Study Estimates
East-West Tie Expansion

Client:	Hydro One Networks Inc.
Project Name:	East West Tie Expansion
Client Ref. Number:	4500072684
SNC Ref. Number:	[redacted]
Date:	May 19, 2010 (Revised)
Author Contact:	[redacted]

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Project Name:	**East West Tie Expansion**
Client Ref. Number:	**4500072684**
SNC Ref. Number:	**062426**
Date:	**May 19, 2010 (Revised)**
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All costing information contained in this document are preliminary and were prepared for option assessment purposes only.

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1 Introduction

SNC Lavalin T&D received purchase order 4500072684 and a preliminary Planning Specification dated March 15, 2010 requesting Study Estimates with +/-50% accuracy for various Line Options and associated breaker installations and line terminations at Wawa TS, Marathon TS, Nipigon SS and Lakehead TS.

The proposed new 230kV line will increase the capability of the East West Tie from its current West to East transfer limit of 325MW to incorporate additional renewable resources in the Northwest. The existing transmission network between northwest and northeast of Ontario comprises of a double circuit 230kV transmission line between Wava TS and Marathon TS (circuit W21m and W22M). The transmission network then extends to west as a double –circuit 230kV transmission line between Marathon TS and Lakehead TS (circuits M23L and M24L). There is also one 115kV transmission line along the Marathon TS – Lakehead TS-Mackenzie TS 230kV circuit.
Where possible the new line will follow the existing right of way (ROW) of 230kV lines between Wava TS-Marathon TS, Nipigon SS and Lakehead TS. The length of the transmission line shall be approx 300 or 400Km depending of Alternatives, L1, L2, L3, L4, L5 and L6.

The estimating services included the review of existing documents, engineering sketches, bill of major materials, assumptions, scope description, project schedule, cost estimate, work breakdown structure, and contingency, risk, and escalation analysis. These are attached.

2 Source Documents and Information

The following documents were used in these estimates:

- Hydro One Planning Specifications
- Video flyover of existing line from Wawa to Lakehead.
- Hydro One –Technical Requirements for The Design, supply and installation of 230kV Transmission Line connecting to Hydro One Network's facilities in Northern, Ontario
- Binder containing Technical specifications, Conceptual Design requirement, Appendix A – Line Plan and Profile Drawings, Appendix B &C – insulator Assemblies and Steel Structures.
- Basic layout drawings for Wawa TS, Marathon TS, Lakehead TS
- Single Line Diagrams for Wawa TS, Marathon TS and Lakehead TS
- Electrical Arrangement Drawings for Wawa TS, Marathon TS and Lakehead TS.

The information noted above forms the basis of these estimates.

3 230kV AC Transmission Line Alternatives

3.1 Alternative L1

Double-circuit 230kV transmission line along the existing ROW, between Wawa TS, Marathon TS, Nipigon SS and Lakehead TS including in & out to required station facilities at these stations.
Transmission line length is about **400Km**, with an average span of **400m** using Hydro One lattice steel double circuit **X10** towers family.

3.2 Alternative L2

Single-circuit 230kV transmission line along the existing ROW, between Wawa TS, Marathon TS, Nipigon SS and Lakehead TS including in & out to required station facilities at these stations.
Transmission line length is about **400Km** with an average span of **400m** using Hydro One lattice steel single circuit **W1** towers family.

3.3 Alternative L3

Double-circuit 230kV transmission line along the existing ROW, between Wawa TS, Marathon TS and Nipigon SS including in & out to required station facilities at these stations.
Transmission line length is about **300Km** with an average span of **400m** using Hydro One lattice steel double circuit **X10** towers family.

3.4 Alternative L4

Single-circuit 230kV transmission line along the existing ROW, between Wawa TS, Marathon TS and Nipigon SS including in & out to required station facilities at these stations.
Transmission line length is about **300Km** with an average span of **400m** using Hydro One lattice steel single circuit **W1** towers family.

3.5 Alternative L5

Double-circuit 230kV transmission line along the existing ROW, between Wawa TS, Marathon TS and Nipigon similar to alternative L3 above plus a new single circuit 230kV line between Nipigon SS and Lakehead TS including in & out to required station facilities at these stations.
There is about:

→ 300Km double circuit transmission line with an average span of **400m** using Hydro One lattice steel double circuit **X10** towers family and
→ 100Km of single circuit transmission line with average span of **400m** using Hydro One lattice steel single circuit **W1** tower family

4 Power System Conditions

System Frequency	60 Hz
Nominal System Voltage	230 kV
Fault current	About 20kA

5 Line Rating

The 230 kV transmission lines in this project will use 795 MCM ACSR Drake conductors. Maximum operating continuous temperature is assumed to be 93°C, and the summer rating is about 1000Amps. The maximum operating temperature for ground clearance shall be 127 °C (emergency summer rating)

6 Lightning Protection and Grounding

Adequate lightning protection shall be provided for transmission line as per Hydro One standards. Shield wires shall be installed on the transmission lines and will be taken into the substation. For double circuit transmission line there shall be one ground wire and one OPGW, while for single circuit transmission line there shall be one OPGW.

7 Line Insulation

The following criteria should be reviewed with Hydro one prior to finalization. General industry standards have been used to obtain the following values. These values are to be reviewed with Hydro One before finalizing detailed design.

Transmission lines will be designed to a minimum insulation level of:

Minimum BIL:	1050 kV
Minimum Every Day Air Gap	2100 mm
Minimum Flashover Air Gap	1830 mm
Minimum Power Frequency Air Gap	610mm

Adequate climbing and working space will be maintained under steady state conditions.
For structures using porcelain or glass insulators:

Suspension string:	120 KN (M&E strength),	14 bells per string
Tension string:	160 KN (M&E strength),	14 bells per string

8 HVDC Light Transmission Line (Alternative L6)

A new +/-250kV HVDC light transmission line (with up to 400MW capacity) shall be constructed along the existing ROW, between Wawa TS, and Lakehead TS.

Transmission line length is about 400Km with an average span of 400m using lattice steel tower +/- 250kV bi-pole and one earth return conductor at mid point. Converter station and required AC connection facilities to these stations are included in station scope of work. There shall be two overhead shield wires, one OPGW and one Alumoweld ground wires. HVDC towers shall be designed for this specific application.. Typical arrangement of HVDC tower is shown in Appendix A.

Nominal system voltage	+/-250kV DC
Switching surge	400kV (Typical value from CSA C22.3-01)
Conductor	ACSR Drake, 795 MCM 26/7 strands
Insulator type	DC Fog type insulators, high creepage, NGK cat# CA-735EZ or equivalent

Insulator string suspension	V type, 160kN, 2x16 discs
Insulator string Tension	Deadend type, 160KN, 2x16 discs
Configuration	Horizontal, one conductor per phase
No of poles	2 (+/-250KV phase to metallic earth return conductor)
Earth return conductor	1
Shield wires	2 , 7#6 Alumoweld wires or One 7#6 Alumoweld wire and One OPGW, 48 Fibers, equivalent to 7#6 Alumoweld

9 Loadings and Tensions for Conductor and shield wires

General industry and Hydro One standards been proposed with the values below:

Heavy Loading as per CSA C22.3 No. 1-01

Radial Thickness of Ice	12.5 mm
Horizontal Wind Loading	400 Pa
Temperature	-20 °C
Maximum tension	60% RTS
Radial Thickness of Heavy Ice	25.4mm (HO loads)
Maximum tension	90% RTS

Other loadings:

Bare conductor at 15 deg.C	20% of RTS
Bare conductor at -30 deg.C	25% of RTS

10 Conductor and Shield wires

Conductor ACSR Drake, 795 MCM 26/7 strands

Number / Phase	1
RTS	140kN
Outside Diameter	28.14 mm
Strands	26/7

Ground Wire type: 7#6 Alumoweld

RTS	101kN
Outside Diameter	12.34 mm
Strands	7
OPGW equivalent to 7#6 Alumoweld	
Number of Fibers	48
Type	Single mode

Additional price for supply and installation of one OPGW versus one Alumoweld ground wire shall be provided.

11 Ground Clearance

Design clearances will apply at the weather/thermal condition that produces the maximum conductor sag.

These clearances will meet or exceed the requirements under CSA C22.3 No. 1-01 and Hydro One standards.

The As-Built clearances will be based on 230 kV nominal voltages, with a 0.3 m safety buffer applied to vertical clearances.

