability**	**Severity**	**Mitigation**
damage to the environment resulting from construction activities	likely		construction activities weekly and monthly and ensure that the environmental mitigation measures that are conditions of its permits are incorporated through the construction contract. Although the construction contractor will be contractually responsible for executing its works in accordance with all applicable provincial and federal standards, EWT LP will employ specialist contractors to ensure the contractor has a managed work system to prevent environmental damage, is applying the work system on site, and is in all ways complying with EWT LP's permitting requirements. The construction contractor will be required to employ sufficient staff to ensure sound management of the environment does not delay the construction program
Delays caused by low productivity of construction teams	Somewhat likely	Moderate	EWT LP will enter in to a fixed price contract with the construction contractor based on a detailed technical specification. The risk of delays caused by low productivity or performance will be borne by the construction contractor, not ratepayers.
Construction resources are not available in sufficient quantity or for the desired construction start date due to competing projects elsewhere in North America	Somewhat likely	Moderate	EWT LP's recent conversations with a major North American construction company suggest that transmission line construction activities are expected to reduce in the second half of the decade and that construction resources should be available by that time. EWT LP plans to start the RFQ

Risk	Probability	Severity	Mitigation
			process to select the construction contractor in March 2015 and therefore will be able to determine the likely availability of construction resources as early as summer 2015. If the need for the Project becomes urgent, then it may be possible to reserve construction capacity for 2018 but there would be an associated cost and a significant increase in risk to ratepayers.
The need for expropriation of a large number of properties following the leave to construct	Not likely	Moderate	EWT LP's current construction schedule contemplates the possibility for expropriation and the need to schedule the erection of towers on expropriated land after all other towers have been completed without extending the overall Project construction schedule. EWT LP will also implement a land acquisition compensation policy that will help ensure it has voluntarily secured as many properties as possible for construction.
Materials are not available for construction in a timely manner – erection is delayed	Not likely	Moderate	EWT LP plans at this time for the construction contractor to be responsible for procuring all materials required for the construction of the Project, and for arranging the logistics to deliver the materials to site. Given the length of the line and the semi-remote location, material logistics will be an important component of the construction contractor's mandate. EWT LP's RFQ process will include logistics capability as a key criteria in the selection of qualified construction

Risk	**Probability**	**Severity**	**Mitigation**
			contractors. Although the construction contractor will be responsible for material logistics and any delays, EWT LP staff will monitor the construction contractor's progress against its agreed construction schedule in order to be ready to require the contractor to take remedial actions to prevent minor issues causing major construction delays.
The line is found to be more difficult to construct than expected at the design stage	Not likely	Moderate	EWT LP has engaged specialist and experienced engineers familiar with constructing transmission lines in difficult terrain to design the line. Furthermore, EWT LP has scheduled the procurement program to ensure that suitably qualified and experienced construction contractors have been formally identified early in the development program and are available to provide advice, although at some cost, as to the constructability of EWT LP's design before the design is finalized.
Construction is delayed due to environmental concerns	Not likely	Moderate	EWT LP will complete a comprehensive environmental assessment for the new line and incorporate appropriate mitigation measures in to its Project. EWT LP therefore does not anticipate that any new environmental concerns will arise between the environmental assessment being approved and construction.
The construction contractor has	Not likely	Moderate	EWT LP will use a rigorous pre-

Risk	Probability	Severity	Mitigation
insufficient resources to complete the job			qualification program (RFQ) to eliminate potential construction contractors who lack the skills, experience or resources to complete the construction of the Project.

7.4 Relevant Experience

7.4.1 Brookfield Utilities Group

The Brookfield Utilities Group has extensive experience in completing major transmission projects. The following are some key examples:

- Transmission Reinforcement Project: This project, which improved the transfer capability of the existing East-West Tie line, entailed the construction of a new 164 km 230 kV electricity transmission line on an existing right of way from HONI's Wawa transformer station to Great Lakes Power's Third Line transformer station in Sault Ste. Marie, Ontario with associated transmission station ("TS") modifications at Wawa TS, Anjigami TS, MacKay TS, Batchawana TS, Goulais Bay TS and Third Line TS. The purpose of the project was to replace existing end-of-life equipment and to reinforce transmission capacity between northwestern and northeastern Ontario (EB-2003-0162). In its application for leave to construct dated September 23, 2003, Great Lakes Power stated that Phase I of the project, which consisted of a new 73 km, 230 kV line from Wawa TS to MacKay TS (designated as line "W23K"), and Phase II, which consisted of a new 91 km, 230 kV line from Mackay TS to Third Line TS (designated as line "K24G"), was to be completed by late November 2005.[11] In its TRP Monitoring Report (Final) sent to the Board, Great Lakes Power noted that all Phase 1 and 2 work had been completed on October 28, 2005.

- Third Line 115kV: This project entailed the construction of a new 115kV switchyard with 17 SF6 circuit breakers and 45 other switches at Third Line TS, the transfer of all existing circuits to the new switchyard and the decommissioning of the old switchyard. Third Line TS is a critical facility in the provincial electricity transmission system supplying the City of Sault Ste. Marie and major industrial loads, and providing connectivity for local generating stations. Asset monitoring suggested that the switchyard, constructed in 1967/68, was reaching the end of its life. Due to the configuration and equipment rating, it was determined that it would be more cost effective to replace rather than refurbish the switchyard. Although the $23.7 million investment was small compared to the proposed East-West Tie, the project was unusually complex due to the need to continue providing supplies to all consumers while working in proximity to energized equipment. The work was completed in accordance with the Board approved schedule in 2012.

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[11] EB-2003-0162, Exhibit A, Tab 1 (Application), page 3; and Exhibit B, Tab 2, Schedule 1, page 225.

- Wind Energy Transmission Texas LLC ("WETT"): WETT, an equal partnership between Brookfield and a global transmission construction company, was awarded the right in January 2009 to build, own and operate approximately 385 miles of 345 kV transmission lines and five switchyards in Texas (plus one jointly with incumbent utility Oncor) in order to facilitate delivery of renewable wind power to population centers in the state. These new transmission facilities are part of the state-wide Competitive Renewable Energy Zone (CREZ) project that will see approximately 3,500 miles (6,000 km) of new transmission constructed at a cost of $6.95 billion (US) to support 18,500 MW of wind power. In its applications for certificates of convenience and necessity, equivalent to a combined application for leave to construct and environmental assessment, WETT indicated that its three projects would be completed in December 2012, February 2013 and April 2013, respectively. In a subsequent application for transmission rates brought by Lone Star Transmission, the Public Utility Commission of Texas indicated its concern based on experience with another recent project that the completion of individual projects should be coordinated and sequenced to ensure related transmission facilities were completed around the same time. To be responsive to this concern, WETT therefore re-sequenced its projects to be in-service in March 2013 (two projects) to better coordinate with other facilities targeted for completion in April 2013, and for May 2013.

7.4.2 Hydro One

Hydro One Inc. through its wholly owned subsidiary HONI has experience developing, constructing and owning electricity transmission projects in Ontario.

- In March 2007, HONI applied to the Board for leave to construct a new 180 km, 500 kV transmission line from the Bruce nuclear generating station to Milton. HONI initially forecast that the line would be completed in December 2011. The new line was completed in June 2012. Publicly available documents show that the development of the new line required an application for the expropriation of land rights across 47 properties and was subject to an appeal to the Environmental Review Tribunal regarding the Niagara Escarpment Commission's decision to grant a conditional development permit for the construction of the new line across the Niagara Escarpment. HONI's successful development and construction of the Bruce to Milton line is the largest transmission project to have been completed in southern Ontario for almost 20 years. It is also an example of how one of EWT LP's partners, through its subsidiary, overcame challenging development circumstances, whilst coming very close to meeting an ambitious development timeline.

- In 2005, Hydro One Networks announced the successful completion of its new 500/230 Parkway Transformer Station on a 170 acre site in Markham[12] on time and budget. The major new station with a budget cost of $140m was required urgently to ensure system reliability after the accelerated closure of the Lakehead generating station as part of the province's off-coal program.

- In September 2004, Hydro One Networks filed an application[13] for leave to construct a 2.2 km underground transmission line from John TS to Esplanade TS in a new tunnel to be constructed 90 feet below Front Street in the heart of downtown Toronto. The application included an in-service date of October 15, 2007. The actual completion was a mere few weeks later than originally planned in December 2007.[14]

[12] Standing Committee on Government Agencies, September 7th 2006, Legislative Assembly of Ontario.
[13] EB-2004-0436.
[14] Hydro One Inc 2007 Annual Report, retrieved from EB-2008-0272.

7.5 Opportunities to Accelerate the Project Schedule

7.5.1 EWT LP's Conservative Approach to Scheduling

EWT LP has prepared its development plan to provide the Board with a true and fair view of the cost and time required to develop the Project up until the filing of the leave to construct. In preparing this development plan, EWT made a number of prudent, but relatively conservative assumptions regarding the necessity and timing of certain environmental assessment and consultation activities. These assumptions were based on:

- EWT LP's development work to date;
- its experience developing electricity projects in the Project area, elsewhere in Ontario and outside Ontario; and
- its knowledge of the local communities and their likely concerns.

However, as development work progresses, it may become apparent that some of these assumptions were overly conservative and that development work can proceed faster than planned. In that case, it may be possible to accelerate EWT LP's development work by as much as approximately nine months so that a leave to construct application can be filed by June 2015, which in turn would advance the in-service date to February 2018.

The following changes in assumptions could give rise to such an accelerated schedule:

- If the first series of public open houses in January 2014 reveals that the public has fewer concerns about the Project, its design and its location than anticipated, it may be possible to eliminate the second set of open houses scheduled for summer 2014. This would allow the environmental field studies to start two months earlier than scheduled and would reduce the overall Project duration accordingly.
- If the initial environmental field studies reveal that there were fewer credible alternative alignments than expected based on EWT LP's initial routing workshop, then it may be possible to advance the LiDAR survey from early summer 2015 to late summer 2014. Although this would likely increase the cost of the Project because it would be necessary to survey both the preferred and alternative routes, it would allow detailed engineering to start earlier (concurrent

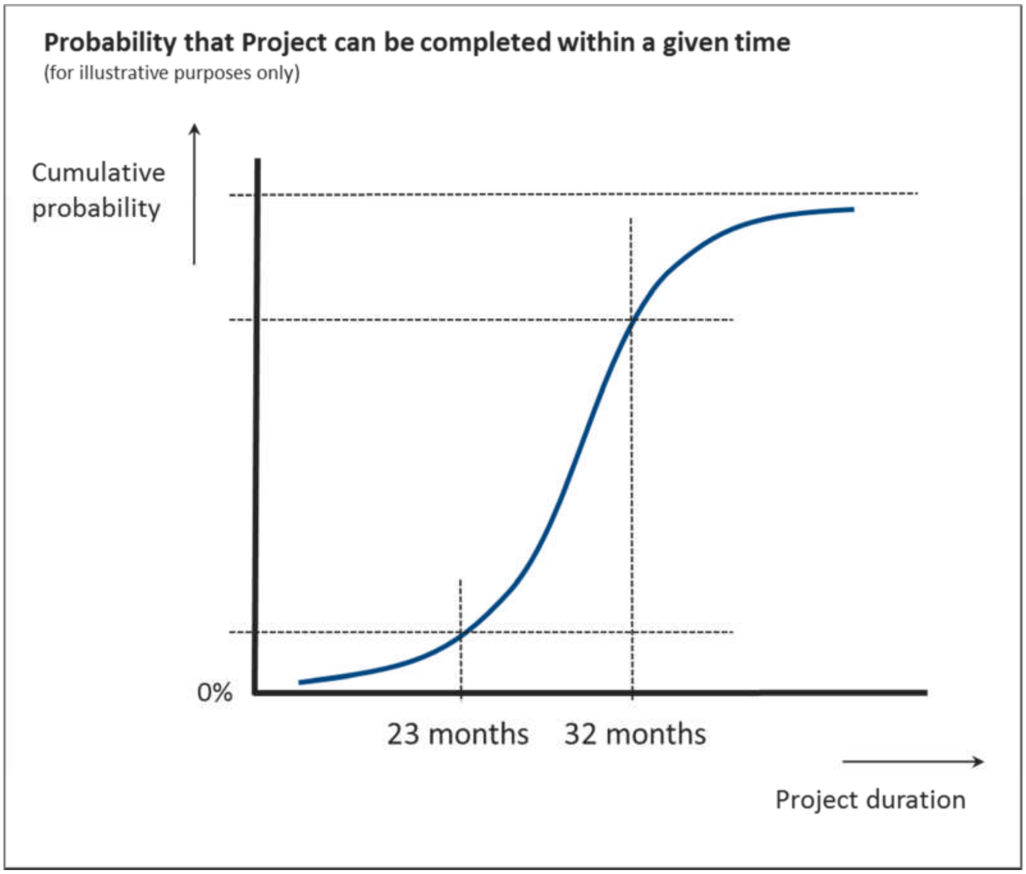
with the analysis of the environmental field studies) and would reduce the development schedule by approximately two months.

- The environmental field studies could reveal that the proposed design results in fewer significant environmental concerns than anticipated. The environmental concerns may be more readily mitigated than anticipated. If stakeholders and regulatory agencies agree with these conclusions, including during the third series of public open houses, then it may be possible to eliminate certain field studies scheduled for the second half of 2015. Any cost savings would be partly offset by the need to increase the duration of the initial environmental field studies to ensure they captured a full twelve months of field data.

- If the environmental field studies reveal fewer significant environmental concerns than anticipated and if the appropriate mitigation measures for any identified concerns were well proven and acceptable to stakeholders, it may also be possible to eliminate the fourth series of open houses. This would reduce the development schedule by approximately three months.

Were all these favorable factors to occur, and assuming travel was not restricted by poor weather, then it may be possible to complete the routing and technical design of the line as early as February 2015 rather than November 2015. This would allow the application for leave to construct to be filed as early as June 2015 rather than March 2016, which would reduce the overall development schedule by as much as eight months to 23 months in total. The Project budget would also be reduced by up to $2.7 million (see Section 8.2.2 for further details). For illustrative purposes only, a probability curve of the Project Schedule duration is shown below.

