Greater Sudbury Hydro Inc

Interrogatory Submission

January 28, 2025

Association of Major Power Consumers in Ontario

EB-2024-0026

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1-AMPCO-1 Reliability Goals based on Investment Plan

Question:

Ref: 1-2-3 p.2

For the test year, GSHI is requesting a rate base that reflects the investments needed to maintain and improve system reliability while accommodating customer growth and modernizing the grid.

a) Please confirm if the overall focus and goal of GSHi's 2025-2029 investment plan is to maintain or improve reliability.

b) Which investments will improve system reliability?

c) Please provide the investment goal over the 2020-2024 period with respect to reliability.

Response:

a) The overall focus and goal of GSHi's 2025-2029 investment plan is to improve reliability.

b) Investments in both the 'System Renewal' and 'System Service' categories are anticipated to have the greatest impact on improving system reliability. Considering the ongoing negative trends in Cause 5 outages, GSHi proposes to maintain a strong focus on a paced System Renewal investment portfolio within its DSP, similar to the approach taken in the 2019 DSP. This strategy aims to align reliability performance with the expectations of both our customers and the OEB.

System Renewal investments are expected to improve reliability by replacing aging components that are at a higher risk of failure due to their condition.

GSHi's renewal efforts are particularly focused on assets with an "effective" age that increases their likelihood of failure. By targeting feeder segments with poor Health Index scores, the probability of replacing these assets before they fail—and thus preventing service outages—is greatly enhanced. Among the key 'System Service' investments, the most critical project is outlined in Section 5.4.2.1.4.5 of the DSP, titled 'Submersible Backup for 28M5.' The 10F5 and 28M5 feeders rank among GSHI's least reliable distribution-class feeders and require supportive renewal investments to improve service quality for our customers. Moreover, this project will relieve capacity on the existing 9M4 feeder, enabling the connection of the Town of Coniston to the GSH--controlled 44kV feeder, which addresses a longstanding reliability concern within the town.

c) The overall focus and investment goal over the 2020-2024 period with respect to reliability was to improve reliability. This overarching focus has continued into the 2025-2029 period.

1-AMPCO-2 Identified Cost Savings

Question:

Ref: 1-2-3 p.5

GSHI indicates it has identified opportunities for cost savings: bundling projects; proactive asset management; voltage conversion.

a) Has GSHI quantified the cost savings? If yes, please provide.

b) Have the cost savings been reflected in the application?

Response:

a) It is not possible to quantitatively determine the cost savings over the 2025-2029 period from the prospective capital investments. However, qualitatively, investments into System Renewal are generally expected to result in a decrease in future O&M expenditure, at a quantum less than it would otherwise trend, because paced, continuous replacement of older-vintage assets with new assets will help to reduce upward pressure on O&M expenditures as there will be fewer equipment failures and reduced expenditures as it relates to unplanned emergency repairs.

   Qualitatively, the prospective investments contemplated throughout this DSP are expected to produce costs savings over the forecast period as well as yield improvements in both reliability and operational efficiency.

b) While cost savings cannot be quantified precisely, they are inherently reflected in GSHi's budgets due to the application of these established historical practices, such as bundling of projects, proactive asset management and voltage conversion.

1-AMPCO-3 30 Day Rate

Question:

Ref: 1-2-6 p.3

GSHI is proposing to determine fixed charges on a 30-day basis, rather than a monthly basis, to align with its billing system.

a) Is GSHI aware of other LDC's who have implemented this proposal? If yes, please discuss.

b) Why now?

Response:

a) GSHi is aware that Toronto Hydro uses a similar 30-day rate structure to the one GSHi is proposing. While GSHi does not have specific information about the history or reasoning behind Toronto Hydro's implementation of 30-day rates, it is GSHi's understanding that the proposed structure aligns with Toronto Hydro's approach.

b) GSHi is proposing to transition to 30-day rates in its 2025 Cost of Service application to address a historical billing system issue that resulted in overcharges. The issue arose because fixed charges were previously prorated as if there were 30 days in every month (360 days annually), while customers were billed for 365 days. This discrepancy was identified in March 2021, and GSHi promptly self-reported it to the Ontario Energy Board (OEB), entering into an Assurance of Voluntary Compliance (AVC) in 2022.

Since then, GSHi has implemented interim measures to correct the issue, including refunding overcharges and auditing bills. The proposed transition to 30-day rates will ensure that fixed charges are calculated accurately and consistently, aligning billing practices with the OEB's tariff structure and promoting transparency and fairness for customers. For more detailed information on why GSHi is proposing to transition to 30-day rates, please refer to Exhibit 8, Tab 2 of GSHi's initial application submission.

GSHi further detailed the benefits of transitioning to 30-day rates in its response to interrogatory question #49 from OEB staff. The three key benefits are as follows:

1. **Charges Better Aligned with Service**
   By transitioning to 30-day rates, customers are billed based on the actual number of days for which service is provided. Under a monthly rate structure, customers are charged proportionately more during shorter months (e.g., February with 28 days) compared to longer months (e.g., March with 31 days). This discrepancy occurs despite the cost to GSHi for providing service being more closely aligned with the number of days service is provided rather than the number of days in the month. GSHi's proposal ensures that customers are charged in proportion to the actual number of days they receive service, promoting a fairer and more equitable approach for both GSHi and its customers.

2. **Simplified Customer Bill Calculation**
   Transitioning to 30-day rates simplifies the calculation of customer bills. A 30-day rate effectively functions as a daily rate, as it can be calculated by dividing the proposed rates by 30. This simplicity allows

customers and stakeholders, even those without advanced knowledge of billing calculations, to easily determine how much of GSHi's tariffs apply to any given bill. For instance, they can multiply the daily rate by the number of days in the billing period, whether for a standard bill or a first/final bill with a different number of days than a typical billing period.

3. **Transparency in Leap Years**

Using a daily rate provides greater transparency regarding billing during a leap year. GSHi's proposal explicitly accounts for the impact of a leap year on its distribution revenue. GSHi can see how an LDC converting monthly rates into their billing systems could inadvertently collect additional revenue in leap years if they do not account for the extra day during their conversion calculations, without explicitly indicating that this is intentional. For reference, GSHi's explanation of the impact of a leap year on 30-day fixed charges, as detailed in Exhibit 8, Tab 2, Schedule 1, Page 3 of its initial submission, is copied below:

<u>Impact of Leap Year on 30-Day Fixed Charges</u>

*In a leap year, which occurs every **four years**, GSHi will bill customers for **366 days**, as the billing system calculates fixed charges based on the number of days in the billing period. This results in GSHi collecting one extra day of **Monthly Service Charge (MSC) revenue**, equivalent to **1/365 of the total annual MSC revenue**. Based on total MSC revenues of **$23,265,220** (see **Revenue Requirement Workform**, Tab 13 "Rate Design", total of column "AK"), this additional revenue amounts to approximately **$63,740**. Conceptually, GSHi considers this outcome reasonable, and no correction mechanism is proposed. In a leap year, GSHi operates for an additional day, incurring extra costs,* *and the mechanics of billing based on the actual number of days fairly reflect these costs. The next leap year will occur in* ***2028****, which falls within this five-year rate-setting cycle from* ***2025 to 2029****. Furthermore, the additional revenue of* ***$63,740*** *is well below the materiality threshold of* ***$163,439*** *for this rate application, representing only* ***39%*** *of materiality, demonstrating that this amount is immaterial.*

1-AMPCO-4 Efficiencies Which Will Move GSH into Cohort II

Question:

Ref: 1-2-9 Attachment #1 p.32

Progressing through the next 5 years, GSHI forecasts efficiencies that, by 2028, will move us into Cohort II where the stretch factor would be 0.15% of the OEB inflation rate.

Please discuss and quantify the efficiencies that will move GSHI to Cohort II by 2028.

Response:

GSHi forecasts that it will move into Cohort II by 2028 based on the results of the benchmarking spreadsheet forecast model. This model uses the Test Year figures from this rate application as a baseline and adjusts them annually for inflation, as described in the response to 1-SEC-4.

The benchmarking spreadsheet forecast model projects that GSHi will achieve efficiencies relative to the expectations embedded in the PEG model. These efficiencies are reflected in GSHi's forecasted cost performance and are aligned with the expectations of utilities progressing within the benchmarking framework.

Specific productivity or efficiency measures for the period from 2026 to 2029 have not been separately identified at this time. However, the responses to 1-SEC-5 and 1-SEC-6 provide a discussion of general productivity and efficiency measures undertaken from 2020 through 2025. These earlier initiatives provide context for GSHi's continued focus on efficiency gains and operational improvements as it aligns with the PEG model's expectations.

1-AMPCO-5 Scheuldded Outage Communication - Residential

Question:

Ref: 1-2-9 Attachment #1 Appendix 1 p.6

The 2023 Customer Satisfaction Survey (2023 Report) with respect to Residential customers provides the customer satisfaction results with respect to effectively communicating with customers about planned electricity interruptions, and shows that for the period 2013 to 2023 the highest result is 68% in 2015 and the lowest result is 55% in 2020.

Please explain GSHI's plans over the 2025-2029 period to improve this result.

Response:

In addition to our current communication efforts—which include posting outage updates on the Greater Sudbury Hydro (GSH) Facebook and X channels, updating the outage section of the GSH and GSU websites, emailing city councillors and media, sending letters to affected parties, and using our IVR system for customer notifications (when applicable)—GSHi is committed to enhancing our processes in five key ways to improve results moving forward.

Community-based bulletins: For outages impacting entire communities, we will boost outreach by posting physical bulletins in strategic locations and centres within the affected areas.

Expanded social media engagement: We will broaden our social media presence by leveraging our growing Greater Sudbury Utilities Instagram page to relay outage information.

Automated outage alerts: Over the next several years, we aim to implement an automated outage management system, enabling us to send real-time text message alerts to customers regarding upcoming outages.

Two-way coordination with partners: We recognize the need for closer collaboration with partners, such as Hydro One, to ensure timely communication of planned outage dates. Addressing existing gaps will allow us to provide customers with earlier and more accurate notices.

New look for websites: In 2025, we will redesign of all our websites to enhance their intuitiveness and user experience, with a focus on refining the accessibility and visibility of the planned outage section, ensuring that customers can easily find the information they need.

These initiatives highlight our commitment to continuous improvement in customer communication and service delivery.

1-AMPCO-6 Scheduled Outage Communication - Business

Question:

Ref: 1-2-9 Attachment #1 Appendix 1 p.21

The 2023 Customer Satisfaction Survey (2023 Report) with respect to Business customers provides the customer satisfaction results with respect to effectively communicating with customers about planned electricity interruptions, and shows that for the period 2013 to 2023 the highest result is 54% in 2023 and the lowest result is 40% in 2016.

Please explain GSHI's plans over the 2025-2029 period to improve this result.

Response:

In addition to our current communication efforts—which include posting outage updates on the Greater Sudbury Hydro (GSH) Facebook and X channels, updating the outage section of the GSH and GSU websites, emailing city councillors and media, sending letters to affected parties, and using our IVR system for customer notifications (when applicable)—GSHi is committed to enhancing our processes in five key ways to improve results moving forward.

Community-based bulletins: For outages impacting entire communities, we will boost outreach by posting physical bulletins in strategic locations and centres within the affected areas.

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New look for websites: In 2025, we will redesign of all our websites to enhance their intuitiveness and user experience, with a focus on refining the accessibility and visibility of the planned outage section, ensuring that customers can easily find the information they need.

These initiatives highlight our commitment to continuous improvement in customer communication and service delivery.

1-AMPCO-7 2024 Scorecard Results

Question:

Ref: 1-2-9 Attachment #1 Appendix 2

Please provide the Scorecard results for 2024.

Response:

GSHi provides the following summary for information that is currently available. Data that is not currently available is also not expected to be available prior to the end of this proceeding. Please note that the First Contact Resolution has been provided based on data to the end of November 2024.

Performance Outcomes	Performance Categories	Measures		2020	2021	2022	2023	2024
Customer Focus Services are provided in a manner that responds to identified customer preferences.	**Service Quality**	New Residential/Small Business Services Connected on Time		99.63%	98.95%	99.49%	99.30%	99.49%
		Scheduled Appointments Met On Time		100.00%	100.00%	100.00%	99.81%	100.00%
		Telephone Calls Answered On Time		67.38%	64.22%	71.07%	71.16%	69.24%
	Customer Satisfaction	First Contact Resolution		87.60%	87.86%	84.86%	93.00%	99.44%
		Billing Accuracy		99.95%	99.97%	99.94%	99.95%	99.95%
		Customer Satisfaction Survey Results		89.00%	93.60%	94.60%	92.83%	94.33%
Operational Effectiveness Continuous improvement in productivity and cost performance is achieved; and distributors deliver on system reliability and quality objectives.	**Safety**	Level of Public Awareness		83.00%	85.00%	85.00%	89.00%	89.00%
		Level of Compliance with Ontario Regulation 22/04		C	C	C	C	N/A
		Serious Electrical Incident Index Number of General Public Incidents		0	0	0	0	N/A
		Serious Electrical Incident Index Rate per 10, 100, 1000 km of line		0	0	0	0	N/A
	System Reliability	Average Number of Hours that Power to a Customer isInterrupted		1.48	1.11	1.15	1.49	0.94
		Average Number of Times that Power to a Customer isInterrupted		0.99	1.16	1.62	1.49	1.04
	Asset Management	Distribution System Plan Implementation Progress		110.00%	90.44%	74.86%	79.31%	113%
	Cost Control	Efficiency Assessment		3	3	3	3	N/A
		Total Cost per Customer		$ 670	$ 679	$ 721	$ 805	N/A
		Total Cost per Km of Line		$ 31,590	$ 31,877	$ 13,572	$ 15,170	N/A
Public Policy Responsiveness Distributors deliver on obligations mandated by government (e.g., in legislation and in regulatory requirements imposed further to Ministerial	**Connection of Renewable Generation**	New Micro-embedded Generation Facilities Connected On Time		100%	100%	100%	100%	100%
Financial Performance Financial viability is maintained; and savings from operational effectiveness are sustainable.	**Financial Ratios**	Liquidity: Current Ratio (Current Assets/Current Liabilities)		1.13	1.3	1.33	1.27	N/A
		Leverage: Total Debt (includes short-term and long-term debt) to Equity Ratio		1.22	1.19	1.13	1.09	N/A
		Profitability: Regulatory Return on Equity	Deemed (included in rates)	8.52%	8.52%	8.52%	8.52%	N/A
			Achieved	2.04%	9.62%	10.52%	8.24%	N/A

2-AMPCO-8 Updated Appendix 2-AA

Question:

Ref: Appendix 2-AA

Please provide Appendix 2-AA on the basis of in-service additions, add a column for 2024 actuals and provide an excel copy.

Response:

Response to this interrogatory requires 2024 figures. The response will be filed by February 4, 2025.

2-AMPCO-9 Recommendations Made by DSP Consultant

Question:

Ref: 2-9-1 p.2

GSHI indicates the DSP was authored by GSHI staff and reviewed by JULA PLT Consulting Inc.

a) Please provide the conclusions and recommendations provided by JULA PLT Consulting Inc. Please provide a copy of any final report prepared by JULA PLT.
b) Please explain how these recommendations were incorporated or not into the final DSP.

