Newfoundland and Labrador Hydro
Hydro Place. 500 Columbus Drive
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 I f. 709.737.1800
nlhydro.com

July 9, 2024

Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

Attention: Jo-Anne Galarneau
Executive Director and Board Secretary

Re: *Reliability and Resource Adequacy Study Review* – Analysis of Recommendations, Mitigations, and Enhancements of the Labrador-Island Link

Please find enclosed Newfoundland and Labrador Hydro's ("Hydro") report on the Analysis of Recommendations, Mitigations, and Enhancements of the Labrador-Island Link ("LIL") which is filed as a part of the *Reliability and Resource Adequacy Study Review* proceeding.

In correspondence dated August 28, 2023, in response to Hydro's listing of Planned Reports, Studies and Analyses, the Board of Commissioners of Public Utilities ("Board") stated:

> The Board directs Hydro to (i) file a report in the next RRAS Update on the options available to mitigate the duration of LIL outages, including the LIL reinforcements and enhancements that are feasible, their costs and what the resulting risk of outages and their consequences remain after the reinforcement or enhancement and (ii) file a report file a report in the first half of 2024 on the actions and activities it has undertaken or plans to undertake in response to the recommendations in the Haldar reports.[1]

On October 12, 2023, the Board gave Hydro further direction:

> Given the extent and significance of these issues and preliminary findings outlined in the Summary of Findings from L3501/3502 Failure Investigations filed on October 4, 2023, the Board believes a thorough and full assessment required and reiterates its direction on the filing of the report in the first half of 2024. This report should include an update on the further work Hydro summarized was being undertaken in its October 4, 2023 reports, including the scope and schedule for the planned work on studying potential enhancements for the LIL.[2]

Hydro has provided this report in response to the directions outlined above.

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[1] "Newfoundland and Labrador Hydro - Reliability and Resource Adequacy Study Review Planned Reports, Studies and Analyses," Board of Commissioners of Public Utilities, August 28, 2023.
[2] "Newfoundland and Labrador Hydro - Reliability and Resource Adequacy Study Review Planned Reports, Studies and Analyses - Further Comments and Directions," Board of Commissioners of Public Utilities, October 12, 2023.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

SWalsh

Shirley A. Walsh
Senior Legal Counsel, Regulatory
SAW/kd

Encl.

ecc:

Board of Commissioners of Public Utilities
Jacqui H. Glynn
Maureen Greene, KC
Board General

Island Industrial Customer Group
Paul L. Coxworthy, Stewart McKelvey
Denis J. Fleming, Cox & Palmer
Dean A. Porter, Poole Althouse

Labrador Interconnected Group
Senwung F. Luk, Olthuis Kleer Townshend LLP
Nicholas E. Kennedy, Olthuis Kleer Townshend LLP

Consumer Advocate
Dennis M. Browne, KC, Browne Fitzgerald Morgan & Avis
Stephen F. Fitzgerald, KC, Browne Fitzgerald Morgan & Avis
Sarah G. Fitzgerald, Browne Fitzgerald Morgan & Avis
Bernice Bailey, Browne Fitzgerald Morgan & Avis

Newfoundland Power Inc.
Dominic J. Foley
Lindsay S.A. Hollett
Regulatory Email

Analysis of Recommendations, Mitigations, and Enhancements of the Labrador-Island Link

Haldar/Labrador-Island Link Investigation Reports

July 9, 2024

A report to the Board of Commissioners of Public Utilities

Executive Summary

This report is filed as part of the ongoing *Reliability and Resource Adequacy Study Review* proceeding (“*RRA Study Review”)*, which addresses Newfoundland and Labrador Hydro’s (“Hydro”) long-term approach to providing continued reliable service for customers. The first installment of the Reliability and Resource Adequacy Study (“RRA Study”) was filed with the Board of Commissioners of Public Utilities (“Board”) in November 2018 (“2018 Filing”).[1] This was the first of many reports, correspondence, technical conferences, and other activities that have occurred as part of the *RRA Study Review*. Since the 2018 Filing, Hydro has provided reports to the Board in relation to the *RRA Study Review*. These reports include the most accurate information available at the time which Hydro utilizes to determine the infrastructure necessary to meet the growing load forecast and overall power demand for the provincial power grid.

The Labrador-Island Link (“LIL”) is an important component of supply for the Island Interconnected System, having delivered over 2.7 TWh of energy in 2023, and has performed reliably since commissioning, achieving an equivalent forced outage rate (“EqFOR”) of 2.34% for the period April 1, 2023 to June 1, 2024. Given the importance of this asset and its reliable operation on the Island Interconnected System, Hydro has completed several reports related to the analysis of infrastructure and operations for the LIL. These reports were completed by both Hydro and external parties to formulate recommendations on the enhancements and procedures that could help prevent component failures while mitigating the duration and frequency of any subsequent outages. These include:

- LIL Investigation Reports - Hydro-led reviews of LIL-related component failures. The reports include full details about the incidents, including location, cause, duration, repairs, testing and recommendations to prevent and mitigate the effects of outages that result. To date, two reports summarizing six investigations have been reported to the Board.
- “Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads" - two reports completed by Haldar and Associates Inc. (“Haldar”), as commissioned by Hydro, to address the reliability of the LIL in relation to the overhead transmission line design standards.

[1] "Reliability and Resource Adequacy Study," Newfoundland and Labrador Hydro, rev. September 6, 2019 (originally filed November 16, 2018).

This report includes updates to the recommendations laid out in each of these filings. While Hydro has previously reported activities and analyses conducted as a result of both Haldar's and its own recommendations, Hydro has since undertaken and planned several initiatives to support the reliability of the assets.

With the LIL in its early operation, the early level of reliability is anticipated to be lower than the long-term level of reliability. This phenomenon, known as the "bathtub curve," theorizes a relationship between equipment age and failures. The initiatives Hydro outlines below demonstrate prudent asset and risk management, with many of the noted deliverables applying to a multitude of recommendations, thus eliminating the need for singular-focused solutions and allowing for cost-efficient means to sustain the reliability of the LIL.

Hydro has also been asked by the Board to provide a report outlining other enhancements it has considered for the LIL, the associated costs, and the mitigation of frequency and length of outages projected to result from those same enhancements. While the work discussed in the recommendation-based reporting outlined below presents a number of such enhancements, Hydro has further engaged its customers, who have said they are concerned about the cost of living and the impacts of rising electricity rates.[2] The results of Hydro's recent customer engagement study indicate that 80% of customers believe the electricity system is reliable and 87% do not want to pay more for reliability; Hydro must keep this in mind when looking at enhancements to the LIL. Hydro has provided additional details on its analysis and planning that further demonstrate Hydro's focus on ensuring reliable operation of the LIL without undue cost to ratepayers.

In Hydro's 2024 Resource Adequacy Plan ("2024 Resource Plan"),[3] Hydro quantified assumed LIL EqFOR—from 1% (best case) to 10% (worst case) unavailability, with 5% as the Reference Case. While the LIL has performed well in its first year of operation post-commissioning, achieving an EqFOR of 2.34%, additional time is required to fully understand the long-term reliability performance of the LIL. Understanding the long-term reliability performance will help ensure Hydro is making prudent investment decisions about further capital investment. It is important to note that the

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[2] Hydro conducted an engagement survey in the first quarter of 2024 which asked customers their thoughts on service reliability and cost, with the intent of informing future asset management decisions. The results of this survey are available on Hydro's website www.nlhydro.com.

[3] "2024 Resource Adequacy Plan – An Update to the Reliability and Resource Adequacy Study," Newfoundland and Labrador Hydro, July 9, 2024.

recommendations and the level of action taken in terms of mitigating potential issues associated with the LIL, as described in this report, do not in any way impact Hydro's analysis and outcomes of the 2024 Resource Plan, including recommendations associated with Hydro's expansion plan. Said another way, any incremental increase in reliability resulting from actions planned or taken as described in this report would not alter the recommendations made in the 2024 Resource Plan.

Hydro has indicated that, as LIL performance statistics become available in the coming years, the forced outage rate ("FOR") range can be narrowed in future filings.[4] To de-risk the decision to proceed with the integration of new supply and avoid overbuilding, Hydro is taking a "Minimum Investment Required" approach, based on the assumption of 1% EqFOR for the LIL.

Hydro is confident in its engineering and operations planning for all of its assets, including the LIL and remains committed to ensuring the safe, reliable, and environmentally responsible supply of electricity to its customers, consistent with the least cost. Hydro also understands and values the importance additional thought and analysis can provide in the management of major infrastructure, and the financial protection and optimal supply of service to the public. The activities outlined in this report demonstrate Hydro's prudent decision-making in the generation and transmission of power to the people in the province.

[4] "Reliability and Resource Adequacy Study Review – Near-Term Reliability Report," Newfoundland and Labrador Hydro, November 15, 2022.

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List of Appendices

1.0 Introduction

Through the *RRA Study Review*, the Board has requested updates relating to activities Hydro has conducted to analyze and enhance the reliability of the LIL.

As part of the proceeding, Hydro committed to undertake an assessment of the as-built structural reliability of the LIL with respect to the CSA 60826 – Design Criteria of Overhead Transmission Lines standard.[5]

To satisfy this commitment, Hydro commissioned Haldar to complete the "Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads" report ("Phase One Report"). The main intent of the Phase One Report was to present the impact two types of ice would have on the LIL – glaze ice, which results from freezing precipitation, and rime ice, which results from in-cloud precipitation. The report, along with Hydro's supplementary response, was provided to the Board in March 2021.[6] In the report, Haldar presented several recommendations to Hydro which Haldar believed would help prevent failures and mitigate outages, if cost-efficient to implement. Hydro completed a preliminary assessment in its summary report filed with the Phase One Report followed by responses to Haldar's recommendations and additional steps deemed necessary outlined in its update to the Board.[7]

Following receipt and analysis of the Phase One Report, Hydro commissioned Haldar to complete a second report ("Phase Two Report"), which was provided to the Board in December 2021.[8] This report presented further analysis to address certain recommendations contained within the Phase One Report and also provided further recommendations, many of which stemmed from the work conducted in response to those in the previous report. As it did for the Phase One Report, Hydro provided a summary outlining the recommendations followed by additional correspondence outlining the related actions it had planned to take concerning the same.