Figure 7.3: Project Schedule Probability Curve



7.5.2 Opportunities to Accelerate the Project Schedule

In addition to its conservative approach to scheduling, which may result in a shorter than anticipated development phase, EWT LP also plans to assesses a number of innovative Project plans that could further accelerate the Project schedule.

7.5.2.1 Opportunities to Accelerate the Development Schedule

Land Acquisition – As has been seen with HONI's recent successful Bruce to Milton 500 kV transmission project, assembling land rights for a new line is critical to avoiding project delays. It is not unusual for a transmission company to use specialist contractors such as Altus Group Inc. to obtain land rights for a new transmission line. It is somewhat unusual to engage them at the beginning of the Project – EWT LP's first meeting with key landowners will be in Fall 2013

– and to make consultation with landowners a priority for the early stages of project development. EWT LP believes it is important to understand the availability of land before developing and evaluating alternative routes. This innovation minimizes the risk that EWT LP decides to route the line across land that can only be obtained after expensive and time consuming expropriation.

First Nation Ownership – As described in Section 3, the active participation of the directly affected First Nations in the ownership and management of EWT LP brings many benefits, including their unique knowledge of the land, local experience and relationships with key stakeholders in the Project area. The participation of Bamkushwada LP in EWT LP's development activities reduces the risk of delays caused, for example, by miscommunication with local stakeholders, a failure to understand the significance of local issues, or the inability to quickly rearrange stakeholder meetings delayed by inclement weather, with the result that the overall Project schedule is shortened. Moreover, and significantly, First Nation ownership also aligns the interests of the Participating First Nations with the Project to ensure the timely completion of the Project. Both the Participating First Nations and EWT LP have an incentive to ensure the Project is brought into service in the most efficient and timely way possible, which ultimately services the interests of ratepayers as well. EWT LP has relied on the advice from Bamkushwada LP and its partners to ensure that EWT LP's First Nation and Métis consultation program is adequate to complete any of the procedural aspects of the Crown's duty to consult delegated to EWT LP.

Public Consultation – Many major energy projects encounter considerable public opposition. Examples include TransCanada Energy Ltd.'s Oakville generating station; the York Region transmission reinforcement initiative; Bruce Power's proposal to ship the decommissioned steam generators through the St. Lawrence Seaway; and Toronto Hydro's proposal to pursue a wind farm 2 km offshore from the Scarborough Bluffs. Managing this opposition requires effective early public consultation. EWT LP's strategy is to meet early and meet often. EWT LP plans to meet key stakeholders in Fall 2013 and hold the first series of public open houses in January 2014. EWT LP's innovation is to consult with stakeholders throughout the Project and include their feedback in the design of the Project, rather than designing the Project and then using open houses as a forum to explain and defend decisions that have already been made.

Local Knowledge – EWT LP understands the local geography and through its partners has extensive experience as both the person conducting the consultation and the person being consulted. EWT LP is uniquely positioned to proactively incorporate local concerns and issues into its development plan in the most efficient way possible (see Part 9 and 10 for further details).

Coordination of Studies – EWT LP has scheduled the system impact assessment studies and the customer impact assessment studies to start as soon as the preferred route has been selected and the key electrical parameters of the line have been determined, rather than wait for the final design of the line to be completed. This prevents these activities from becoming critical path and delaying the Project.

Local experts – EWT LP has committed to using suitably qualified local contractors where available to provide resources to complete development work. This eliminates the need for the contractors to familiarize themselves with the terrain, the stakeholders and the regulatory processes. EWT LP itself is an Ontario company with strong roots in the Project area through its partners.

Incorporating the Environmental Assessment into the Development Program – The environmental assessment process in Ontario is intended to be a systematic methodology for evaluating alternatives based on their impact on the built and natural environment. Rather than identifying the preferred alignment for the new line, designing the line and then subjecting the resulting design to an environmental assessment to determine how the design needs to be changed to allow the Minister to grant approval, EWT LP has taken the innovative approach of making the environmental assessment the backbone of its development program. EWT LP has compressed the overall development schedule by coordinating the environmental studies with the engineering and economic studies, the final design representing the simultaneous optimization of all four considerations. This is particularly noticeable in the Fall of 2015, when EWT LP plans to simultaneously complete the technical design of the line while assessing its environmental impact, thus reducing the overall development schedule by approximately five months.

Compressing the Environmental Assessment Process – EWT LP has scheduled the field studies to start before receiving approval of the terms of reference for the environmental assessment from the Minister of the Environment. This reduces the duration of the development program by approximately three months and allows field studies to start in summer 2014, with a second series of field studies programmed for summer 2015 to clear up any remaining issues. Although EWT LP will pursue this innovative approach, there is a small risk that the Minister may require EWT LP to conduct additional field studies as part of the Minister's approval of EWT LP's terms of reference in October 2014. This would push completion of the environmental field studies back on to a more 'normal' schedule with a small delay to the overall Project.

Early Appointment of Construction Contractor – EWT LP plans to identify suitably qualified and experienced construction contractors in 2015 through a competitive RFQ process so that they are available to opine on the constructability of alternative designs, and to have substantially completed the construction contractor procurement process by the time that leave to construct and approval of the environmental assessment are granted. This approach reduces the technical design risk (i.e., that the design is difficult to construct), but in itself has little effect on the development schedule. This approach does, however, expedite the final in-service date for the line by allowing EWT LP to go straight to construction as soon as the permits are granted.

Optioning Land – EWT LP plans to acquire land rights or options for the Project prior to receiving the Board's leave to construct. This compresses the development schedule by up to 10 months compared to awaiting the Board's leave before acquiring the land and is consistent with EWT LP's overall approach of working closely with landowners from the start of the Project.

7.5.2.2 <u>Opportunities to Accelerate the Construction Schedule</u>

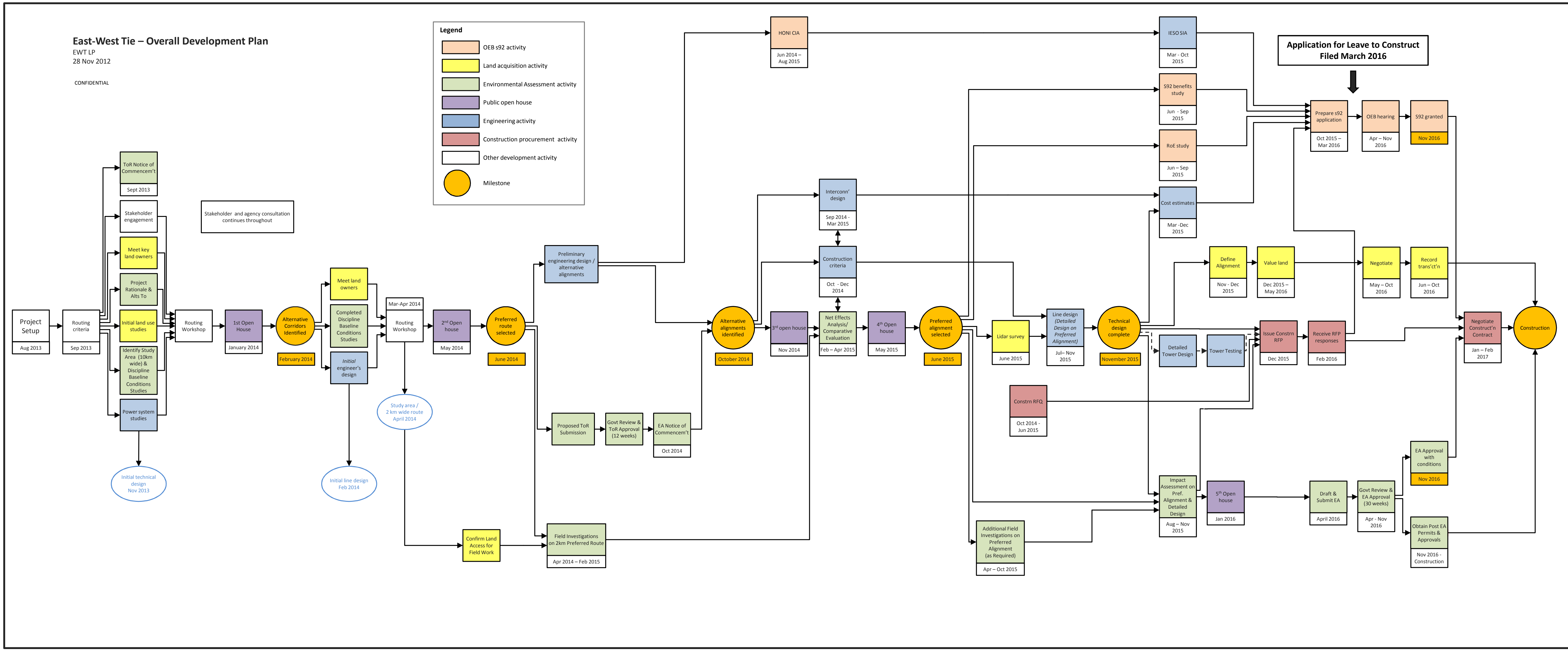
Cross Rope Suspension ("CRS") Alternative – The greatest time saving at least risk to ratepayers remains the adoption of CRS transmission structures. If studies determine that a single circuit meets the required technical performance requirements, then a CRS line will be quicker to build because the individual structures are considerably easier to assemble, are lighter, and are easier to transport to site and erect. As discussed further in Section 7, this is why EWT LP is so keen to explore the viability of selecting a single circuit design for the Project.

Additional Construction Segments – Another change that would reduce the duration of the construction program would be to divide the Project into more segments and to use more construction resources. The construction program currently assumes the line is divided into three discrete segments with construction teams working simultaneously in each segment. If construction resources were available, there is no reason, other than the availability of construction resources, why the Project could not be divided into six segments with six construction teams working simultaneously on all six segments. This would reduce the construction schedule by approximately six months, noting that doubling Project resources reduces the schedule by less than 50%, due to the need to allow for set-up time on site and other preparations. The actual availability of construction resources in 2017/18 cannot reasonably be estimated at this time and depends on their commitment to work on other projects so the potential to reduce the schedule by engaging more construction resources is not readily quantifiable. Increasing the number of construction teams also increases the amount of management effort required to manage the work and ensure there is no risk to worker or public safety.

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 7
SCHEDULE

Appendix 7A
Project Workflow (Regular)