Response:

a) As part of the drafting of its DSP, GSHI sought to obtain a review for completeness by an independent third-party contractor. The review for completeness did not provide conclusions or recommendations, but rather general comments to assist with clarity and depth of the document. The ensuing completeness review performed by JULA PLT Consulting Inc ("JULA") did not include any final report.

b) As mentioned in the response to a), JULA did not provide any formalized recommendations as part of its review of GSHI's DSP. Comments that JULA provided as part of their work were considered by GSHI staff and were adopted where appropriate to enhance clarity and depth of the explanation in response to the filing requirements.

2-AMPCO-10 Load and Generation Growth - Inquiries Made to Municipality

Question:

Ref: 2-9 Attachment #1 DSP p.14

The evidence states "Within the last several planning cycles, GSHI has taken a 'business as usual' approach to load and generation growth. In recent year, however, inquiries to our municipality from large power consumers have increased significantly."

Please explain/provide further details on the nature of these inquiries.

Response:

To support industrial growth, the City of Greater Sudbury has outlined plans through its Employment Lands Strategy (ELS) to develop and expand six industrial parks, encompassing over 2,000 acres of land across the municipality. In August 2022, City Council approved the ELS to promote economic growth and ensure a diversified economy, both now and in the future. This strategy is expected to position the City to proactively address Employment Land demands by considering future trends, projected needs, land availability, municipal services, and incentives to foster growth and adapt to economic changes.

The ELS integrates planning, infrastructure, and economic development to ensure an adequate supply of serviced employment land, along with policies and incentives that drive investment, development, and job creation. As a key driver of economic development in the community, GSHi plays a vital role in ensuring the capacity to serve these strategically important areas is available. Notably, the demand for customer connections in designated ELS areas has risen significantly, with an increasing number of customers requiring 44kV connections—requests that, until the ELS declaration, were relatively rare within GSHi's service territory.

To meet this demand, significant upgrades to area transmission stations will be necessary, including enhancements to Hydro One's Martindale TS which is one of the primary power sources for Greater Sudbury. However, the Martindale TS is approaching capacity, and expansion is particularly challenging due to limited land availability. This station is located near the boundary between GSHi's and Hydro One's service territories, an area actively promoted by both the City and the Province for large industrial projects. Additionally, this area is likely to see continued residential and commercial growth in the near future.

2-AMPCO-11 Projects and Costs Not Included in DSP

Question:

Ref: 2-9 Attachment #1 DSP p.38

The level of investment in the next five years was decreased from the first proposal of $65M to $60M.

Please provide a breakdown of the projects/costs not included.

Response:

Please see the table below for a breakdown of the projects/costs not included as a result of the decrease in investment from $65M to $60M ($5,095,862) in the next five years:

PROJECT	COST ($)
Windermere/Chestnut/Dearbourne/Woodbine UG Renewal	671,406
Downland Ave/Soloy Dr UG Renewal	273,640
Beatrice/Manchester/Cumberland UG Renewal	635,834
Cedarview/Springdale UG Renewal	567,648
Auger Ave/Rear Courtland Dr UG Renewal	372,698
Levert MS6 Relay Upgrades; Studies/Install	295,000
Silver Lake Rd (S966 to B20347)	198,715
Ramsey Lake Rd (S6563 to S6577)	177,781
Niemi,kivinen (golf course) rebuild	630,513
Poplar St, Coniston	165,534
Ida St (S9089 to S9101)	192,174
Howey Dr (S6284 to S6289)	172,931
Montel/Virginia	142,219
East St, Coniston	252,558
Eden Point Dr UG Renewal	347,211

2-AMPCO-12 Table 9 - System Reliability Metrics, 2024 Results

Question:

Ref: 2-9 Attachment #1 DSP p.52

Please add 2024 results to Table 9 System Reliability Metrics.

Response:

Table 9 has been updated (below) to show the 2024 results:

Metric	2019	2020	2021	2022	2023	2024	GSHI Target
SAIDI	1.89	1.48	1.11	1.15	1.49	0.94	1.43
SAIDI5	39.80%	58.60%	12.40%	26.70%	46.60%	5.33%	≤ 15%
SAIFI	1.03	0.99	1.16	1.62	1.49	1.04	1.18
SAIFI5	43.80%	56.20%	27.10%	36.80%	47.90%	15.90%	≤ 20%

System Reliability Metrics

2-AMPCO-13 O.Reg 22/04 Total Audit Findings

Question:

Ref: 2-9 Attachment #1 DSP p.58

Please explain why GHSI did not meet its target in 2021 related to O.Reg 22/04 Total Audit Findings.

Response:

GSHI's target related to O.Reg 22/04 audit findings is ≤ 5 (all audits). In 2021, there were 10 findings, which exceeded the target by five (5). GSHi did not meet its target due to the following audit findings:

5 - secondary pole missing guy wire
2 - excess slack in guy wire
1 - guy wire too close to secondary buss
1 - ground guard missing
1 - incorrect nomenclature/stamp

These items, identified as "Needs Improvement" in the ESA report(s), were subsequently repaired in the field.

2-AMPCO-14 2024 Historical SAIDI & SAIFI Data

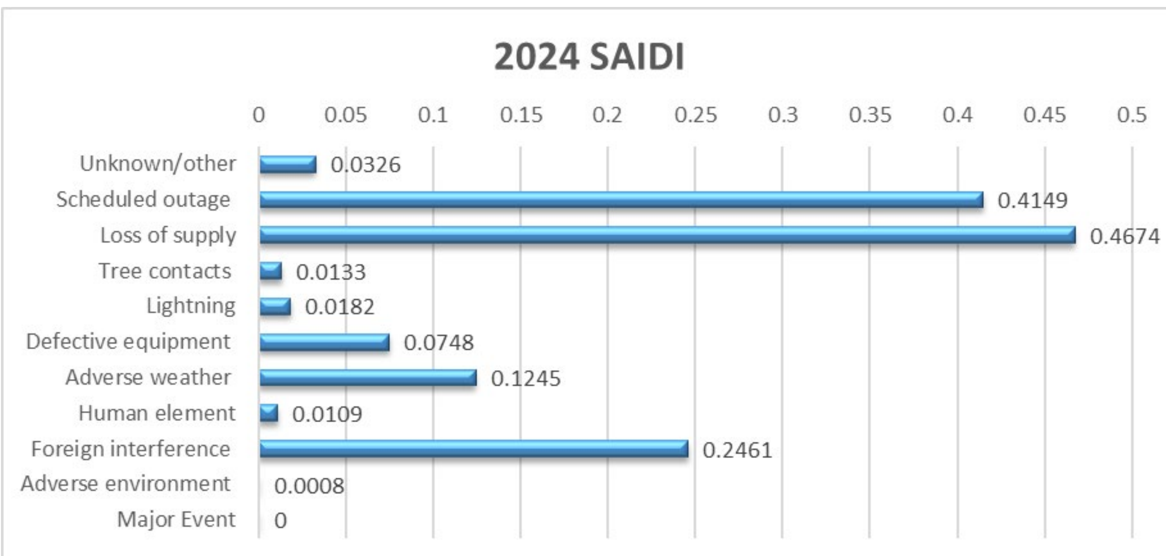
Question:

Ref: 2-9 Attachment #1 DSP p.65-69

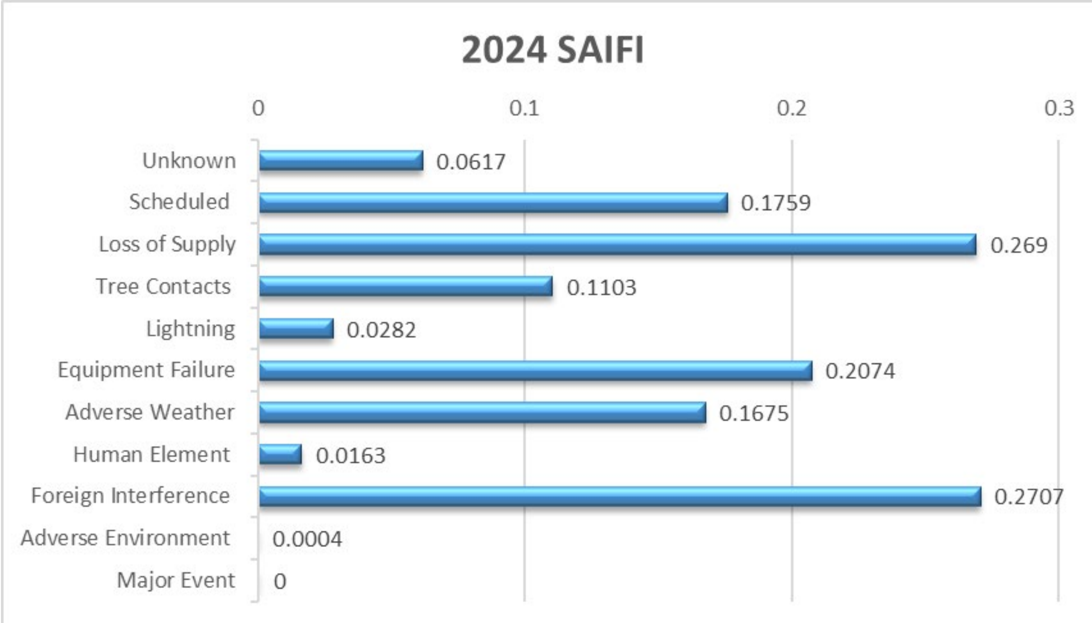
Please provide 2024 Historical SAIFI and SAIDI Data.

Response:

Historical 2024 data for both SAIFI and SAIDI are shown below:



2024 Historical SAIDI Data



2024 Historical SAIFI Data

2-AMPCO-15 SAIDI & SAIFI Equipment Failure by Equipment Type

Question:

Ref: 2-9 Attachment #1 DSP p.71

Please provide a breakdown of SAIDI and SAIFI Equipment Failure by Equipment Type and include 2024 data.

Response:

GSHI does not track the data required to provide the requested breakdown of Equipment Failure by Equipment Type. The granularity of data tracking with respect to outages at GSHi is limited to the requirements of the OEB's "Electricity Reporting & Record Keeping Requirements", latest edition.

2-AMPCO-16 DSP Tables 19 & 20 with 2024 Actuals

Question:

Ref: 2-9 Attachment #1 DSP p.78

Please add 2024 actuals to Tables 19 and 20.

Response:

Table 19 and Table 20 have been updated (below) to show 2024 data.

# of Interruptions by Cause	2019	2020	2021	2022	2023	2024
Unknown	9	39	39	27	21	40
Scheduled	154	134	128	83	76	75
Loss of Supply	11	6	24	16	9	8
Tree Contacts	9	12	9	12	17	14
Lightning	5	11	0	5	1	6
Equipment Failure	71	100	54	96	61	40
Adverse Weather	36	8	31	26	4	12
Human Element	7	4	7	6	0	3
Foreign Interference	74	73	62	80	72	93
Adverse Environment	3	9	10	4	2	1
Major Event	0	0	0	0	0	0

Table 19 # of Interruptions by Cause 2019-2024

# of Customer Interruptions by Cause	2019	2020	2021	2022	2023	2024
Unknown	266	1,992	6,553	3,975	6,895	2,997
Scheduled	5,708	4,308	6,573	2,751	6,241	8,537
Loss of Supply	5,515	2,737	28,966	9,501	11,417	13,055
Tree Contacts	467	561	1,789	3,893	3,707	5,352
Lightning	264	5,570	0	1,574	18	1,369
Equipment Failure	23,020	28,266	23,008	32,255	40,107	10,069
Adverse Weather	6,755	810	5,693	9,681	619	8,130
Human Element	1,799	2,425	3,968	16,797	0	793
Foreign Interference	10,093	3,553	5,744	6,401	14,050	13,137
Adverse Environment	22	549	2,706	851	602	20
Major Event	0	0	0	0	0	0

Table 20 # of Customer Interruptions by Cause 2019-2024

2-AMPCO-17 Projects & Expenditures - Worst Performing Feeder

Question:

Ref: 2-9 Attachment #1 DSP p.126

Please provide the projects and expenditures in the 2025-2029 plan resulting from the Worst Performing Feeder Analysis.

Response:

The following tables depict the projects and expenditures in the 2025-2029 plan resulting from the worst performing feeder analysis:

Year	Project Name	Estimated Project Cost ($)
2025	Moonglo Phase 1 UG Renewal	552,350
	Papineau/Frontenac	156,227
	Drummond St	102,825
	Rideau St (Lavoie to Grandview)	95,916
	Drummond St/ Village Cres	452,215
	Grenoble Village	374,029
	Latimer S689 to S31366	210,270
	CBC Hill, Kingsway S30649 to S6128)	395,286

Year	Project Name	Estimated Project Cost ($)
2026	Ramsey Lake Rd/Kirkwod Dr 44kV Rebuild	1,125,339
	Telstar @ Jupiter	414,141
	Summerhill Cres Ph.1	230,403
	Summerhill Cres Ph.2	239,456
	Ramsey View Crt (S11129 to S11127)	106,412
	Elm St/Clarabelle 44kV Rebuild	1,120,766

Year	Project Name	Estimated Project Cost ($)
2027	Bayview Lane Rebuild	160,983
	Roderick Ave Rebuild	140,662
	Galaxy Crt	290,236
	Jupiter Crt	223,006
	Portage Ave	157,327

Year	Project Name	Estimated Project Cost ($)
2028	Colonial Crt	299,118
	Skyward Dr	211,142
	Dew Drop Rd	665,203
	Frood Rd	245,776
	Moonlight Beach/Dube/Navanod	338,877
	CNR Tracks/Whissell Junction	331,603

Year	Project Name	Estimated Project Cost ($)
2029	Attlee/Soloy Dr	212,048
	Briar Ave	182,969
	Dollard Ave	216,573
	Robin/Eastern Ave/Crestmoor Rd	397,292
	Sherwood Ave/Carling Cres	189,618

2-AMPCO-18 2022 Roof Asset Management Program

Question:

Ref: 2-9 Attachment #1 DSP p.135

The 2022 Roof Asset Management Program was completed by independent consultant Garland Canada Inc.

Please provide the projects and expenditures in the investment plan resulting from this report.

Response:

The projects in the investment plan stemming from the work completed by Garland Canada Inc are as follows:

2028: Membrane Replacement and Replace Damaged Insulation

Roof Section 5	$125,350
Roof Section 6	$248,400

2029: Membrane Replacement and Replace Damaged Insulation

Roof Section 2	$498,432

Please note that Garland's work was dated August 9th, 2023. The estimated costs in the investment plan have been increased by 3% yearly from the base amount in Garland's report to account for anticipated inflation.

2-AMPCO-19 Cost Savings over the 2025-2029 - Capital Investments

Question:

Ref: 2-9 Attachment #1 DSP

Please provide the forecast costs savings over the 2025-2029 from the prospective capital investments.

Response:

It is not possible to quantitatively determine the cost savings over the 2025-2029 period from the prospective capital investments. However, qualitatively, investments into *System Renewal* are generally expected to result in a decrease in future O&M expenditure, at a quantum less than it would otherwise trend, because paced, continuous replacement of older-vintage assets with new assets will help to reduce upward pressure on O&M expenditures as there will be fewer equipment failures and reduced expenditures as it relates to unplanned emergency repairs.