12 Terrain type

Terrain information is based on flyover video provided by Hydro One. The terrain is generally uneven, mostly rocky and covered with trees. In each section of the line there are muskeg, lake and river crossings.. Almost 60 % of the line route is not accessible by vehicle. ROW clearing and access road shall be required during construction.
There are about 26 road crossings, 12 river crossings and 45 small lake/muskeg crossings and one 115kV line crossing from Wawa TS to Lakehead TS.

13 Foundations

Ground bearing and shear strength will be confirmed through basic soil investigations and should allow the installation of the following.
Foundation type shall be concrete auger/caisson or pad and chimney footings in clay soil, and rock anchor or grillage in rocky terrain. Almost 25% of foundations are expected auger type, 15% pad and chimney type and 60% rock anchor type.

14 Wind Induced Line Vibration

Stock bridge type vibration dampers will be installed on full tensions spans of 100 m or greater on conductor and ground wire.

15 Aerial Markers

At navigable river/lake crossing tower shall be painted and Aerial signage shall be installed on conductor.

16 Structure Type

Standard HO double circuit 230kV lattice steel structures (X10 tower family) and single circuit W1 tower family shall be for 230kV AC transmission line.

17 Scope of Supply for 230kV AC Transmission line

Conductor	**795 MCM, 26/7 ACSR Drake.**
OHGW	7#6 ALW
OPGW	7#6 ALW equivalent with 48 fibers
Circuit Configuration	**Single circuit and Double circuit**
Insulator Type	Porcelain/Glass ball & socket type Or Synthetic string with corona ring.
Deadend string (Heavy Angles & Dead Ends)	**14 Units, Porcelain/Glass ball & socket type**
Mechanical Strength of	160 kN
Porcelain/Glass type	ANSI 52-8
Corona Rings	No

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[redacted]

[redacted]

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[redacted]

[redacted]

18 Assumptions – Lines

1. All TS and SS sites to be approved and purchased by Hydro One
2. Additional easement will be obtained by HO at TS, SS and for ROW of the new line
3. Line R/W brushing, trimming, and site clearing will be required for almost entire line length. We have not accounted for acre-for –acre reforestation.
4. Outages will be available as required.
5. Hydro One will arrange regulatory approvals, right of way agreements, easement, and environmental approvals landowner consultation.
6. Hydro One will provide lay down area(s) for transmission line material and allow for roadside drop off.
7. The soil condition is mostly rocky, covered with trees, river and lake crossings, most of the transmission line route is inaccessible by vehicle. The soil condition, terrain and constructability have been estimated without geotechnical reports on the basis of visual observation.
8. It is assumed that generally there will be truck /surface delivery of line material, However transportation of line material and tower erection by helicopter will also be required.
9. Hydro One will provide information on existing line records, structure drawings, and line tensions.
10. Standard Hydro One lattice steel tower structures will be used. Structure drawings shall be provided by Hydro One.
11. No improved appearance double circuit steel poles have been used.
12. The last span of transmission conductor and OHGW for each circuit will be carried into the substations as a slack span.
13. The meteorological loadings for this project will be CSA Heavy Loading.

19 Not Included in Scope

1. No unusual anti-cascade requirements or contamination levels are included.
2. No temporary bypass included for this project. Hydro One to advise if otherwise.

20 Station Work

For each line option, additional 230kV breakers and Line Terminations will be required at one or more of the stations at Wawa TS, Marathon TS, Nipigon SS and Lakehead TS. The work is described below. It is assumed that Nipigon SS will already be built under the Northwest Plan and as such there will be adequate space both in the yard and control building to accommodate the work under this plan. At the other 3 stations, the fenced area is adequate and no expansion is necessary for Line options L1 to L5 inclusive. Also there appears to be adequate space in the buildings to accommodate additional Protection and Scada Panels.

- Add facilities at Wawa TS to allow the addition of one double circuit 230 kV line out of Wawa TS alternative L1, L3 and L5.
- Add facilities at Wawa TS to allow the addition of one single circuit 230 kV line out of Wawa TS, alternative L2 and L4

- Add facilities at Marathon TS to allow the addition of two double circuits 230 kV line out of Marathon TS, alternative L1, L3 and L5.
- Add facilities at Marathon TS to allow the addition of two single circuits 230 kV line out of Marathon TS, alternative L2 and L4.
- Add facilities at Nipigon TS to allow the addition of two double circuits 230 kV line out of Nipigon TS alternative L1.
- Add facilities at Nipigon TS to allow the addition of either one double circuit 230 kV, alternative L3 or two single circuit, 230kV alternative L2 out of Nipigon TS
- Add facilities at Nipigon to allow the addition of one double circuit 230 kV line and one single 230kV circuit line out of Nipigon alternative L5.
- Add facilities at Nipigon to allow the addition of one single circuit 230 kV line out of Nipigon alternative L4.
- Add facilities at Lakehead to allow the addition of one double circuit 230 kV line out of Lakehead, alternative L1.
- Add facilities at Lakehead to allow the addition of one single circuit 230 kV line out of Lakehead, alternative L2 and L5.
- HVDC option between Wawa and Lakehead including all new AC requirements to the existing system and new DC converter substation requirements at Wawa and Lakehead substations, alternative L6.

21 Description of Facilities

21.1 General

Wawa TS is located just east of the town of Wawa, Ontario. Presently, the station arrangement is a ring bus configuration with 5 breakers arrangement in bay 1&2. To modify the station to accommodate 3 diameters with 4 breakers in each one, as per HO Planning Specification, existing breakers or the existing transmission line terminations have to be relocated to provide additional span for one breaker position. Both options require extensive modifications and outage requirements. Building the arrangement of 4 diameters with three breakers in each one (as existing arrangement) would be a better solution.

Marathon TS is located about 2 km north of the town of Marathon, Ontario. The station is presently a four breakers ring bus configuration. This will be modified to two buses with three folding diameters, 4 breakers in each one.

Nipigon TS This is a new station to be built under North West Transmission Expansion, to be located near Nipigon, Ontario. The station design will be revised to accommodate the present requirements.

Lakehead TS is located approximately 15km east of the city of Thunder Bay, Ontario. The station 230kV East area has two existing folding diameters with three breakers in each one (Bay 11 to 14). The third diameter that is now allocated for deferred Birch T.S project (Bay 9 and 10) will be used to accommodate the new Lakehead project.

It should be noted that all proposals including that for Wawa are in agreement with the Hydro One Ultimate stage for each station.

The proposed single line diagrams are shown in Appendix B1 to B11.

21.2 Wawa TS

21.2.1 Wawa Alternative L1, L3, L5, one double 230 kV Circuits

- 6-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manual vertical break disconnect switches, compatible with the breaker ratings. .
- 2-230 kV motorized 2000 Ampere, 40kA, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6-230 kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit (This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 3000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed to be suitable for the new breaker installations.
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductors per phase to a total conductor length of 1000 meter is required.

Communications are assumed to be available based on existing microwave or OPGW.

Modifications and additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Additions and modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be sandy clay based, with bedrock within one meter below surface. Rock footings may be assumed in 50% of the locations; the remainder shall be split as auger or spread footings where soil depth permit.

21.2.2 Wawa Alternative L2 and L4, one single 230 kV Circuit

- 4-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manual vertical break disconnect switches, compatible with the breaker ratings.
- 1-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 3-230 kV CVTs.
- 3 230kV surge arresters.
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.

- One set of wave trap and coupling capacitor each for one phase of single circuit with line matching unit (This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 2000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed to be suitable for the new breaker installations.
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required

Communications are assumed to be available based on existing microwave or OPGW.

Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be sandy clay based, with bedrock within one meter below surface. . Rock footings may be assumed in 50% of the locations; the remainder shall be split as auger or spread footings where soil depth permit.

21.3 Marathon TS

21.3.1 Marathon Alternative L1, L3 and L5 two double 230 kV Circuits

- 7-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 4-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 12-230 kV CVTs
- 12 230kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- Four sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 3000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed to be suitable for the new breaker installations.
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 2000 meter is required

Communications are assumed to be available based on existing microwave and new fibre circuits.

Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be sandy clay based, with bedrock within one meter below surface. Rock footings may be assumed in 50% of the locations; the remainder shall be split as auger or spread footings where soil depth permit.