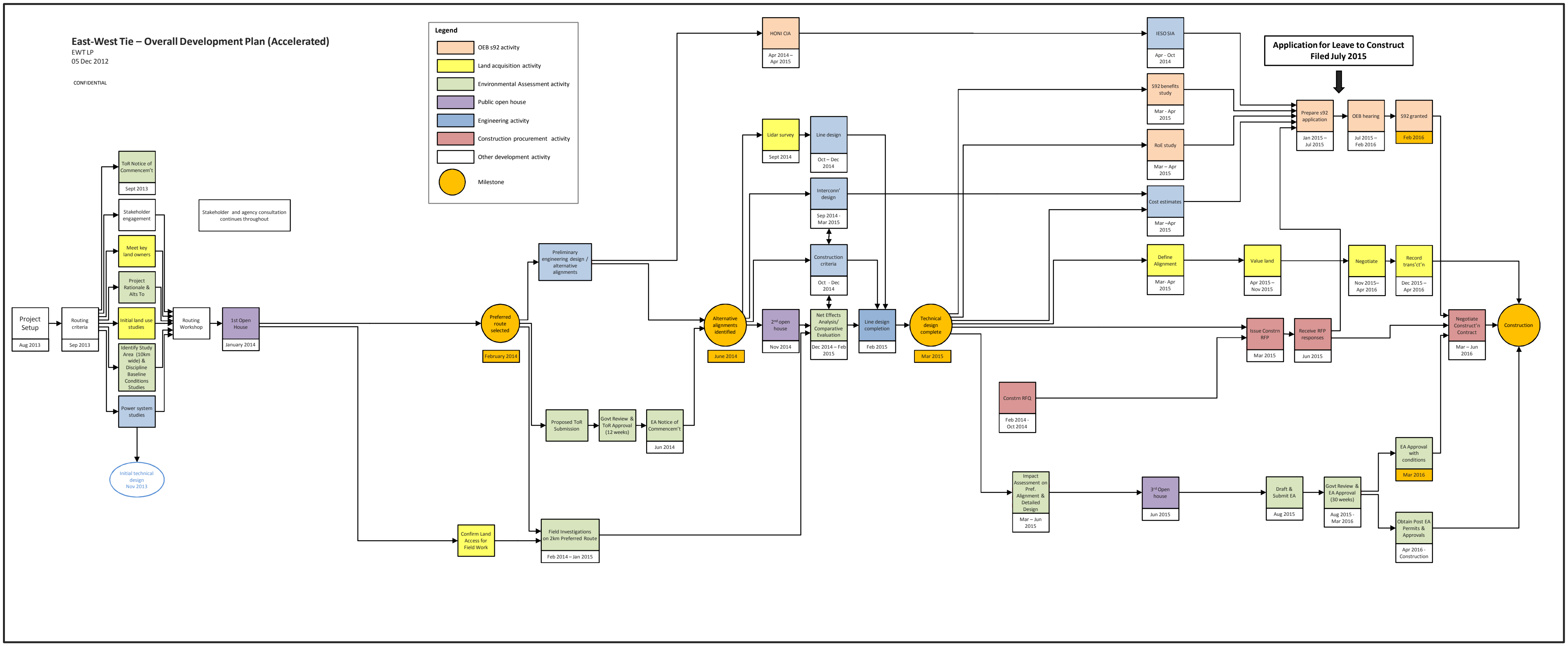


East-West Tie – Overall Development Plan
EWT LP
28 Nov 2012
CONFIDENTIAL
Legend
OEB s92 activity
Land acquisition activity
Environmental Assessment activity
Public open house
Engineering activity
Construction procurement activity
Other development activity
Milestone
Stakeholder and agency consultation continues throughout
Project Setup
Aug 2013
Routing criteria
Sep 2013
ToR Notice of Commencem't
Sept 2013
Stakeholder engagement
Meet key land owners
Project Rationale & Alts To
Initial land use studies
Identify Study Area (10km wide) & Discipline Baseline Conditions Studies
Power system studies
Initial technical design Nov 2013
Routing Workshop
1st Open House
January 2014
Alternative Corridors Identified
February 2014
Meet land owners
Completed Discipline Baseline Conditions Studies
Initial engineer's design
Initial line design Feb 2014
Mar-Apr 2014
Routing Workshop
Study area / 2 km wide route April 2014
Confirm Land Access for Field Work
2nd Open house
May 2014
Preferred route selected
June 2014
Preliminary engineering design / alternative alignments
Proposed ToR Submission
Govt Review & ToR Approval (12 weeks)
EA Notice of Commencem't
Oct 2014
Field Investigations on 2km Preferred Route
Apr 2014 – Feb 2015
HONI CIA
Jun 2014 – Aug 2015
Alternative alignments identified
October 2014
Interconn' design
Sep 2014 - Mar 2015
Construction criteria
Oct - Dec 2014
3rd open house
Nov 2014
Net Effects Analysis/ Comparative Evaluation
Feb – Apr 2015
4th Open house
May 2015
Preferred alignment selected
June 2015
Lidar survey
June 2015
Line design (Detailed Design on Preferred Alignment)
Jul– Nov 2015
Constrn RFQ
Oct 2014 - Jun 2015
Additional Field Investigations on Preferred Alignment (as Required)
Apr – Oct 2015
IESO SIA
Mar - Oct 2015
S92 benefits study
Jun - Sep 2015
RoE study
Jun – Sep 2015
Cost estimates
Mar -Dec 2015
Technical design complete
November 2015
Detailed Tower Design
Tower Testing
Impact Assessment on Pref. Alignment & Detailed Design
Aug – Nov 2015
5th Open house
Jan 2016
Application for Leave to Construct Filed March 2016
Prepare s92 application
Oct 2015 – Mar 2016
OEB hearing
Apr – Nov 2016
S92 granted
Nov 2016
Define Alignment
Nov - Dec 2015
Value land
Dec 2015 – May 2016
Negotiate
May – Oct 2016
Record trans'ct'n
Jun – Oct 2016
Issue Constrn RFP
Dec 2015
Receive RFP responses
Feb 2016
Draft & Submit EA
April 2016
Govt Review & EA Approval (30 weeks)
Apr - Nov 2016
EA Approval with conditions
Nov 2016
Obtain Post EA Permits & Approvals
Nov 2016 - Construction
Negotiate Construct'n Contract
Jan – Feb 2017
Construction

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 7
SCHEDULE

Appendix 7B
Project Workflow (Accelerated)



East-West Tie – Overall Development Plan (Accelerated)
EWT LP
05 Dec 2012
CONFIDENTIAL
Legend
OEB s92 activity
Land acquisition activity
Environmental Assessment activity
Public open house
Engineering activity
Construction procurement activity
Other development activity
Milestone
Stakeholder and agency consultation continues throughout
Project Setup
Aug 2013
Routing criteria
Sep 2013
ToR Notice of Commencem't
Sept 2013
Stakeholder engagement
Meet key land owners
Project Rationale & Alts To
Initial land use studies
Identify Study Area (10km wide) & Discipline Baseline Conditions Studies
Power system studies
Initial technical design
Nov 2013
Routing Workshop
1st Open House
January 2014
Preferred route selected
February 2014
Preliminary engineering design / alternative alignments
Proposed ToR Submission
Govt Review & ToR Approval (12 weeks)
EA Notice of Commencem't
Jun 2014
Confirm Land Access for Field Work
Field Investigations on 2km Preferred Route
Feb 2014 – Jan 2015
Alternative alignments identified
June 2014
HONI CIA
Apr 2014 – Apr 2015
Lidar survey
Sept 2014
Line design
Oct – Dec 2014
Interconn' design
Sep 2014 - Mar 2015
Construction criteria
Oct - Dec 2014
2nd open house
Nov 2014
Net Effects Analysis/ Comparative Evaluation
Dec 2014 – Feb 2015
Line design completion
Feb 2015
Technical design complete
Mar 2015
IESO SIA
Apr - Oct 2014
S92 benefits study
Mar - Apr 2015
RoE study
Mar – Apr 2015
Cost estimates
Mar –Apr 2015
Define Alignment
Mar- Apr 2015
Constrn RFQ
Feb 2014 - Oct 2014
Impact Assessment on Pref. Alignment & Detailed Design
Mar – Jun 2015
3rd Open house
Jun 2015
Application for Leave to Construct Filed July 2015
Prepare s92 application
Jan 2015 – Jul 2015
OEB hearing
Jul 2015 – Feb 2016
S92 granted
Feb 2016
Value land
Apr 2015 – Nov 2015
Negotiate
Nov 2015– Apr 2016
Record trans'ct'n
Dec 2015 – Apr 2016
Issue Constrn RFP
Mar 2015
Receive RFP responses
Jun 2015
Draft & Submit EA
Aug 2015
Govt Review & EA Approval (30 weeks)
Aug 2015 - Mar 2016
EA Approval with conditions
Mar 2016
Obtain Post EA Permits & Approvals
Apr 2016 - Construction
Negotiate Construct'n Contract
Mar – Jun 2016
Construction