Qualitatively, the prospective investments contemplated throughout this DSP are expected to produce costs savings over the forecast period as well as yield improvements in both reliability and operational efficiency.

- Proactive, planned refurbishment and/or removal of both distribution system and substation assets exhibiting poor health index scoring is anticipated to help minimize future O&M costs. O&M costs are inversely correlated with declining asset condition; therefore, GSHI anticipates a reduction in future O&M costs as these low-HI assets are replaced proactively through a paced *System Renewal* portfolio of investments.

- To take advantage of economies of scale, if possible, “pockets” of assets are identified and individual investments are grouped together (e.g., renewing an entire subdivision in one year as opposed to individual streets over many years) which minimizes construction costs by reducing crew/equipment mobilization activities and by streamlining project planning and work execution.
- The voltage conversion of the existing 4kV system will help reduce equipment failure, eliminate safety hazards and correct substandard conditions prevalent with this vintage of construction, all of which could lead to a potential reduction in future O&M costs. The elimination of the 4kV system offers the potential to reduce line losses, reduce inventory levels and lower carrying costs - all of which will help to minimize future O&M costs.
- Further, voltage conversion will enable the de-commissioning of an existing 4kV municipal substation. This will produce additional benefits under system O&M as it will free staff from current tasks such as monthly station inspections, major preventative maintenance activities, annual infrared scanning, annual oil sampling, and the myriad other small items needed to keep a substation operating suitably (battery replacements, property maintenance, fence maintenance, etc.)
- GSHI is streamlining inspections, asset defect and field observation reporting with mobile technologies and innovation using ESRI’s Location Platform and ecosystem of web-based and mobile enterprise applications. The roll-out continues today with extensions occurring across multiple additional processes which is resulting in true business transformation at the utility.
- Whenever possible, the bundling of drivers to substantiate a prospective investment ensures that the timing of construction activities provides the highest possible value for our customers (e.g., avoiding re-work costs by

delaying prospective *System Renewal* activities until there is an accompanying *System Service* or *System Access* driver that stacks additional value).

2-AMPCO-20 Table 49 - Quantity of Assets Replaced over 2020-2024

Question:

Ref: 2-9 Attachment #1 DSP p.166

Please provide the last three columns of Table 49 to reflect the quantity of assets replaced over the 5-year period 2020-2024.

Response:

Please see revised Table 49 below that reflects the quantity of assets replaced over the 5-year period 2020-2024:

Asset Category	Years 2020-2024 Inclusive		
	Total Number of Units	Yearly Average	Action Strategy
Pad Mounted Transformers	97	19.4	reactive
Pole Mounted Transformers	465	93	reactive
Submersible Transformers	0	0	reactive
Vault Transformers	9	1.8	reactive
Overhead Line Switches 44kV	3	0.6	reactive
Overhead Line Switches 12kV	2	0.4	reactive
Overhead Line Switches 4kV	1	0.2	reactive
Pad Mounted Switchgear	2	0.4	reactive
Pad Mounted Junction Enclosures	1	0.2	reactive
GSU Wood Poles	1,074	214.8	proactive
GSU Concrete Poles	23	4.6	proactive
Bell Wood Poles	154	30.8	proactive
Hydro One Wood Poles	0	0	proactive
Underground Cables 44kV	0.08	0.02	proactive
Underground Cables 12kV	8.7	1.7	proactive
Underground Cables 4kV	3.3	0.7	proactive

2-AMPCO-21 2024 Data Added to table 55 of DSP

Question:

Ref: 2-9 Attachment #1 DSP p.191

Please add 2024 data to Table 55.

Response:

Table 55 has been updated (below) to show 2024 data.

Flagged for Action Plan - Levelized										
Asset Category	2020		2021		2022		2023		2024	
	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
Substation Transformers	5	1	0	6	1	0	0	0	0	1
Pad Mounted Tranformers	49	17	49	22	49	21	42	28	42	9
Pole Mounted Transformers	18	98	18	90	18	99	18	104	18	74
Submersible Transformers	2	0	2	0	2	0	1	0	1	0
Vault Transformers	4	0	4	3	4	3	5	3	5	0
Overhead Line Switches	21	8	21	2	21	2	23	1	23	18
Pad Mounted Switchgear	1	0	0	0	0	0	0	0	0	2
Pad Mounted Junction Enclosure	1	0	0	0	0	0	0	0	0	1
GSU Wood Poles	233	219	233	259	233	214	225	293	225	89
GSU Conc. Poles	12	0	12	0	12	0	10	0	10	23
Bell Wood Poles	90	42	90	12	90	13	87	17	87	70
Hydro One Wood Poles	1	0	1	0	1	0	2	0	2	0

2-AMPCO-22 System Renewal Lines Spending and Projects

Question:

Ref: 2-9 Attachment #1 DSP p.223-229

With respect to the Lines budget, the forecast spend in 2025 is $2,539,064.

a) Please provide the System Renewal Lines spending for the years 2020 to 2024.

With respect to the proposed rebuilds in 2025 on page 224, please confirm all projects are included in Appendix 2-AA for 2025.

Response:

Response to this interrogatory requires 2024 figures. The response will be filed by February 4, 2025.

2-AMPCO-23 System Renewal Underground Spending and Projects

Question:

Ref: 2-9 Attachment #1 DSP p.229-234

a) Please provide the System Renewal Underground spending for the years 2020 to 2024.
b) With respect to the proposed rebuilds in 2025 on page 230, please confirm all projects are included in Appendix 2-AA.
c) Please provide the underground km to be replaced in 2025.
d) Please provide the underground km to be replaced over the period 2026-2029.
e) Please provide the underground km replaced over the period 2020-2024.

Response:

Response to this interrogatory requires 2024 figures. The response will be filed by February 4, 2025.

2-AMPCO-24 Pacing of Utility Network Migration/GIS Modernization

Question:

Ref: 2-9 Attachment #1 DSP p.240

With respect to the Utility Network Migration/GIS Modernization (General Plant) investment of $500,000 in 2025 and $380,000 in 2026, please explain why this work could not be paced over the 2025-2029 period.

Response:

The transition from Milsoft to the Utility Network Model (UNM), along with adopting a new engineering analysis software and updating the Survalent Wizard in OMS, requires a complete overhaul of the GIS data schema, enterprise mapping services, and system integrations. Managing both legacy and new environments in parallel presents significant challenges, including increased operational risks, data inconsistencies, and excessive resource demands.

A prolonged transition would necessitate dual maintenance of critical infrastructure, compounding complexity, delaying efficiencies, and increasing costs. The cut-over must be carefully coordinated to ensure minimal disruption, with OMS and Engineering Analysis switching as soon after as feasible to avoid prolonged duplicative efforts and integration challenges.

Given these factors, the proposed timeline aims at achieving a streamlined, cost-effective migration while maintaining system reliability and operational efficiency.

2-AMPCO-25 Appendix 2-AA - Major Repairs to Substations

Question:

Ref: 2-9 Attachment #1 DSP p.349

Please provide the project in Appendix 2-AA that includes this work (System Renewal – Major Repairs to Substations).

Response:

The project that includes the work (System Renewal – Major Repairs to Substations) does not appear in Appendix 2-AA because the yearly costs that are budgeted are below the materiality threshold and are thus included in the line 'Miscellaneous (projects below the materiality threshold)' in Appendix 2-AA. When emergency repair work is required, these funds are charged to the specific substation assets that have failed.

2-AMPCO-26 Vehicle Replacements

Question:

Ref: 2-9 Attachment #1 DSP p.362

a) Please confirm the vehicle types replaced in 2024 and the corresponding cost.
b) Please confirm the vehicles to be replaced in 2025.

Response:

a)

Vehicles Replaced in 2024	
#778 2009 Ford Econoline Van	$25,721.08
#758 2009 Dodge Nitro	$26,007.23
#749 2015 Ford F-250	$38,829.72
#717 2016 Dodge Journey	$29,637.64

b) The following vehicles are being replaced in 2025:

- #838 1996 Int. Telelect RBD
- #877 2011 Freightliner FM2
- #876 2016 Freightliner

2-AMPCO-27 General Plant Building Costs with 2024 Actuals

Question:

Ref: 2-9 Attachment #1 DSP p.365

a) Please detail the work undertaken in 2024 with respect to General Plant Building Costs.

b) Please provide 2024 actuals.

Response:

Response to this interrogatory requires 2024 figures. The response will be filed by February 4, 2025.

2-AMPCO-28 Table 3-1 Health Index Summary

Question:

Ref 1: 2-9 Attachment #1 DSP

In 2011, GSHI selected and engaged Kinectrics Inc. (Kinectrics) to perform the first ACA on GSHI's key distribution assets. Two more assessments, which covered the GSHI asset population to the end of 2015 and 2019 respectively, were conducted.

Ref 2: Appendix A p. 19

a) Please provide Table 3-1 Health Index Summary on the basis of quantity of assets in very poor, poor, fair, good and very good condition.
b) Please provide the same table in Reference #2 with data from the 2019 ACA.
c) Please provide a copy of the 2019 ACA.
d) Please explain how GHSI has responded to the recommendations in the 2019 ACA.

Response:

a) An updated Table 3-1 (2024 ACA) is provided below:

Asset Category	Population	Sample Size	Average Health Index	Health Index Distribution					Average Age	% of Population with Age	Average DAI
				Very Poor (<25%)	Poor (25 - < 50%)	Fair (50 - < 70%)	Good (70 - < 85%)	Very Good (>= 85%)			
Pad Mounted Transformers	1,403	1,403	75%	135	210	64	128	866	19	100%	94%
Pole Mounted Transformers	3,933	3,933	88%	112	171	232	441	2,977	15	100%	100%
Submersible Transformers	14	14	15%	14	0	0	0	0	48	100%	92%
Vault Transformers	229	229	69%	16	23	64	77	49	33	100%	95%
Overhead Line Switches 44kV	48	48	80%	2	2	8	9	27	17	100%	100%
Overhead Line Switches 12kV	152	152	70%	4	40	27	26	55	21	100%	100%
Overhead Line Switches 4kV	8	8	63%	2	0	3	0	3	26	100%	100%
Pad Mounted Switchgear	84	84	93%	1	0	1	15	67	21	100%	82%
Pad Mounted Junction Enclosures	74	74	94%	2	0	0	8	64	21	100%	83%
GSU Wood Poles	11,639	11,639	74%	835	1,823	1,246	2,052	5,683	31	100%	80%
GSU Concrete Poles	110	110	92%	0	2	0	13	95	51	100%	74%
Bell Wood Poles	2,686	2,686	61%	384	762	390	400	750	41	100%	80%
Hydro One Wood Poles	345	345	83%	0	40	46	49	210	24	100%	79%
Underground Cables 44kV*	13	13	56%	4	1	2	1	5	30	100%	Age Only
Underground Cables 12kV*	388	388	68%	50	71	39	66	162	24	100%	Age Only
Underground Cables 4kV*	21	21	66%	6	2	2	1	10	25	100%	Age Only

b) An updated Table 3-1 (2019 ACA) is provided below:

Assset Category	Population	Sample Size	Average Health Index	Health Index Distribution					Average Age	% of Population with Age	Average DAI
				Very Poor (<25%)	Poor (25 - < 50%)	Fair (50 - < 70%)	Good (70 - < 85%)	Very Good (>= 85%)			
Substation Transformers	43	43	73%	3	6	6	8	20	40	100%	44%
Pad Mounted Transformers	1,440	1,418	76%	142	120	247	66	843	18	100%	51%
Pole Mounted Transformers	3,232	3,132	94%	124	9	49	90	2,860	14	100%	34%
Submersible Transformers	16	16	16%	12	4	0	0	0	43	100%	34%
Vault Transformers	131	116	83%	12	3	6	5	90	30	100%	28%
Overhead Line Switches	2,173	2,016	95%	49	23	50	53	1,841	19	100%	10%
Pad Mounted Switchgear	80	80	96%	1	0	0	2	77	18	100%	42%
Pad Mounted Junction Enclosures	70	70	95%	2	0	0	0	68	17	100%	51%
GSU Wood Poles	11,755	11,755	83%	730	1,118	753	970	8,184	31	100%	37%
GSU Concrete Poles	120	120	96%	0	0	3	7	110	46	100%	35%
Bell Wood Poles	2,695	2,693	73%	145	567	315	321	1,345	40	100%	36%
Hydro One Wood Poles	349	339	93%	0	7	15	67	250	19	100%	34%

c) Please see Tab 2, Interrogatory 28, Attachment 1 for an updated 2019 ACA.

d) Items a) through g) were the recommendations from the 2019 ACA performed by Kinetrics. Individual responses are provided after each bullet.

a) A total of 21% of Substation Transformers were found to be in poor or very poor condition. Based on the levelized flagged for action plans, a total of 8 transformers should be looked at in the next 5 years. This is cause for concern, as substation transformers are a large asset class with significant consequences of failure. It is therefore recommend that GSU address this issue (e.g. additional monitoring, accelerate replacement/refurbishment).

As part of the 2020-2024 capital investments, eight (8) power transformer units were addressed, in line with the recommendation.

b) GSU Wood Poles also have significant quantities (16% of the population) that were found to be in poor or very poor condition. Since it is projected that more *than 16% of poles require replacement/refurbishment within the next 5 years, it is important for GSU to have an annual program to address a certain percentage of poles every year, so as not to create a backlog of assets needing attention.*

As part of the 2020-2024 capital investment plan and the 'Flagged for Action Plan – Levelized,' a total of 1,074 GSHi-owned wood poles were addressed, representing approximately 93% of the recommended 1,149 poles outlined in the report.

c) The Data Availability Indicator (DAI) and data gaps were outlined for each asset category. It is recommended that GSHI make efforts to increase the DAI for each asset category and to put efforts to close the data gaps in order of priority.

DAI for health indexing has continued to improve between the filing of the 2019 ACA and the 2024 ACA. GSHi will continue to make efforts to further close the data gaps in order of priority, as recommended by Kinectrics.

d) It is recommended that GSHI implement a system that standardizes and computerizes inspection records. It is further recommended that the inspection-based condition and sub-condition parameters presented in this study be included as standard inspection items. Such parameters can be found in the Health Index formula for each asset group. The suggested point systems, or condition criteria, for evaluating the parameters are also included.

This system has been successfully implemented and has played a key role in enhancing DAI across asset classes. GSHi will continue to refine and maintain the system, further advancing data collection efforts.

e) GSHI collects removal data for all asset categories. There was sufficient data to develop life curves for Pad Mounted transformers. GSHI should continue to *collect this information to enable development of life curves for all other asset categories.*

GSHi has been collecting this information since 2015 and will continue to do so going forward.

f) GSU may wish to consider health indexing of other assets, e.g. Breakers, Reclosers, and Underground Cables.

The 2024 *Substation Condition Assessment Report* by Lakeside Power Consulting Inc includes health indexing of both breaker and reclosers, whereas the 2024 *Asset Condition Assessment* by Kinectrics contains health indexing of underground cables.

g) The data used in this assessment was from different locations (e.g. numerous spreadsheets or PDF files). For more efficient record keeping and ease of future assessments, GSHI may wish to consider implementing platform that consolidates asset information and condition data (e.g. nameplate information, test results, operational information, inspection records, etc.) and that can perform live asset analytics.