21.3.2 Marathon Alternative L2 and L 4, two single 230 kV Circuits

- 4-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 2-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6 230kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 2000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed to be suitable for the new breaker installations.
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required

Communications are assumed to be available based on existing microwave or new fibre circuits.
Additions to the existing P&C system are required in redundant A and B systems. Assume the

A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be sandy clay based, with bedrock within one meter below surface. . Rock footings may be assumed in 50% of the locations; the remainder shall be split as auger or spread footings where soil depth permit.

21.4 Nipigon SS

21.4.1 Nipigon, Alternative L1, two double 230 kV Circuits

- 7-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 4-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 12-230 kV CVTs
- 12 230kV surge arresters
- Additional bus work and structures to accommodate the third diameter. Note HONI uses 8 inch IPS bus as standard.
- Four sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 3000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed in the existing proposal.

Communications are assumed to be available on commissioning the new substation.

Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be clay based, with bedrock many meters below surface. Conventional spread or augured footings may be used.

21.4.2 Nipigon, Alternative L2- two single 230 kV or L3- one double 230kV Circuits

- 5-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 2-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6 230kV surge arresters

- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Additional bus work and structures to accommodate the third diameter. Note HONI uses 8 inch IPS bus as standard.
- Ground grid 4/0 copper conductor and connection to equipment 2000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed in the existing proposal.

Communications are assumed to be available on commissioning the new substation.
Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be clay based, with bedrock many meters below surface. Conventional spread or augured footings may be used.

21.4.3 Nipigon, Alternative L5- one single and one double 230 kV Circuit

- 6-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 3-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 9-230 kV CVTs
- 9 230kV surge arresters
- Three sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Additional bus work and structures to accommodate the third diameter. Note HONI uses 8 inch IPS bus as standard.
- Ground grid 4/0 copper conductor and connection to equipment 3000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed in the existing proposal.

Communications are assumed to be available based on commissioning the new substation.

Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be clay based, with bedrock many meters below surface. Conventional spread or augured footings may be used

21.4.4 Nipigon, Alternative L4, one single 230 kV Circuit

- 4-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 1-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 3-230 kV CVTs
- 3 230kV surge arresters
- One set of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Additional bus work and structures to accommodate the third diameter. Note HONI uses 8 inch IPS bus as standard. .
- Ground grid 4/0 copper conductor and connection to equipment 2000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed in the existing proposal.

Communications are assumed to be available based on commissioning the new substation.
Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be clay based, with bedrock many meters below surface. Conventional spread or augured footings may be used.

21.5 Lakehead TS

21.5.1 Lake Head Alternative L1 One double 230 kV Circuit

- 3-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 2-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6 230kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.

- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 1500 meters
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required
- Space for new panels in the control panel, existing AC station service and DC supply is assumed to be suitable to be suitable for the new breaker installations.

Communications are assumed to be available based on existing microwave or new fibre circuits.
Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be glacial till subsoil. Conventional spread or pile footings may be used

21.5.2 Lake Head Alternative L2, L5 One single 230 kV Circuit

- 2-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 1-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 3-230 kV CVTs
- 3 230kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- One set of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 1000 meters
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required
- Space for new panels in the control panel, existing AC station service and DC supply is assumed to be suitable for the new breakers installation.

Communications are assumed to be available based on existing microwave or new fibre circuits.
Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use

equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.
Soils in the area are understood to be glacial till subsoil. Conventional spread or pile footings may be used

22 HVDC option between Wawa TS and Lakehead TS:

A Bipolar HVDC with ground return path option is considered for a high degree of flexibility of operation. Both Wawa and Lakehead will have unique arrangement. Following are the requirements and modifications in respective substations for the HVDC option between Wawa and Lakehead.

22.1 Wawa TS:

Site Requirements:
A land size of approximately 200 meter by 125 meter is required for the installation of "DC substation" adjacent to existing Wawa TS is required. In addition to this, ac harmonic filters and shunt capacitor banks have to be included to the existing substation. The new arrangements to the Wawa TS will also require expansion of AC station property by about 200 meter by 125 meter.

22.2 Electrical Requirements

- The DC substation comprises of converters and DC filters connected to converter transformers.
- A Converter Valve station complete with converter arrangement.
- DC filters with Smoothing reactor connected to the DC incoming side.
- Bus works and terminations for the above arrangement to be connected to the converter transformers.
- A new ground grid is required to be installed with approximately 6000 meters of 4/0 conductor.
- Site preparation including drainage and other environmental requirements for the identified location close by the existing substation is required.
- Noise barrier walls suitable with fire fly requirements are required for both converter transformers.
- Oil containment system is required for the oil filled converter transformers.
- Protection system for the HVDC converter control, converter transformer protection as required to be provided in a separate HVDC control and relay room.
- Station service requirements with duel 100kVA transformer and auto change over switch is required.
- Station 250V dc supply for the control and protection in the order of approximately 400AH battery bank with charger in duplicate is required.
- SCADA and communication is required to be provided to have access to OGCC at Barrie.

22.3 AC Substation Additional Requirements

The AC output from converter transformers is connected to the existing AC System through AC Harmonic filters. Additional shunt capacitor banks are required to meet the reactive power requirements. Bus works and terminations for the above arrangement are required. New 250V, 250AH dual DC battery bank, chargers and a DC Distribution board is required. Station service requirements with duel 100kVA transformer and auto change over switch is required

A new ground grid is required to be installed with approximately 4000 meters of 4/0 conductor and suitably connected to the existing ground. Grounding requirements of the equipments to the ground grid would require another 1000 meters of 4/0 conductor approximately.

The line Terminations at Wawa TS are similar to Option L1 as follows

- 6-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manual vertical break disconnect switches, compatible with the breaker ratings. .
- 2-230 kV motorized 2000 Ampere, 40kA, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6-230 kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 3000 meters
- Space for new panels in the control panel, existing AC station service and DC supply is assumed as designed to be suitable for the new breaker installations.
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required.

Communications are assumed to be available based on existing microwave or fiber circuit.

Modifications and additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Additions and modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be sandy clay based, with bedrock within one meter below surface. Rock footings may be assumed in 50% of the locations; the remainder shall be split as auger or spread footings where soil depth permit..

22.4 Lakehead TS:

A similar set of facilities as mentioned for Wawa TS HVDC, are required for the converter station at the Lakehead substation, as below:

22.4.1 Site Requirements:

A land size of approximately 200 meter by 125 meter is required for the installation of "DC substation" adjacent to existing Lakehead TS is required. In addition to this, ac harmonic filters and shunt capacitor banks have to be included to the existing substation. The new arrangements to the Lakehead TS will also require expansion of AC station property by about 200 meter by 125 meter.

22.4.2 Electrical Requirements:

- Components in the DC SUBSTATION:
- The DC substation comprises of converters and DC filters connected to converter transformers.
- A Converter Valve station complete with converter arrangement.
- DC filters with Smoothing reactor connected to the DC incoming side.
- Bus works and terminations for the above arrangement to be connected to the converter transformers.
- A new ground grid is required to be installed with approximately 6000 meters of 4/0 conductor.
- Site preparation including drainage and other environmental requirements for the identified location close by the existing substation is required.
- Noise barrier walls suitable with fire fly requirements are required for both converter transformers.
- Oil containment system is required for the oil filled converter transformers.
- Protection system for the HVDC converter control, converter transformer protection as required to be provided in a separate HVDC control and relay room.
- Station service requirements with duel 100kVA transformer and auto change over switch is required.
- Station 250V dc supply for the control and protection in the order of approximately 400AH battery bank with charger in duplicate is required.
- SCADA and communication is required to be provided to have access to OGCC at Barrie.

22.4.3 AC Substation additional requirements

The AC output from converter transformers is connected to the existing AC System through AC Harmonic filters. Additional shunt capacitor banks are required to meet the reactive power requirements. Bus works and terminations for the above arrangement are required. New 250V, 250AH dual DC battery bank, chargers and a DC Distribution board is required. Station service requirements with duel 100kVA transformer and auto change over switch is required

A new ground grid is required to be installed with approximately 4000 meters of 4/0 conductor and suitably connected to the existing ground. Grounding requirements of the equipments to the ground grid would require another 1000 meters of 4/0 conductor approximately.