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 7
SCHEDULE

Appendix 7C
Development Gantt Chart

ID	WBS	Task Name	Start	Finish
1	1	**PROJECT SET UP**	Thu 01/08/13	Tue 07/01/14
2	1.1	GLPT Designated	[illegible]	[illegible]
3	1.2	Project Team Mobilized	[illegible]	[illegible]
4	1.2.1	Establish Start Office and Administrative Support	[illegible]	[illegible]
5	1.2.1.1	Determine Office and Staff Requirements	[illegible]	[illegible]
6	1.2.1.2	Liaison with Local Groups to Determine Space Availability	[illegible]	[illegible]
7	1.2.2	Establish Project Management Plan and Protocols	[illegible]	[illegible]
8	1.2.2.1	Establish Project Management Plan	[illegible]	[illegible]
9	1.2.2.2	Health and Safety Management Plan	[illegible]	[illegible]
10	1.2.2.3	Quality Management Plan	[illegible]	[illegible]
11	1.2.2.4	Document Management System and Policies	[illegible]	[illegible]
12	1.2.2.5	Develop work budget	[illegible]	[illegible]
13	1.2.3	Establish Communications Policies and Procedures	[illegible]	[illegible]
14	1.3	Establish GIS mapping protocols	[illegible]	[illegible]
15	1.3.1	User requirements and business process definition	[illegible]	[illegible]
16	1.3.2	Conceptual system design and documentation	[illegible]	[illegible]
17	1.3.3	Data standards with regards to updates concurrency and revisions	[illegible]	[illegible]
18	1.3.4	Document metadata standards and detailed geospatial format requirements	[illegible]	[illegible]
19	1.3.5	Document specific data requirements for use in each phase	[illegible]	[illegible]
20	1.3.6	Create mapping layers for route planning selection utilizing base map and key constraints/opportunities affecting existing data	[illegible]	[illegible]
21	1.4	Land Acquisition Preparing Resources and Procedures	[illegible]	[illegible]
22	1.4.1	Establish and Prepare Legal Team	[illegible]	[illegible]
23	1.4.2	Prepare consultation material	[illegible]	[illegible]
24	1.4.3	Develop Land Acquisition Process and Land Compensation Protocols	[illegible]	[illegible]
25	1.4.4	Determine land agents team (internal, outside and local)	[illegible]	[illegible]
26	1.4.5	Preliminary acquisition templates drafted: (purchase offers, licenses, draft agreements, easements, Section 30, access, fencing	[illegible]	[illegible]
27	1.4.6	Prepare agent's communications package	[illegible]	[illegible]
28	1.5	Regulatory Consultation	[illegible]	[illegible]
29	1.5.1	Identify key regulatory contacts	[illegible]	[illegible]
30	1.5.2	Meet with EAAB staff	[illegible]	[illegible]
31	1.5.3	Meet with MNR on Crown Land	[illegible]	[illegible]
32	1.5.4	Meet with regulatory contacts - Parks Canada, MTO, TC, DFO, Municipalities, First Nations	[illegible]	[illegible]
33	1.5.5	Prepare and submit application to become an IESO Market Participant	[illegible]	[illegible]
34	2	**CORRIDORS, ROUTES AND TERMS OF REFERENCE**	**Fri 30/08/13**	**Wed 08/10/14**
35	2.1	Develop Preliminary Evaluation Criteria, Indicators and Associated Rationale	Fri 30/08/13	Fri 06/09/13
36	2.2	Prepare ToR Notice of Commencement	Mon 16/09/13	Fri 27/09/13
37	2.3	Identify Project Rationale and Range of Alternatives	Mon 09/09/13	Wed 16/10/13
38	2.3.1	Define Study Area	Mon 09/09/13	Tue 10/09/13
39	2.3.2	Develop Purpose of and Rationale for the Undertaking	Wed 11/09/13	Tue 24/09/13
40	2.3.3	Describe and Evaluate Alternatives to the Undertaking	Wed 25/09/13	Tue 08/10/13
41	2.3.4	Describe and Evaluate Alternative Technologies	Wed 25/09/13	Tue 08/10/13
42	2.3.5	Draft Documentation for Rationale and Selected Alternative To	Wed 09/10/13	Wed 16/10/13
43	2.3.6	Final Rationale & Alternative To	Wed 16/10/13	Wed 16/10/13
44	2.4	Preliminary Data gathering	Fri 30/08/13	Mon 09/12/13
45	2.4.1	Land Use Data	Mon 09/09/13	Mon 25/11/13
46	2.4.1.1	Obtain Property Ownership Data - GeoWarehouse, Local Land Registry, Title Searches (Major Properties only)	Mon 09/09/13	Fri 27/09/13
47	2.4.1.2	Obtain land use information	Mon 09/09/13	Fri 27/09/13
48	2.4.1.3	Identify broad land valuations	Mon 30/09/13	Mon 04/11/13
49	2.4.1.4	Identify constraints buffers etc	Tue 05/11/13	Mon 11/11/13
50	2.4.1.5	Populate GIS database	Tue 12/11/13	Mon 25/11/13
51	2.4.1.6	Develop contact list for land / municipal / crossing / acquisition	Mon 30/09/13	Tue 01/10/13
52	2.4.1.7	Meet with any significant important land owners	Tue 29/10/13	Mon 25/11/13
53	2.4.2	Environmental Data	Mon 09/09/13	Mon 25/11/13
54	2.4.2.1	Secondary Source Baseline Data Collection	Mon 09/09/13	Fri 27/09/13
55	2.4.2.2	Conduct scan of previous recent EA along route	Mon 09/09/13	Fri 27/09/13
56	2.4.2.3	Undertake Remote Sensing	Mon 30/09/13	Fri 11/10/13
57	2.4.2.4	Populate GIS database	Tue 15/10/13	Mon 25/11/13
58	2.4.3	Power System Data	Fri 30/08/13	Fri 27/09/13
59	2.4.3.1	Obtain up to date power system model data from IESO	Fri 30/08/13	Fri 27/09/13
60	2.4.3.2	Obtain up to date plan from OPA	Fri 30/08/13	Fri 27/09/13
61	2.4.3.3	Obtain latest CSA etc. standards	Fri 30/08/13	Fri 06/09/13
62	2.4.4	Conduct Electrical Studies (Preliminary)	Mon 30/09/13	Mon 09/12/13
63	2.4.4.1	Power System Studies	Mon 30/09/13	Mon 11/11/13
64	2.4.4.2	Transmission Line	Mon 30/09/13	Mon 11/11/13
65	2.4.4.3	Interconnections	Mon 30/09/13	Mon 11/11/13
66	2.4.4.4	Develop Alternative Technical Solutions and Prepare Rationale for Each Alternative	Tue 12/11/13	Mon 25/11/13
67	2.4.4.5	**Initial Technical Design**	**Mon 25/11/13**	**Mon 25/11/13**
68	2.4.4.6	Populate GIS database	Tue 26/11/13	Mon 09/12/13
69	2.5	Identify Recommended Corridor(s)	Tue 26/11/13	Tue 07/01/14
70	2.5.1	Review decision criteria and GIS database	Tue 26/11/13	Mon 02/12/13
71	2.5.2	Model alternative corridors	Tue 03/12/13	Mon 30/12/13
72	2.5.3	Select corridor(s) and document	Tue 31/12/13	Tue 07/01/14
73	2.6	First Round of Consultation: "Project Purpose / Rationale, Alternative Corridors"	Tue 26/11/13	Wed 19/02/14
74	2.6.1	Public Consultation	Tue 26/11/13	Wed 19/02/14
75	2.6.1.1	Prepare position on EMF	Tue 26/11/13	Tue 07/01/14
76	2.6.1.2	Prepare for Open House 1	Tue 10/12/13	Tue 14/01/14
77	2.6.1.3	Hold public open houses and meetings	Wed 15/01/14	Tue 28/01/14
78	2.6.1.4	Collect Feedback on Open House	Wed 29/01/14	Tue 11/02/14
79	2.6.1.5	Document Feedback & Communicate Updates	Wed 12/02/14	Wed 19/02/14
80	2.7	**Preferred Corridors Identified**	**Tue 11/02/14**	**Tue 11/02/14**
81	2.8	Data collection & analysis	Wed 08/01/14	Tue 15/07/14
82	2.8.1	Refine Evaluation Criteria, Indicators and Associated Rationale	Wed 12/02/14	Wed 19/02/14
83	2.8.2	Conduct Engineering Studies	Wed 08/01/14	Wed 12/03/14
84	2.8.2.1	Power Flow	Wed 08/01/14	Tue 28/01/14
85	2.8.2.2	Stability	Wed 29/01/14	Wed 19/02/14
86	2.8.2.3	Insulation & Clearances	Wed 08/01/14	Fri 17/01/14
87	2.8.2.4	EMF/RF & Audible Noise Calcs	Mon 20/01/14	Fri 24/01/14
88	2.8.2.5	Develop Preliminary Engineering Design for Transmission Line and Associated Facilities	Thu 20/02/14	Wed 26/02/14
89	2.8.2.6	Update GIS database	Thu 27/02/14	Fri 28/02/14
90	2.8.2.7	Visualization Modeling for Round Two Open House	Thu 27/02/14	Wed 12/03/14
91	2.8.3	IESO Feasibility Study	**Thu 27/02/14**	**Tue 15/07/14**
92	2.8.3.1	Submit feasibility study application	Thu 27/02/14	Wed 05/03/14
93	2.8.3.2	Execute feasibility study agreement	Thu 06/03/14	Wed 26/03/14
94	2.8.3.3	Receive confidential feasibility study report	Thu 27/03/14	Tue 15/07/14
95	2.8.4	Conduct Routing Studies	Wed 08/01/14	Wed 19/03/14
96	2.8.4.1	Review public input to Open House 1	Thu 20/02/14	Mon 24/02/14
97	2.8.4.2	Confirm land ownership along alternative corridors (update GeoWarehouse land registry title searches)	Wed 08/01/14	Tue 21/01/14
98	2.8.4.3	Confirm land use along alternative corridors	Wed 08/01/14	Tue 14/01/14
99	2.8.4.4	Land Valuations along alternative corridors - MPAC, recent sales	Wed 08/01/14	Tue 21/01/14
100	2.8.4.5	Undertake Initial Discussions with Property Owners Regarding Acquisition	Mon 10/02/14	Mon 10/03/14
101	2.8.4.6	Identify constraint buffers, no-go areas etc	Tue 11/03/14	Mon 17/03/14
102	2.8.4.7	Update GIS database	Tue 18/03/14	Wed 19/03/14
103	2.8.5	Conduct EA desktop studies	Wed 12/02/14	Fri 28/02/14
104	2.8.5.1	Update EA information on alternative routes	Wed 12/02/14	Wed 26/02/14
105	2.8.5.2	Update GIS database	Thu 27/02/14	Fri 28/02/14
106	2.8.6	Conduct Construction Feasibility Desktop Study	Thu 20/02/14	Fri 21/03/14
107	2.8.6.1	Assess geology/topography of alternative routes	Thu 20/02/14	Wed 26/02/14
108	2.8.6.2	Assess site access / logistics	Thu 20/02/14	Wed 26/02/14
109	2.8.6.3	Develop Alternative Construction Methods and Prepare Rationale for Each Alternative	Thu 27/02/14	Wed 19/03/14
110	2.8.6.4	Update GIS database	Thu 20/03/14	Fri 21/03/14
111	2.9	Identify preferred route	Mon 24/03/14	Tue 29/04/14
112	2.9.1	Review decision criteria and GIS database	Mon 24/03/14	Fri 28/03/14
113	2.9.2	Model alternative routes	Mon 31/03/14	Fri 04/04/14
114	2.9.3	Prepare preferred alternatives maps	Mon 07/04/14	Tue 22/04/14
115	2.9.4	Preferred Route selected and documented	Tue 22/04/14	Tue 22/04/14
116	2.9.5	Prepare Supporting Document on Routing	Wed 23/04/14	Tue 29/04/14
117	2.10	Second Round of Consultation: "Alternative Routes, Route Selection and Draft ToR"	Mon 14/04/14	Wed 25/06/14
118	2.10.1	Regulatory Consultation	Mon 14/04/14	Wed 28/05/14
119	2.10.2	Public Consultation	Wed 23/04/14	Wed 25/06/14
120	2.10.2.1	Prepare for Open House 2	Wed 23/04/14	Wed 21/05/14
121	2.10.2.2	Hold public open houses and meetings	Thu 22/05/14	Wed 04/06/14
122	2.10.2.3	Collect Feedback on Open House	Thu 05/06/14	Wed 18/06/14
123	2.10.2.4	Document Feedback & Communicate Updates / Route Impacts	Thu 19/06/14	Wed 25/06/14
124	2.11	**Preferred Route Selected**	**Wed 25/06/14**	**Wed 25/06/14**
125	2.12	Prepare Draft ToR	Fri 14/02/14	Wed 25/06/14
126	2.12.1	Prepare Draft ToR	Fri 14/02/14	Tue 13/05/14
127	2.12.2	Review of Draft ToR	Wed 14/05/14	Wed 21/05/14
128	2.12.3	Revise Draft ToR	Thu 22/05/14	Wed 28/05/14
129	2.12.4	Presubmission of Draft ToR	Thu 29/05/14	Wed 25/06/14
130	2.13	Finalize ToR	Thu 26/06/14	Wed 08/10/14
131	2.13.1	ToR Preparation & Submission	Thu 26/06/14	Thu 10/07/14
132	2.13.1.1	Prepare Final ToR	Thu 26/06/14	Thu 10/07/14
133	2.13.1.2	JV Review of Final ToR	Thu 10/07/14	Thu 10/07/14
134	2.13.1.3	Revise Final ToR and Prepare for Submission	Thu 10/07/14	Thu 10/07/14
135	2.13.1.4	ToR Notice of Submission	Thu 10/07/14	Thu 10/07/14
136	2.13.2	ToR Public Agency Review & Approval	Fri 11/07/14	Wed 08/10/14
137	2.13.2.1	Respond to Comments During Public Agency Review	Fri 11/07/14	Tue 07/10/14
138	2.13.2.2	Ongoing Consultation on Key ToR Issues	Fri 11/07/14	Wed 08/10/14
139	2.14	**ToR Approved**	**Wed 08/10/14**	**Wed 08/10/14**
140	3	**FEDERAL ENVIRONMENTAL ASSESSMENT PROCESS (If required)**	**Wed 23/04/14**	**Wed 11/01/17**
141	3.1	Federal Project Description	Wed 23/04/14	Wed 23/07/14
142	3.1.1	Prepare Federal Project Description	Wed 23/04/14	Thu 15/05/14
143	3.1.2	Submit Federal Project Description	Fri 16/05/14	Fri 16/05/14
144	3.1.3	CEA Agency 45-day Legislated Review	Tue 20/05/14	Tue 22/07/14
145	3.1.4	CEA Agency Decision on Federal EA Requirements	Wed 23/07/14	Wed 23/07/14
146	3.2	Conduct Federal EA Studies	Wed 23/04/14	Tue 30/06/15
147	3.2.1	Collect field data on migratory birds, fish/fish habitat, SAR	Wed 23/04/14	Mon 27/04/15
148	3.2.2	Assess Cumulative Effects	Tue 28/04/15	Tue 30/06/15
149	3.2.3	Assess Malfunctions and Accidents	Tue 28/04/15	Tue 30/06/15
150	3.3	Prepare Draft and Final Federal EA Documentation	Thu 02/07/15	Tue 22/09/15
151	3.4	Federal EA Report Filed	Tue 22/09/15	Wed 11/01/17
152	3.4.1	Notice of Submission	Tue 22/09/15	Tue 22/09/15
153	3.4.2	Federal Review Period (Max 12 months)	Fri 08/01/16	Wed 11/01/17
154	3.5	**Federal EA Report Approved**	**Wed 11/01/17**	**Wed 11/01/17**
155	4	**SELECTION OF PREFERRED ALIGNMENT AND PROVINCIAL ENVIRONMENTAL ASSESSMENT**	**Mon 24/03/14**	**Fri 04/11/16**
156	4.1	Prepare Notice of Tor Approval and EA Commencement	Thu 09/10/14	Thu 09/10/14
157	4.2	Natural Heritage Field Work & Reporting	Mon 24/03/14	Thu 12/02/15
158	4.2.1	Meet with any affected land owners to acquire right to enter for field work	Mon 24/03/14	Wed 18/06/14
159	4.2.2	Field Investigations	Wed 23/04/14	Thu 12/02/15
160	4.2.3	Update to Constraints	Fri 30/01/15	Thu 12/02/15
161	4.2.4	Baseline Report	Thu 12/02/15	Thu 12/02/15
162	4.3	Identify Alternative Alignments	Thu 26/06/14	Mon 06/10/14
163	4.3.1	Constructability Evaluation	Thu 26/06/14	Thu 24/07/14
164	4.3.2	Environmental/Permitting Evaluation	Fri 25/07/14	Fri 08/08/14
165	4.3.3	JV Review (Operations/Maintenance/Reliability/Land Use)	Fri 25/07/14	Fri 08/08/14
166	4.3.4	Cost Estimates - Line	Mon 11/08/14	Mon 08/09/14
167	4.3.5	Cost Estimates - Interconnection	Mon 11/08/14	Mon 08/09/14
168	4.3.6	Cost Estimates - Land/Permitting	Mon 11/08/14	Mon 08/09/14
169	4.3.7	Lifetime Costing (NPV Analysis)	Tue 09/09/14	Mon 06/10/14
170	4.3.8	Detailed land use	Thu 26/06/14	Mon 08/09/14
171	4.3.9	Report/Recommendation	Tue 09/09/14	Mon 06/10/14
172	4.3.10	**Alternative Alignments Identified**	**Mon 06/10/14**	**Mon 06/10/14**
173	4.4	Third Round of Consultation: "Post TOR / Alternative Alignments	Mon 20/10/14	Tue 06/01/15
174	4.4.1	Regulatory Consultation	Mon 20/10/14	Fri 19/12/14
175	4.4.2	Public Consultation	Mon 27/10/14	Tue 06/01/15
176	4.4.2.1	Prepare for Open House 3	Mon 27/10/14	Fri 21/11/14
177	4.4.2.2	Hold public open houses and meetings	Mon 24/11/14	Fri 05/12/14
178	4.4.2.3	Collect Feedback on Open House	Mon 08/12/14	Fri 19/12/14
179	4.4.2.4	Document Feedback & Communicate Updates	Mon 22/12/14	Tue 06/01/15
180	4.5	Conduct Comparative Evaluation	Fri 13/02/15	Mon 20/04/15
181	4.5.1	Conduct Net Effects Analysis	Fri 13/02/15	Fri 20/03/15
182	4.5.2	Compare Alignments Based on Net Effects	Mon 23/03/15	Mon 20/04/15
183	4.5.3	Recommended Alignments Selected	Mon 20/04/15	Mon 20/04/15