This recommendation was the key driver for Project 2022-A18, "General Plant – Asset Management Software," during the historical period. However, the project experienced delays due to the pandemic and the resulting operational uncertainties. In the forecast period, the same recommendation is reflected in the 2024 ACA. Similarly, Project 2027-A16, outlined in Section 5.4.2.1.3.5 of the DSP, has been proposed, with the Kinectrics recommendation serving as the primary basis for the project.

Attachment 1 (of 1):

2-AMPCO-28 Attachment 1: 2019 Asset Condition Assessment

KINECTRICS

GREATER SUDBURY HYDRO 2019 ASSET CONDITION ASSESSMENT

K-814186-RA-0001 R00

Prepared for

Greater Sudbury Hydro Inc.
038154

Issue Date

2019-Sep-26

Prepared by	Reviewed by	Approved by
Katrina Lotho 2019.09.26 11:59:41 -04'00'	Fan Wang 2019.09.26 12:02:14 -04'00'	Digitally signed by Garreth Coelho Date: 2019.09.26 12:42:15 -04'00'
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DISCLAIMER

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1 Introduction

Greater Sudbury Hydro Inc. (GHSI) owns, operates, and maintains the electricity distribution system in and around Sudbury. In keeping with a commitment to strategic and prudent investment planning, GSHI recognizes the need to develop an asset management strategy for its key distribution assets.

Asset Condition Assessment (ACA) is crucial part of Asset Management, and provides a systematic process for determining and justifying long-term sustainment needs. Health indexing and risk assessment form the basis of ACA process. The Health Index (HI) expresses the condition of an asset as a single number, and risk assessment accounts for the consequence of asset failure. Using this process, the quantities of assets that will require attention in the next several years can be estimated.

In 2011, GSU selected and engaged Kinectrics Inc. (Kinectrics) to perform the first ACA on GSU's key distribution assets. A second assessment, which covers the GSU asset population to the end of 2015, was conducted. This report presents the results of Kinectric's third assessment. GSHI's first quarter 2019 asset information and Kinectrics's up to date methodologies to develop HI distributions and estimate condition-based action plans were used. This report presents the results of Kinectrics' assessment.

1.1 Objective and Scope of Work

The objective of the work was to conduct ACA on a GSHI's key distribution assets. The ACA was designed to quantify the extent of aging, and to estimate the number of assets that likely need to be addressed in the near future.

The categories and subcategories of assets included in this study are as follows:

- Substation Transformers
- Pad Mounted Transformers
- Pole Mounted Transformers
- Submersible Transformers
- Vault Transformers
- Overhead Line Switches
- Pad Mounted Switchgear
- Junction Enclosures
- Poles
    - GSHI Wood Poles
    - GSHI Concrete Poles
    - Bell Wood Poles
    - Hydro One Wood Poles

For each asset category, the following are included:

- HI formula
- Age distribution
- HI distribution
- Condition-based flagged for action (FFA) Plan
- Assessment of data availability and a data gap analysis

For substation transformers, a list of assets requiring attention, prioritized by risk, is also provided.

2 Asset Condition Assessment Methodology

The ACA methodology involves the process of determining asset HI, as well as developing a condition-based FFA Plan for each asset group. In this project, GSHI customized algorithms were developed using existing utility data and information, as well as input from the utility technical and field staff.

2.1 Health Index

Condition parameters are the asset characteristics or properties that are used to derive the HI. A condition parameter may be comprised of several sub-condition parameters. For example, a parameter called “Oil Quality” may be a composite of parameters such as “Moisture”, “Acid”, “Interfacial Tension”, “Dielectric Strength” and “Color”.

In formulating a HI, condition parameters are ranked, through the assignment of *weights*, based on their contribution to asset degradation. The *condition parameter score* for a particular parameter is a numeric evaluation of an asset with respect to that parameter.

HI, which is a function of scores and weights, is therefore given by:

$$HI = \frac{\sum_{m=1}^{\forall m} \alpha_m (CPS_m \times WCP_m)}{\sum_{m=1}^{\forall m} \alpha_m (CPS_{m.\max} \times WCP_m)} \times DR$$

Equation 1

where

$$CPS_m = \frac{\sum_{n=1}^{\forall n} \beta_n (SCPS_n \times WSCP_n) \times DR_n}{\sum_{n=1}^{\forall n} \beta_n (WSCP_n)} \times DR_m$$

Equation 2

CPS	Condition Parameter (CP) Score, 0-4
WCP	Weight of Condition Parameter
α_m / β_n	Data availability coefficient for condition/sub-condition parameter (1 if input data available; 0 if not available)
SCPS	Sub-Condition Parameter (SCP) Score, 0-4
WSCP	Weight of Sub-Condition Parameter
DR	De-Rating Multiplier

The scale that is used to determine an asset's score for a particular parameter is called the *condition criteria*. In the Kinectrics methodology, a condition criteria scoring system of 0 through 4 is used. A score of 0 is the "worst" possible score; a score of 4 is the "best" score, i.e. $CPS_{max} = SCPS_{max} = 4$.

The α and β values are set to 0 if the parameter data is unavailable and 1 if the data is available. It is evident from the equations that the HI formula will, in essence, be readjusted for each unit depending on the specific data available for each unit. For example, if the HI formula for a certain asset category is based originally on 5 condition parameters (i.e. $m = 5$ in Equation 1) but a specific unit only has parameters 1 and 3 available (e.g. $\alpha_1 = 1$, $\alpha_2 = 0$, $\alpha_3 = 1$, $\alpha_4 = 0$, $\alpha_5 = 0$), its HI calculation will only be based on parameters 1 and 3.

De-Rating (DR) Multipliers are also used to adjust a condition or sub-condition parameter score or calculated Health Index so as to reflect certain conditions. These may be factors that may or may not be related to asset condition, but may impact asset service life. For example, certain breaker operating mechanisms may be problematic, so a DR Multiplier may be associated with operating mechanism. A certain population of wood poles may be in a region that is prone to lightning strikes. The HI of these poles may be de-rated to reflect higher likelihood of lightning.

Dominant parameters may be used as de-rating factors. These are asset properties that are considered to be of such importance that its status has a dominant impact on the value of the Health Index. An example is winding dissipation factor for transformers. If the dissipation factor is poor, a DR Multiplier can be applied to the HI, placing the transformer in poor condition, regardless of the scores of the other condition parameters.

In this methodology, the final HI assigned to an individual asset is limited by the asset's age. An *Age Limiter* (AL), which is equal to the cumulative survival probability at a given age of an asset group, is compared to the calculated HI. If the calculated HI is less than or equal to the AL, the final HI assigned is the calculated HI. Otherwise, the final HI assigned is equal to the AL. Note in using the AL that it is possible that condition data (i.e. test results, inspections, loading, etc.) may be good and the thus the calculated HI is high.

The final HI score is:

$$HI_{Final} = \begin{Bmatrix} if\,(AL < HI, HI_{Final} = AL) \\ else(HI_{Final} = HI) \end{Bmatrix}$$

Equation 3

AL	Age Limiter
HI	Health Index calculated per Equation 1

As stated previously, an asset's HI is given as a percentage, with 100% representing "as new" condition. The HI is calculated if there is age or condition data available. The subset of the population with data is called the *sample size*. Results are presented in terms of number of units and as a percentage of the sample size. If the sample size is sufficiently large and the units within the sample size are sufficiently random, the results may be extrapolated for the entire population.

The HI distribution given for each asset group illustrates the overall condition of the asset group. Further, the results are aggregated into five categories and the categorized distribution for each asset group is given. The HI categories are as follows:

Very Poor	Health Index < 25%
Poor	25 $\leq$ Health Index < 50%
Fair	50 $\leq$ Health Index <70%
Good	70 $\leq$ Health Index <85%
Very Good	Health Index $\geq$ 85%

2.2 Condition Based Flagged for Action Plan

In this project the term "removals" is used to describe the removal of assets from service, regardless of the reason removed. Reasons for removal can include asset failure, proactive replacement because of condition, system growth, obsolescence, etc.

A frequency of removals that grows exponentially with age generally provides a good overall model of asset service life. Based on Kinectrics' experience in failure rate studies of multiple power system asset groups, Kinectrics has selected the Weibull equation to model the removals as functions of asset age. The Weibull distribution has no specific characteristic shape and, as such, can model the exponentially increasing removal rate using appropriate parameters.

The Weibull distribution is a continuous probability distribution with the following probability density function equation:

$$f(t) = \frac{\beta t^{\beta-1}}{\alpha^{\beta}} e^{-(\frac{t}{\alpha})^{\beta}}$$

Equation 4

f(t)	= probability density function (PDF), *i.e. likelihood that an asset will be removed from service when it's age is within a particular range*
t	= time (age in years)
α, β	= constant parameters that control the shape of the curve

The corresponding cumulative distribution function is as described in the equation below. The function models cumulative likelihood of removals over time. The likelihood of survival is the complement of the likelihood of removal:

$$Q(t) = 1 - R(t) = 1 - e^{-(\frac{t}{\alpha})^{\beta}}$$

Equation 5

Q(t)	= cumulative distribution function (CDF), i.e. *cumulative likelihood of removals*
R(t)	= survival function

The removal rate (i.e. percentage of removals associated with a certain age) is:

$$\lambda(t) = \frac{f(t)}{1 - Q(t)} = \frac{\beta t^{\beta-1}}{\alpha^{\beta}}$$

Equation 6

$\lambda(t)$	= percent removals per year per age, i.e. *removal rate*

Different asset groups experience different removal rates. The parameters α and β define the shape of the Weibull distribution for a specific asset group. Examples of the three functions described above are shown in Figure 2-1, where α = 57.503 and β = 4.132. It can be seen from the graph and from Equation 4 that Q(40) = 0.2 and Q(75) = 0.95. In other words, the cumulative distribution functions (i.e. cumulative likelihood of removals) at age = 40 and 75 years are 20% and 95% respectively. The area beneath the red PDF curve between the purple hatched lines (at age = 45 and 60 years) equates to 41.6% of the entire area under the beneath curve. This represents a 41.6% likelihood that an asset removed from service will be between the ages of 45 to 60 years.

For each asset group, the values of these constant α and β parameters were calculated such that they reflect typical service lives of the asset groups. With assets that are run to failure, the removal curve may closely resemble the failure curve of the asset. Note however, that the removal curves will include assets that have been removed for reasons other than failure (e.g. removals because of proactive replacement based on condition, system growth, obsolescence, etc.).

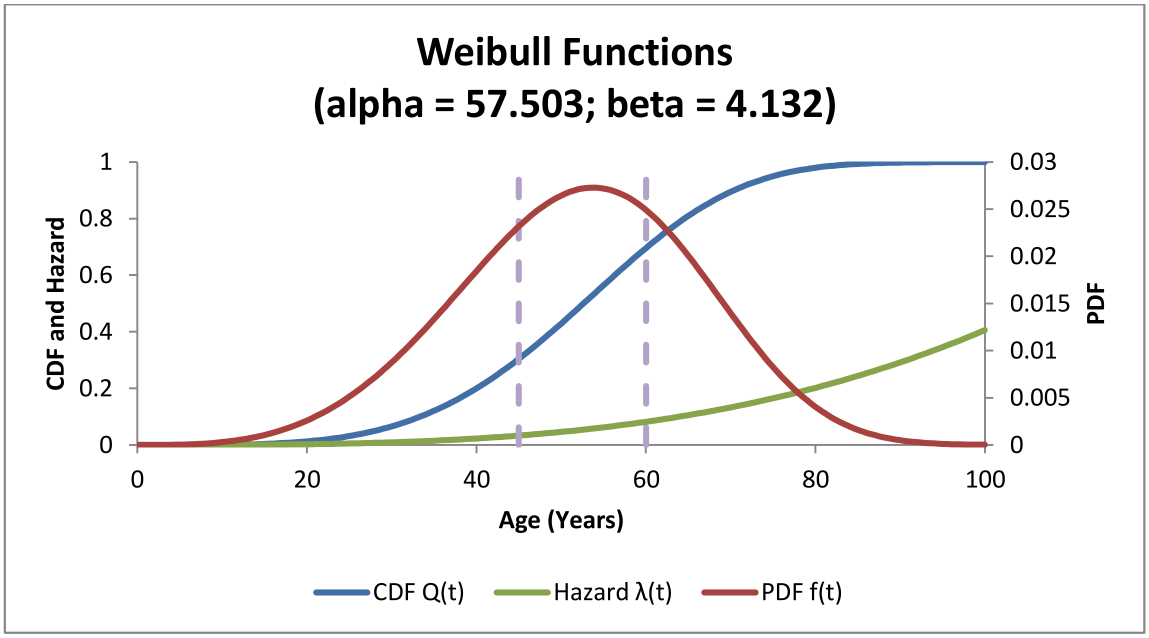

Figure 2-1 Weibull Functions

<u>Flagged for Action Plan Using a Reactive Approach</u>

Because the consequences of failure are relatively small, many types of distribution assets are reactively replaced.

For such asset types, the number of units expected to be replaced in a given year are determined based on the asset's removal rates (Equation 6).

An example of such a Flagged for Action Plan is as follows: Consider an asset distribution of 100 - 5 year old units, 20 – 10 year old units, and 50 - 20 year old units. Assume that the failure rates for 5, 10, and 20 year old units for this asset class are f_5 = 0.02, f_{10} = 0.05, f_{20} = 0.1 failures / year respectively. In the current year, the total number of replacements is 100(.02) + 20(0.05) + 50(0.1) = 2 + 1 + 5 = 8.

In the following year, the expected asset distribution is, as a result, as follows: 8 – 1 year old units, 98 – 6 year old units, 19 – 11 year old units, and 45 - 21 year old units. The number of replacements in year 2 is therefore 8(f_1) + 19(f_6) + 45(f_{11})+ 45(f_{21}).

Note that in this study the "age" used is in fact "effective age", or condition-based age if available, as opposed to the chronological age of the asset.

The Levelized Flagged for Action plan smooths or levelizes the peaks and valleys of the Flagged for Action plan.

Flagged for Action Plan Using a Proactive (Risk-Based) Approach

For substation transformers, costs of replacement and/or consequences of failure are more significant, and, as a result planning for replacement requires more consideration. For these assets, a risk-based approach is taken when developing the FFA Plan. Further, an FFA Year (the year that a particular unit is flagged for action) is calculated for each asset unit.

This risk-based methodology considers both the asset likelihood of removal (as related to HI) and its consequence of failure (criticality). The product of likelihood or removal and consequence of failure determines asset risk.