[5] "Reliability and Resource Adequacy Study Review – 2022 Update," Newfoundland and Labrador Hydro, October 3, 2022.
[6] "Labrador-Island Link Reliability Assessment – Summary Report," Newfoundland and Labrador Hydro, March 12, 2021.
[7] "*Reliability and Resource Adequacy Study Review* – Assessment of Labrador-Island Link Reliability – Further Information," Newfoundland and Labrador Hydro, April 30, 2021.
[8] "Reliability and Resource Adequacy Study – Additional Considerations of the Labrador-Island Link Reliability Assessment and Outcomes of the Failure Investigation Findings," Newfoundland and Labrador Hydro, December 22, 2021.

In addition to these reports, Hydro has filed two LIL Investigation Report documents,[9,10] which outlines the investigation of six incidents that have occurred on the LIL as a result of equipment issues. In addition to details surrounding the cause of these incidents and the remedies taken to restore service, Hydro provides its recommendations for how infrastructure and/or procedures can be strengthened to prevent similar incidents in the future.

This report outlines a summary and status of the recommendations and actions Hydro has undertaken in response to its LIL investigations. Also included in the report is information regarding enhancements to the reliability of the LIL, as requested by the Board. Appendix A includes further detail regarding the recommendations stemming from each LIL Investigation and the Phase One Report and Phase Two Report, organized first by investigation or report and then by recommendation.

It should be noted that no remaining Haldar recommendations are outstanding, as all are either considered addressed appropriately at this time or are recommendations that will be addressed through the LIL Investigations. This has been outlined in Appendix A.

2.0 LIL Reliability

With the LIL in its early operation, the early level of reliability is anticipated to be lower than the long-term level of reliability, due to expected sources of potential issues associated with new assets, such as defective components or manufacturing issues. This phenomenon is known as the "bathtub curve." This concept, which theorizes a relationship between equipment age and failures, has been presented by The Liberty Consulting Group ("Liberty") in previous reliability assessments. Despite expectations of unavailability being at the higher end of this range early in its commissioned operation, the LIL has experienced good reliability performance, achieving an EqFOR of 2.34% for the period April 1, 2023 to June 1, 2024, which is well within Hydro's long-term planning reliability assumptions of 1% to 10%, and

[9] "*Reliability and Resource Adequacy Study Review* – Labrador-Island Link Failure Investigation Reports," Newfoundland and Labrador Hydro, May 31, 2021.
[10] "Summary of Labrador-Island Link Failure Investigations- Line L3501/2," Newfoundland and Labrador Hydro, October 4, 2023.

better than Hydro's base planning assumption of 5%.[11] As the LIL remains in the first phase of the bathtub curve in the first several years of operation, Hydro expects that the EqFOR will change as issues are identified and addressed and mitigations are implemented.

> ***Equipment failures in relation to equipment age generally exhibit a "bathtub-shaped curve." Incidents of failure tend to be high when equipment is new and again after 30-50 years, depending on equipment type***[12]
>
> ***-Liberty, Supply Outages and Power Review 2014***

As shown in Figure 1, the bathtub curve has three regions—the first region represents the early years of an asset's life and has a decreasing failure rate due to early failures that are found and corrected contributing to improved reliability. The middle is a constant, lower instance of failure rate due to the normalized frequency of expected failures, and the last region represents the later years of an asset's useful life and shows an increasing failure rate due to age and end-of-life failures. The first region or early years of a utility asset's lifecycle is generally several years long, while the middle period can often be decades long, as is the case for the LIL.

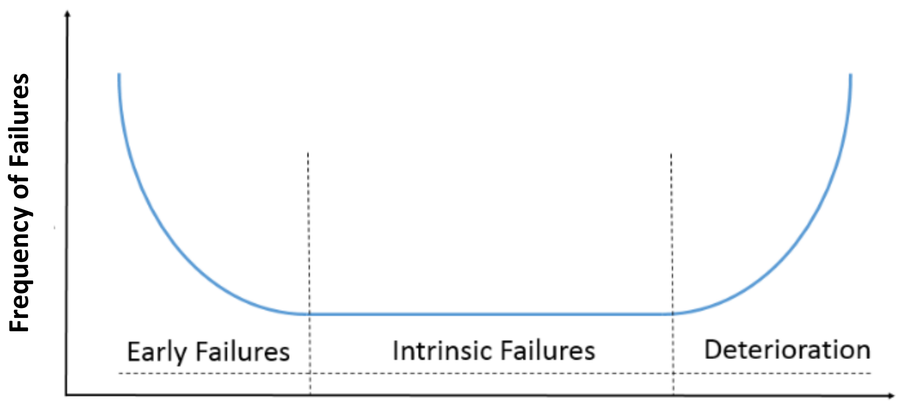

Figure 1: Bathtub Curve[13]

[11] Hydro has established a new reliability metric "EqFOR" to measure the performance of this asset as it relates to the supply of electricity to the Island. This EqFOR measures the percentage of time that the LIL bipole is unable to deliver its maximum continuous rating to the Island due to forced outages, derates, or unplanned monopole outages. The effect of deratings and unplanned monopole outages is converted to equivalent bipole outage time using the same methodology as outlined above for generating units.

[12] "Supply Issues and Power Outages Review, Island Interconnected System, Executive Summary of Interim Report," The Liberty Consulting Group, April 24, 2014, sec. D, p. 57.

[13] Carroll, James & McDonald, Alasdair & Barrera, Oswaldo & Mcmillan, David & Bakhshi, Roozbeh. (2015). Offshore Wind Turbine Sub-Assembly Failure Rates Through Time.

Early component failures on the LIL have largely arisen due to items that were not considered during project design that have come to light during testing and early years of operation. Examples of such items include aspects of LIL software, LIL hardware, and those applicable to the overland transmission line. In terms of LIL software, the commissioning software was installed in April 2023 and has been operating since that time. The final version of the software, which includes non-essential updates which were appropriately moved to a final version, has passed factory acceptance testing and is scheduled to be installed and commissioned in the third quarter of 2024.

For LIL hardware, all DCCT[14] noise mitigations have been implemented and therefore issues around noise have been resolved. Replacement of DCCTs to mitigate performance issues that include measurement drifting in cold temperature conditions is ongoing, with two DCCTs replaced and two remaining DCCTs to be replaced in the third quarter of 2024. In addition, Hydro is in the process of replacing turnbuckles to address issues related to line galloping, with all priority areas completed in 2023 and the majority of the remaining work to be completed in 2024. To date, 340 turnbuckles, or approximately 26% of turnbuckles identified for replacement, have been replaced. As stated earlier, Hydro is taking action to understand and address the root causes of the overland transmisssion line component failures.

2.1 LIL Reliability and its Impact on Reliability and Resource Adequacy

In the context of the *RRA Study Review*, the reliability of the LIL is a key consideration in terms of supply requirements for the Island Interconnected System. To this end, Hydro is undertaking efforts to understand the FOR of the LIL based on operational data in consideration of the bathtub curve, the issues experienced during early operation, and the engineering solutions that are being implemented to mitigate issues and maintain reliability.

In Hydro's 2024 Resource Plan, for system planning purposes, Hydro quantified assumed LIL reliability using EqFOR—from 1% (best case) to 10% (worst case) unavailability, with 5% as the Reference Case.[15] Hydro indicated that as LIL performance statistics become available in the coming years, the EqFOR range can be narrowed in future filings.[16] To de-risk the decision to proceed with the integration of new

[14] Direct Current-Current Transformer ("DCCT").
[15] The LIL EqFOR for the period April 1, 2023 to June 1, 2024 was 2.34%.
[16] *Supra,* f.n. 4.

supply and avoid overbuilding, Hydro is taking a "Minimum Investment Required" approach, based on the assumption of 1% EqFor for the LIL.

Hydro continues to compile and analyze reliability and outage data on the LIL. It is noted that this data is complicated in consideration of the relatively brief time since commissioning and the complexities of operational data before commissioning. However, Hydro will continue to monitor performance and, through the activities discussed herein, maintain the reliability of the LIL and all system assets consistent with good utility practices. Through these efforts, sustained LIL reliability can be expected as the LIL transitions to the second phase of the bathtub curve. It is the projected FOR for this period that should be used by Hydro for long-term planning purposes.

3.0 LIL Investigation Reports

3.1 Summary of Investigations and Scope of Incidents

The LIL is a 900 MW high-voltage direct current ("HVdc") transmission line that carries electricity from the Muskrat Falls Hydroelectric Generating Station ("Muskrat Falls") to the Soldiers Pond Terminal Station ("Soldiers Pond"). Line L3501/2[17] is the 350 kV HVdc overland transmission line portion of the LIL, also referred to as Pole 1 and Pole 2 of the line, respectively. Although the LIL is one transmission line, it runs through vastly different geographic and climatic conditions with large variations in terms of wind and ice. As a result, the line consists of many different types of towers, each designed for the specific conditions of each geographic region. The LIL is also located and operates in areas of harsh terrain; it is subject to heavy wind and ice loads and experiences multiple winter seasons and weather events.

As shown in Figure 2, the overland transmission line is a bipole line with a single conductor per pole, dual electrode conductors for a portion of the line,[18] and an optical ground wire ("OPGW") communication cable. The lines are supported by galvanized steel lattice towers. The LIL consists of 3,223 towers, of which 10% (327) are dead-end insulator assembly towers and 90% (2,896) are suspension insulator assembly towers.

[17] L3501 and L3502 are referred to as Poles 1 and 2 from an electrical perspective, respectively, whereas the full overland transmission line from a structural perspective is referenced as L3501/2.

[18] The electrode conductor system in Labrador is a redundant system that consists of two conductors supported on the 1,229 transmission line steel towers of the LIL and provides a connection between the converter station in Muskrat Falls to the grounding site in L'Anse au Diable. The electrode conductor system on the Island provides a connection between the converter stations in Soldiers Pond and the grounding site in Dowden's Point.