184	4.6	Fourth Round of Public Consultation: "Preferred Alignment & Construction"	Mon 23/03/15	Tue 02/06/15
185	4.6.1	Regulatory Consultation	Mon 23/03/15	Tue 26/05/15
186	4.6.2	Public Consultation	Mon 30/03/15	Tue 02/06/15
187	4.6.2.1	Prepare for Open House 4	Mon 30/03/15	Mon 27/04/15
188	4.6.2.2	Conduct Open House	**Tue 28/04/15**	**Mon 11/05/15**
189	4.6.2.3	Feedback on Open House	Tue 12/05/15	Tue 26/05/15
190	4.6.2.4	Document Feedback & Communicate Updates	Wed 27/05/15	Tue 02/06/15
191	4.7	**Preferred Alignment Selected**	**Tue 02/06/15**	**Tue 02/06/15**
192	4.8	Conduct Effects Assessment	Tue 21/04/15	Tue 17/11/15
193	4.8.1	Capture Missing Field Data (as required)	Tue 21/04/15	Fri 30/10/15
194	4.8.2	Conduct Impact Assessment on Preferred Alignment	Mon 17/08/15	Tue 10/11/15
195	4.8.3	Confirm EA Commitments	Wed 11/11/15	Tue 17/11/15
196	4.9	Fifth Round of Public Consultation: "Net Effects"	Wed 25/11/15	Wed 10/02/16
197	4.9.1	Regulatory Consultation	Wed 25/11/15	Wed 03/02/16
198	4.9.2	Public Consultation	Wed 02/12/15	Wed 10/02/16
199	4.9.2.1	Prepare for Open House 5	Wed 02/12/15	Wed 06/01/16
200	4.9.2.2	Conduct Open House	Thu 07/01/16	Wed 20/01/16
201	4.9.2.3	Feedback on Open House	Thu 21/01/16	Wed 03/02/16
202	4.9.2.4	Document Feedback & Communicate Updates	Thu 04/02/16	Wed 10/02/16
203	4.10	Prepare Draft and Final EA Report	Wed 18/11/15	Fri 08/04/16
204	4.10.1	Prepare & Review Draft EA	Wed 18/11/15	Thu 18/02/16
205	4.10.2	Pre-Submission of Draft EA	Fri 19/02/16	Thu 24/03/16
206	4.10.3	Prepare Final EA (including page turning workshop with JV)	Mon 28/03/16	Fri 01/04/16
207	4.10.4	Revise Final EA and Prepare for Submission	Mon 04/04/16	Fri 08/04/16
208	4.10.5	EA Notice of Submission	Fri 08/04/16	Fri 08/04/16
209	4.11	Public Agency Review & Approval	Mon 11/04/16	Fri 04/11/16
210	4.11.1	Government & Public Review of EA	Mon 11/04/16	Mon 30/05/16
211	4.11.2	Ministry Drafts Blue Book Review of EA	Tue 31/05/16	Mon 04/07/16
212	4.11.3	Notice of Completion of Ministry Review of EA	Tue 05/07/16	Tue 05/07/16
213	4.11.4	Public Inspection of Ministry Review	Wed 06/07/16	Tue 09/08/16
214	4.11.5	Minister of Environment's Review	Wed 10/08/16	Fri 04/11/16
215	4.12	**Provincial EA Approved**	**Fri 04/11/16**	**Fri 04/11/16**
216	5	**DETAILED DESIGN AND LAND ACQUISITION**	**Tue 30/09/14**	**Tue 11/04/17**
217	**5.1**	**Route LiDAR Data Acquisition**	**Wed 03/06/15**	**Tue 18/08/15**
218	5.1.1	Prepare tech spec for LiDAR acquisition and award to supplier	Wed 03/06/15	Tue 09/06/15
219	5.1.2	Establish ground control for LiDAR (this will be control for entire project)	Wed 10/06/15	Tue 16/06/15
220	5.1.3	Flight to acquire LiDAR data	Wed 17/06/15	Fri 26/06/15
221	5.1.4	Process LiDAR data	Mon 29/06/15	Tue 11/08/15
222	5.1.5	Add to GIS	Wed 12/08/15	Tue 18/08/15
223	5.1.6	Prepare CL profile from LiDAR	Tue 07/07/15	Tue 18/08/15
224	**5.2**	**Construction Engineering**	**Tue 07/10/14**	**Tue 16/06/15**
225	**5.2.1**	**Construction Criteria**	**Tue 07/10/14**	**Tue 16/12/14**
226	5.2.1.1	Consult with OMNR on planning and execution requirements	Tue 07/10/14	Tue 04/11/14
227	5.2.1.2	Material & Structure Criteria	Wed 05/11/14	Tue 16/12/14
228	5.2.1.3	Foundation Criteria	Wed 05/11/14	Tue 16/12/14
229	5.2.1.4	Access Road Criteria	Wed 05/11/14	Tue 16/12/14
230	5.2.1.5	Construction Practices Criteria	Wed 05/11/14	Tue 16/12/14
231	5.2.1.6	Vegetation Management Criteria	Wed 05/11/14	Tue 16/12/14
232	**5.2.2**	**Constructability Evaluation**	**Wed 17/12/14**	**Tue 16/06/15**
233	5.2.2.1	Construction techniques (lines)	Wed 17/12/14	Thu 05/02/15
234	5.2.2.2	Construction techniques (switchyards)	Wed 17/12/14	Thu 05/02/15
235	5.2.2.3	Access routes & logistics	Wed 17/12/14	Tue 16/06/15
236	5.2.2.4	Temporary staging areas	Wed 17/12/14	Thu 22/01/15
237	**5.3**	**Detailed Design**	**Tue 30/09/14**	**Tue 10/11/15**
238	**5.3.1**	**Interconnection Designs**	**Tue 30/09/14**	**Fri 13/03/15**
239	5.3.1.1	Data Acquisition	Tue 30/09/14	Tue 14/10/14
240	5.3.1.2	Electrical design	Wed 15/10/14	Tue 09/12/14
241	5.3.1.3	Major Equipment Specifications	Wed 10/12/14	Fri 13/03/15
242	5.3.1.4	Physical Design Criteria	Wed 10/12/14	Fri 13/03/15
243	5.3.1.5	Confirmation of interconnection land requirements	Wed 10/12/14	Tue 23/12/14
244	5.3.1.6	Civil/Structural Design Criteria	Wed 10/12/14	Fri 13/03/15
245	5.3.1.7	Control and Relaying Criteria	Wed 10/12/14	Thu 05/02/15
246	5.3.1.8	Protective Relay Settings Criteria	Fri 06/02/15	Fri 06/03/15
247	5.3.1.9	Control Building Criteria	Wed 10/12/14	Fri 13/03/15
248	**5.3.2**	**Transmission Line Design**	**Fri 06/02/15**	**Tue 10/11/15**
249	5.3.2.1	Line Layout	Fri 10/07/15	Mon 14/09/15
250	5.3.2.2	Electrical design	Wed 03/06/15	Wed 29/07/15
251	5.3.2.3	Permitting/Landowner Constraints	Tue 15/09/15	Tue 13/10/15
252	5.3.2.4	Confirmation of RoW width and structure locations/heights	Tue 15/09/15	Tue 13/10/15
253	5.3.2.5	Material & Structures	Tue 15/09/15	Tue 10/11/15
254	5.3.2.6	Foundations	Tue 15/09/15	Tue 10/11/15
255	5.3.2.7	Access Roads	Wed 19/08/15	Thu 05/11/15
256	5.3.2.8	Construction Practices Criteria	Fri 06/02/15	Mon 04/05/15
257	5.3.3	**Detailed Design Complete**	**Tue 10/11/15**	**Tue 10/11/15**
258	**5.4**	**Costing and Economic Efficiency**	**Mon 16/03/15**	**Tue 22/12/15**
259	5.4.1	Cost Estimates - Line	Wed 11/11/15	Tue 24/11/15
260	5.4.2	Cost Estimates - Interconnection	Mon 16/03/15	Mon 13/04/15
261	5.4.3	Cost Estimates - Land/Permitting	Wed 11/11/15	Tue 08/12/15
262	5.4.4	Cost Estimates - System Losses	Wed 11/11/15	Tue 01/12/15
263	5.4.5	Cost estimates - Lifetime Operations and Maintenance	Wed 11/11/15	Tue 01/12/15
264	5.4.6	Lifetime Costing (NPV Analysis)	Wed 09/12/15	Tue 22/12/15
265	5.4.7	Identification and quantification of benefits (if IPSP not approved)	Wed 11/11/15	Tue 01/12/15
266	**5.5**	**Land Acquisition**	**Fri 06/11/15**	**Tue 11/04/17**
267	**5.5.1**	**Defining the Route**	**Fri 06/11/15**	**Tue 22/12/15**
268	5.5.1.1	Confirm route selection / structure locations with engineering	Wed 11/11/15	Tue 17/11/15
269	5.5.1.2	Develop crossing line lists	Wed 11/11/15	Tue 24/11/15
270	5.5.1.3	Develop access and laydown lists	Fri 06/11/15	Thu 19/11/15
271	5.5.1.4	Detailed analysis of property data for preferred route selection	Wed 25/11/15	Tue 22/12/15
272	5.5.1.5	Updated title searches, surveys for all properties and land along selected route	Wed 25/11/15	Tue 22/12/15
273	5.5.1.6	All properties identified	Tue 22/12/15	Tue 22/12/15
274	**5.5.2**	**Crossing Drawings**	**Wed 25/11/15**	**Thu 25/02/16**
275	5.5.2.1	Field survey to collect specific crossing data	Wed 25/11/15	Wed 13/01/16
276	5.5.2.2	Prepare crossing drawings	Thu 14/01/16	Thu 25/02/16
277	**5.5.3**	**Individual Ownership Plans**	**Wed 23/12/15**	**Thu 24/03/16**
278	5.5.3.1	Prepare Crown IOPs based on title info from GIS	Wed 23/12/15	Thu 24/03/16
279	5.5.3.2	Prepare freehold IOPs based on title info from GIS	Wed 23/12/15	Thu 24/03/16
280	**5.5.4**	**Valuing the Land**	**Wed 23/12/15**	**Fri 06/05/16**
281	5.5.4.1	Multiple Listing Service sale and active listing research	Wed 23/12/15	Fri 06/05/16
282	5.5.4.2	Estimate benchmark value ranges for various land types in the difference geographic areas along the route.	Wed 23/12/15	Fri 06/05/16
283	**5.5.5**	**Negotiating with Owners**	**Mon 09/05/16**	**Tue 11/04/17**
284	5.5.5.1	Prepare property specific reports provided to land agents for negotiations with property owners	Mon 09/05/16	Mon 20/06/16
285	5.5.5.2	Prepare other acquisition documentation (temporary access, field testing consent, grading, etc.)	Mon 09/05/16	Mon 20/06/16
286	5.5.5.3	Undertake Discussions with Property Owners / Crossing Owners Regarding Acquisition and make offers	Mon 09/05/16	Fri 28/10/16
287	5.5.5.4	Review appraisals completed for the owner by 3rd party appraisers and make recommendations to GLPT land acquisition team under	Mon 09/05/16	Thu 15/09/16
288	5.5.5.5	Crown Land - (i.e. land use permit and approval process)	Mon 09/05/16	Fri 28/10/16
289	5.5.5.6	Municipal (easements and consent)	Mon 09/05/16	Fri 28/10/16
290	5.5.5.7	First Nation section 28 consent	Tue 21/06/16	Tue 11/04/17
291	5.5.6	Finalize offers and record transactions	Tue 21/06/16	Fri 28/10/16
292	6	**LEAVE TO CONSTRUCT**	**Thu 27/02/14**	**Tue 15/11/16**
293	**6.1**	**Initial Economic Evaluation of Options**	**Thu 27/02/14**	**Wed 20/08/14**
294	6.1.1	Identify generation, transmission and conservation options	Thu 27/02/14	Wed 26/03/14
295	6.1.2	Evaluate options	Thu 27/03/14	Mon 09/06/14
296	6.1.3	Prepare report of preliminary findings	Tue 10/06/14	Tue 08/07/14
297	6.1.4	Discuss findings with OPA	Wed 09/07/14	Tue 22/07/14
298	6.1.5	If study shows transmission is clearly not cost effective, report to OEB	Wed 23/07/14	Wed 20/08/14
299	**6.2**	**IESO System Impact Assessment (SIA)**	**Mon 09/03/15**	**Fri 02/10/15**
300	6.2.1	Prepare and submit system impact assessment application	Mon 09/03/15	Fri 13/03/15
301	6.2.2	Negotiate and sign SIA agreement with IESO	Mon 16/03/15	Mon 13/04/15
302	6.2.3	Prepare draft SIA report	Tue 14/04/15	Wed 08/07/15
303	6.2.4	Prepare and post agreed draft SIA	Thu 09/07/15	Thu 06/08/15
304	6.2.5	Prepare final SIA report	Fri 07/08/15	Thu 20/08/15
305	6.2.6	IESO review final SIA	Fri 21/08/15	Fri 02/10/15
306	6.2.7	SIA Approved	Fri 02/10/15	Fri 02/10/15
307	**6.3**	**Transmitter Customer Connection Process**	**Thu 26/06/14**	**Mon 17/08/15**
308	6.3.1	Pre-discussions with Hydro One on Connection agreement	Thu 26/06/14	Mon 22/09/14
309	6.3.2	Submit Customer Impact Assessment application to Transmitter	Tue 23/09/14	Tue 23/09/14
310	6.3.3	Customer Impact Assessment developed	Wed 24/09/14	Wed 03/12/14
311	6.3.4	Study Agreement negotiation	Thu 04/12/14	Wed 17/12/14
312	6.3.5	Cost estimate provided under Study Agreement	Thu 18/12/14	Mon 23/02/15
313	6.3.6	Connection & Cost Recovery Agreement negotiated	Tue 24/02/15	Tue 07/04/15
314	6.3.7	Transmission Connection Agreement negotiation	Wed 08/04/15	Fri 14/08/15
315	6.3.8	Transmission Connection Agreement completed	Mon 17/08/15	Mon 17/08/15
316	**6.4**	**Prepare OEB s92 application**	**Wed 03/06/15**	**Thu 10/03/16**
317	**6.4.1**	**Evaluation of required rate treatment**	**Wed 03/06/15**	**Fri 11/09/15**
318	6.4.1.1	Appoint consultants	Wed 03/06/15	Wed 08/07/15
319	6.4.1.2	Prepare scope of study	Thu 09/07/15	Wed 29/07/15
320	6.4.1.3	Perform study	Thu 30/07/15	Fri 11/09/15
321	**6.4.2**	**Revise economic evaluation of benefits**	**Wed 03/06/15**	**Thu 02/07/15**
322	6.4.2.1	Gather data	Wed 03/06/15	Wed 03/06/15
323	6.4.2.2	Repeat studies with updated data	Thu 04/06/15	Wed 24/06/15
324	6.4.2.3	Prepare report on findings	Thu 25/06/15	Thu 02/07/15
325	**6.4.3**	**Prepare application**	**Wed 21/10/15**	**Thu 10/03/16**
326	6.4.3.1	Meet with OEB staff	Wed 21/10/15	Wed 18/11/15
327	6.4.3.2	agree strategy	Wed 02/12/15	Wed 09/12/15
328	6.4.3.3	prepare filing	Wed 23/12/15	Wed 10/02/16
329	6.4.3.4	internal review & changes	Thu 11/02/16	Thu 03/03/16
330	6.4.3.5	external legal review & changes	Fri 04/03/16	Thu 10/03/16
331	**6.5**	**Submit Application**	**Fri 04/03/16**	**Tue 26/04/16**
332	6.5.1	Submit section 92 application	Thu 10/03/16	Thu 10/03/16
333	6.5.2	agree notice of filing	Fri 04/03/16	Thu 10/03/16
334	6.5.3	publish notice of filing	Mon 28/03/16	Mon 28/03/16
335	6.5.4	OEB procedural order	Tue 26/04/16	Tue 26/04/16
336	**6.6**	**Application Public Review**	**Wed 27/04/16**	**Wed 01/06/16**
337	6.6.1	Attend technical conference	Wed 27/04/16	Wed 27/04/16
338	6.6.2	Intervenors review filing and file interrogatories	Wed 27/04/16	Tue 10/05/16
339	6.6.3	respond to intervenor interrogatories	Wed 11/05/16	Wed 01/06/16
340	**6.7**	**OEB hearing**	**Wed 11/05/16**	**Fri 26/08/16**
341	6.7.1	Prepare witness panel	Wed 11/05/16	Wed 25/05/16
342	6.7.2	Participate in hearings	Fri 08/07/16	Thu 28/07/16
343	6.7.3	Prepare and submit closing arguments	Fri 29/07/16	Fri 26/08/16
344	**6.8**	**Decision**	**Mon 29/08/16**	**Tue 15/11/16**
345	6.8.1	OEB Board deliberations	Mon 29/08/16	Tue 15/11/16
346	6.8.2	**OEB decision published**	**Tue 15/11/16**	**Tue 15/11/16**
347	7	**EPC CONTRACT**	**Tue 26/11/13**	**Wed 08/02/17**
348	**7.1**	**Develop Contractor Selection Process**	**Tue 26/11/13**	**Tue 14/01/14**
349	7.1.1	Confirm selection process	Tue 26/11/13	Tue 14/01/14
350	7.1.2	List potential contractors	Tue 26/11/13	Mon 09/12/13
351	**7.2**	**Contractor(s) Selection**	**Tue 10/12/13**	**Wed 06/08/14**
352	7.2.1	Shortlist potential vendors / consortia	Tue 10/12/13	Tue 07/01/14
353	7.2.2	Prepare RFQ	Wed 15/01/14	Wed 09/04/14
354	7.2.3	Determine RFQ evaluation criteria	Thu 10/04/14	Fri 25/04/14
355	7.2.4	Send out RFQ	Fri 25/04/14	Fri 25/04/14
356	7.2.5	Receive RFQ responses from vendors	Mon 28/04/14	Mon 23/06/14
357	7.2.6	Evaluate responses	Tue 24/06/14	Wed 06/08/14
358	7.2.7	Qualify potential EPC contractors	Wed 06/08/14	Wed 06/08/14
359	**7.3**	**EPC Specification**	**Wed 11/11/15**	**Tue 01/12/15**
360	7.3.1	Prepare detailed technical specification	Wed 11/11/15	Tue 01/12/15
361	**7.4**	**EPC Contract**	**Wed 15/01/14**	**Wed 08/02/17**
362	7.4.1	Prepare EPC T&C	Wed 15/01/14	Wed 26/02/14
363	7.4.2	Issue RFP	Tue 01/12/15	Tue 01/12/15
364	7.4.3	EPC contractors prepare RFP responses	Wed 02/12/15	Thu 25/02/16
365	7.4.4	Evaluate RPF responses	Fri 26/02/16	Thu 24/03/16
366	7.4.5	Negotiate final contract	Thu 12/01/17	Wed 08/02/17
367	7.4.6	**Execute Fixed Price EPC contract**	**Wed 08/02/17**	**Wed 08/02/17**
368	8	**PRE-CONSTRUCTION ACTIVITIES**	**Mon 31/10/16**	**Tue 14/11/17**
369	**8.1**	**Land Registration**	**Mon 31/10/16**	**Tue 14/11/17**
370	**8.1.1**	**Final Legal ROW survey**	**Mon 31/10/16**	**Thu 25/05/17**
371	8.1.1.1	Final Legal ROW survey	Mon 31/10/16	Thu 25/05/17
372	8.1.1.2	Prepare and register legal RoW plans	Mon 31/10/16	Tue 14/03/17
373	8.1.2	Closings and Title Registrations	Fri 26/05/17	Tue 14/11/17