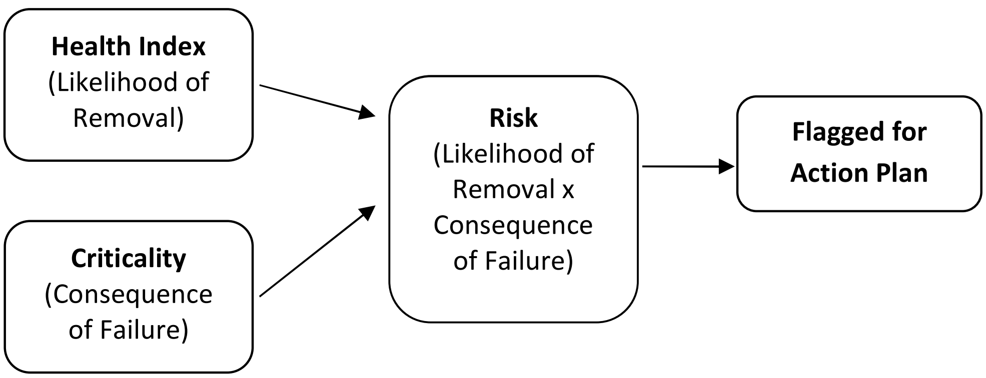

Figure 2-2 Risk Assessment Procedure

Relating Health Index to Likelihood of Removal

The health of an asset correlates to condition based likelihood of removal. The methodology that this project uses to relate HI to likelihood of removal considers asset stress as described below.

If there are no dominant sources, it is assumed in this methodology that the stress to which an asset is exposed is not constant and will have a somewhat normal frequency distribution. This is illustrated by the probability density curve of stress below. The vertical lines in the figure represent condition or strength (HI) of an asset.

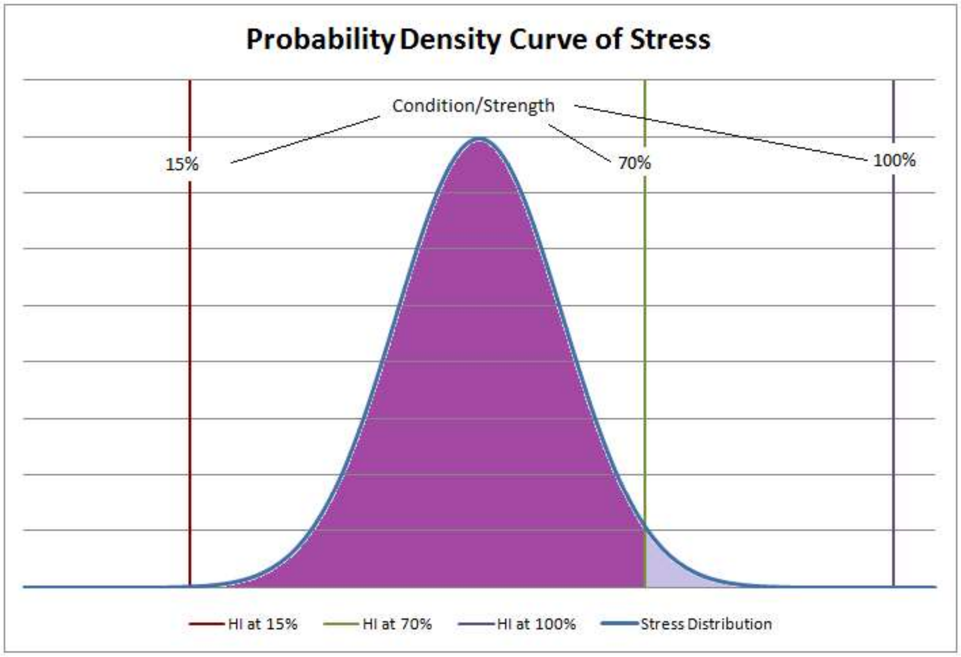

Figure 2-3 Stress Curve

An asset in as-new condition (100% strength) should be able to withstand most levels of stress. As the condition of the asset deteriorates, it may be less able to withstand higher levels of stress. Consider, for example, the green vertical line that represents 70% condition/strength. The asset should be able to withstand magnitudes of stress to the left of the green line. If, however, the stress is of a magnitude to the right of the green line, the asset can fail and consequently be removed from service.

To create a relationship between the HI and likelihood of removal, assume two "points" on the stress curve that correspond to two different HI values. In this example, assume that an asset that has a condition/strength (HI) of 100% can withstand all magnitudes of stress to the left of the purple line. It then follows that probability that an asset in 100% condition will fail is the probability that the magnitude of stress is at levels to the right of the purple line. This corresponds to the area under the stress density curve to the right of the purple line. Similarly, if it assumed that an asset with a condition of 15% will fail if subjected to stress at magnitudes to the right of the red line, the probability of failure at 15% condition is the area under the stress density curve to the right of the red line.

The likelihood of removal at a particular HI is found from plotting the HI on the X-axis and the area under the probability density curve to the right of the HI line on the Y-axis, as shown on the graph of the figure below.

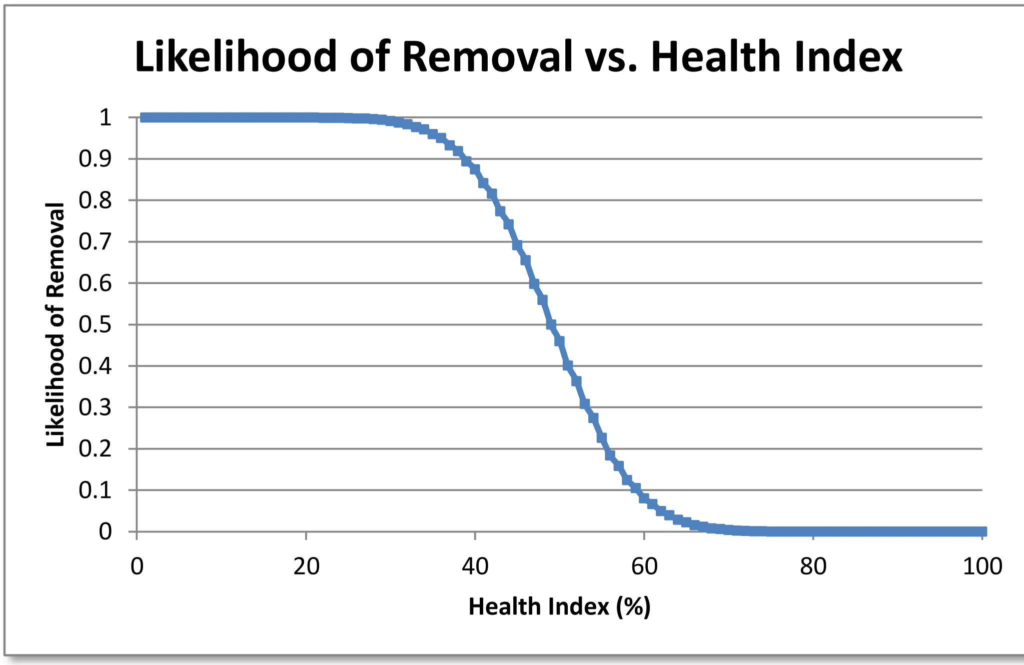

Figure 2-4 Likelihood of Removal vs. Health Index

Criticality

In this study, the metric used to measure consequence of failure is referred to as *Criticality*. Criticality may be determined in numerous ways, with monetary consequence or degree of risk to corporate business values being examples. The higher the criticality value assigned to a unit, the higher it's consequence of failure.

The asset's criticality is defined as follows:

$$\text{Criticality} = (\text{Criticality}_{max} - \text{Criticality}_{min}) * \textit{Criticality\_Index} + \text{Criticality}_{min}$$

Equation 7

Where the maximum and minimum criticality values are as follows:

$\text{Criticality}_{max} = 1/(75\%) = 1.33$

$\text{Criticality}_{min} = 1/(95\%) = 1.05$

This study flags an asset as a candidate for action when the risk (product of its likelihood of removal and criticality) is greater than or equal to one. The above maximum and minimum Criticality values were selected to ensure that units with highest relative importance are flagged as soon as the likelihood of removal is 75% (i.e. Consider an asset whose HI corresponds to an 75% likelihood of removal and whose Criticality = 1.33. Its risk = likelihood of removal x

Criticality = 80% X 1.33 = 1. Since the risk = 1, the asset is flagged for action). Action for units that are least critical can be deferred until likelihood of removal is 95%.

As seen in Equation 6 above, a *Criticality Index* (CI) will be calculated for each asset to quantify Criticality. Similar to the HI, the CI is a sum-product of scores and weights of parameters that represent a unit's consequence of failure. CI ranges from 0% to 100%, with 100% representing the unit with the highest possible consequence of failure.

$$Criticality\_Index = \frac{\sum_{i=1}^{\forall i}(SCRP_i \times WCRP_i)}{\sum_{i=1}^{\forall i}(WCRP_i)}$$

Equation 8

SCRP Score of criticality risk parameter
WCRP Weight of criticality risk parameter

Risk

As previously mentioned, asset risk is the product of likelihood of removal and Criticality:

Risk = Likelihood of Removals x Criticality

Equation 9

Since the likelihood of removal ranges from 0 to 1 and Criticality ranges from 1.05 to 1.33 in this methodology (i.e. $Criticality_{min.}$ = 1.05 and $Criticality_{max.}$ = 1.33), asset Risk will range from 0 to 1.33. However, to better visualize the relative risk of each asset within an asset category, a normalized *Risk Index* for each asset is also given. The Risk Index is simply the asset's calculated Risk divided by the maximum Criticality (i.e. Risk Index = (Likelihood of Failure x Criticality) / $Criticality_{max}$). The Risk Index ranges from 0% to 100%.

2.3 Data Assessment

The condition data used in this study was provided by GSHI and included the following:

- Asset Properties (e.g. age, size, voltage, location information)
- Test Results (e.g. Oil Quality, DGA, power factor, transformer turns ratio, winding resistance, leakage reactance, etc.)
- Loading information
- Preventative Maintenance (PM) records and Corrective Maintenance (CM) work orders records

There are two dimensions for assessing the availability and completeness of data used in this study: Data Availability Indicator (DAI) and data gap.

2.3.1 Data Availability Indicator (DAI)

The Data Availability Indicator (DAI) is a measure of the amount of condition parameter data that an asset has, as measured against the condition parameters included in the HI formula. It is determined by the ratio of the weighted condition parameters score and the subset of condition parameters data available for the asset over the "best" overall weighted, total condition parameters score. The formula is given by:

$$DAI = \frac{\sum_{m=1}^{\forall m} (DAI_{CPS\,m} \times WCP_m)}{\sum_{m=1}^{\forall m} (WCP_m)}$$

Equation 10

where

$$DAI_{CPSm} = \frac{\sum_{n=1}^{\forall n} \beta_n \times WSCPn}{\sum_{n=1}^{\forall n} (WSCPn)}$$

Equation 11

DAI_{CPSm}	Data Availability Indicator for Condition Parameter m with n Sub-Condition Parameter (SCP)
β_n	Data availability coefficient for sub-condition parameter (=1 when data available, =0 when data unavailable)
$WSCP_n$	Weight of Sub-Condition Parameter n Parameters
WCP_m	Weight of Condition Parameter m

For example, consider an asset with the following condition parameters and sub-condition parameters:

Condition Parameter		Condition Parameter Weight (WCP)	Sub-Condition Parameter		Sub-Condition Parameter Weight (WSCP)	Data Available? (β = 1 if available; 0 if not)
m	Name		n	Name		
1	A	1	1	A_1	1	1
2	B	2	1	B_1	2	1
			2	B_2	4	1
			3	B_3	5	0
3	C	3	1	C_1	1	0

The DAI is calculated as follows:

DAI_{CP1} = (1*1) / (1) = 1
DAI_{CP2} = (1*2 + 1*4 + 0*5) / (2 + 4 + 5) = 0.545
DAI_{CP3} = (0*1) / (1) = 0
DAI = (DAI_{CP1}*WCP_1 + DAI_{CP2}*WCP_2 + DAI_{CP3}*WCP_3) / (WCP_1 +WCP_2 +WCP_3)
= (1*1 + 0.545*2 + 0*3) / (1 + 2 + 3)
= 35%

An asset with all condition parameter data represented will, by definition, have a DAI value of 100%. In this case, an asset will have a DAI of 100% regardless of its HI score. Provided that the condition parameters used in the HI formula are of good quality and there are few data gaps, there will be a high degree of confidence that the HI score accurately reflects the asset's condition.

Note that although this methodology uses age as a limiter and not as a condition parameter, age is treated as a weighted parameter in the calculating the DAI.

2.3.2 Data Gap

The HI formulas developed and used in this study are based only on GSHI's available data. There are additional data or tests that GSHI may not collect or perform at the present time, but such data/tests are important indicators of the deterioration and degradation of assets. While these will not be included in the HI formula, the set of unavailable data are referred to as data gaps. I.e. a data gap is the case where **none** of the units in an asset group has data. This could be because the data is not collected, certain tests are not conducted, no inspection procedures are in place to obtain condition data, etc. The situation where data is provided for only a sub-set of the population is not considered as a data gap. Consider a utility that has just implemented a wood pole testing program. The "pole strength" parameter will be added to the wood pole HI formula. Say that because the program is new, only 5% of the wood pole population presently have test data. In this case, wood pole is **not** a data gap. However, 95% of the wood pole population will have reduced DAI because they lack data pole strength data.

It is generally recommended that data collection be initiated for the most critical items because such information will result in higher quality HI formulas.

The more critical and important data included in the HI formula of a certain asset group, and the higher the DAI of a particular unit in that group, the higher the confidence in the HI calculated for the particular unit.

If an asset group has significant data gaps and the data used to derive the HI is not good condition data (e.g. age only), there is less confidence that the HI score of a particular unit accurately reflects its condition, regardless of the value of its DAI.

To facilitate the incorporation of data gap items into improved HI formulas for future assessments, the data gap items are presented in this report as condition parameters. Given are a description of the data, priority, and possible data sources.

The following is an example for "Tank Corrosion" on a pad mounted transformer:

Data Gap	Priority	Description	Source
Tank Corrosion	2	Tank surface rust or deterioration due to environmental factors	Inspections or corrective work orders.

3 Results

This section summarizes the findings of this study.

3.1 Health Index Results

A summary of the HI results is shown in Table 3-1. For each asset category the population, sample size (number of assets with sufficient data for Health Indexing), and average age are given. The average HI and HI distribution are also shown. A summary of the HI distribution for all asset categories are also graphically shown in Figure 3-1.

A significant percentage of substation transformers were determined to be in very poor and poor condition (7%, 14% respectively). Many of these assets are aging; the average age of the population is 40 years.

Pad mounted transformers have an average HI of 76%. A total of 18%, or 262 assets, were found to be in poor or very poor condition. A total of 75% submersible transformers were also in very poor condition, and the remaining 25% were found in poor condition. Note however, that the submersible population is very small (16) so these results do not represent a significant concern.

Wood poles are also cause for concern. Of the total 14,700 poles for which health indices were calculated (GSHI, Bell, and Hydro One poles), a total of 2,567 (or 17%) were found to be in poor or very poor condition. The majority of these poles are GSU and Bell poles as, the population of Hydro One poles is relatively small (only 2% of all wood poles assessed).

3.2 Condition-Based Flagged for Action (FFA) Plan

When there is a large quantity of assets that are at or near the end of their service lives, there may be large quantities of assets flagged for action in the first year. This represents a "backlog" of assets that required attention from past years. The FFA Plan estimates the number of units expected to require attention in a given year. As it would not be feasible or practical for a utility to address all assets immediately, a levelized flagged for action plan, where quantities are spread over subsequent years, is also given.