The Line Terminations are similar to Option L1 as follows:

- 3-230 kV 3000 ampere 40 kA 900 kV BIL rated dead tank breakers each with two associated manually operated vertical break disconnect switches, compatible with the breaker ratings.
- 2-230 kV motorized 2000 Ampere, 1050 kV BIL vertical break line disconnect switches with motor operated grounding switches.
- 6-230 kV CVTs
- 6 230kV surge arresters
- 8 inch IPS pipe for additional bus work and structures to accommodate the above new diameters is required.
- Two sets of wave trap and coupling capacitor each for one phase of single circuit with line matching unit(This may not be required if OPGW alternative is used)
- Ground grid 4/0 copper conductor and connection to equipment 1500 meters
- Addition or replace the existing strain main buses rated 1000A with 2 x 3603 MCM aluminum conductor per phase to a total conductor length of 1000 meter is required
- Space for new panels in the control panel, existing AC station service and DC supply is assumed to be suitable to be suitable for the new breaker installations.

Communications are assumed to be available based on existing microwave or new fibre circuits.
Additions to the existing P&C system are required in redundant A and B systems. Assume the A system uses SEL 421 relays, the B system will use equivalent GE Multilin relays. Existing bus protections will have to be expanded and modified.

Modification for existing Telecommunication and SCADA are required.

Soils in the area are understood to be glacial till subsoil. Conventional spread or pile footings may be used.

22.5 Land and Properties Scope

No additional land is expected to be required for the line terminations and breaker installations at Wawa TS, Marathon TS, Nipigon TS and Lakehead TS. It is assumed that Nipigon TS will be built before The East West Tie project. Additional land will be required for the new 230kV lines. Additional land will be required for the DC Converter stations in the vicinity of Wawa TS and Lakehead TS as well as for the AC equipment.

22.6 Switching/Outage Scope

Outages will be required to tie the new buses at each Station

23 Schedule

High Level schedules are attached as Appendix D1 and D2 for the Stations and Lines. The Key Hydro One dates are shown on each schedule.

Description	Date
Issue Detailed Planning Spec for Proposed Alternative	July 2010
Preliminary Engineering	July 2010 – Nov 2010
Issue Detailed Estimate for Management Review	November 2010
Submit Sect 92 Application	February 2011
Submit Draft TOR of EA to MOE	October 2010
Receive Section 92 Approval	February 201
Begin Voluntary Acquisition of Property	September 2012
Submit EA Request	September 2012
EA Approval	May 2013
Begin Expropriation	May 2013
Issue Final Planning Spec and Release Project	May 2013
Detailed Engineering	June 2013
Construction start	May 2014
In Service	November 2016

Long Lead Items

[redacted]

24 Study Estimates

The Study Estimates are shown in Appendix E for each individual option and an overall summary is included. Escalation is based on 3% for construction and 5% for other items.

The study estimates are based on historical information. Not all major item quantities were identified. The Construction Costs shown under Construction Material-Direct Shipped included labour, construction equipment, and material sundry. Under foundations, are also included, material such as concrete, rebar and anchor bolts.

24.1 Assumptions

24.1.1 Lines

1) The estimate does not include cost associated with sitting, consultation, facility application, regulatory and land etc.
2) Hydro One is responsible for obtaining environmental approvals, highway permits, railway permits, forestry permits and land owner issues etc.
3) New/Additional easement will be obtained by Hydro One
4) Outages will be available as required.
5) Hydro One will provide lay down area(s) for transmission line material and allow for roadside drop off of poles.
6) The soil is assumed to be sufficient for auger foundations. If soil conditions are different, additional foundation design and material may be required, which will increase the foundation cost.
7) 20% of the total cost of foundation is allocated for transportation assumed via helicopter to 60% of the foundation locations which are assumed to be inaccessible by access roads. If access by road is viable, this cost will decrease while the Access road cost will increase.
8) Hydro One will provide information on existing line records, structure drawings, and line tensions.
9) No under build work is included in the estimate.
10) No provision for concurrent engineering has been made.
11) Standard Hydro One structures are considered
12) No improved appearance steel poles have been used.
13) Double overhead shield wire is assumed in all (D/C options).
14) Communication cable is considered under separate estimate (1x OPGW & 1x OHSW).
15) OHSW & OPGW for each circuit will be carried into the substations as a slack span.
16) No mitigation costs for any extraordinary R/W included in the estimate.
17) Cost for temporary facilities (bypasses, temporary lines, temporary supply etc.) is not included in the estimate.
18) No unusual anti-cascade requirements or contamination levels are included.
19) The meteorological loadings for this project will be CSA Heavy Loading in South Ontario.
20) Use of Helicopter is considered for construction
21) 20% of the total cost is considered as contingency.
22) 20% winter construction is considered for foundation
23) Cost of four (4) storage yard set up is considered in each option of 400Km lines and three (3) are considered for 300Km lines options.

24.1.2 Stations

1) No site expansion is considered for the Nipigon substation. Assumed it was covered in the NW-expansion proposal.
2) No site expansion is considered for the addition for the new diameters at Lakehead, Marathon and Wawa stations.
3) AC/DC loading studies are included for all stations (for all options)

4) No TRV studies are considered for all substations (for all options)
5) No relay settings are assumed for all substations (for all options)
6) Winter construction cost is included for all substations (for all options)
7) For HVDC options (Lakehead and Wawa substations) instead of 100 kVA , 1 MVA station service transformer is assumed.
8) The estimate does not include cost associated with siting, consultation, facility application, regulatory and land etc.
9) This estimate is based on the following documents: East – West Tie Expansion SNC Ref. No - 062426, Date 27 04 2010; Development Work for East – West Tie Expansion Plan Rev 2. – Planning Specification and Request for Study estimate (March 15, 2010)
10) Cost for relay settings is not included.
11) All approvals, access and P&L are available when required.
12) Project will proceed in a continuous manner without interruptions or delays.
13) Outages will be available as required.
14) No provision for concurrent engineering has been made.
15) 20% of the total cost is considered as contingency.
16) Assumed each Alternative (Option) will be standalone project.

25 Risk Identification

A risk assessment, mitigation and monitoring plan will be developed at the project planning stage. For these Study Estimates, no risk differences have been identified since all options use the same corridor for the Lines and all Station work is similar and contained with the existing fenced area and existing building spaces. However several risk areas are identified for all options and these are shown in Appendix C1 and C2.

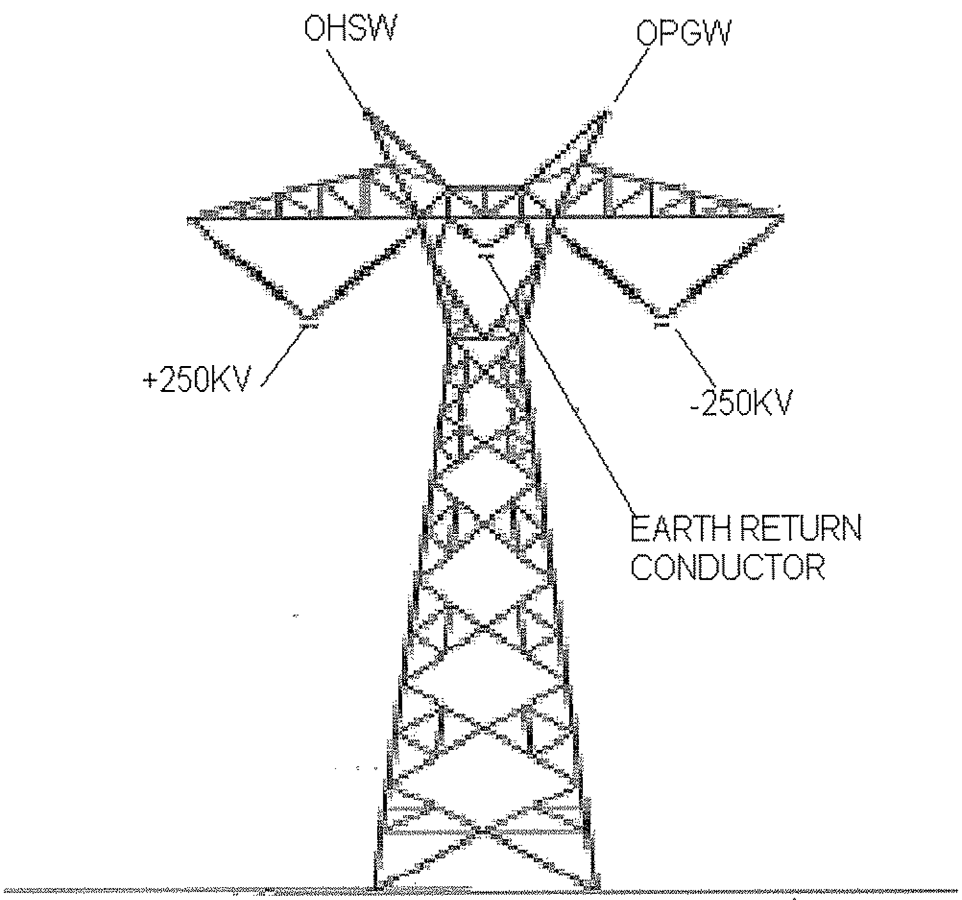
A quantitative assessment of the Risk will be done for the preferred Alternative. For these studies we have assumed a [redacted] contingency to cover the Risk.