Project: EWT Dev Plan v39 2012-12-12
Date: Wed 12/12/12

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 8
COSTS

8. Costs

8.0 Overview

This part of the Designation Plan presents EWT LP's estimated costs with respect to designation, development, construction and operation and maintenance of the East-West Tie Line (the "Project").

In accordance with the Ontario Energy Board's (the "Board's") filing requirements, this Section includes the following:

- Designation Costs (8.1);
- Development Costs (8.2), including Estimated Development Cost Budget (8.2.1) and Accuracy of the Development Budget Estimate (8.2.2);
- Cost Estimate Assumptions and Management (8.3), including Development Cost Assumptions (8.3.1) and Management of Development Costs (8.3.2);
- Schedule of Development Expenditure (8.4);
- Development Cost Risks (8.5);
- Allocation of Development Cost Risks (8.6);
- Estimated Budget for Construction Costs (8.7), including Issues Affecting the Accuracy of the Construction Budget Estimates (8.7.1);
- Cost of Variations from the Board's Reference Option (8.8);
- Construction Cost Risks and Mitigation (8.9);
- Relevant Budgeting Experience (8.10);
- Allocation of Construction Cost Risks (8.11); and
- Estimated Operations and Maintenance Costs (8.12).

8.1 Designation Costs

As of the date of filing its designation plan, EWT LP estimates that it will have incurred a cost of $1,545,000. Subsequent to the filing date, EWT LP is not able to predict as to how the designation proceeding will evolve and, therefore, is not in a position to estimate the costs that will be incurred during the proceeding. However, given the Board's stated process, EWT LP anticipates that the cost per applicant will be similar in amount.

8.2 Development Costs

8.2.1 Estimated Development Cost Budget

This section provides a budget for development costs for the Project. For purposes of the development stage, EWT LP has estimated the costs for the period commencing with designation and ending with the filing of the leave to construct application.[1]

Development of the Project's technical design forms a key part of the development costs; however, it is not the predominant part. It is the practical reality that a line can be technically achievable but never built if there is no acceptance of the Project from the public and the Aboriginal Communities. EWT LP believes that the key to a transmitter's success in developing and successfully completing the Project is largely dependent on its ability to establish broad-based public support for the Project. Establishing this public support can only be done through properly assessing the environmental impact of the Project; consulting with stakeholders, landowners, agencies and the public; and consulting with First Nations and Métis communities.

As has been noted elsewhere, the technical and engineering challenge presented by the terrain and weather were overcome in the construction of the original East-West Tie line. The nature of these challenges remain unchanged and, assuming the transmitter has the knowledge and experience, the designated transmitter will now have the benefit of advanced technology, better means of transportation and improved technical structures. Permitting, licensing, environmental assessment, acquisition of land rights and public consultation therefore comprise the majority of the development costs for the Project.

Below is an accurate estimate of the cost of developing the Project. It includes all the work necessary to develop the Project to the point of filing the leave to construct application based on

[1] "The Board's primary objective in this proceeding is to select the most qualified transmission company to develop, and to bring a leave to construction application for, East-West Tie Line": Ontario Energy Board, Phase 1 Decision and Order (July 12, 2012), p. 3.

the project scope provided by the Ontario Power Authority in its report dated June 2011,[2] including, but not limited to, the following:

- Consultation with all stakeholders, including landowners resulting in the identification of the preferred route for the Project;
- All engineering and design associated with the Project necessary to make an application to the Board for leave to construct, to undertake a provincial environmental assessment, and to prepare a complete technical specification for the engagement of a construction contractor;
- Completion of an individual environmental assessment in accordance with the *Environmental Assessment Act* sufficient to make a leave to construct application;
- Application to the Board for leave to construct the Project in accordance with the *Ontario Energy Board Act*;
- Substantive completion of any procedural aspects of the Crown's duty to consult delegated to EWT LP;
- The estimated transaction costs for acquiring land rights for the Project excluding expropriation and the cost of the land rights themselves; and
- All project management activities.

The estimated total development costs for the Project are summarized below and shown in greater detail in Appendix 8A.

Table 8.1: Project Development Costs Budget

Category	**Total Cost (millions)**
Permitting, licensing, EA & other regulatory approvals	**$5.8 m**
Engineering and Design	**$4.5 m**
Routing	**$2.3 m**
Procurement of material and equipment	**$0.1 m**
Land rights acquisition	**$1.0 m**

[2] Long Term Electricity Outlook for the Northwest and Context for the East-West Tie Expansion, Ontario Power Authority, June 20, 2011.

Category	Total Cost (millions)
Public Consultation	**$4.1 m**
Project Management	**$4.3 m**
Total	**$22.1 m**

The costs provided in the table above do not include an Allowance for Funds Used During Construction ("AFUDC"). However, as described in Section 0 below, EWT LP's position is that development work is being undertaken under a conventional cost-of-service regime which allows for the inclusion of an AFUDC. As a result, assuming the Project is ultimately approved for construction, any development costs that are prudently incurred will form a part of the Construction Work in Progress ("CWIP") and ultimately form a part of the rate base of EWT LP as an operating transmitter. Therefore, EWT LP anticipates that AFUDC costs will be calculated and included in CWIP, and will be incremental to the costs provided above. Assuming AFUDC is calculated using the value of 5.6% provided in the Board's Minimum Design Criteria, EWT LP estimates that the AFUDC added to the development costs would be approximately $1.6 million.

8.2.2 Accuracy of the Development Budget Estimate

EWT LP has estimated the likely range of budget outcomes based on an analysis of the risk associated with each group of activities. However, contingency is inherent in any development project. The key areas where the budget is subject to uncertainty are as follows:

- Environmental studies. The environmental studies require a significant commitment of skilled labour over an extended period of time. EWT LP has worked closely with AECOM, its environmental consultant, to determine the likely range of studies and the associated effort required. This understanding has informed EWT LP's budget. Assuming an August 2013 designation award, the environmental studies required to be undertaken will not be identified and finalized until October 2014 when EWT LP will have had the opportunity to consult with stakeholders, and expects the Minister of the Environment to have approved EWT LP's terms of reference for the environmental assessment (which sets parameters for the studies to be undertaken as per the *Environmental Assessment Act*). EWT LP's budget is subject to finalization of study requirements.

- Route selection. As set out in Section 9.4, based on its knowledge of the topography and local issues in this part of Ontario, and the predevelopment work completed during the preparation of this application, EWT LP has identified the likely number of alternatives to be studied and evaluated and has based its budget estimates accordingly. However, the cost of the route selection process is difficult to narrow because of its dependence on the number and range of issues raised by affected stakeholders. This will not be fully known until EWT LP has met with stakeholders, as more fully described in Sections 9 and 10.

- Stage 2 Archeological Studies. The need to complete stage 2 archaeological studies will not be known until stage 1 studies have been completed. EWT LP has budgeted $550,000 for stage 2 studies. The participation of Bamkushwada LP (BLP) and the Participating First Nations' familiarity with potential archeological sites may enable EWT LP to identify a route that reduces these costs.

- Public Engagement. Given the importance of public consultation and the need to gain a social licence for the Project, EWT LP has included a comprehensive program of public engagement. It may be possible to reduce the number of rounds of public consultation from five (as contemplated in Section 9) to four or, less likely, three[3] but this will not become apparent until the level of public interest has been gaged through initial consultation. EWT LP notes that the successful completion of an environmental assessment will require consultation activities beyond those necessary to establish the route. Reducing the number of rounds of public consultation would reduce public consultation costs.

EWT LP has prepared a conservative development plan to provide ratepayers with a true and fair indication of the likely cost of developing the Project. It estimates that the error in this budget is approximately ±8%. The development cost is therefore likely to lay in the range $20.3 million to $23.9 million.

However, if as discussed in Section 7.5, EWT LP is able to accelerate the development schedule, and also as noted above determine that stage 2 archaeological studies are not required, EWT LP believes it would also be possible to reduce the development budget by $3.2 million. The development cost would therefore lie in the range of $17.1 million to $20.7 million. For illustrative purposes only, a probability curve of the development budget is shown below.

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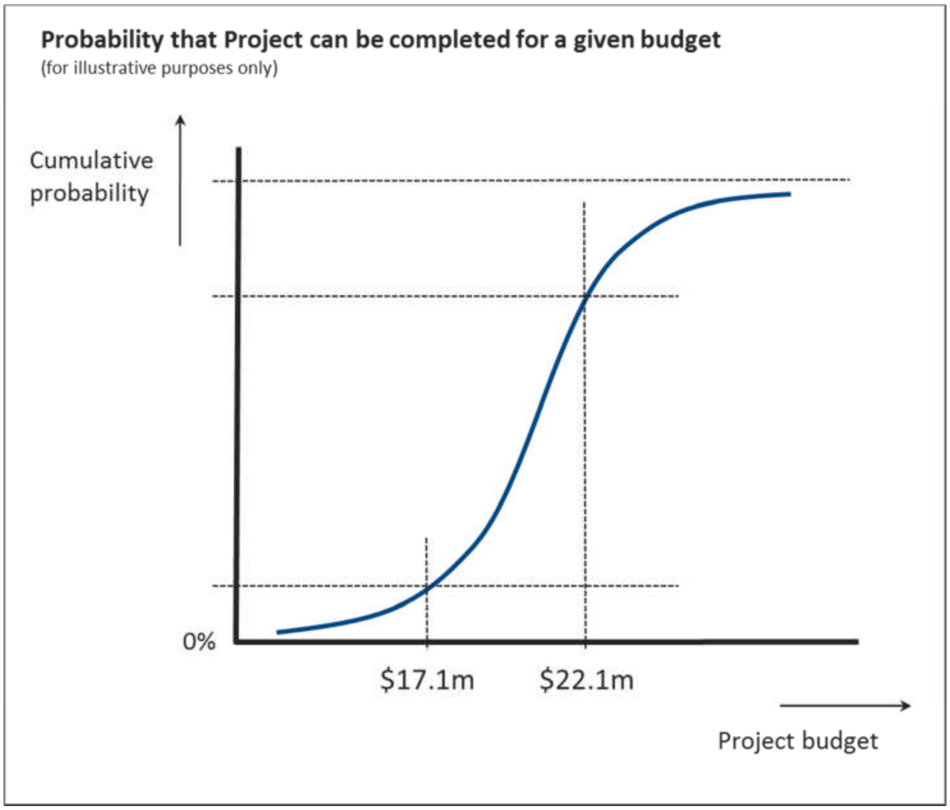
[3] Hydro One held three series of open houses to widen an existing transmission right of way for a new Bruce to Milton 50 kV double circuit overhead line. See http://www.hydroone.com/Projects/BrucetoMilton/Pages/Public%20Consultation.aspx.

Figure 8.1: Development Budget Probability Curve



8.3 Cost Estimate Assumptions and Management

Subject to the issues above and the assumptions set out below, EWT LP has provided its best estimate of the cost of the development work required to develop the proposed Project. EWT LP has prepared this estimate based on a detailed bottom-up budget of its transmission project development plan.

EWT LP managed the collection of data and estimates to ensure there would be no duplication of tasks or budget estimates provided in this plan. In Appendices 7C, EWT provides a detailed schedule of activities of over 360 tasks and subtasks for the Project as a whole. Based on this schedule of activities, EWT LP has established a budget from the ground up by assigning a cost to each task or group of tasks and calculating the total required.

8.3.1 Development Cost Assumptions

EWT LP's development cost estimate is based on the following key assumptions:

- EWT LP is designated by the Board on or about August 1, 2013.
- Development work is to be completed as quickly as reasonably practicable without incurring excessive risk.
- EWT LP will be required to do an individual environmental assessment and seek the Board's leave to construct.
- No significant regulatory changes will occur between the preparation of the budget and the completion of the Project, including changes to North American electric reliability standards and provincial land use policies.
- The Project is the Reference Option as described in Section 6.1, recognizing that certain assumptions may change,[4] and will provide approximately 650 MW of firm transmission capacity between the existing transmission switchyards at Lakehead and Wawa with an interconnection at Marathon.
- EWT LP will develop the Project only as far as terminal structures located in close proximity to the existing switch yards at a location to be agreed with Hydro One Networks Inc. ("HONI"). All work associated with the connection of the

[4] See Section 6.4.

Project to the existing switchyard from these structures, including the design of switching, protection and control systems, will be undertaken by HONI.

- Government agencies, including the Ontario Power Authority, HONI and the Independent Electricity System Operator, will not unreasonably delay the Project by failing to provide information, perform studies or complete reviews in an expeditious manner.

- The Director at the Environmental Assessments and Approval Branch of the Ministry of the Environment will not extend the period of government review for either the terms of reference or the environmental assessment beyond the regulatory review periods.

- There are no sustained periods of unusually adverse weather in Ontario during the development phase that have a material impact on travel or study conditions.

- The Canadian – United States exchange rate remains close to unity.

- Municipal and community consultation can be completed with five rounds of open houses, with each round of open houses being held at no more than six separate locations along the Project.