Table 3-2 and Table 3-3 show the 10 year FFA and Levelized FFA Plans respectively. The action strategy (proactive or reactive) is also given. The percentage of population requiring action in Year 0 (now) is also shown. Additionally, the yearly average for Years 0 through 5 (i.e. sum of assets flagged for action between years 0 through 5 divided by 6) is also shown. The results are shown graphically in Figure 3-2 and Figure 3-3.

In terms of quantities of assets that need to be addressed, GSU wood poles require the most attention. Within the next 5 years, 1374 (12%) are flagged for action (per the Levelized Plan). Approximately 20% of Bell wood poles were also flagged for action in the next 5 years per the Levelized Plan. Because of the considerably smaller population, however, this equates to 531 poles.

Pad mounted transformers also have large quantities requiring action in the first 5 years of the Levelized plan. A total of 273 transformers (19% of the population) are flagged.

The results also flag 8 (or 19%) of substation transformers require action in the next 5 years of the Levelized Plan. This is cause for concern as substation transformers are a significant asset with high consequences of failure. GSU needs to address this issue, possibly through additional monitoring, replacement, refurbishment, etc.

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Table 3-1 Health Index Summary

Asset Category	Population	Sample Size	Average Health Index	Health Index Distribution					Average Age	% of Population with Age	Average DAI
				Very Poor (< 25%)	Poor (25 - <50%)	Fair (50 - <70%)	Good (70 - <85%)	Very Good (>= 85%)			
Substation Transformers	43	43	73%	7%	14%	14%	19%	47%	40	100%	44%
Pad Mounted Transformers	1440	1418	76%	10%	8%	17%	5%	59%	18	100%	51%
Pole Mounted Transformers	3232	3132	94%	4%	< 1%	2%	3%	91%	14	100%	34%
Submersible Transformers	16	16	16%	75%	25%	0%	0%	0%	43	100%	34%
Vault Transformers	131	116	83%	10%	3%	5%	4%	78%	30	100%	28%
Overhead Line Switches	2173	2016	95%	2%	1%	2%	3%	91%	19	100%	10%
Pad Mounted Switchgear	80	80	96%	1%	0%	0%	3%	96%	18	100%	42%
Pad Mounted Junction Enclosures	70	70	95%	3%	0%	0%	0%	97%	17	100%	51%
GSU Wood Poles	11755	11755	83%	6%	10%	6%	8%	70%	31	100%	37%
GSU Concrete Poles	120	120	96%	0%	0%	3%	6%	92%	46	100%	35%
Bell Wood Poles	2695	2693	73%	5%	21%	12%	12%	50%	40	100%	36%
Hydro One Wood Poles	349	339	93%	0%	2%	4%	20%	74%	19	100%	34%

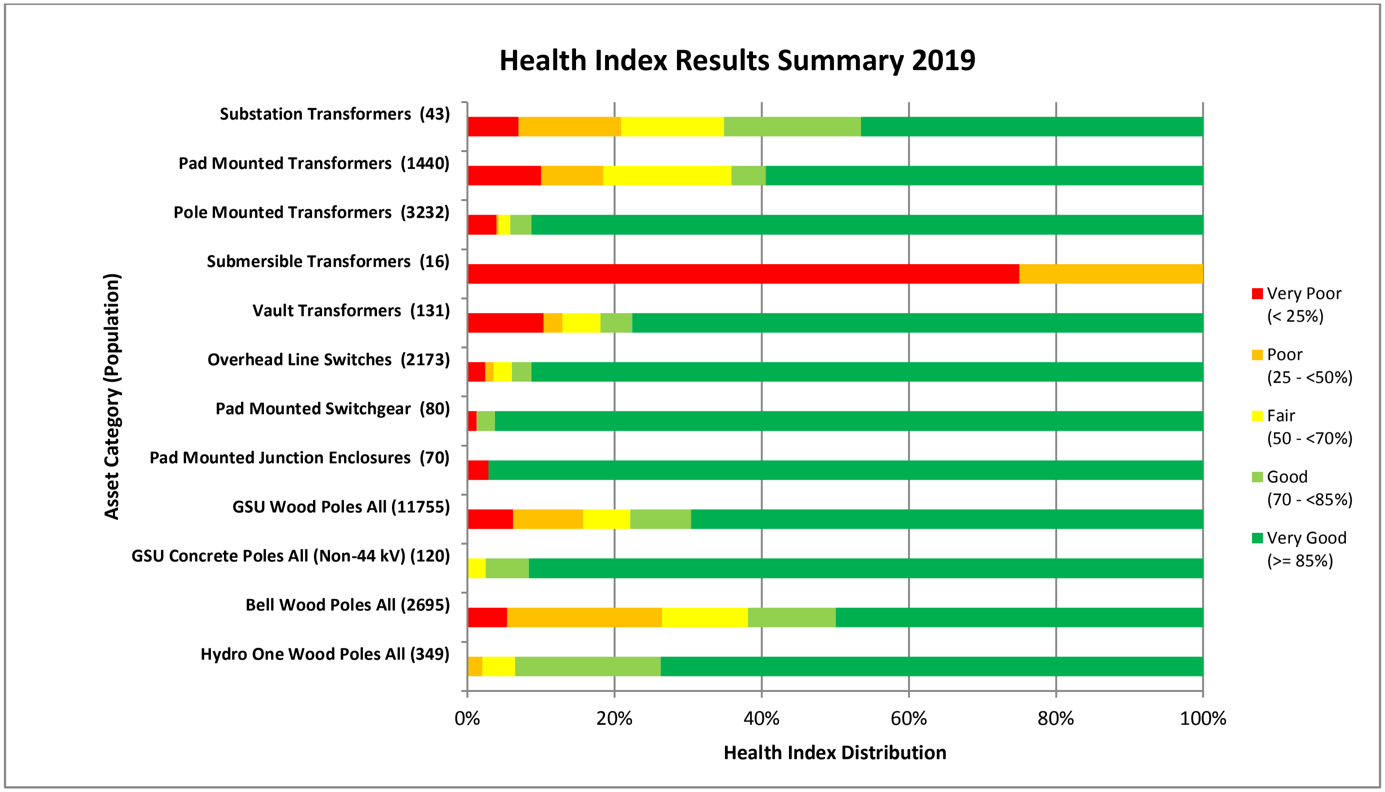

Figure 3-1 Health Index Summary (Graphical)

Table 3-2 Flagged for Action Plan

Asset Category	Ten Year Flagged for Action Plan (years from now)											Year 0 (Now)		Years 0 - 5 Inclusive		Action Strategy
	0	1	2	3	4	5	6	7	8	9	10	Number of Units	Percentage of Population	Total Number of Units	Yearly Average	
Substation Transformers	8	0	0	0	0	1	0	0	0	0	0	**8**	**19%**	**9**	**< 2**	proactive
Pad Mounted Transformers	186	9	17	27	46	50	55	47	29	22	16	186	**13%**	**335**	< 56	reactive
Pole Mounted Transformers	103	4	13	2	11	5	5	5	20	11	21	103	**3%**	**138**	23	reactive
Submersible Transformers	15	1	0	0	0	0	0	0	0	0	0	15	**94%**	**16**	< 3	reactive
Vault Transformers	15	2	2	1	3	2	0	2	7	10	11	15	**11%**	**25**	< 5	reactive
Overhead Line Switches	64	15	19	20	19	20	13	25	6	9	34	**64**	**3%**	**157**	**< 27**	reactive
Pad Mounted Switchgear	1	0	0	0	0	0	0	0	0	1	7	**1**	**1%**	**1**	**< 1**	reactive
Pad Mounted Junction Enclosures	2	0	0	0	0	0	0	0	0	1	0	**2**	**3%**	**2**	**< 1**	reactive
GSU Wood Poles	1279	76	312	111	80	113	67	103	68	119	193	**1279**	**11%**	**1971**	**< 329**	proactive
GSU Concrete Poles	2	0	0	0	9	109	0	0	0	1	0	**2**	**2%**	**120**	**20**	proactive
Bell Wood Poles	448	31	142	64	33	56	28	41	21	37	97	**448**	**17%**	**774**	**129**	proactive
Hydro One Wood Poles	4	0	4	1	0	0	0	0	0	2	1	**4**	**1%**	**9**	**< 2**	proactive

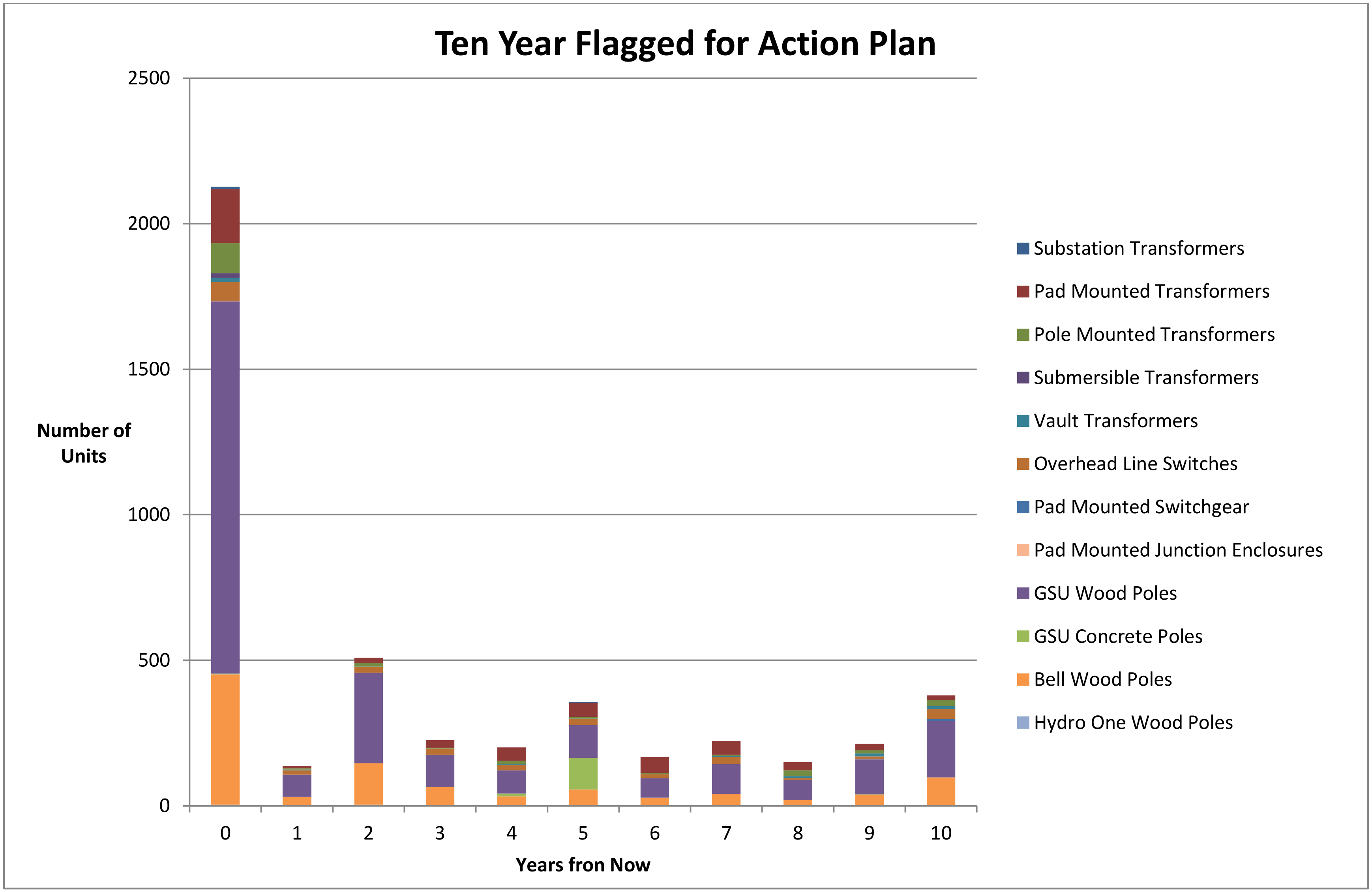

Figure 3-2 Flagged for Action Plan (Graphical)

Table 3-3 Flagged for Action Plan - Levelized

Asset Category	Ten Year Levelized Flagged for Action Plan (years from now)											Year 0 (Now)		Years 0 - 5 Inclusive		Action Strategy
	0	1	2	3	4	5	6	7	8	9	10	Number of Units	Percentage of Population	Total Number of Units	Yearly Average	
Substation Transformers	5	0	1	0	0	2	0	1	0	0	0	**5**	**12%**	**8**	**< 2**	proactive
Pad Mounted Transformers	49	49	49	42	42	42	29	29	28	28	28	49	**3%**	**273**	< 46	reactive
Pole Mounted Transformers	18	18	18	18	18	18	19	19	19	19	19	18	**1%**	**108**	18	reactive
Submersible Transformers	2	2	2	1	1	1	1	1	1	1	1	2	**13%**	**9**	< 2	reactive
Vault Transformers	4	4	4	5	5	5	6	6	6	6	6	4	**3%**	**27**	< 5	reactive
Overhead Line Switches	21	21	21	23	23	23	28	28	27	27	27	**21**	**1%**	**132**	**22**	reactive
Pad Mounted Switchgear	1	0	0	0	0	0	1	1	1	1	1	**1**	**1%**	**1**	**< 1**	reactive
Pad Mounted Junction Enclosures	1	0	0	0	0	0	0	0	0	0	0	**1**	**1%**	**1**	**< 1**	reactive
GSU Wood Poles	233	233	233	225	225	225	209	209	187	187	187	**233**	**2%**	**1374**	**229**	proactive
GSU Concrete Poles	12	12	12	10	10	10	6	6	5	5	5	**12**	**10%**	**66**	**11**	proactive
Bell Wood Poles	90	90	90	87	87	87	81	81	71	71	71	**90**	**3%**	**531**	**< 89**	proactive
Hydro One Wood Poles	1	1	1	2	2	2	3	3	4	4	4	**1**	**0%**	**9**	**< 2**	proactive