Appendix C3 and C4 show the Risk Assessment on the Hydro One Risk Assessment Forms of Medium Risk for the options L1 to L5 and High Risk for the L6 option.

26 APPENDIX A

Typical Tower

APPENDIX A

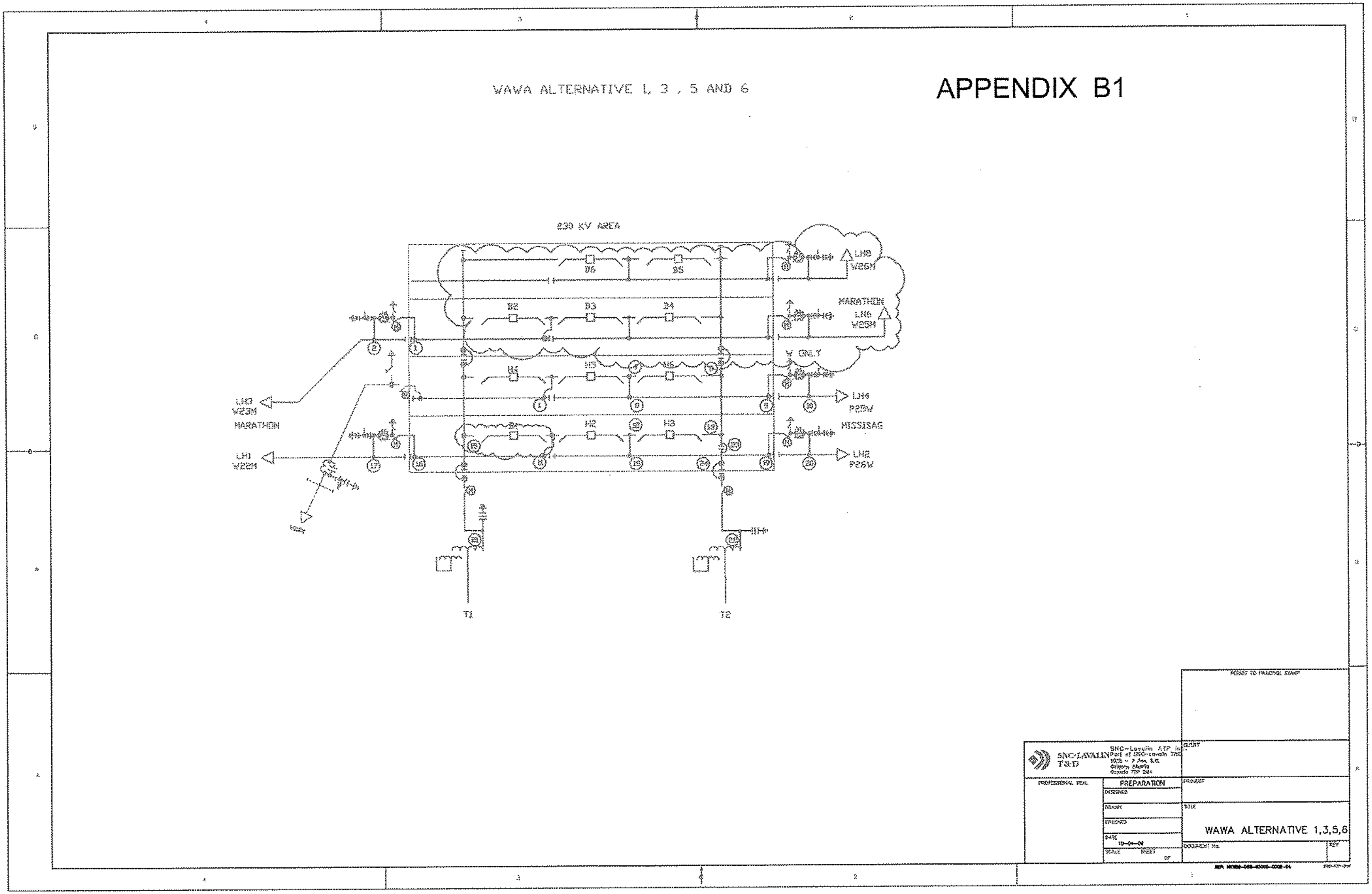


TYPICAL ARRANGEMENT OF +/-250KV HVDC TOWER

27 APPENDIX B1 to B11

Single Line Diagrams

APPENDIX B1



WAWA ALTERNATIVE 1, 3 , 5 AND 6
230 KV AREA
D6
D5
B2
D3
D4
H4
H5
H6
H2
H3
LH8
W26M
MARATHON
LH6
W25M
W ONLY
LH4
P25W
MISSISAG
LH2
P26W
LH3
W23M
MARATHON
LH1
W22M
T1
T2
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WAWA ALTERNATIVE 1,3,5,6
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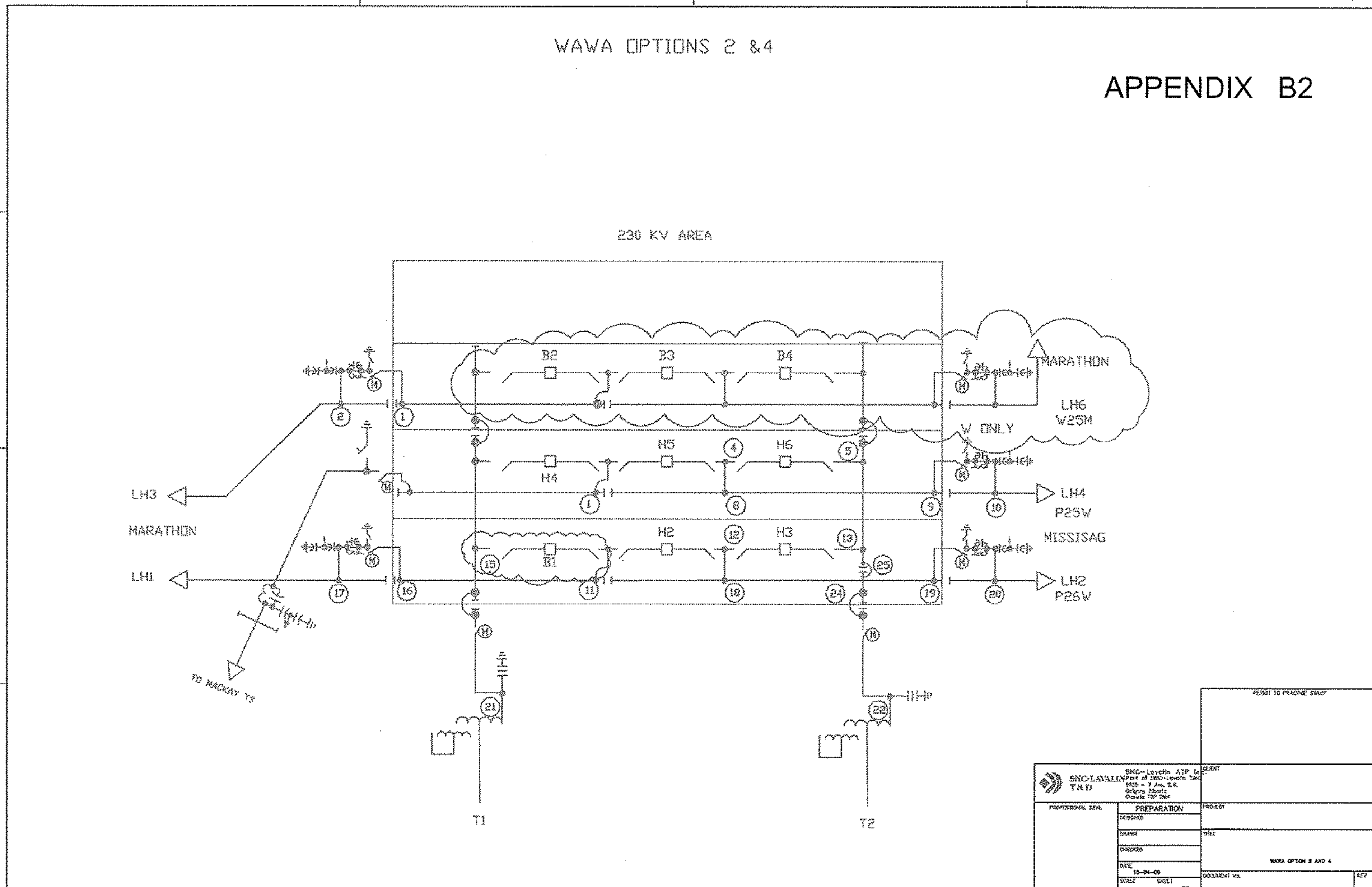
APPENDIX B2