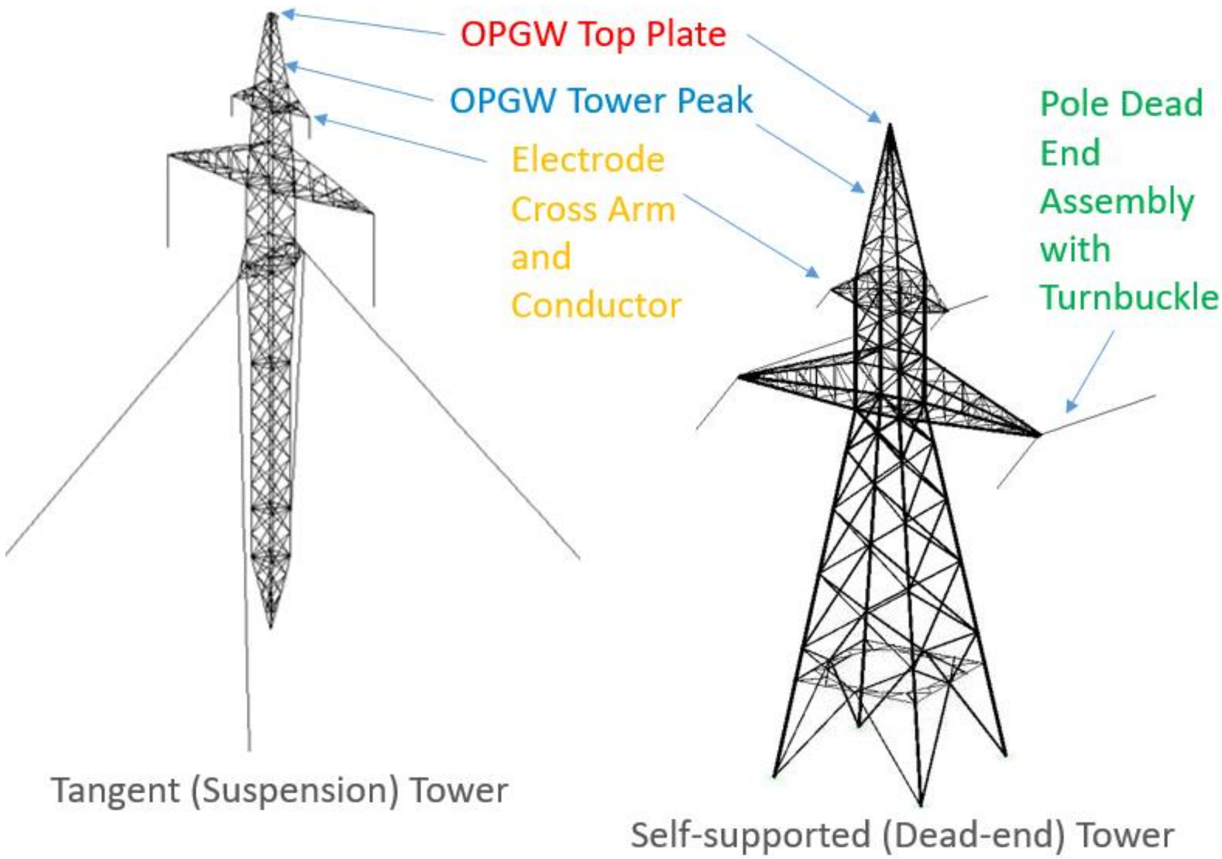

Figure 2: L3501/2 Towers Showing Components

As is expected during early operation, Hydro has encountered hardware damage to the LIL over the past three winters caused by wind and ice during harsh weather events, particularly in the areas along the LIL where Hydro has observed microclimates. In each instance, root causes were determined through an extensive investigation process, immediate actions were taken to repair the damage, and recommendations were made to reduce the risk of customer impact in the future.

To date, Hydro has provided two reports to the Board which have outlined six incidents on the L3501/2 portion of the LIL that have led to an investigation. In its investigation reports, Hydro provides details about the location and cause of the incidents, restrictions on operations or impact on customers (if any), repair and testing activities to return the LIL to optimal operation, and recommendations on mitigations to prevent similar LIL issues in the future.

The six completed investigations have been summarized in Table 1.

Table 1: Summary of LIL Investigations

	Turnbuckles[19]		**OPGW Tower Peaks**	**Electrode Cross Arms and Conductors**		**OPGW Top Plates**
Date	February 2021	December 2022	December 2022	January 2021	December 2022	December 2022
Zone/Location	Southern Labrador	Southern Labrador and the west coast of Newfoundland	Southern Labrador	Central Labrador	Central Labrador	Central Newfoundland
Line Component Damaged[20]	Turnbuckles within Pole Dead-end Assembly	Turnbuckles within Pole Dead-end Assembly	OPGW Tower Peak Steel	Electrode Cross Arm Steel and Grounding System Conductors (wire)	Electrode Cross Arm Steel and Grounding System Conductors (wire)	Tower Plates located at the OPGW connection
Number of Structures[21]	2 of 1,308	3 of 1,308	2 of 3,223	36 of 1,229	3 of 1,229	2 of 502
Failure Rate	< 1%	< 1%	< 0.1%	3%	0.2%	0.4%
Customer Impact[22]	No	No	No	No	No	No
Long-Term Reliability Impact[23]	None	None	None	None	None	None
Root Cause	Galloping		Unbalanced ice loads due to uneven ice shedding[24]			Detailed bolt design calculation error for the A3 Tower Top Plate

[19] Turnbuckles are present only on dead-end towers (327 or 10% of towers), with each tower having four turnbuckles.
[20] Please refer to Figure 2 for a diagram of the towers and components.
[21] There are a total of 3,223 towers overall; however, the number of specific subcomponents and similar tower types varies. This represents the number of structures damaged out of all similar tower types.
[22] There was no customer impact associated with these issues; however, in certain cases, outages to the LIL were taken to complete repairs, from a work safety perspective.
[23] The expected impact of each type of incident on the long-term reliability of the LIL once recommended action items have been completed.
[24] For the OPGW Tower Peaks, although the ice load was not above the max ice design criteria, the unbalanced ice loads were higher than the design loads. For the January 2021 Electrode Cross Arm and Conductors, the ice load was above max ice design criteria and unbalanced ice design criteria. For the December 2022 Electrode Cross Arm and Conductors, the ice load was at or above the max ice design criteria and above unbalanced ice design criteria.

These incidents were all localized issues impacting a small amount of specific transmission line components on a small number of structures. The overall tower itself was not impacted; just smaller components of the tower as outlined in Figure 2. In addition, each incident impacted a small number of the overall total towers, as outlined in Table 1. For instance, in the case of the OPGW tower peaks, this incident impacted only two structures or less than 0.1% of all structures and, in this case, the LIL performed as expected under the loading conditions experienced. The issues outlined below did not affect Hydro's ability to provide customers on the Island with reliable service during the period and all critical repairs associated with these incidents have been completed, as noted in Table 2.

Although these issues impact a small amount of specific transmission line components, Hydro is taking proactive steps to mitigate the risk of customer impact in the long term, particularly where capital expenditures will improve the long-term performance of the LIL.

Specifically, for turnbuckle damage related to galloping, Hydro is mitigating possible future issues and any potential customer impact by replacing all 1,308 turnbuckles, with critical areas completed in 2023 and the majority of the remaining work scheduled to be completed in 2024. Based on the outcome of its galloping study, Hydro is also installing airflow spoilers on certain sections of the LIL to control galloping and mitigate further damage to turnbuckles. This scope of work is approximately 40% complete and Hydro is currently mobilizing planned work for 2024.

For the remaining incidents, damage was isolated to system communications cables and the electrode conductor system, which are not required for power to flow and, as a result, would not cause a prolonged power interruption. In these cases, the ice load on the line was above the maximum ice design load or the unbalanced ice load design in that area, causing the damage. To address these issues, Hydro has increased real-time monitoring of the ice conditions along the transmission line by installing a weather station in the Labrador Straits, with another slated for installation in central Labrador in 2025. Hydro has also increased line patrols and the collection of field observation data, as maintenance activities are performed. During maintenance activities, Hydro is proactively replacing any identified components that are deemed required for replacement arising from the investigation. Hydro is studying the unbalanced ice loads, and changes in weather patterns and is engaging external consultants to determine the potential design changes to facilitate further informed decision-making for operations in the future. This report, including design modification for certain components and cost estimates for supply and construction, is expected to be complete by the fourth quarter of 2024.

Recommendations included in any investigation report are made utilizing all information available at the time of the investigation. Hydro also utilizes internal and external data collection to map trends and conducts infrastructure and environmental scans that further inform its practices and procedures.

As new information becomes available, Hydro will incorporate this knowledge into its decision-making process and determine any appropriate adjustments to its ongoing and planned activities. These practices ensure Hydro's recommendations with respect to an issue manage the balance of providing safe, reliable energy, in an environmentally responsible manner, without incurring unnecessary costs.

Table 2 includes a summary of the recommendations stemming from the LIL investigations, organized by root cause, and a status update on each. Recommendations which are complete are highlighted in green with recommendations nearing completion are highlighted in yellow. The table also references each recommendation to the LIL Investigation or incident that the actions are mitigating. Lastly, the table references each recommendation to the corresponding Haldar recommendation that the actions are also serving to address.

Additional details, including a brief synopsis of each of the investigations and root causes, along with an overview of all recommendations, organized by report are included in Appendix A.

Table 2: Summary and Status of LIL Investigations Recommendations

<table>
<tr><th>Recommendation</th><th>Status Update</th><th>Estimate Timeline of Final Completion</th><th>LIL Investigation</th><th>Haldar Recommendation</th></tr>
<tr><td colspan="5">Root Cause: Unbalanced Ice Loads</td></tr>
<tr><td rowspan="2">1. Ice Monitoring and Removal</td><td>Installed a real-time monitoring test span along with a weather station in Labrador Straits in 2021.