- BLP, EWT LP's First Nations-owned partner, will facilitate consultations with Aboriginal communities and other stakeholders, including municipalities, parks, the general public and landowners. EWT LP will pay the reasonable costs of one Aboriginal Liaison Officer in each of the six directly affected First Nation communities located in the proposed Project area, who will work part-time to assist the Project.

- The Project will not be subject to a federal environmental assessment. Under the *Canadian Environmental Assessment Act, 2012*, the Project as currently proposed is not on the *Regulations Designating Physical Activities*[5] list, which is the basis for determining whether a project proceeds under the federal environmental assessment process.[6] However, it should be noted that the federal Minister of Environment has the discretion to require a project/undertaking that is not on the list to undertake a federal environmental assessment.[7]

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[5] *Regulations Designating Physical Activities* (SOR/2012-147).
[6] This assumes that the Project will not have a voltage of 345 kV or greater and will not be built through certain prescribed wildlife areas and migratory bird sanctuaries.
[7] If the Minister exercises his discretion to designate the Project for the purposes of the CEAA 2012, EWT LP will coordinate the completion of provincial and federal environmental assessment processes to the extent possible.

8.3.2 Management of Development Costs

Development costs for the Project will be managed through three distinct processes: (i) investment approval, (ii) procurement and (iii) cost control. Each of these processes is summarized below.

8.3.2.1 Investment Approval

The Project will be subject to an internal process for the approval of investments that ensures appropriate internal controls and audit trails are in place. The development phase of the Project will require investment approval. Approval from the EWT Inc. board will be sought initially for the Project as a whole based on an internal investment appraisal and detailed work schedule/budget. Given the value of the Project, the development phase will be broken into a number of separate phases, each of which will be subject to individual investment approval. Approval will be sought to undertake each phase of work and to authorize the budget required to complete the itemized work. Investment approval is required prior to the release of funds to cover Project costs.

8.3.2.2 Procurement

As discussed in Section 4.1.3.2, EWT LP plans to select a specialized construction contractor to undertake material and equipment procurement activities for the Project, subject to the specifications and quality stipulated by EWT LP and reviewed and agreed to by EWT LP through the competitive procurement process.

In order to manage procurement costs, EWT LP will enter in to an individual master service agreement with each service provider. The agreement will contain the appropriate commercial terms and conditions for the services to be provided and a rate schedule. Separate project addendum will be issued under the master service agreement for each discrete package of work to be performed by the service provider.

The development stage of the Project will be divided into a number of separate stages. The project addendum will describe the services to be provided, the required outputs, the schedule of work, the budget, the specific personnel (if any) that are required to perform the work, and the reporting milestones. The project addendum will be signed by the service provider's designated representative and the Project Manager. If the value of the project addendum exceeds the Project Manager's delegated level of authority, it will be submitted to the Project Director for further review and authorization.

The Project Manager will monitor each service provider's performance against its individual Project Addendum and the overall Project schedule. Each contractor will invoice the company for services provided during the previous month. The Project Manager will compare the actual services provided against the approved Project Addendum to determine whether the invoice is to be approved or rejected. If the value of the invoice exceeds the Project Manager's delegated level of authority, the invoice will be reviewed by the Project Director. Only approved invoices will be paid. EWT LP will track project progress against plan (i.e. cost, schedule, risk) using standard project management software.

8.3.2.3 Cost Control

The development work for the Project will be subject to standard internal cost management procedures. Expenditures (salaries, expenses, service provider payments) will be tracked against the approved budget. Monthly, quarterly and annual budget reports with variance analysis will be prepared for review by the Project Director, Project Manager and EWT LP.

Given the duration of the Project, it will also be subject to an annual business planning process that will provide an additional level of authorization and oversight.

8.4 Schedule of Development Expenditures

The schedule of development costs is tabled below. The costs reflected in the table are the same costs as those provided in Section 0, where the annual costs are broken out into various major categories. The schedule below is provided to outline EWT LP's expectations as to how the costs will be incurred on a quarterly basis. Similar to the table in Section 0, the costs in this table to do not reflect EWT LP's AFUDC estimate of $1.6 million.

Year	**Q1**	**Q2**	**Q3**	**Q4**	**Total (millions)**
2013			$1.2 m	$2.1 m	**$3.3 m**
2014	$2.4 m	$2.1 m	$2.2 m	$2.1 m	**$8.8 m**
2015	$1.5 m	$2.1 m	$1.9 m	$2.5 m	**$8.0 m**
2016	$2.0 m				**$2.0 m**
Total					**$22.1 m**

A detailed breakdown of these costs is provided in Appendix 8A.

8.5 Development Cost Risks

EWT LP has prepared its project development budget in consultation with BLP and EWT LP's consultants, making full use of each consultant's experience and expertise. However, the scope and cost of any development work is always difficult to budget accurately due to the uncertain and inherent exploratory nature of project development. The budget is also subject to a number of risks that are charted below.

Risk	Probability[8]	Severity[9]	Mitigation
EWT LP's development plan is incomplete or inaccurate	Unlikely	Major	EWT has prepared its plan with the advice of its expert technical consultants and of its partners in accordance with the Board's July 12, 2012 decision. EWT LP has prepared a comprehensive and conservative plan that includes all the activities necessary to file an application for leave to construct and to fully permit the Project expeditiously and cost effectively.
Ministry rejects EWT LP's terms of reference for an environmental assessment – the work needs to be repeated	Unlikely	Major	EWT LP has mitigated this risk as follows: • EWT LP has adopted a comprehensive consultation plan to solicit stakeholder input during the preparation of the terms of reference. • EWT LP's stakeholder engagement plan includes the establishment of a government agency consultation team. EWT LP will work diligently with this group during the preparation of the environmental assessment terms of reference to ensure that all known issues are captured.
Changes in the Project need identified by OPA require partial	Unlikely	Major	EWT LP plans to mitigate this risk by verifying Ontario Power Authority's studies early in its development work. EWT LP will work closely with OPA

[8] Probability prior to mitigation.
[9] Severity prior to mitigation.

Risk	**Probability**[8]	**Severity**[9]	**Mitigation**
reengineering of the Project and repetition of studies			staff. If these studies conclude that the need has changed significantly, then EWT LP will revise its project plan. EWT LP will let work to its contractors in discrete tasks so the Project plan can be readily revised without incurring cancellation fees.
Development work is delayed and this increases the cost of development	Somewhat likely	Moderate	The most likely source of delays is believed to lie with consultations with Aboriginal communities, landowners and local communities. • The risk of Aboriginal issues delaying Project development has been partly mitigated through BLP's direct economic participation in EWT LP. See also Section 10.1.1. • The risk of landowner consultations delaying the Project has been mitigated by: EWT LP's program of landowner consultation to proactively identify land rights issues as part of the initial routing exercise; and the development and implementation of fair, uniform and transparent land acquisition compensation principles. • The risk of public consultation delaying the Project has been mitigated by planning for a comprehensive program of public consultation. • The risk that poor weather delays development has been mitigated by allowing additional time for activities requiring travel during the winter months. • See also the development schedule risks and associated mitigation measures described in Section 7.2.5.
Phase 2 Archaeological assessment costs	Somewhat likely	Moderate	The requirement for and the cost of a Stage 2 Archeological Study will not be certain until the Stage 1 study is complete.

Risk	Probability[8]	Severity[9]	Mitigation
			EWT LP has budgeted a conservative sum of $550,000 for the cost of a Stage 2 archaeological study. If fewer archaeological studies are required than planned, then the Project cost will be correspondingly reduced.
Land acquisition transaction costs increase	Somewhat likely	Moderate	Land acquisition transaction costs are dependent on the number of properties across which land rights are to be acquired. The costs include EWT LP's legal costs, land appraisal costs, registration fees and title search fees; and the landowners' third party appraisal costs, legal fees and other reasonable costs. A route close to Lake Superior will increase the number of affected properties. A route further from the Lake, making greater use of Crown land, will reduce the number of affected properties. The number of affected properties will not be known until public consultation and the environmental assessment have been substantially completed and the route has been confirmed
Cost control management issues	Somewhat likely	Moderate	EWT LP will control Project costs by breaking the work into individual tasks and issuing fixed price work orders to its consultants at an agreed price – the consultant takes the risk of poor employee productivity, and their own mistakes and omissions. EWT LP has appointed a team of experienced managers to manage the Project. They will be assisted by cost management resources, and by program management services provided by the partners, the management team, and the owner's engineer.
EWT LP is unable to reach stakeholder consensus as to the	Somewhat likely	Moderate	EWT LP has mitigated this risk by developing a comprehensive plan for confirming the route of the new line with

Risk	Probability[8]	Severity[9]	Mitigation
preferred route			ample opportunity for consultation with all stakeholders. EWT LP will benefit from the advice of its partner BLP for interpreting the local issues, identifying critical issues, and seeking proposals for overcoming them. EWT LP has adopted a comprehensive plan for stakeholder consultation which has been designed to identify stakeholder issues and provide a mechanism for their treatment prior to any hearing for leave to construct.
LiDAR etc. survey costs are higher than planned	Somewhat likely	Moderate	EWT LP has mitigated this risk in part by delaying expensive aerial survey work until the preferred alignment has been identified and the area to be surveyed has been minimized.
Development cost estimates are inaccurate	Unlikely	Moderate	EWT LP has mitigated this risk by doing a bottom up estimate of development costs, working closely with its consultants to identify the scope of development work and preparing detailed cost estimates for the various tasks.
Secondary source data is unavailable for studies – additional costs are incurred to collect primary source data through field studies	Unlikely	Moderate	EWT LP has mitigated this risk by determining the availability of secondary source data during the preparation of its Project development plan.
Field studies have to be undertaken over a larger area than planned because EWT LP is unable to narrow the Project area using secondary source data	Unlikely	Moderate	EWT LP has mitigated this risk by adopting a two-step routing methodology for narrowing the study area prior to undertaking environmental field studies. EWT LP has conservatively assumed a study area width of 2 km for the purpose of its plan – the alternative of widening the existing 230 kV corridor will allow study area to be significantly reduced with consequential development cost savings

Risk	Probability[8]	Severity[9]	Mitigation
			for ratepayers.
More open houses are required	Unlikely	Moderate	EWT LP has mitigated this risk by conservatively basing its plan on five rounds of open houses in each of six locations. There will be an open house for local consultation and an open house for Aboriginal consultation at each location, for a total of 60 open houses. There may be an opportunity to reduce the number of rounds of open houses or the number of discrete locations, and any cost savings will be passed on to ratepayers.
Government requires more environmental studies to be done than anticipated	Somewhat likely	Minor	EWT LP has scoped the studies in consultation with its environmental consultant AECOM. EWT LP will work with the Environmental Assessments and Approvals Branch of the Ministry of the Environment during the preparation of the terms of reference for the environmental assessment so that any additional studies can be identified and completed (at additional cost) without delaying the overall Project, which would significantly increase the Project cost.

8.6 Allocation of Development Cost Risks

EWT LP believes its development cost estimates are both prudent and reasonable. However, as with any development project, there are a number of variables that can impact costs both positively and negatively. As outlined in Section 0 above, EWT LP has evaluated these variables and risks, and where possible has implemented measures to mitigate the risks to ensure the best value to the ratepayer.

EWT LP recognizes the Board's designation of a transmitter will indicate that the Board has found the development costs to be reasonable as part of an overall development plan. EWT LP believes ratepayers should be protected by allowing regulated utilities to only recover prudently incurred costs that have been subjected to public scrutiny. As such, EWT LP will be seeking development cost recovery consistent with the Board's existing regulatory cost-of-service framework. To the extent that an overage occurs, the overage will be subject to a prudency review. To the extent there are cost savings relative to the development cost budget, the cost savings will be passed 100% to the benefit of the ratepayer.

EWT LP believes that a traditional cost-of-service methodology is the most reasonable and transparent approach for a project at this "greenfield" stage. Without project history, an incentive-based scheme may simply push project costs to be claimed at a later stage. Once the Project is operating, however, an incentive regime could be more fully considered. EWT LP also notes that the $6.87 billion of new transmission projects being built as part of Texas' *Competitive Renewable Energy Zone*[10] continue to be subject to conventional cost-of-service rate making by the Public Utility Commission of Texas even though the transmitters were selected through a highly innovative new process that shares many of the features of the Board's own new designation process.

Development costs are a necessary component of the Project. A proponent may claim zero development costs or submit an artificially discounted bid in order to make its application for

[10] Competitive Renewable Energy Zone Program Oversight, CREZ Progress Report No. 9 (October Update) Prepared for Public Utility Commission of Texas Prepared by RS&H October 2012.

designation appear more cost-effective to the Board. However, a bid with zero development costs is not a credible bid. Although it provides a discount for ratepayers with respect to development costs, it provides no means for the Board to ensure that the development plan is carried out. An applicant bidding zero has nothing at risk at that point. The threat of disallowance of costs by the Board for a failure to meet milestones has little immediate impact. As such, the Board has no direct means to regulate the behavior of that applicant. If the Board is pursuing the development of the Project in the public interest, then it needs some means to ensure or incent the pursuit of the public interest - if there is none, then the regulatory risk has shifted to the Board.

In addition, a zero bid or artificially low bid creates the concern of a lack of transparency. An applicant bidding zero has the incentive to shift costs from the development phase to the construction phase to ensure ultimate recovery. The ratepayer may not get any real benefit. As a result, a zero bid must have additional conditions attached to any Board approval. In particular, a zero bid must include an estimate of budgeted costs notwithstanding that cost recovery will not be sought. Throughout the development phase, a comparison between budgeted and actual expenses must be filed at milestone dates to guard against the transfer of costs to ratepayers at a later date in the construction phase. Furthermore the transmitter should be required to provide additional confirmation that it will be able to finance the construction and operation of the Project even though it will not be recovering its true development costs, which are likely to be in the order of 5% of the overall Project cost.

8.7 Estimated Budget for Construction Costs

As required by the Board's filing guidelines, EWT LP has provided below an estimated budget for the construction of the Project based on the Board's Reference Option and EWT LP's assumed reference route. The EWT LP's estimated budget has been prepared in conjunction with its owner's engineer, Power Engineers Inc.[11]

EWT LP has also sought and received input on its estimated budget from two major North American construction companies, Kiewit Corporation ("Kiewit") and Valard Construction LP ("Valard"), and has incorporated their feedback. Both companies have recent experience building major electricity transmission lines in Ontario.