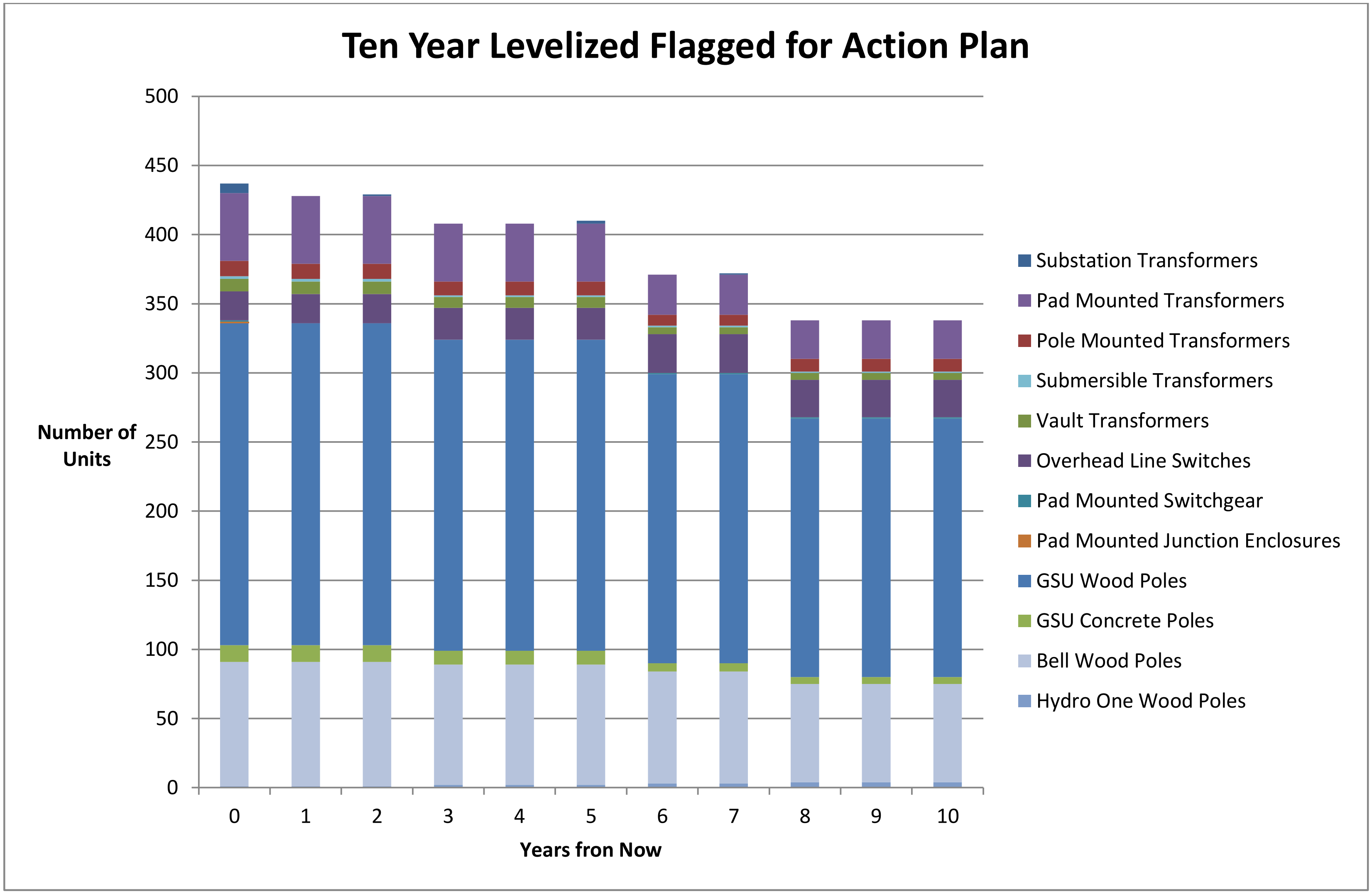

Figure 3-3 Flagged for Action Plan – Levelized (Graphical)

3.3 Data Assessment

This section summarizes the data that was used for the assessment and observations and recommendations pertaining to the data used in the assessment. Note that details for each asset category are given in Appendix A.

Recall from Section 2.3.1 that the DAI is a measurement that is relative to the information that GSHI currently collects (and is included as an HI parameter), whereas data gaps are HI parameter information that GSHI does not collect for any of the units within an asset group. As such, even if an asset group has a high DAI, this does not mean that ideal information for this asset group is complete. If numerous high priority data gaps exist, the degree of confidence that the HI reflects true conditions may still be low. GSHI collects removal data for all asset categories. There was sufficient data for Pad Mounted transformers to enable the development of GSHI specific asset life curves. The life curve used for this asset category was based on removal statistics. The curves used for all other asset categories were based on typical industry experience.

Table 3-4 shows the overall data assessment, data feeding the health index, average DAIs, and data gaps.

GSHI collects removal data for all asset categories. There was sufficient data for Pad Mounted transformers to enable the development of GSHI specific asset life curves. The life curve used for this asset category was based on removal statistics. The curves used for all other asset categories were based on typical industry experience.

Table 3-4 Data Assessment Summary

Asset Category	Basis of Health Index Formula	Average DAI	Data Gaps and Observations (H, M, L = high, medium, low priority respectively)
Substation Transformers	Nameplate GOQ DGA Non-conformance logs	44%	*Test results* Turns ratio test (M) Winding resistance (M) Power factor (H) Furans (M) Insulation resistance (L) Main tank ASTM D1816 (M) Main tank ASTM 924 (M) Bushing power factor (M) LTC DGA and GOQ *Loading (M)* *Auxiliary component information (L)* **Inspections to replace non-conformance logs (H)**
Distribution Transformers	Nameplate Non-conformance logs	Pad Mounted - 51% Pole Mounted - 34% Submersible - 34% Vault - 28%	**Inspections to replace non-conformance logs (H)**

Overhead Switches	Nameplate Non-conformance logs	10%	*Operating mechanism component information (H)* *Switch blade information (L)* *Arc extinction information (L)* *Insulator information (L)* *Operating history (M)* **Inspections to replace non-conformance logs (H)**
Pad Mounted Switches	Nameplate Non-conformance logs	42%	**Inspections to replace non-conformance logs (H)**
Junction Enclosure	Nameplate Non-conformance logs	51%	**Inspections to replace non-conformance logs (H)**
Poles	Nameplate Non-conformance logs	Sudbury Wood - 37% Sudbury Concrete - 35% Bell Wood - 36% Hydro One Wood - 34%	*Pole Strength* (H) *Pole physical condition (H)* Crossarm condition (M) Insulator condition (M) Guy condition (M) Hardware and conductor condition (L) Foundation condition (L) Vegetation condition (L) **Inspections to replace non-conformance logs (H)**

4 Conclusions and Recommendations

Below are the conclusions and recommendations from this study.

1. An Asset Condition Assessment was conducted for GSU's key distribution assets, namely substation transformers, distribution transformers, overhead line switches, pad mounted switchgear and junction enclosures, and wood and concrete poles. Additionally, four other pole categories with varying owners (GSU, Bell, Hydro One) of varying types (wood, concrete) were assessed. For each asset category, the Health Index distribution was determined and a condition-based replacement plan was developed.

2. A total of 21% of Substation Transformers were found to be in poor or very poor condition. Based on the levelized flagged for action plans, a total of 8 transformers should be looked at in the next 5 years. This is cause for concern, as substation transformers are a large asset class with significant consequences of failure. It is therefore recommend that GSU address this issue (e.g. additional monitoring, accelerate replacement/refurbishment).

3. Pad mounted transformers have an average HI of 76%. As a result, approximately 19% of the population are flagged for action in the next 5 years.

4. GSU Wood Poles also have significant quantities (16% of the population) that were found to be in poor or very poor condition. Since it is projected that more than 16% of poles require replacement/refurbishment within the next 5 years, it is important for GSU to have an annual program to address a certain percentage of poles every year, so as not to create a backlog of assets needing attention.

5. The DAI and data gaps were outlined for each asset category. It is recommended that GSHI make efforts to increase the DAI for each asset category and to put efforts to close the data gaps in order of priority.

6. Currently, problems found during inspections of distribution transformers, switches, switchgear and junction enclosures, and poles are recorded in non-conformance logs. A disadvantage of such a system is that if a unit is inspected and no issues are found, there is no record that the unit was inspected and is in good condition. Another disadvantage of the non-conformance log is that it does not facilitate the use of standardized inspection items or components, or a standard point system to evaluate the item or component being inspected. The user is free to enter comments, making it difficult to search for specific problems.

   It is recommended that GSHI implement a system that standardizes and computerizes inspection records. It is further recommended that the inspection-based condition and sub-condition parameters presented in this study be included as standard inspection items. Such parameters can be found in the Health Index formula for each asset group. The suggested point systems, or condition criteria, for evaluating the parameters are also included.

   From an Asset Condition Assessment standpoint, standardized inspections will not only ensure that all critical items are collected during inspections, it will also facilitate the data collection and the process of Health Index evaluation. Ultimately, it will result in a higher degree of confidence in the Health Index.

7. GSHI collects removal data for all asset categories. There was sufficient data to develop life curves for Pad Mounted transformers. GSHI should continue to collect this information to enable development of life curves for all other asset categories.

8. GSU may wish to consider health indexing of other assets, e.g. Breakers, Reclosers, and Underground Cables.

9. The data used in this assessment was from different locations (e.g. numerous spreadsheets or PDF files). For more efficient record keeping and ease of future assessments, GSHI may wish to consider implementing platform that consolidates asset information and condition data (e.g. nameplate information, test results, operational information, inspection records, etc.) and that can perform live asset analytics.

10. It is important to note that the Flagged for Action plan presented in this study is based primarily on asset condition. It is worth noting that there are numerous other considerations

that may influence GSHI's asset management plan. Among these are obsolescence, system growth, corporate priorities, technological advancements, etc.

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Appendix A Results for Each Asset Category

The results for each individual asset category are detailed in this section.

1 Substation Transformers

This asset class includes GSHI's substation power transformers. Sizes range from 1 to 20 MVA, with primary voltages ranging from 22 to 44 kV. The assessment included 46 transformers.

The data used in the assessment are as follows:

- Asset Properties (e.g. age, size, voltage, location information)
- DGA and GOQ test results
- Station inspections
- Non-conformance records

There are a total of 43 Substation Transformers at GSHI. Of these, 43 had sufficient data for Health Indexing.

1.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 1-1 Substation Transformers Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Internals	10	H2	5	Table A 1-2
		CH4 (Methane)	3	Table A 1-2
		C2H6 (Ethane)	3	Table A 1-2
		C2H4 (Ethylene)	3	Table A 1-2
		C2H2 (Acetylene) Non-OLTC	5	Table A 1-2
Insulation Oil	8	Dissipation Factor	2	Table A 1-3
		Moisture	4	Table A 1-3
		Dielectric Strength	5	Table A 1-3
		Interfacial Tension	3	Table A 1-3
		Acid Number	2	Table A 1-3
		Colour	1	Table A 1-3
		Particle Count	0*	

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	Weight (WCP)	Description	Weight (WSCP)	Criteria
		Oxygen Inhibitor	0*	
Windings	0*	Turns Ratio	0*	
		Winding Resistance	0*	
		Exciting Current	0*	
		Leakage Reactance	0*	
Paper/Pressboard	8	Furanic Compund	0*	
		Power Factor	**5**	Table A 1-4
		Insulation Resistance	0*	
		Capacitance	0*	
		PF Tip-Up	0*	
		DGA CO	**2**	Table A 1-2
		DG CO2	**1**	Table A 1-2
Bushings	5	Capacitance	0*	
		Power Factor	0*	
		Dielectric Loss	0*	
		Oil Level (bushings only)	0*	
		Partial Discharge (PD)	0*	
		Non-Conformance	1	Table A 1-5
LTC	5	Non-Conformance	5	Table A 1-5
		Oil Test	0*	
Rads, Coolers, and Valves	2	Non-Conformance	1	Table A 1-5
Fans	1	Non-Conformance	1	Table A 1-5
Pump	0*	Non-Conformance	1	Table A 1-5
Conservator	2	Non-Conformance	1	Table A 1-5
Tank	2	Non-Conformance	1	Table A 1-5
Auxilliary Components	1	Non-Conformance	1	Table A 1-5
Service Record	5	Loading	3	Table A 1-6
		Overall CM	1	Table A 1-6
HI De-Rating Multiplier (DR)		GOQ, DGA	Equation 12	
Age Limiter (AL)		Based on 45-70 year typical life	Figure A 1-1	
*where there is no available data for any assets, the weight of the parameter is set to 0				

Oil DGA – Transformer Oil

Table A 1-2 DGA Criteria –Transformers

	Dissolved Gas	Scores					
		4	3.2	2.4	1.6	0.8	0
2.5 MVA to 10 MVA	H2 (Hydrogen)	X ≤ 70	70 < X ≤ 100	100 < X ≤ 200	200 < X ≤ 400	400 < X ≤ 1000	X >1000
	CH4 (Methane)	X ≤ 70	70 < X ≤ 120	120 < X ≤ 200	200 < X ≤ 400	400 < X ≤ 600	X > 600
	C2H6 (Ethane)	X ≤ 75	75 < X ≤ 100	100 < X ≤ 150	150 < X ≤ 250	250 < X ≤ 500	X > 500
	C2H4 (Ethylene)	X ≤ 60	60 < X ≤ 100	100 < X ≤ 150	150 < X ≤ 250	250 < X ≤ 500	X > 500
	C2H2 (Acetylene)	X ≤ 3	3 < X ≤ 7	7 < X ≤ 35	35 < X ≤ 50	50 < X ≤ 100	X > 100
	CO (Carbon Monoxide)	X ≤ 750	750 < X ≤ 1000	1000 < X ≤ 1300	1300 < X ≤ 1500	1500 < X ≤ 1700	X > 1700
	CO2 (Carbon Dioxide)	X ≤ 7500	7500 < X ≤ 8500	8500 < X ≤ 9000	9000 < X ≤ 12000	12000 < X ≤ 15000	X > 15000
> 10 MVA	H2 (Hydrogen)	X ≤40	40 < X ≤ 100	100 < X ≤ 300	300 < X ≤ 500	500 < X ≤ 1000	X >1000
	CH4 (Methane)	X ≤ 80	80 < X ≤ 150	150 < X ≤ 200	200 < X ≤ 500	500 < X ≤ 700	X > 700
	C2H6 (Ethane)	X ≤ 70	70 < X ≤ 100	100 < X ≤ 150	150 < X ≤ 250	250 < X ≤ 500	X > 500
	C2H4 (Ethylene)	X ≤ 60	60 < X ≤ 100	100 < X ≤ 150	150 < X ≤ 250	250 < X ≤ 500	X > 500
	C2H2 (Acetylene)	X ≤ 3	3 < X ≤ 7	7 < X ≤ 35	35 < X ≤ 50	50 < X ≤ 80	X > 80
	CO (Carbon Monoxide)	X ≤ 350	350 < X ≤ 500	500 < X ≤ 600	600 < X ≤ 1000	1000 < X ≤ 1500	X > 1500
	CO2 (Carbon Dioxide)	X ≤ 3000	3000 < X ≤ 4500	4500 < X ≤ 5700	5700 < X ≤ 7500	7500 < X ≤ 10000	X > 10000