Helicopter patrols currently occur six times a year, with four taking place during the winter period. Environment and Climate Change Canada provides data which Hydro uses to inform the scheduling of additional patrols.

Weather preparedness meetings are held in advance of forecasted storms with potential actions taken including placing crews on stand-by, locating crews in alternate locations for a faster response, booking post-storm helicopter patrols, and verifying contractor availability.

Developed and implemented a standardized approach and reporting protocols to collect and gather real-time ice data.

Identified training opportunities for employees, as well as key information that will help further inform protocols and procedures.</td><td>Complete</td><td rowspan="2">L3501/2 Tower and Conductor Damage – Appendix A Section 2.1.1

Turnbuckle Failures Str. 1872, 1806, and 1014 – Appendix A Section 2.3.2

OPGW Tower Peaks – Str. 1230 and 1231 – Appendix A Section 2.4.1

Electrode Conductor – Str. 514 and 515 – Appendix A Section 2.6.2</td><td rowspan="2">Phase One – Unbalanced Ice Loads – Appendix A Section 3.1.2

Phase Two – Wind Speed Measurements – Appendix A Section 3.2.1

Phase Two – Section 3A Towers – Appendix A Section 3.2.2

Phase Two – Remote Monitoring of LIL – Appendix A Section 3.2.3

Phase Two – A1 Towers – Appendix A Section 3.2.4

Phase Two – Statistical Analysis and Correlation Effects of Wind and Ice Loads – Appendix A Section 3.2.5</td></tr>
<tr><td>Another real-time weather station will be installed in central Labrador in 2025.

Monitoring equipment that will be attached directly on the line will be installed in three locations, beginning in 2025.</td><td>Scheduled to be completed in 2025.</td></tr>
<tr><td>2. Engineering Studies Project – Tower Modifications and Design</td><td>Hydro is undertaking engineering assessments under its Engineering Studies Project to evaluate unbalanced loading design across the entire length of the line.

Following these assessments, consultants will be secured to provide cost estimates and designs for any appropriate tower modifications that will meet recommendations regarding unbalanced ice loading.

This assessment will cover multiple areas and identify modifications, if necessary, such as:
1. Whether additional bracing is needed to strengthen the capacity of the electrode cross arm;
2. Whether a change to the damper design or a new technical specification is recommended;
3. Whether an increase in the distance between the insulator and conductor in the electrode conductor is warranted; and
4. Whether Hydro should strengthen the OPGW tower peaks to withstand higher unbalanced ice loads.</td><td>Ongoing with all engineering assessments and the majority of cost estimates scheduled to be complete in Q4, 2024.</td><td>L3501/2 Tower and Conductor Damage – Appendix A Sections 2.1.2 and 2.1.3

OPGW Tower Peaks – Str. 1230 and 1231 – Appendix A Section 2.4.2

Electrode Conductor – Str. 514 and 515 – Appendix A Sections 2.6.4 and 2.6.6</td><td>Phase One – Unbalanced Ice Loads – Appendix A Section 3.1.2

Phase One – Correlation Study – Appendix A Section 3.1.4

Phase Two – Wind Speed Measurements – Appendix A Section 3.2.1

Phase Two – Section 3A Towers – Appendix A Section 3.2.2

Phase Two – Statistical Analysis and Correlation Effects of Wind and Ice Loads – Appendix A Section 3.2.5</td></tr>
</table>

Recommendation	Status Update	Estimate Timeline of Final Completion	LIL Investigation	Haldar Recommendation
	Tower modification design and cost estimates for supply and construction items 1, 3 and 4 above are scheduled to be completed in Q4 2024. Tower modification design for item 2 above is also scheduled to be complete by Q4, 2024 with cost estimates to follow, if necessary, at a later date.			
Root Cause: Unbalanced Ice Loads (continue)				
3. Strengthen Suspension Clamp Design	Three different types of clamps have been procured by Hydro and will be installed on the line in 2024 in locations where damage occurred. Hydro began conducting regular inspections of the clamps to ensure that any issues were identified and necessary refurbishments or repairs were completed in a timely manner. These inspections will also help compare the performance of the clamp types.	Scheduled for completion in 2024.	L3501/2 Tower and Conductor Damage – Appendix A Section 2.1.5 Electrode Conductor – Str. 514 and 515 – Appendix A Section 2.6.5	N/A
4. Establishment of Protocols for Evidence Collection Post-Failure	Implemented staff protocols for evidence collection after a transmission line failure, formalized in February 2024 based on existing practices and lessons learned.	Complete	Electrode Conductor – Str. 514 and 515 – Appendix A Section 2.6.1	N/A
5. Completion of Detailed Inspections on Cable and Clamp in Critical Areas	Hydro, through its preventative maintenance program, has identified multiple opportunities for clamp and conductor inspection, with refurbishment or replacement of parts made according to findings.	Complete	Electrode Conductor – Str. 514 and 515 – Appendix A Section 2.6.3	N/A
Root Cause: Galloping				
1. Air Flow Spoilers	Hydro is currently completing a multi-year capital project to install air flow spoilers per this recommendation in areas where damage due to galloping has occurred, or galloping has been observed. Hydro had identified the sections of the line which had the most critical need for air spoilers and completed those first.	High-priority areas are complete with the majority of the remaining installations scheduled to be complete by Q4 2024.	L3501/2 Pole Assembly Turnbuckle Failure -Appendix A Section 2.2.4 L3501/2 Pole Assembly Turnbuckle Failure -Appendix A Section 2.2.1 Turnbuckle Failures Str. 1872, 1806, and 1014 – Appendix A Section 2.3.1 L3501/2 Tower and Conductor Damage – Appendix A Section 2.1.4	N/A
2. Galloping Study	Study to determine the geographical areas and sections on the line that are prone to galloping to identify the areas where airflow spoilers would be best installed - see "1. Air Flow Spoilers" above.	Complete	L3501/2 Pole Assembly Turnbuckle Failure -Appendix A Section 2.2.2	N/A

Recommendation	Status Update	Estimate Timeline of Final Completion	LIL Investigation	Haldar Recommendation
3. Alternate Dead-End Assembly Design	Hydro is replacing turnbuckles with extension straps and will continue to do so for the entire line. Installation in priority locations was completed first.	Priority locations are complete with the majority of the remaining installations to be completed by Q4 2024.	L3501/2 Pole Assembly Turnbuckle Failure -Appendix A Section 2.2.4 Turnbuckle Failures Str. 1872, 1806, and 1014 – Appendix A Sections 2.3.3 and 2.3.4	N/A
Root Cause: Design Issue of A3 Tower Type				
1. Improvement of Tower Connection for A3 Tower	Consultation with a tower designer led to the re-design of the connection detail for the A3 tower type, adding steel reinforcement to the tower to transfer the load from the top connection to the sides. Tower design work along with an assessment of installation procedures for the redesigned connection was completed at the end of 2023.	Complete	OPGW Top Plates – Str. 2135 and 2136 – Appendix A Section 2.5.1	N/A
2. Evaluation of Connection Types in non-A3 Towers	Hydro evaluated the connection in all remaining tower types, completed in 2023. No issues were identified for the A1 tower type, which represents over half of all tangent towers. The remaining tower types could see loads which exceed the connection design and therefore analysis was completed in 2024 on a structure-by-structure basis noting 63 towers, or only 2% of the total of all tangent towers, have the potential to experience these issues.	Complete	OPGW Top Plates – Str. 2135 and 2136 – Appendix A Section 2.5.2	N/A
3. Cost Estimates for Strengthening OPGW Top Plate	Estimates are currently being completed for the necessary repair work to strengthen the connection of the top plate of the OPGW suspension on the A3 towers and the 63 non-A3 towers.	Estimates for necessary repair work are expected in Q4 2024.	OPGW Top Plates – Str. 2135 and 2136 – Appendix A Section 2.5.3	N/A

3.2 Ongoing Investigations

Investigations are ongoing for two incidents that occurred in 2024; Hydro will communicate the findings of these investigations to the Board upon completion. These incidents and their associated investigations are described below.

3.2.1 OPGW Tower Peaks – Central Newfoundland

During an icing event on February 9, 2024, there was damage to Hydro's Transmission Line L3501/2. The issues occurred on eight structures in three groups: 2543 to 2545, 2596 to 2599, and 2620 and were similar in nature, the top peak of the tower where the OPGW is connected sustained damage; however, the OPGW wire itself did not physically fail. This represents a failure rate of 0.2% (8 of 3,223 tower peaks). While damage to the OPGW tower peaks will not cause extended power outages, for safety reasons, outages were taken to complete the repair work. These structures are all located in central Newfoundland.

This investigation is ongoing. While the conclusions and recommendations are not finalized, the incident is similar to the investigation "OPGW Tower Peaks – Str. 1230 and 1231" detailed in Table 1 and Table 2 as well as Appendix A, Section 2.4.

3.2.2 Electrode Cross Arm, Conductor and OPGW Tower Peak – Southern Labrador

On the morning of March 30, 2024, Pole 2 tripped followed by a trip on Pole 1. Line patrol determined that the electrode conductor was broken and damaged during an ice storm at several locations between Structures 1218 to 1228. In some locations, the electrode conductor was touching or close to the pole conductor, which would explain the line trip. There was also damage to the steel lattice towers at the electrode cross arm and OPGW tower peaks. There was damage on a total of 12 structures representing a <0.4% failure rate (12 of 3,223 towers affected). There was no customer impact as a result of the incident; however, an outage was required to clear the damaged conductor from the line, while repairs were being completed. These structures are all located in southern Labrador.

This investigation is ongoing. While the conclusions and recommendations are not finalized, the incident is similar to the investigation "L3501/2 Tower and Conductor Damage" detailed in Table 1 and Table 2 along with Appendix A, Section 2.1. Material testing of the conductor is included in this investigation and may provide additional insight into the cause of the issue.