Kiewit is a major North American construction company based in Kansas City employing 10,400 core staff and 15,600 skilled craft workers. Kiewit have successfully completed a number of energy projects in Ontario, including the 189 MW Prince Wind Farm for Brookfield and the 185 km 230 kV private transmission line in northern Ontario for Detour Gold, and major transmission lines in British Columbia and Utah.

Valard is a major Canadian electricity transmission line construction company based in Edmonton, Alberta and employing more than 1,200 people. Valard is part of the Quanta Services Group ("Quanta"). Quanta, an S&P 500 company based in Houston, TX, is a leading provider of specialized contracting services, delivering infrastructure solutions for the electric power, natural gas and pipeline and telecommunication industries. Valard has successfully completed a number of energy projects, including the 186 km 500 kV Bruce to Milton transmission line for HONI, 420 km of 115 kV transmission for DeBeers in the James Bay area of northern Ontario, and numerous major projects in Alberta and British Columbia.

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[11] See Appendix 6A. Power Engineers, *East West Tie Expansion: Engineer's Report on the EWT Transmission Line OEB Reference Option*, November 20, 2012.

8.7.1 Issues Affecting the Accuracy of the Construction Budget Estimates

One of the purposes of conducting development work is to finalize the design, location and construction methodology for the Project and to prepare a detailed, high quality cost estimate for its construction.

At this time, EWT LP's construction budget is subject to a high degree of uncertainty for a number of reasons:

- EWT LP's budget is based on the Board's Reference Design, as described in Section 6.1, and an assumed route. EWT LP has not completed the consultations and environmental studies typical for a project of this scope and scale, and has not therefore been able to finalize the design, location or means of construction. Specifically,
    - The final line length is subject to uncertainty. For example, a decision to avoid Pukaskwa National Park could increase the overall line length and hence the construction cost by approximately 5%.
    - It may be possible to use single circuit structures including cross-rope suspension towers[12] to obtain the desired increase in transfer capacity and reliability performance - these are cheaper than conventional double circuit lattice towers.
    - In the absence of a completed environmental assessment with associated consideration of the visual impact, it has not been possible to finalize the tower design.
    - In the absence of public consultation and a completed environmental assessment, it has not been possible to finalize the tower location, construction access or the construction methodology. For example, a need for significant use of helicopters during construction either to avoid environmental damage or to accelerate the schedule will significantly increase construction costs above those estimated.
- Equipment costs are subject to changes in the underlying commodity costs e.g. steel, aluminum, gypsum (for concrete). In the recent past, the cost of commodities has been both variable and volatile. Construction is not scheduled to

[12] See CRS Report, Appendix 6D.

start until four years' time in 2017. Material costs are therefore subject to a high degree of error.

- Most commodities and energy are priced in US dollars, so the construction cost is subject to changes in the Canadian – United States dollar exchange rate.
- Interest during construction is a material component of the overall construction cost, and interest rates tend to vary.
- Construction and material costs are subject to changes in inflation.

8.7.2 Estimated Construction Budget

EWT LP has prepared an estimate for the construction of the Project based on the following key assumptions:

- Per unit costs are in 2012 values
- Construction is in 2017/2018
- Double circuit steel lattice towers with average 270m span using a conventional tower design
- Two circuits each with 1 x 1192.5 ACSR conductor per phase
- Foundations are 50% piers, 50% grillages
- Cleared 30m of a 40m right of way
- Construction of access roads
- Visual inspection of the terrain and ground conditions using desktop data and publicly available aerial photography
- AFUDC is calculated using the parameters provided in the Board's Minimum Technical Requirements Appendix A

Table 8.2: Estimated Construction Budget

Item	**Cost (millions)**
Line material	$53 m
Civil	$114 m

Item	Cost (millions)
Erection	$175 m
Engineering, construction management, environmental monitoring	$57 m
AFUDC	$28 m
TOTAL	**$427 m**

A high level sensitivity analysis has been performed to determine the accuracy of this estimate. The error ranges are as follows:

Item	Variance
Materials	15%
Civil	25%
Erection	25%
Engineering, construction management, environmental monitoring	10%
AFUDC	30%
Overall accuracy	22%

The overall accuracy of the construction budget estimate is therefore ±22%.

The expected construction costs including AFUDC lie in the range of approximately $340 million - $510 million.

8.8 Cost of Variations from the Board's Reference Option

EWT LP's transmission project development plan has been based on the Board's Reference Option, as described in Section 6.1. No different work will be required at the transformer stations to which the line connects.

For evaluation of the cost savings of alternatives, please see Section 6.5.1.

8.9 Construction Cost Risks and Mitigation

EWT LP has charted below the typical major cost risks expected during the construction of a transmission line such as the Project, and also how EWT LP might mitigate them.

EWT LP plans to complete an exhaustive construction risk assessment as part of its planned development work. The risk assessment will be completed once EWT LP has identified the preferred alignment of the Project, completed a detailed 3-dimensional aerial survey, and concluded the necessary environmental field studies to understand any limitations on the Project's design or construction. This development work will identify the construction risks and inform EWT LP as to how best to mitigate them, i.e. avoidance, reduction, sharing or retention.

EWT LP's preference is to enter into a fixed price contract for the construction of the Project with a suitably qualified and experienced construction contractor with the capacity to undertake a project of this size. However, at the time of selecting a contractor EWT LP will have to consider pricing considerations of risk transfers arising from a fixed price contract. The mitigation options discussion below are in the context of EWT LP entering a fixed price contract.

Risk	**Mitigation**
Labour Costs (labour rates, labour availability, labour productivity, labour mix)	Fixed price contract will cause the contractor to control labour and other costs. EWT LP will monitor the contractor's performance on site to ensure that they are meeting the appropriate safety standards, have suitably qualified staff, are meeting quality standards, and have systems in place to meet quality, cost and schedule commitments.
Project is more difficult to construct than expected at the design stage	The construction contractor is expected to have considered the cost and difficulty of constructing the Project, including installing foundations in rocky and boggy areas and the difficulty of access, and to have priced its proposal accordingly.
Material costs	The contractor will be expected to provide the correct quantities of materials of the appropriate quality within its agreed fixed price. EWT LP will inspect materials to ensure they comply with the appropriate standards set out in the contract, and will monitor quantities to ensure the

Risk	Mitigation
	contractor is constructing the line to the required design.
Length of access tracks is greater than expected/more expensive to construct than expected	The construction contractor is expected to have considered the length, type and cost of widening, strengthening or building any access tracks required for the construction of the Project, and to have priced its proposal accordingly.
Equipment costs	The contractor will be responsible for ensuring it has the appropriate equipment, e.g. cranes, trucks, helicopters, excavators, tension stringers, etc., available given the nature of the work and the environment. EWT LP will monitor the contractor's performance to ensure it is meeting cost, quality and schedule commitments.
Delays	Delays within the management control of the contractor will be the responsibility of the contractor. Delays resulting from EWT LP's errors or omissions will be borne by EWT LP to the extent that EWT LP is found to have not acted prudently. The incremental cost of delays caused by force majeure will be subject to the Board's prudency review. EWT LP will monitor the contractor's performance to ensure it is meeting cost, quality and schedule commitments and intervene early when it becomes apparent that there may be a delay.
Change orders	EWT LP plans to minimize the opportunity for contractor change orders by: • designing the Project in consultation with likely construction contractors, as discussed in Section 7.3.1.1, to minimize the risk that the design is flawed or difficult to build, or the technical specifications are incomplete or inaccurate; • basing its final project design on well-proven designs and construction techniques familiar to North American construction contractors; • completing approximately 80% of the detailed design but providing the construction contractor latitude to complete those parts of the design within its own expertise, e.g. selection of foundations; • using experienced procurement experts to prepare comprehensive and legally enforceable bid

Risk	Mitigation
	documents; • using a highly experienced owner's engineer to prepare a comprehensive and detailed technical specification for the work; • finalizing the contract only after major government permits have been issued and any permit conditions have been negotiated into the technical specification; and • employing field staff to monitor the contractor's performance against schedule, cost and quality commitments.
Quantity/difficulty of vegetation management	The construction contractor is expected to have considered the quantity and difficulty of vegetation clearance required for the construction of the new line, and to have priced its proposal accordingly. EWT LP anticipates that the selected construction contractor will employ a First Nations owned locally based forestry company to clear part or all of the route. EWT LP believes that this will be the most cost effective option.
Construction contractor default	The construction contractor will be required to bond/insure its work to provide financial protection against default, insolvency, etc. and to provide the relevant insurance.

8.10 Relevant Budgeting Experience

Below is a discussion of the relevant budgeting experience of EWT LP, as reflected by its partners.

8.10.1 Hydro One

As noted in Section 2.1.3, Hydro One (through HONI) has significant experience in managing major transmission projects. In the years 2009-2011, HONI's rate base additions were approximately $2.6 billion. Direct evidence related to HONI's rate base additions can be found in its last two transmission rate applications: EB-2012-0031 and EB-2010-0002. For example, as described in EB-2012-0031, the current cost estimate for the Bruce to Milton project totals $709 million,[13] which is approximately $44 million less than the $753 million budgeted for the project.[14]

8.10.2 Brookfield Utilities Group

As shown in Section 2.1.2, the Brookfield Utilities Group has extensive experience managing transmission projects. In Ontario, Great Lakes Power Transmission LP ("GLPTLP") is an important part of the Brookfield Utilities Group. In 2003, GLPTLP sought and received Board approval to reinforce a significant portion of a transmission facility between Sault Ste. Marie and Wawa ("Transmission Reinforcement Project").[15] The Transmission Reinforcement Project consisted of two stages and was completed at a cost of $81 million.

The Brookfield Utilities Group is ultimately part of the wider Brookfield family of companies. Brookfield Asset Management Inc. is a major company listed on the Toronto and New York stock exchanges with total revenues in 2011 of $15.9 billion. Part of the Brookfield philosophy is cost management. EWT LP will put in place appropriate controls to manage the Project budget.

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[13] EB-2012-0031, Exhibit D1, Tab 3, Schedule 3, p. 15 (August 15, 2012).
[14] EB-2010-0002, Exhibit A, Tab 11, Schedule 5.
[15] EB-2003-0162.

8.11 Allocation of Construction Cost Risks

The ratepayer should be appropriately protected, and as a result only prudently incurred costs, reviewed in a transparent fashion, should be recovered by the utility.

As such, EWT LP will be seeking construction cost recovery consistent with the Board's existing regulatory cost-of-service framework for all other regulated transmission activities in Ontario. To the extent that the EWT LP incurs an overage during construction, the overage would be subject to a prudency review. To the extent there are cost savings, the cost savings would be passed 100% to the benefit of the ratepayer.

8.12 Estimated Operations and Maintenance Costs

EWT LP has prepared a preliminary estimate of the resources required to operate and maintain the Project once complete. From this it has prepared a draft annual budget which has been provided below.

OM&A Budget for EWT LP	**Estimated Annual Expense**
Transmission Expenses - Operation	
Operation Supervision & Engineering	$ 345,000
System Supervision & Control (Load Dispatching)	$ 750,000
Buildings & Fixtures Expenses	$ 50,000
Overhead Line Expenses	$ 600,000
Rents	$ 60,000
Transmission Expenses - Maintenance	
Maintenance of Overhead Conductors & Devices	$ 300,000
Maintenance of Overhead Lines – ROW	$ 1,800,000
Maintenance of Overhead Lines – Roads & Trails	$ 150,000
Administrative and General Expenses	
Management Salaries & Expenses	$ 405,000
General Administrative Salaries & Expenses	$ 728,000
Office Supplies & Expenses	$ 113,300
Outside Services Employed	$ 300,000
Insurance	$ 50,000
Regulatory Expenses	$ 250,000
Electrical Safety Authority Fees	$ 30,000
Total Operations	**$ 1,805,000**
Total Maintenance	**$ 2,250,000**
Total Administrative & General	**$ 1,876,300**
Total OM&A	**$ 5,931,300**
Add: Contingency of 20%	$ 1,186,260
Total Estimated OM&A	**$ 7,117,560**

Given that the Project reinforces an existing transmission line owned by a subsidiary of one of EWT LP's partners (HONI) and is in close proximity to the network assets of GLPTLP, a related entity to Great Lakes Power Transmission EWT LP ("GLPT-EWT"), EWT LP believes that there may be opportunities to significantly reduce operations and maintenance costs by contracting with one or more EWT LP partner-related entities. EWT LP notes that operating costs will be subject to the Board's future review and approval in one or more subsequent applications.

PART B
PLAN FOR THE EAST-WEST TIE LINE

EXHIBIT 8
COSTS

Appendix 8A
Detailed Development Budget

Appendix 8A – Detailed Development Budget

ACTIVITY	TOTAL million	
Licensing and Permitting		
Environmental Assessment		
EA program management and agency consultation	$	0.97
EA Terms of Reference	$	0.95
EA Field Studies	$	1.36
Environmental Assessment	$	1.88
Sub-total (environmental assessment)	$	5.15
Leave to Construct		
Application	$	0.56
Hearing	$	-
Sub-total (leave to construct)	$	0.56
Total (licensing and permitting)	$	5.71
Engineering		
Program management, QA/QC	$	0.77
Engineering and design	$	2.57
Interconnection	$	0.38
System studies	$	0.82
Total (engineering)	$	4.54
Routing		
Land use studies & land owner engagement	$	0.55
Route selection	$	0.72
PPM	$	1.04
Total (routing)	$	2.32
Consultation		
Public engagement	$	2.43
First Nation and Metis consultation	$	1.71
Total (consultation)	$	4.14
Land Acquisition		
Land appraisal	$	0.12
Title searches	$	0.40
Land acquisition	$	0.48
Total (land acquisition)	$	0.99
Procurement		
Construction RFQ/RFP process	$	0.14
Total (procurement)	$	0.14
Project Management		
GLPT management team	$	3.68
Health and safety	$	0.16
Program administration and cost control	$	0.44
Total (procurement)	$	4.28
TOTAL	$	22.12