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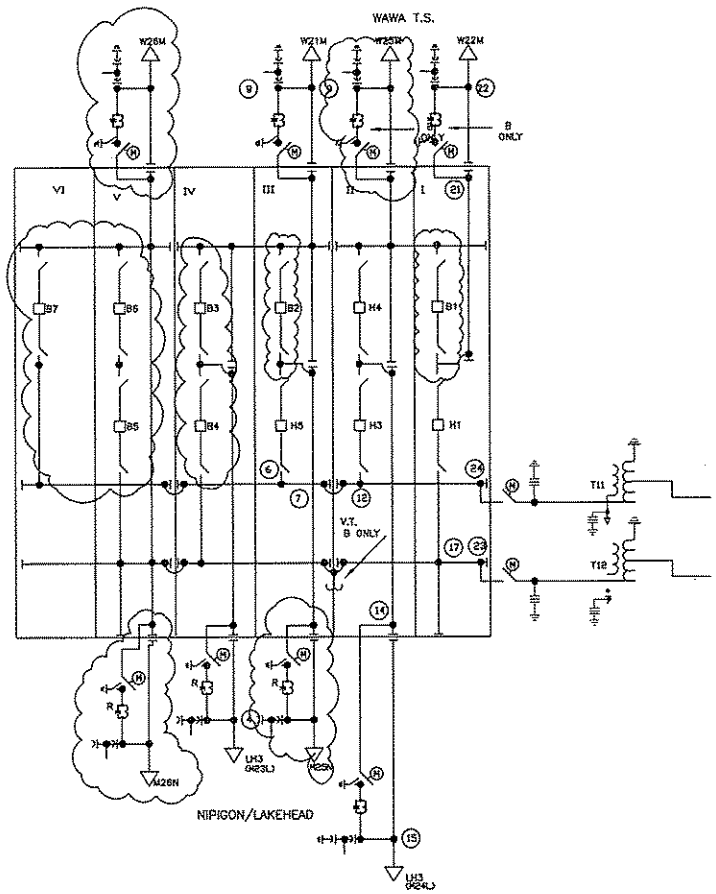
APPENDIX B3

MARATHON ALTERNATIVE 1,3,5



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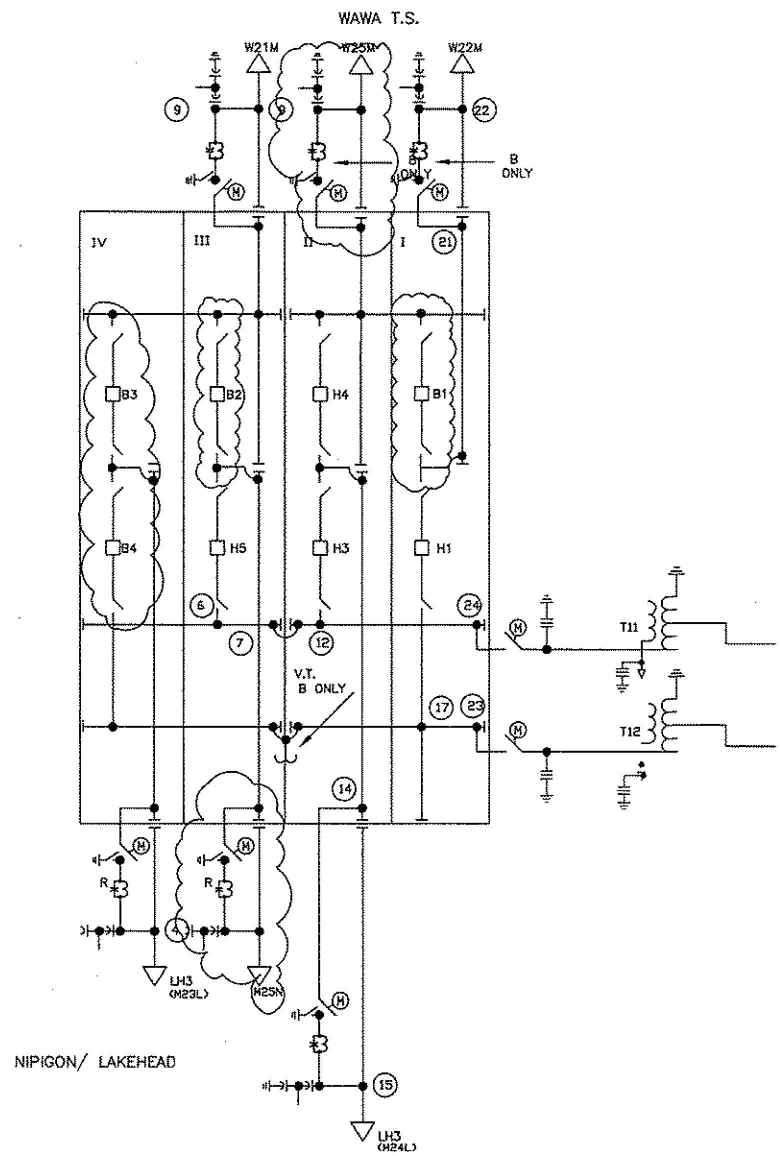
APPENDIX B4

MARATHON ALTERNATIVE 2,4



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CLIENT	
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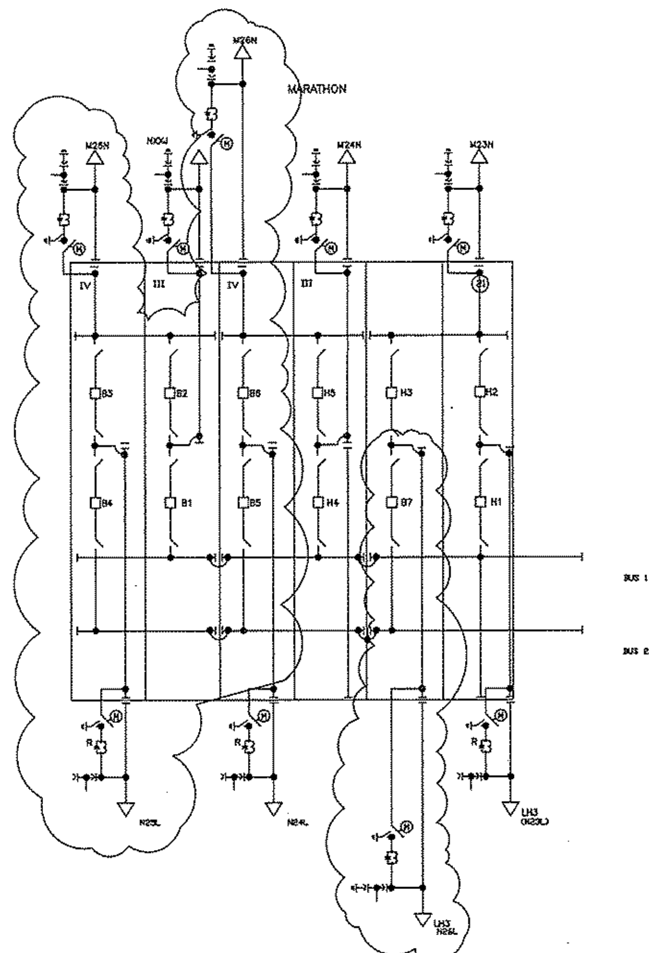
PROJECT	
TITLE	MARATHON ALTERNATIVE 2, 4
DATE	10-04-09