4.0 Further Mitigations and Enhancements

In this report, Hydro is providing further information on additional initiatives it is taking to determine potential enhancements that can be made to help prevent issues and mitigate outage effects from, the LIL. The Board requested this information in its letter dated October 12, 2023.[25]

Hydro believes that in many instances, the work that has been outlined above will help to mitigate LIL outage duration and frequency. Further to that, Hydro has identified additional activities to examine and

[25] "Newfoundland and Labrador Hydro – Reliability and Resource Adequacy Study Review Planned Reports, Studies and Analyses -Further Comments and Directions," Board of Commissioners of Public Utilities, October 12, 2023.

implement enhancements for the LIL that sustain planned reliability without excess cost, in line with customer feedback.

4.1.1 Engineering Studies

Since its commissioning in April 2023, Hydro has gained valuable insight into LIL operations and potential failure modes, as detailed in Section 3.0 of this report. Using Hydro's operating experience and recommendations from its investigations, supplemented by the recommendations made by Haldar, Hydro has identified three potential reinforcements to LIL assets to sustain reliability, address common failure modes, and mitigate risks to the Island Interconnected System. While these potential reinforcements have been identified, further engineering assessment is required to determine the benefits, costs, schedule, and feasibility of these modifications. These include:

- Review of unbalanced ice loads for the entire line length to determine appropriate design unbalanced ice loading, followed by design and cost estimates for tower design modifications to meet unbalanced design loads;
- Feasibility assessment and cost estimates for installation of mid-span structures[26] to reduce tower loading in critical areas; and
- Engineering design and cost estimates to relocate electrode conductors from towers to wood poles in some sections, to reduce tower loading, improve access and logistics, and minimize outages to address electrode line issues in critical areas.

These assessments are planned for completion in the fourth quarter of 2024, at which point Hydro will be in a position to evaluate these projects based on their anticipated reliability benefits and their estimated costs.

4.1.2 Restoration Plans and Operational Strategy

In addition to engineering studies to inform potential reinforcements to mitigate the risk of component failures and outages, Hydro plans to engage a consultant in 2024 to review Hydro's restoration plans, including review and development of specific restoration plans for a variety of potential and previously experienced scenarios. It is expected that this review will include the identification of alternative

[26] A mid-span structure is a new tower that would be installed between two existing structures which reduces tower loading on adjacent towers, especially during icing events

restoration approaches that can be selected based on the situation for the most efficient and effective execution of the work. Restoration plans will consider geographic and weather challenges. Restoration plan reviews will include estimates of the time to effect the repairs as well as time challenges and opportunities for restoration duration and provide cost and benefit information to identify incremental investment in restoration time improvement and quantify the associated benefits.

4.1.3 Expansion Plan and Resource Adequacy Plan

On July 9, 2024, Hydro filed its 2024 Resource Plan, including its expansion plan for the Island Interconnected System. The reliability of the LIL remains a key consideration in assessing resource adequacy and determining the level of system expansion required to meet the growing needs of the system. More specifically, the assumed EqFORs modelled in Hydro's expansion plan impact the level of planning reserve margins required to maintain appropriate reliability criteria. To gain an understanding of how ranges of LIL reliability impact system expansion requirements, Hydro has modelled LIL EqFOR ranging from 1% to 10%. With the LIL in operation, the early level of reliability is anticipated to be lower than the long-term level of reliability. While Hydro does not currently have sufficient operating experience with regards to the LIL to determine what EqFOR is appropriate for long-term planning, Hydro's recommended expansion plan is based on a "Minimum Investment Required" approach, and assumes a 1% EqFOR for the LIL. The impact of this is simply that a highly reliable line of 1% would require minimal additions to the system and therefore is not overestimating the system's needs. If the LIL is not as reliable as 1% in the long term, Hydro could need additional resources. The resource plan; however, has common first elements in both the Minimum Investment Required and the Reference Case.[27] This approach reduces the risk of not utilizing the Reference Case for the expansion proposal.

As Hydro gains further insight into LIL operation and reliability, Hydro will further understand the long-term reliability of the LIL, which will help determine long-term EqFORs for future planning and help inform subsequent expansion requirements. It is worth noting; however, that improving the reliability of the LIL provides diminishing returns with regard to the avoidance of the expansion investment required. This is evidenced by the following example: the difference in on-Island firm generation requirements between an assumed 1% EqFOR and a hypothetical 0% FOR, based on Hydro's 2023 Load Forecast, is

[27] Hydro's Reference Case in its 2024 Resource Plan assumes a higher degree of load growth than the "Minimum Investment Required" and assumes a LIL EqFOR of 5%.

approximately 50 MW, compared to a difference of approximately 140 MW when comparing FORs of 1% and 5%.[28]

Therefore, it is prudent and necessary that Hydro fully understand the current level of reliability of the LIL, and consider the costs and benefits of improving LIL reliability against those of on-Island supply expansion when making investment decisions, all while taking into account concerns expressed by customers regarding the cost of living and the impacts of rising electricity rates.

5.0 Conclusion

Hydro continues to ensure optimal reliability of the LIL, and all of its assets, by utilizing the most up-to-date information available to manage its infrastructure.

Each of the overland transmission line failure incidents and subsequent investigations provide Hydro with critical data and information to better understand, and plan for, how the LIL will operate in the future. Through operational experience and strategic monitoring, Hydro will gain an understanding of the effectiveness of potential investments to upgrade LIL structures. Such investments have and will be made in consideration of risk and value-based assessments that will be better informed by other critical factors that impact system reliability, including response times for emergency repairs.

The ongoing, completed, and planned work Hydro has undertaken in relation to both internal and external recommendations, as well as in making general enhancements to the LIL, demonstrates a prudent, customer-focused approach. Each activity helps to satisfy multiple outcomes and goals.

Monitoring activities (e.g., weather stations, online infrastructure, patrols, external data collection, communications/reporting/review processes etc.), will not only help Hydro employees best prepare the LIL before oncoming storms to reduce outage occurrences but will also help shorten repair duration and inform proper load considerations that will be utilized in future enhancement planning.

Replacement and upgrading of equipment (e.g., turnbuckles, extension straps, air flow spoilers, dampers, clamps, etc.) have allowed for the mitigation of effects due to climatological factors and

[28] Reserve margins are dependent on peak system demand; however, the relationship between required reserve margins and LIL reliability remains consistent at varying levels of peak demand.

helped prevent reliability issues stemming from phenomena exacerbated by weather events, such as galloping.

Analysis and studies, both internal and external, have also provided key information which has informed future planning but also has helped Hydro avoid making unnecessary expenditures (e.g., tower and foundation adjustments) in sustaining the reliability of the LIL. Further studies, such as the engineering studies and restoration plan and operational strategy review being completed in 2024, will help Hydro understand the costs and benefits of various options to further reinforce the LIL assets and will help inform options to improve response to LIL outages to mitigate the impacts to customers.

Hydro has made considerable progress in satisfying all recommendations stemming from reporting and investigations and will continue to introduce new improvements when prudent, as it does for all system assets and in accordance with good utility practice.

Appendix A

Summary of Labrador-Island Link Investigation and Haldar Report Recommendations

Contents

1.0 Purpose

The purpose of this appendix is to provide further detail regarding the recommendations stemming from each LIL Investigation and the Haldar Phase One Report and Phase Two Reports, organized first by investigation or report and then by recommendation. It should be noted that no remaining Haldar recommendations are outstanding, as all are either considered complete or are being addressed through the LIL Investigation recommendations. In addition, all recommendations stemming from completed LIL Investigation reports have either been addressed or are anticipated to be addressed by the end of 2025.[1]

2.0 LIL Investigation Reports

2.1 L3501/2 Tower and Conductor Damage (January 2021)

This damage was caused by a freezing rain storm event. Precipitation during the weather event led to damage to electrode cross arms and electrode conductors on the portion of the LIL located in central southeastern Labrador. 36 towers were reported to have sustained damage after the storm event, which represents a failure rate of only 3%. There was no customer impact associated with the incident, which occurred in central Labrador.

The investigation report was originally submitted to the Board on May 31, 2021.[2] Full details of the incident can be found in the report; however, the general conclusion on the root cause of the issue was that ice loads experienced at the site were above the design ice load.

Hydro made five recommendations in this report, a description of and update on each is outlined below.

2.1.1 Ice Monitoring and Removal

Hydro identified that monitoring ice levels and removing ice before accumulating to a point where it could overload the line, would be beneficial to reduce the risk of future, similar occurrences. This

[1] Projects stemming from Hydro's engineering assessment of the UBI loading design of the full length of the line and assessments of the design of the OPGW suspension top plates are subject to future decisions by Management and the Board of Directors and are not included in this timeline.
[2] "Failure Investigation Report - L3501/2 Tower and Conductor Damage – Icing Event January 2021 in Labrador," Nalcor Energy, May 28, 2021, was filed in "*Reliability and Resource Adequacy Study Review* – Labrador-Island Link Failure Investigation Reports," Newfoundland and Labrador Hydro, May 31, 2021.

initiative could include line patrols and additional real-time monitoring equipment. Ground patrol was also outlined as a potential option for this recommendation.

Since that time Hydro has made significant advancements in this area. As previously reported in investigation reports and through the *RRA Study Review*, Hydro installed a real-time monitoring test span, which monitors ice loads, along with a weather station, next to the LIL in the Labrador Straits in 2021. The weather station measures wind, which was not a factor in this situation, but is otherwise a consideration for optimal operation, and is discussed in the update on Haldar recommendations found in Section 3.0. After its installation, the station experienced damage which has rendered it inoperable at this time; however, its repair is planned for 2024. Another real-time weather station will be installed in central Labrador in 2025.

In addition to these stations, monitoring equipment attached directly to the line will be installed in three locations, beginning in 2025. In addition to ice loads, this equipment will help measure wind loads, vibration, and galloping, which have all been identified as potential causes of damage. This weather monitoring equipment will allow Hydro to assess ice accumulations to inform removal and preparedness activities and also provide Hydro with ongoing data that it can use in its analysis of trends and environmental effects that could help Hydro prevent failures or mitigate their effects.