APPENDIX B5

NIPIGON ALTERNATIVE 1



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SNC-Lavalin ATP Inc.
Part of SNC-Lavalin T&D
1035 – 7 Ave. S.W.
Calgary, Alberta
Canada T2P 3E4

CLIENT

PROFESSIONAL SEAL

PREPARATION

DESIGNED

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DATE 10-04-09

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PROJECT

TITLE

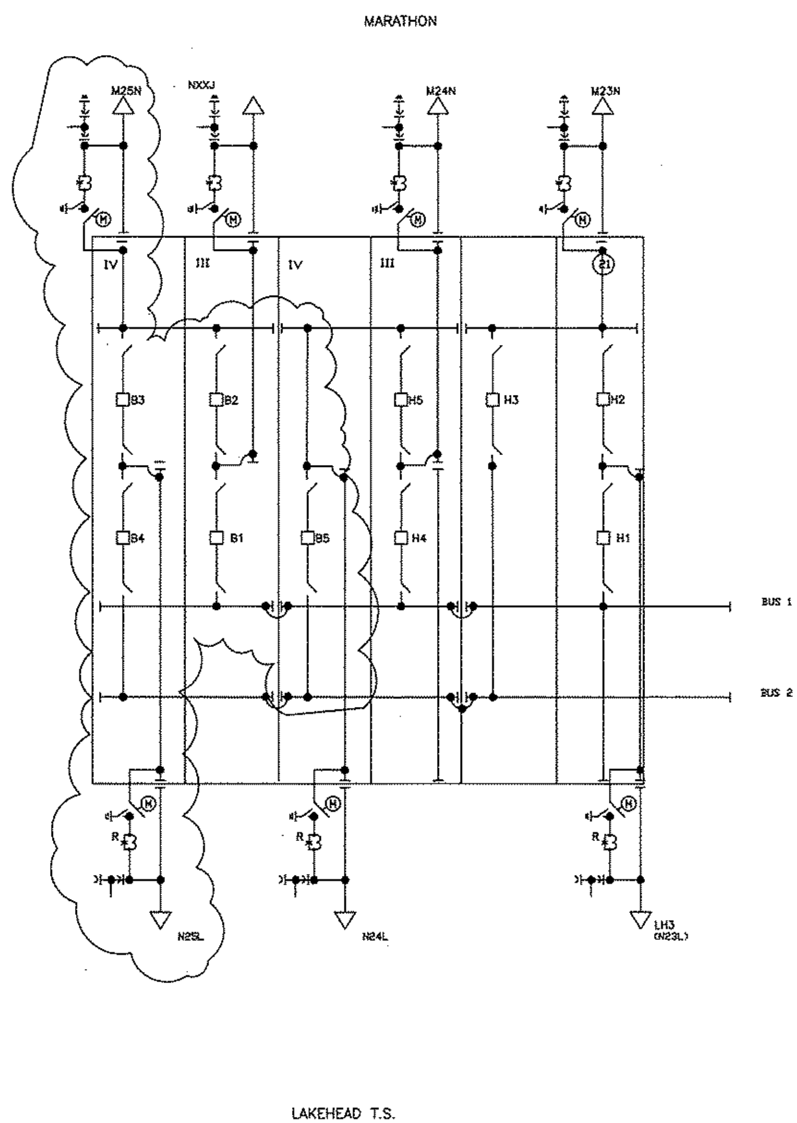
NIPIGON ALTERNATIVE 1

DOCUMENT No.

REV

APPENDIX B6

NIPIGON ALTERNATIVE 2



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DATE 10-04-09	DOCUMENT No.
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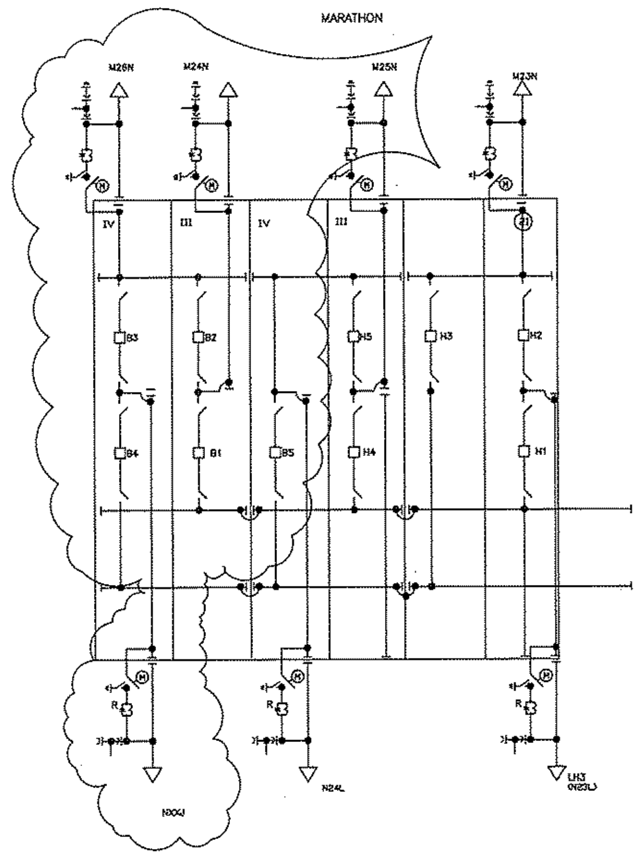
NIPIGON ALTERNATIVE 3



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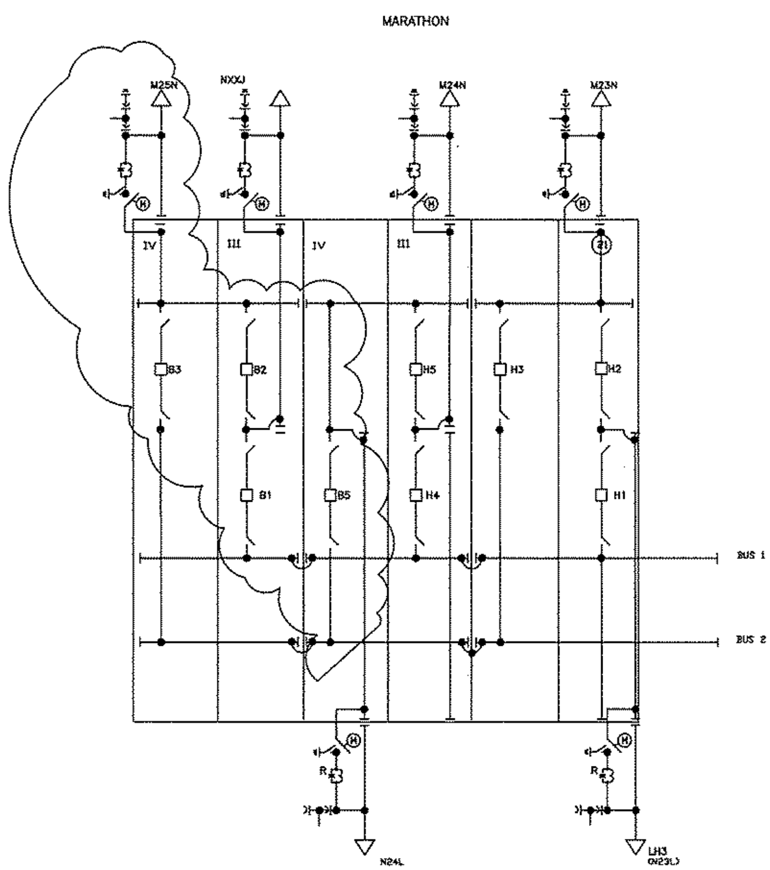
NIPIGON ALTERNATIVE 4

APPENDIX B8



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SNC-Lavalin ATP Inc.
Part of SNC-Lavalin T&D
1036 - 7 Ave. S.W.
Calgary, Alberta
Canada T2P 2K4