Helicopter patrols currently occur six times a year, with four taking place during the winter period to provide insight into ice accumulation levels. As well, Environment and Climate Change Canada also provides data that can highlight upcoming weather that could affect LIL assets, which Hydro uses to inform the scheduling of additional patrols. To expedite response time, weather preparedness meetings are held in advance of forecasted storms. Based on storm information and the risk to the line, several actions may be taken including placing crews on standby, locating crews in alternate locations for a faster response, booking post-storm helicopter patrols, and verifying contractor availability.

Hydro has developed and implemented a standardized approach and reporting protocols to collect and gather ice data in the field from those who witness higher ice accumulation allowing for a near real-time understanding of potential issues which could lead to additional mitigation efforts.

Hydro has also identified training opportunities for employees, as well as key information that will help further inform protocols and procedures to determine how to safely complete ice removal in this area.

Status: The majority of Hydro's recommendations for ice monitoring and removal are complete with the exception of the second weather station and monitoring equipment, which will both be completed in 2025.

2.1.2 Additional Bracing

Bracing could strengthen the capacity of the cross arm to protect against a failure due to unbalanced ice ("UBI"). Hydro outlined how this particular option would require additional analysis to see if and how the addition would affect the structure and operations.

Hydro is undertaking an engineering assessment as part of its Engineering Studies Project to evaluate unbalanced loading design across the entire length of the line. Hydro will use all available data, including its own investigations, recommendations from Haldar, internal and legislative standards, weather data and industry best practices, to determine the best information to use when considering the evaluation of UBI loads.

Following this assessment, a consultant will be secured to provide a cost estimate and designs for any appropriate tower modifications that will meet this new standard. Tower modification design and cost estimates for supply and construction for additional bracing are scheduled to be completed in the fourth quarter of 2024, which will provide the information necessary to determine which options to implement and plan the projects accordingly.

Status: Engineering assessment including tower modification and cost estimates for supply and construction is scheduled to be complete in the fourth quarter of 2024.

2.1.3 Alternate Damper Design

Vibration dampers, which help control the Aeolian vibration (low amplitude, high-frequency vibration) of the conductors could be replaced with those of a design which performs better with ice accumulation on the lines.

Hydro is also undertaking an engineering assessment as part of its Engineering Studies Project that will provide a new technical specification for damper requirements, as well as reviewing information from incidents, monitors, and studies to determine the areas of the line where the damping system will require upgrading. Recommendations from this assessment are expected to be available in the fourth quarter of 2024.

Status: Engineering assessment including recommendations is scheduled to be completed in the fourth quarter of 2024 with cost estimates, if necessary, to follow.

2.1.4 Air Flow Spoilers

Air flow spoilers help mitigate galloping by disrupting air flow over the conductor.

After conducting further analysis of this option, Hydro determined this recommendation could provide meaningful benefits in reducing line galloping, thereby reducing the risk of a failure. Hydro is currently completing a multi-year capital project, which is 40% complete, to install air flow spoilers per this recommendation in areas where damage due to galloping has occurred, or galloping has been observed. Hydro had identified the sections of the line which had the most critical need for air spoilers and completed them in 2023. The majority of the remaining installations will be completed by the fourth quarter of 2024.

Status: All critical areas were completed in 2023 with the majority of the remaining installations to be completed by the fourth quarter of 2024.

2.1.5 Suspension Clamp Design

At the time of the investigation report in 2021, the clamp design was identified as something which could be strengthened, and a larger clamp with armor rods could be considered to help improve slip strength.

Since this recommendation was made, three different types of clamps have been procured by Hydro and will be installed on the line in 2024 in locations where events occurred. The alternate clamp designs all protect the conductor from contact with the clamp. Bending, pinching, or wear on the conductor from the clamp could be a contributing factor to failure under high ice loads. Hydro has also begun conducting regular inspections of the clamps to ensure that any issues are identified and necessary refurbishments or repairs are completed on time. These inspections will also help compare the performance of the clamp types.

Status: This recommendation is scheduled to be completed in 2024.

2.2 L3501/2 Pole Assembly Turnbuckle Failure

This incident occurred in February 2021 and involved grounded Pole 2 conductors on two towers as a result of damaged turnbuckles, representing a failure rate of <1%. These two towers were located in southern Labrador.

The investigation report was originally submitted to the Board on May 31, 2021.[3] Full details can be found in the report; however, the general conclusion on the root cause of the issue was that the turnbuckles fractured due to a fatigue crack, most likely due to galloping on the line.

Hydro made four recommendations in this report, a description of and update on each is outlined below.

2.2.1 Air Flow Spoilers

Please refer to Section 2.1.4 for more information.

2.2.2 Galloping Study

The galloping study was noted as an opportunity to review weather modelling in Labrador and determine the geographical areas and sections on the line that are prone to galloping. This would help identify the areas where air flow spoilers would be best installed. The study was completed in January 2022 and helped inform the installation of air flow spoilers as outlined in Section 2.1.4.

Status: This recommendation is complete.

2.2.3 Check Turnbuckle Installation

It was noted at the time of the investigation that deviations from the installation procedure for the turnbuckles were evident and, although this was not the root cause of the failure, it could be a contributing factor. As such, Hydro outlined the potential for drone and human-based inspections of the turnbuckles, to mitigate any potential damage caused by galloping.

[3] "Reliability and Resource Adequacy Study Review – Labrador-Island Link Failure Investigation Report" Newfoundland and Labrador Hydro, May 31, 2021.

Hydro has opted not to conduct drone or x-ray analysis of the turnbuckles as, since this recommendation was made, Hydro has begun replacing turnbuckles with extension straps, as outlined in Section 2.2.3.

Status: Recommendation addressed through actions taken in Section 2.2.3.

2.2.4 Alternate Dead End Assembly Design

This recommendation specified that alternatives to turnbuckles would better handle galloping loads.

Since this recommendation was made, Hydro has begun replacing turnbuckles with extension straps and will continue to do so for the entire line. Part of a multi-year capital project, installation began in priority locations in 2023, with the completion of the majority of the remaining installations by the fourth quarter of 2024. The extension straps can better accommodate galloping loads, as was identified in the previously mentioned galloping study discussed in Section 2.2.2.

Hydro has further identified the option of installing extra turnbuckles to reinforce areas where maintenance is occurring in advance of receipt of a sufficient supply of extension straps. Once the availability of extension straps is sufficient, Hydro will cease this practice and use only extension straps to reinforce required areas.

Status: Priority locations are complete with the majority of the remaining installations to be completed by the fourth quarter of 2024.

2.3 Turnbuckle Failures on Structures 1872, 1806, and 1014

On December 1, December 29, and December 30, three incidents occurred on the LIL impacting a total of three towers representing a <1% failure rate. The first incident occurred on section L3501 and the latter two on section L3502. Similar to Section 2.2, the issues were all related to grounded pole conductors as a result of turnbuckle damage. There was no customer impact resulting from these incidents. One of the structures was located in southern Labrador, while the other two were located in the Long Range Mountains on the west coast of Newfoundland.

The investigation report was originally submitted to the Board on October 4, 2023.[4] Full details can be found in the report; however, the general conclusion on the root cause was consistent with that of the February 2021 events that the turnbuckles fractured due to a fatigue crack, most likely due to galloping on the line. At the time of the February 2021 investigation, these issues were believed to be isolated events with continual monitoring required. However, the December 2022 incidents indicated a trend. Further testing was completed as a result confirming fatigue and that preventative maintenance would be difficult to manage.

As a result, Hydro made four recommendations in this report, a description of and update on each is outlined below.

2.3.1 Air Flow Spoilers

Please refer to Section 2.1.4 for more information.

2.3.2 Increased Field Monitoring and Reporting

The increased helicopter patrols Hydro has established, as described above, allow for observations of line galloping in addition to ice formation. The same is true for the standardized reporting protocols, as well as the weather stations and installation of line-equipped monitoring technology, all of which have been outlined in Section 2.1.1.

Status: This recommendation is complete.

2.3.3 Replacement of Turnbuckles

Please refer to Section 2.2.3 for more information.

2.3.4 Short-Term Hardware Installation[5]

Please refer to Section 2.2.4 for more information.

2.4 OPGW Tower Peaks – Structures 1230 and 1231

Two failures occurred on December 14, 2022, both resulting from the OPGW connection to the peak tower, representing a failure rate of <0.1%. The top section of the tower, the OPGW peak, experienced

[4] "Summary of Labrador-Island Link Failure Investigations – Line L3501/2," Newfoundland and Labrador Hydro, October 4, 2023.
[5] Installation of multiple turnbuckles in advance of receipt of sufficient extension straps to replace turnbuckles.

damage to the steel member. Neither the OPGW nor the rest of the tower below the OPGW peak failed, only the connection. These were two adjacent structures located in southern Labrador.

The investigation report for this was originally submitted to the Board on October 4, 2023.[6] Full details can be found in the report; however, the general conclusion on the root cause of the issue was UBI loads due to ice shedding, which were above the design loads of the corresponding section of the line.

Hydro made two recommendations in this report, a description of and update on each is outlined below.

2.4.1 Ice Monitoring and Removal

Please refer to Section 2.1.1 for more information.

2.4.2 Strengthening of the Tower to Withstand Higher Unbalanced Ice Loads

UBI loads are normally a result of ice shedding. As ice can shed from different sections of the line at different times, the exact loading is hard to predict. As such, Hydro has undertaken an engineering assessment as part of its Engineering Studies Project, as described in Section 2.1.2, which will allow for the evaluation of UBI loading design, which will inform UBI determinations specifically made for the LIL. Hydro will use all available data, including its own investigations, recommendations and analysis from Haldar in both Phase One Report and Phase Two Report, internal and legislative standards, weather data and industry best practices, to determine the best information to use when considering the creation of UBI loads.

As noted in Section 2.1.2, a consultant will provide a cost estimate and designs for any appropriate tower modifications that will meet these recommendations.

Status: Engineering assessment including tower modification and cost estimates for supply and construction is scheduled to be complete in the fourth quarter of 2024.

2.5 OPGW Top Plates – Structures 2135 and 2136

Two failures occurred stemming from events taking place on December 20 and 21, 2022, representing a failure rate of 0.4%. In both cases, the connection of the top plate of the OPGW suspension detached

[6] *Supra,* f.n. 4.

from the tower, falling onto the cross arm. These are two adjacent structures located in the central-west part of the Island.

The investigation report was originally submitted to the Board on October 4, 2023.[7] Full details can be found in the report; however, the general conclusion on the root cause of the issue was a design issue of the noted connection of the top plate of the OPGW suspension.

Hydro made three recommendations in this report, a description of and update on each is outlined below.

2.5.1 Improvement of Tower Connection for A3 Tower

Hydro recommended consultation with a tower designer to identify a potential solution for the correction of the connection of the top plate of the OPGW suspension. This consultation led to the re-design of the connection detail for the A3 tower type, which was the tower type that experienced the applicable issues. The design adds steel reinforcement to the tower, transferring the load from the top connection to the sides. The installation did not require the removal of the OPGW attachment from the tower or the removal of any existing parts. Tower design work along with an assessment of installation procedures for the redesigned connection was completed by the end of 2023. Please refer to Section 2.5.3 for planned next steps associated with the A3 towers.

Status: This recommendation is complete.

2.5.2 Evaluation of Connection Types in Other Non-A3 Towers

To help ensure that a similar issue did not exist in other non-A3 tower types, Hydro suggested evaluating all remaining tower types, a process that was also completed in 2023. The review determined that the A1 tower type, which represents over half of all tangent towers,[8] did not experience a similar issue as the A3 towers. However, the remaining tower types could see loads which would also exceed the connection design, and therefore Hydro identified that a structure-by-structure analysis was needed. This analysis was completed in 2024 and determined that 63 towers, which represent only 2% of the

[7] *Supra,* f.n. 4.
[8] There are 2,896 tangent towers which represent 90% of the total towers. Tangent towers have a tangent or suspension assembly, which is the connection to the conductor. There are six tangent tower types: A1, A2, A3, A4, B1, and B2.

total of all tangent towers, have the potential to experience loads that could cause similar failures. Please refer to Section 2.5.3 for the planned next steps associated with these 63 towers.

Status: This recommendation is complete.

2.5.3 Cost Estimates for Strengthening OPGW Top Plate

For the A3 towers noted in Section 2.5.1 and the 63 towers identified in Section 2.5.2, estimates are currently being completed for the necessary repair work to strengthen the connection of the top plate of the OPGW suspension.

Status: Estimate for necessary repair work to be received in the fourth quarter of 2024.

2.6 Electrode Conductor – Structures 514 and 515

On December 31, 2022, an electrical fault occurred on the LIL transmission line. It was determined that the failure resulted from a damaged electrode cable. These incidents occurred in central Labrador on three structures, representing a failure rate of 0.2%.

The investigation report was originally submitted to the Board on October 4, 2023.[9] Full details can be found in the report; however, the general conclusion on the root cause of the issue was tensile overloading due to ice accumulation.

Hydro made six recommendations in this report, a description of and update on each is outlined below.

2.6.1 Establishment of Protocols for Evidence Collection Post-Failure

Hydro implemented staff protocols staff for evidence collection, such as photographic evidence and ice sampling, after a transmission line failure. These protocols were formalized in February of 2024 based on existing practices, and lessons learned from past investigations. This will help ensure all information necessary for investigations is collected in a timely manner, including any data on ice accumulation amounts.

Status: This recommendation is complete.

[9] *Supra,* f.n. 4.

2.6.2 Ice Monitoring and Removal

Please refer to Section 2.1.1 for more information.

2.6.3 Completion of Detailed Inspections on Cable and Clamp in Critical Areas

Hydro has identified, through its preventative maintenance program, multiple opportunities for clamp and conductor inspection, with refurbishment or replacement of parts made according to findings.

Status: This recommendation is complete.

2.6.4 Increasing the Distance between Insulator and Conductor in the Electrode Conductor

Hydro will be completing an investigation of the option to increase the electrode insulator distance to decrease the load on the tower and the bending of the conductor. This work will be completed as part of the Engineering Studies Project outlined in Section 2.1.2.

Status: Engineering assessment including tower modification and cost estimates for supply and construction is scheduled to be complete in the fourth quarter of 2024.

2.6.5 Suspension Clamp Design

Please refer to Section 2.1.5 for more information.

2.6.6 Detailed Engineering Study to Upgrade Impacted Line Section

Please refer to Section 2.1.2 for more information on Hydro's planned engineering assessment.

Status: Engineering assessment including tower modification and cost estimates for supply and construction is scheduled to be complete in the fourth quarter of 2024.

3.0 Haldar Reports

Throughout the reporting and analysis process, Hydro has reviewed all recommendations in the Haldar Phase One Report and Phase Two Report and determined the feasibility and impact acting on each recommendation would have in improving the reliability of the LIL in a safe, least cost and environmentally responsible manner. Hydro does not believe that each recommendation is necessary to implement as it may not be cost-beneficial when considering incremental reliability benefits. However, Hydro has determined a number of improvements to infrastructure and processes both linked to Haldar's findings and Hydro's LIL Investigation Reports.

A number of the recommendations from the Phase One Report were purposefully addressed through additional analysis completed in the Phase Two Report. In addition, a number of Haldar's other recommendations are covered by the work that Hydro is completing or has completed as a result of the actions stemming from the LIL Investigation Reports outlined in Section 2.0. In these cases, Haldar's recommendations have been referenced in the relevant discussion included above. All other actions associated with the remaining Haldar recommendations are considered complete and have been noted as such. Therefore, the only recommendations and associated actions that are considered ongoing or incomplete at this stage are those which are outlined as part of the LIL Investigations in Section 2.0 and Table 2 in the main body of this report.

3.1 Haldar Phase One Report

3.1.1 Ultimate Limit States

In the Phase One Report, Haldar looked at Damage Limit States ("DLS")[10] criteria versus Ultimate Limit States ("ULS")[11] and recommended the following:

> The decision to make appropriate generation expansion study should not be done strictly based on DLS criteria satisfying CSA 60826-10 rather by doing a full ULS analysis of the structure-cable system and its impact on the LIL failure rate.

Hydro noted in its initial response that ULS is outside of the CSA[12] standard and that further internal analysis and discussion are required on this recommendation. Subsequently, this recommendation was covered in the analysis performed in the Phase Two Report by considering more extreme loading scenarios where support structures, as opposed to OPGW, would become the governing component. Under these conditions, Haldar concluded that there was no differentiation between DLS and ULS failure models. In addition, progressive failure analysis would also not be required in such a case. Progressive failure analysis would only be required if the initial component failure was not deemed likely to cause significant damage to the line. No further analysis was deemed necessary.

[10] The state at which some repair is needed because a component has experienced permanent deformation.
[11] The state where the structure experiences significant damage or collapse.
[12] Canadian Standards Association ("CSA").

Status: This recommendation is complete.

3.1.2 Unbalanced Ice Loads

In the Phase One Report, Haldar was concerned about UBI on the LIL, and suggested the following:

> LIL line should be checked for UBI with load combinations to assess the tower vulnerability and assess the gaps due to complete omission of load combinations in the design and exposures that exist in the current LIL design and a plan should be developed on what measures can be put in place to mitigate this specific issue, particularly for the line section in Labrador.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

b. Evaluation of the Impact of UBI

Please refer to Section 2.1.2 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.1.3 Topographic Analysis

With respect to topographic analysis, Haldar recommended the following:

> Based on the results of one topographic analysis for a tower located on the top of Hawke Hill, the author recommends a full topographic analysis of the LIL line be considered to identify all remaining “hot spots” and to assess the site-specific wind loading considering local terrain characteristics, topography, and the environmental exposures/hazards. The terrain characteristics and topographic information can be gathered using modern (digital) mapping technology regarding the profile of a specific site. The site-specific wind loads should include the uncertainties in terrain data along the line routing and address local terrain roughness issues. This analysis should also assess the impact of the “wind speed-up effect” on combined wind and ice loads and the effects on these towers that are located either on the top of an 3D axisymmetric hill, a 2D ridge, or an escarpment. This was not considered in the LIL design and it is recommended that a plan be developed to identify these towers, assess the POF[13] considering “wind speed-up effect”, and assess its impact on overall line POF (reliability,

[13] Point-of-failure (“POF”).

> failure rate) to determine what POF (reliability, failure rate) level is acceptable based on a cost-risk scenario. A mitigation action plan should be developed if the reliability level does not meet the industry's best practices.

In the Phase One Report, Hydro outlined that it had utilized high-speed estimations in the design of the LIL. Hydro also pointed to sensitivity analyses that determined infrastructure could withstand the speeds Haldar was estimating in that report. Noting the same, Hydro agreed to complete an analysis, which was conducted by third-party experts at Western University, that would help further identify any potential "hot spots" which hadn't already been identified, and that these findings would help evaluate risk. Results of this assessment were discussed in the Phase Two Report in which Haldar indicated it may be overly conservative to accept the extreme ice and wind combinations, which could lead to overdesign and further pointed to the fact that the high ends of ice/wind combination ranges were not historically seen in associated topographical data.

No further analysis is required for this recommendation, Hydro uses data from weather monitoring activities, investigation analysis, and expert external sources to monitor potential changes in climatological trends.

Status: This recommendation is complete.

3.1.4 Correlation Study

In the Phase One report, Haldar had outlined the belief that a regional correlation study was required, stating:

> A full correlation study of the line route to past extreme storm events in establishing the correlation between various regions; if a strong correlation among various regions can be established, it may be possible to further improve the POF under Scenarios # 4B and # 4D and reduce the LIL POF (hence, increasing the reliability), and ultimately reduce the failure rate.