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	DESIGNED	PROJECT
	DRAWN	TITLE
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	DATE 10-04-06	DOCUMENT No. / REV
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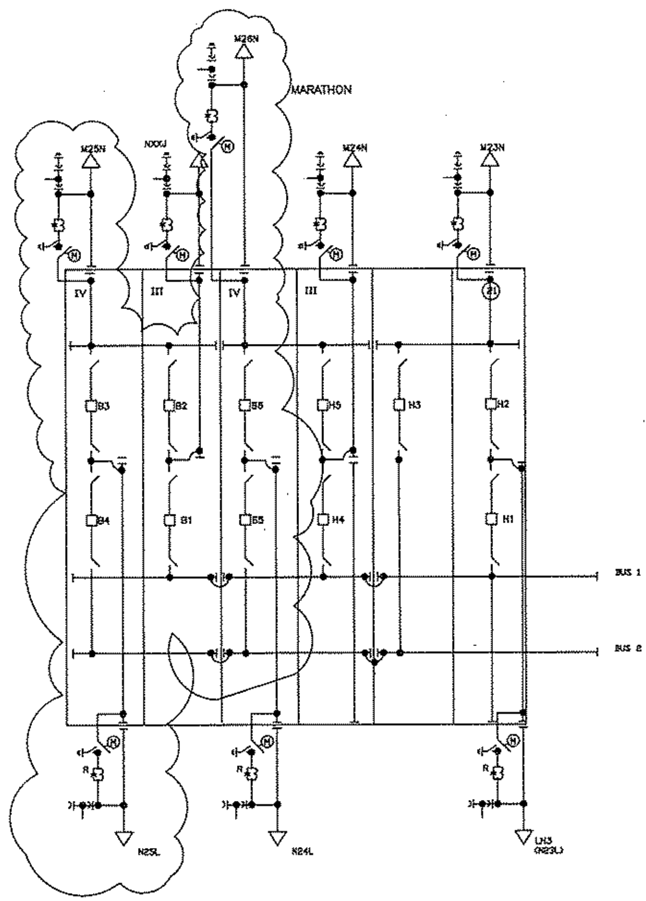
APPENDIX B9

NIPIGON ALTERNATIVE 5



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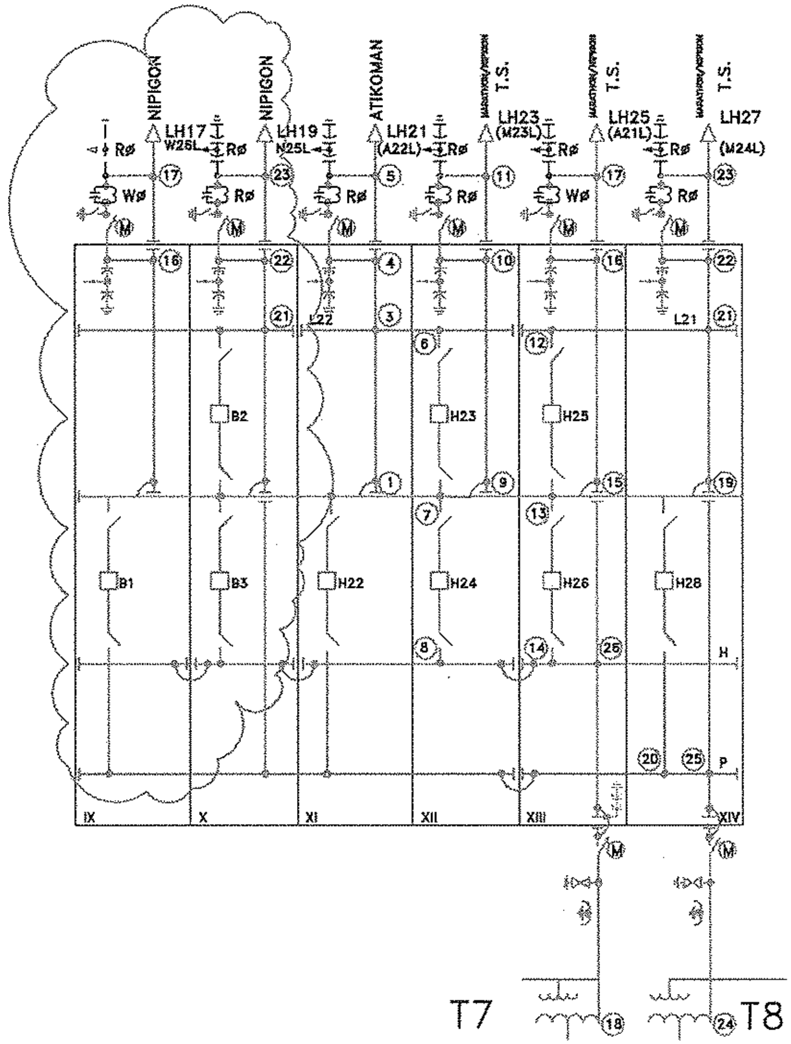
LAKEHEAD ALTERNATIVE 1 AND 6

APPENDIX B10



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PREPARATION	
DATE	10-04-09
TITLE	LAKEHEAD ALTERNATIVE 1

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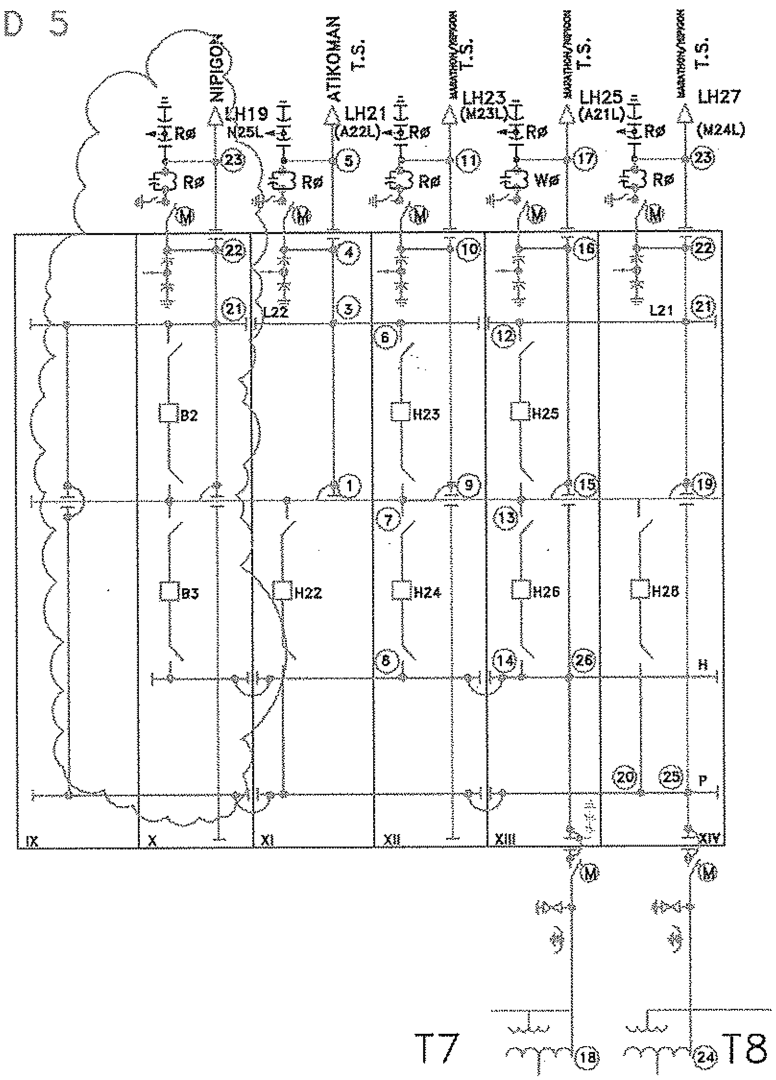
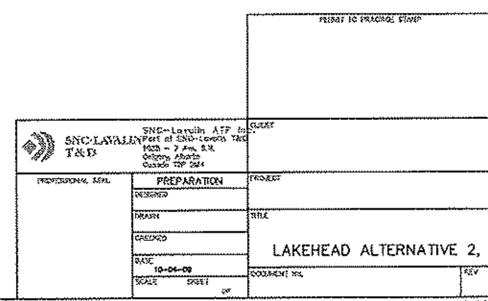
LAKEHEAD ALTERNATIVE 2 AND 5

APPENDIX B11





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28 APPENDIX C1 to C4

C1 – Risk Table for L1 – L5
C2 – Risk Table for L6
C3 – Hydro One Risk Assessment for L1 – L5
C4 – Hydro One Risk Assessment for L6

Ten Pages of Risk Tables and Risk Assessments have been deleted.

29 APPENDIX D1 to D2

D1 – Schedule Stations
D2 – Schedule Lines

Two pages of Schedules have been deleted.

30 APPENDIX E1 to E2

E1 – Estimate Summary
E2 – Estimate Detail (Below, refer to list)

Six pages of tables and 52 Excel spreadsheets, containing hundreds of dollar amounts, have been deleted.