Hydro was concerned full line length was not a reasonable consideration for a correlation study as it would require unreasonable return periods and point-of-failure rates, and is also not in line with industry or professional standards. Hydro noted how consideration was given by Haldar for regional independence when assessing the reliability of the LIL. While the concept would reduce the reliability of the LIL under certain climatological conditions, Hydro pointed to a lack of validation of these concepts and historical data to meaningfully adopt them and act on the recommendations. Hydro did see how the recommendation would theoretically lead to benefits and agreed to consider it further from the perspective of general potential benefits to the line.

Therefore, instead, Hydro is determining the appropriate balanced ice load to be considered for the LIL. This will allow for a line-specific analysis of how to best consider climatological effects on reliability. No further action will be taken on this recommendation as the intent of the recommendation will be covered by Hydro's Engineering Studies Project on UBI loads. Please refer to Section 2.1.2 for more information.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.1.5 Event Tree

In the Phase One report, Haldar recommended the following:

> An Event tree analysis for all possible violations of DLS including the clearance violations due to load increase and the ones that may lead to ULS should be assessed. In this analysis POF and consequences should be studied carefully to quantify the risk of such DLS violations and LIL outage exposures. The present study did not consider the "clearance violations" issue.

Hydro considered this a low priority as the work could be completed at any time if deemed necessary based on experience with the line. At the time, Hydro deemed other pieces of the analysis and work to be of a higher priority to ensure the reliable operation of the LIL. There was no follow-up discussion by Haldar of the event tree analysis in the Phase Two Report. Given an event tree was not deemed necessary by Hydro, no further action was taken to address this recommendation.

Status: This recommendation is complete.

3.1.6 Pole Conductor

In the Phase One report, Haldar recommended the following:

> The present study has also identified an opportunity in revising the current design loads considering the effect of large diameter of pole conductor on the design ice thickness. This was not considered in the original LIL design and in the earlier studies. The revised loads and combinations, once assessed fully, will reduce and improve the baseline POF values for existing LIL design and reduce some of the expected increases from combined

> wind and ice loads considering topographic effects. This improvement will only affect the POF (or reliability) under glaze ice exposure. It is likely that the increase in the loads due to increased values for reference wind speed and glaze ice load effects may be compensated to an extent due to the decrease in the transverse and vertical load effects on pole conductor considering the impact of cable size on ice accretion. This will also reduce the UBI load effect, but this should be assessed quantitatively.

Hydro agreed to review the concept further in the Phase One Report and outlined, in its initial assessment of this recommendation, that Haldar's analysis was based on the typical CSA standard calculation of a 30 mm rod diameter. The LIL has a rod diameter of 50 mm. Hydro also noted that Environment Canada modelling data noted that larger cables reduce ice loads by 30%. In both reports, Haldar acknowledged the reduction of pole conductor loads does not apply in rime ice situations, which is the typical ice type observed in critical regions.

Hydro concluded this analysis as part of the Haldar Phase Two Report and therefore no further action is required to address this recommendation.

Status: This recommendation is complete.

3.1.7 Comparative Evaluation

In the Phase One Report, Haldar recommended the following with respect to comparative evaluation:

> A comparative evaluation of Combined loads using Environment Canada model data and EFLA Consulting Engineers ("EFLA") data versus combined wind and ice load data based on CSA 60826-10 should be done and if it is shown there is a significant gap, this needs to be closed particularly considering past failure experiences and lessons learned. The author suggests in using combined wind and ice loads directly from Environment Canada model runs and EFLA study rather the use of combined probability based loads from CSA 60826-10; however, reference values for wind speed and ice loads should be derived from COV of data and ice residence time as the model runs suggest for a typical LIL weather zone. It is known that the combined probability based method for wind and ice loads often overestimates the loads compared to historical storm method and this may contribute to the increased baseline POF values.

Hydro noted it could utilize historical data for glaze ice and wind combination estimates, which led to using the lower limit of the reference when designing the LIL. Hydro also increased the maximum ice loading compared to CSA standards in the region where it had no previous experience. EFLA[14] model

[14] EFLA Consulting Engineers ("EFLA").

data demonstrated a reduction in rime ice estimations by a factor of six, which would also reduce the combined wind and ice loads noted for this recommendation. Hydro agrees that using actual model data would likely decrease the POF and give more favourable results; however, this would only change the POF calculation, and not impact any practical changes to the line. A comparative evaluation was thus not deemed necessary.

Given a comparative evaluation was not deemed necessary, no further action is required to address this recommendation.

Status: This recommendation is complete.

3.1.8 Progressive Collapse Analysis

In the Phase One Report, Haldar recommended the following with respect to progressive collapse analysis:

> Progressive collapse analyses of four suspension towers under reliability class of loads (extreme events) should be carried out at critical segments These analyses cannot be done in PLS TOWER and would require different type of FEM program but should be pursued at least for the above sections. The analysis should also consider the test data to validate the results. By analyzing these towers for progressive collapse, NLH will be able to determine the reliability index under a collapse load and therefore, will be able to assess the POF and the failure rate for the structure support system under ULS in a realistic manner. Any adjustment of the POF can be done that has been assessed in this report and this POF and failure rate will be more realistic than what has been reported here under DLS. Although failure under DLS can also cause extended outages as explained before and should not be underestimated and ignored. The analysis should also consider the impact of terrain roughness and topographic effects in considering the revised combined wind and ice loads in the structural collapse analysis.

In addition, with respect to foundations, Haldar recommended:

> Foundations should be also modelled under the same progressive collapse model and in determining the limit load and the reliability index and the failure rate.

Haldar is suggesting that progressive collapse analysis of multiple towers or the foundation would result in a more realistic POF. However, analysis performed in the Phase Two Report on ULS versus DLS, as noted in Section 3.1, showed the governing component in most failures was a critical component, which would result in a ULS failure, and therefore it was concluded that progressive collapse analysis is not necessary and no further action is required to address this recommendation.

Status: This recommendation is complete.

3.2 Haldar Phase Two Report

3.2.1 Wind Speed Measurements

In the Phase Two Report, Haldar suggested increased monitoring and data collection in relation to wind, specifically in cases of a recent ice storm, to help determine the levels of combined loads that may affect the LIL. Specifically, Haldar stated:

> Measure wind speed after an ice storm and during line inspections in validating combined wind and ice load and ice plus wind loads for the critical sections of LIL, particularly the line sections in the Labrador Region where the reliable data is currently unavailable.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

b. Evaluation of the Impact of UBI

Please refer to Section 2.1.2 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.2.2 Section 3A Towers

In the Phase Two Report, Haldar noted that the climatological activity in Section 3A[15] was of particular concern, and that the towers that existed in this area could be more susceptible to issues than in other regions. To help mitigate the potential issues caused by this belief, Haldar recommended the following:

> Assess the mitigation option of upgrading the capacities of several towers in Section 3A, either by redesigning the A1 tower or by installing mid-span towers to upgrade the line in Section 3A and the other sections where similar problems may be encountered.

[15] Section 3A is a loading zone in southern Labrador from Structure 1209 to 1245 that is designed for relatively low wind and ice loads.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

b. Evaluation of the Impact of UBI

Please refer to Section 2.1.2 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.2.3 Remote Monitoring of LIL

In the Phase Two Report, Haldar believed that additional monitoring could be efficiently achieved through remote monitoring of the effects weather phenomena on the LIL. Specifically, Haldar noted Hydro should:

> Consider monitoring LIL remotely for ice and wind loads and validate this by occasional in field measurements, particularly for loads on the "wire support system" (OPGW, electrode and pole conductor etc.); one objective should be to validate whether the pole conductor collects less ice compared to the other two cables during a storm. This may also provide data to clarify whether in the future, the OPGW should be designed for the conductor design ice loads as stipulated in CSA 60826-10.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.2.4 A1 Towers

Haldar identified A1 towers as a potential area of review for Hydro in the Section 3A region recommendation outlined in Section 3.2.2. Furthering that suggestion, Hydro felt A1 towers on the island portion of the province should receive the same scrutiny as those in Labrador. Haldar stated:

> The author has checked a few critical A1 towers outside of the Labrador region. It is suggested that NLH check all the A1 towers in the Island Part of the line in addition to the ones in the Labrador region to ensure that all these A1 towers where UF are considerably higher (>100%) are fully identified.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro is taking resulting from its LIL Investigations.

3.2.5 Statistical Analysis and Correlation Effects of Wind and Ice Loads

Haldar outlined two recommendations in relation to what it believed to be the potential threats caused by a combination of wind and ice loads. The belief was that additional statistical analysis and information gathering would help educate Hydro on the true effects that combined loads could have on the LIL, and help fill any gaps in knowledge that could prevent maximizing mitigation efforts in relation to this perceived issue. Haldar stated the following:

> NLH may want to consider developing a better statistical procedure in determining the combined wind and ice loads that include the NLH's operational experiences for the past fifty (50) years supported by the icing that has been observed during past line failures. This requires further investigation and it is outside the scope of this study. It must also be understood that the combined ice and wind load prediction method (post storm event) often produces loads that are more conservative and higher than the loads based on the historical storm method. One of the reasons for this is that the correlation between the ice thickness and wind speed is totally ignored in the combined probability method and this is the reason, a factor or factors for various NLH service regions must be developed to correct these loads with respect to the historical storm method. This can only be done based on calibration with measured data during ice storm events or based online field monitoring.

and:

> With respect to wind plus ice load, correlation effect among the ice thickness, concurrent wind speed and the duration of the event needs to be understood. The data from Environment Canada for nearby weather stations coupled with field observation data and the data from NLH's operational experience should be used to develop this wind plus ice map for the regions identified in Haldar report (2021). This analysis can also be validated by NWP model along the line route and NLH has already used this

numerical modelling technique in predicting combined rime loads. Once validated by measured data, this can be considered in the future possible upgrading of this LIL line.

To satisfy this recommendation, Hydro has identified the following actions:

a. Wind and Ice Monitoring

Please refer to Section 2.1.1 for further information on actions Hydro is taking.

b. Evaluation of the Impact of UBI

Please refer to Section 2.1.2 for further information on actions Hydro is taking.

Status: This recommendation is being addressed through actions Hydro takes resulting from its LIL Investigations.