General Oil Quality

Table A 1-3 Oil Quality Test Criteria

Oil Quality Test		Voltage Class [kV]	Score 4	Score 3	Score 2	Score 1	Score 0
Water Content (D1533) [ppm]	Main Tank	V ≤ 69	< 30	30-33.3	33.3-36.6	36.6-40	> 40
		69 < V < 230	< 20	20-25	25-30	30-35	> 35
		V ≥ 230	< 15	15-18.3	18.3-21.6	20-25	> 25
	Tap	V ≤ 69	< 30	30-33.3	33.3-36.6	36.6-40	> 40
		V > 69	< 20	20-25	25-30	30-35	> 35
Dielectric Strength (D1816 – 1mm gap) [kV]	Main Tank	V ≤ 69	> 20	20-17.5	12.5-17.5	10-12.5	< 10
		69 < V < 230	> 25	21-25	17-21	13-17	< 13
		V ≥ 230	> 27	23-27	20-23	17-20	< 17
	Tap	V ≤ 69	> 25	21.6-25	18.3-21.6	15-18.3	< 15
		V > 69	> 30	26-30	22-26	18-22	< 18
Dielectric Strength (D877) [kV]	Main Tank	All	> 40	33.3-40	22.6-33.3	20-22.6	< 20
	Tap	All	> 25	21.6-25	18.3-21.6	15-18.3	< 15
IFT (D971) [dynes/cm]	Main Tank	V ≤ 69	> 25	21.6-25	18.3-21.6	15-18.3	< 15
		69 < V < 230	> 30	26-30	22-26	18-22	< 18
		V ≥ 230	> 32	28-32	24-28	20-24	< 20
	Tap	All	> 25	21.6-25	18.3-21.6	15-18.3	< 15
Color	Main Tank	All	< 1.5	1.5-1.8	1.8-2.1	2.1-2.5	> 2.5
	Tap	All	< 2.0	2.0-2.3	2.3-2.6	2.6-3.0	> 3.0
Acid Number (D974) [mg KOH/g]	Main Tank	V ≤ 69	< 0.05	0.05-0.1	0.1-0.15	0.15-0.2	> 0.2
		69 < V < 230	< 0.04	0.04-0.077	0.077-0.113	0.113-0.15	> 0.15
		V ≥ 230	< 0.03	0.03-0.053	0.053-0.076	0.076-0.1	> 0.1
	Tap	All	< 0.05	0.05-0.1	0.1-0.15	0.15-0.2	> 0.2
Dissipation Factor (D924 - 25C)	Main Tank and Tap	All	< 0.5%	0.5%-1%	1-1.5%	1.5-2%	> 2%
Dissipation Factor (D924 - 100C)		All	< 5%	5%-10%	10%-15%	15%-20%	> 20%

Power Factor Test

Table A 1-4 Power Factor Test Criteria

Score	Power Factor Reading (PF)
4	PF < 0.5%
3	0.5% ≤ PF < 1%
2	1% ≤ PF < 1.5%
1	1.5% ≤ PF < 2%
0	PF ≥ 2%

Where PF is the worst case power factor measurement.
Example: If C_H, C_L, and C_{HL} are available, PF = Min (C_H, C_L, C_{HL})

Multiple Years Non-Conformance

Table A 1-5 Multiple Years Non-Conformance Criteria

Score = 4*DR

Where DR is as follows:

DR	Non-Conformance (NC) Value
1	NC = 0
0.95	0 ≤ NC < 0.2
0.9	0.2 ≤ NC < 0.25
0.8	0.25 ≤ NC < 0.5
0.7	0.5 ≤ NC < 0.75
0.6	0.75 ≤ NC < 1

Where "Non-Conformance Count" is a function of the number and severity of non-conformances in a given year, calculated as below:

Non-Conformance Count (NC) = $\sum_i \left(\sum_j N_{ij} \times TW_j \right) \times YW_i$

- Nij = Number of problems/issues reported in the year "i" that are classified as type "j"
- YWi = Weight of problems/issues that occurred in year "i"
- TWj = Weight of problems/issues that are classified as having a type "j"

i	Year	Year Weight (YW_i)
1	2019	1
2	2018	0.9
3	2017	0.8
4	2016	0.7

5	2015	0.6
6	2014	0.5
7	2013	0.4
8	2012	0.3
9	2011	0.2
10	2010	0.1
11	2009	0
j	**Corrective Type**	**Type Weight (TW_j)**
1	1 - Immediate	4
2	3 - Within 7 Days of Start	3.5
3	4 - Within 1 Month of Start	3
4	6 - Within One Year	2
5	7 - Next Maintenance	1.5
6	0 - None	0

Example: Sample Data set = { 2017: 1 – type "Within 1 Month of Start", 1 type "Next Maintenance"; 2015: 2 – type "Within One Year"}

Corrective Maintenance Count = (1*3 + 1*1.5)*1 + (2*2)*0.8 = 7.7

Loading History

Table A 1-6 Loading History

Data: $S_1, S_2, S_3, \ldots, S_N$ recorded data (monthly peaks)

S_B= rated MVA

N_A=Number of S_i/S_B which is lower than 0.6
N_B= Number of S_i/S_B which is between 0.6 and 0.8
N_C= Number of S_i/S_B which is between 0.8 and 1.0
N_D= Number of S_i/S_B which is between 1 and 1.2
N_E= Number of S_i/S_B which is greater than 1.2

$$Score = \frac{4 * N_A + 3 * N_B + 2 * N_C + 1 * N_D}{N}$$

De-Rating Multiplier

The de-rating is based on the following equation and DR is described in the subsequent tables.

$$DR = \min(DR_1, DR_2)$$

Equation 12

DR$_1$: Oil Quality

Table A 1-7 De-Rating Multiplier Based on Oil Quality Score

$$DR_1 = \min(DR\_Score_{Moisture}, DR\_Score_{Dielectric\ Strength})$$

Where DR_Oil

DR_Score	(SCP$_{Oil\ Quality}$ Score) Score$_{Oil\ Quality}$ is defined in Table A 1-3
0.4	$0 \leq$ Score $_{Oil\ Quality\ Test} < 1$
0.6	$1 \leq$ Score$_{Oil\ Quality\ Test} < 2$
1	Score$_{Oil\ Quality\ Test} \geq 2$

DR$_2$: Dissolved Gas Trend

DR$_2$ is based on the daily rate of increase of the Total Dissolved Combustible Gas (TDCG) content.

Table A 1-8 De-Rating Multiplier Based on Dissolved Gas Trend

Daily Rate Increases (ppm)	DR$_2$ TDCG Category			
	Condition 1	Condition 2	Condition 3	Condition 4
TDCG Rate < 10	1	1	1	1
10 ≤ TDCG Rate < 30	1	0.9	0.75	0.5
TDCG Rate ≥ 30	0.9	0.75	0.5	0.25

where

Condition 1	0 < TDCG < 720
Condition 2	720 < TDCG < 1920
Condition 3	1920 < TDCG < 4630
Condition 4	TDCG > 4630

Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 45 years is 20% and that at 70 years the likelihood of removal is 95% (i.e. Q(45) = 1-0.8=0.2; Q(70) = 1-0.5=0.95). The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

Figure A 1-1 Station Transformers Age Limiter

1.2 Criticality

For this asset category, the FFA Plans were developed using the risk based approach described in Section 2.2.

A Criticality Index (CI) was calculated for each transformer using the parameters and weights below. A transformer is then assigned the CI of its substation.

Table A 1-9 Substation Criticality

Criticality Parameter (CRP)		Weight (WCRP)	Score (SCRP)
Location (near waterbeds)	Environmental stewardship is of the utmost importance.	30	No = 0 Yes = 1
Number of Customers	Reliable service to the greatest number of customers is vital. Does the transformer service more than 1000 customers?	25	Low = 0 High = 1
Bus Structure (open/enclosed)	Is the transformer under consideration located in an open-bus scheme within a residential subdivision? Can public safety be affected if a catastrophic failure were to occur?	20	No = 0 Yes = 1
Backup Capabilities	Does the transformer have backup capabilities?	10	Yes = 0 No = 1
Tap Changer Equipped	Can the transformer under consideration be backed-up with the portable?	10	No = 0 Yes = 1
Transformer Primary Protection	Is the unit's primary protection a fuse or breaker?	5	Breaker = 0 Fuse = 1

1.3 Age

The average age of all in-service Substation Transformers units was 40 years.

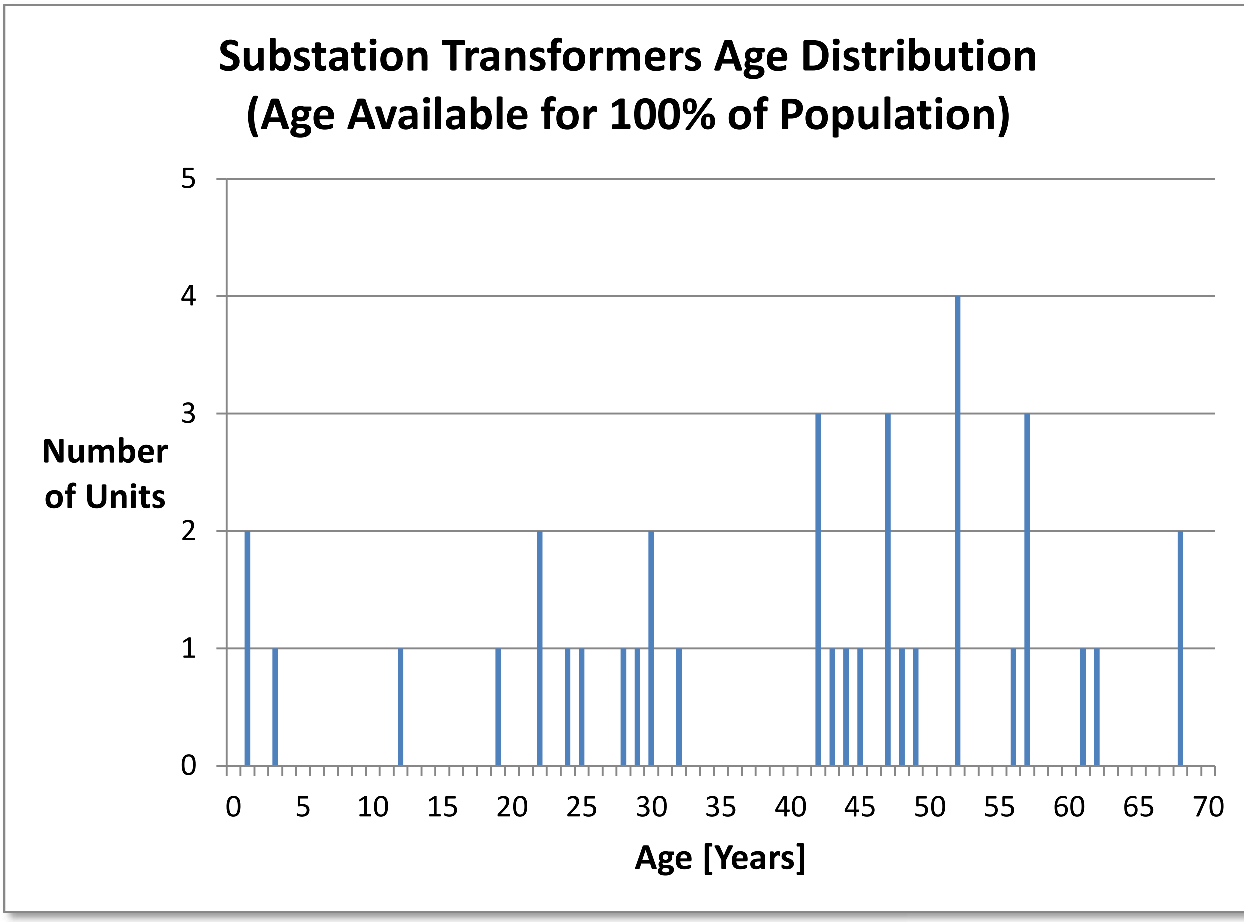

Figure A 1-2 Substation Transformers Age Distribution

1.4 Health Index Results

The average Health Index for this asset group was 74%. Approximately 21% were found to be in “poor” or “very poor” condition.

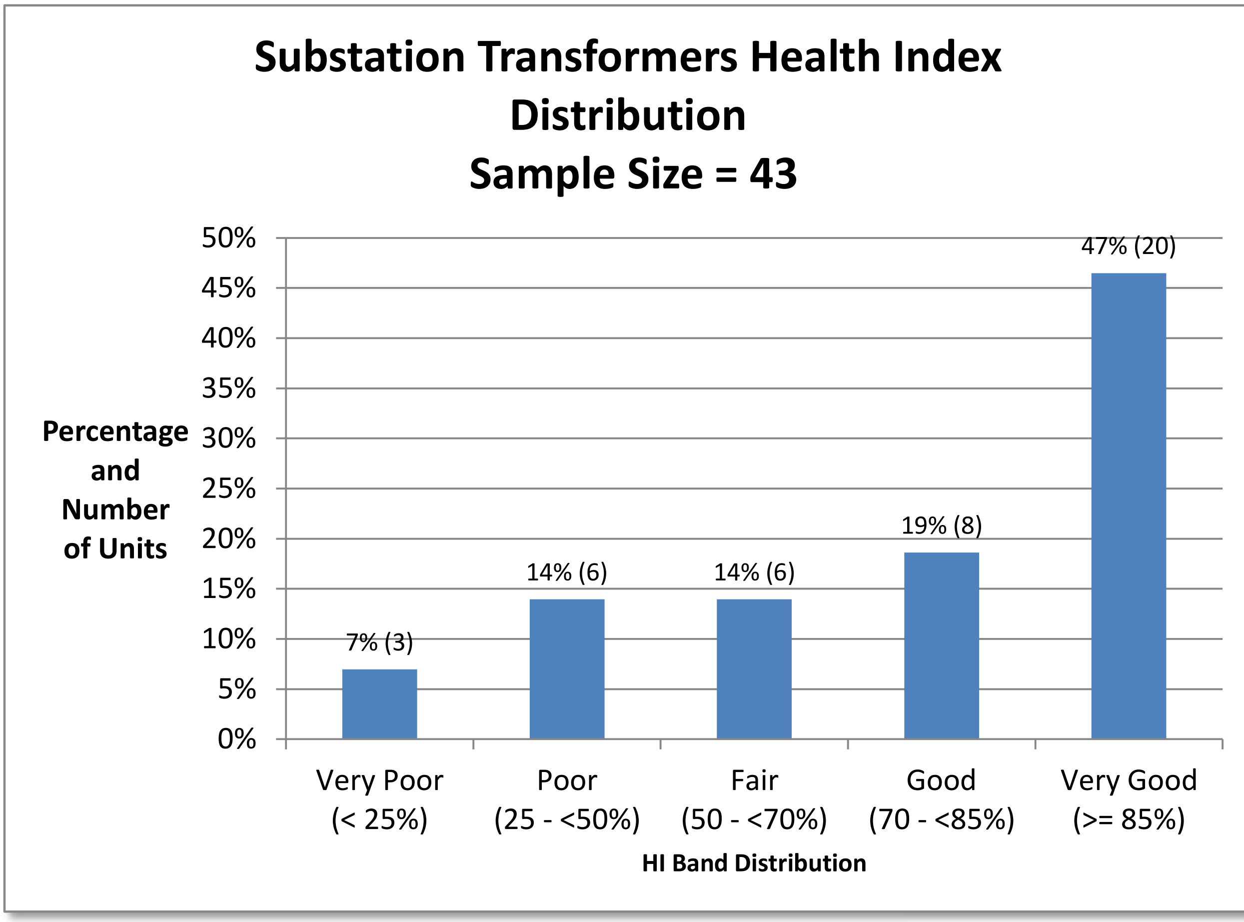

Figure A 1-3 Substation Transformers HI Distribution

1.5 Flagged for Action Plan

Because Substation Transformers are reactively addressed, the 10 Year flagged for action plan was based on the risk, i.e. asset failure rate and criticality. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

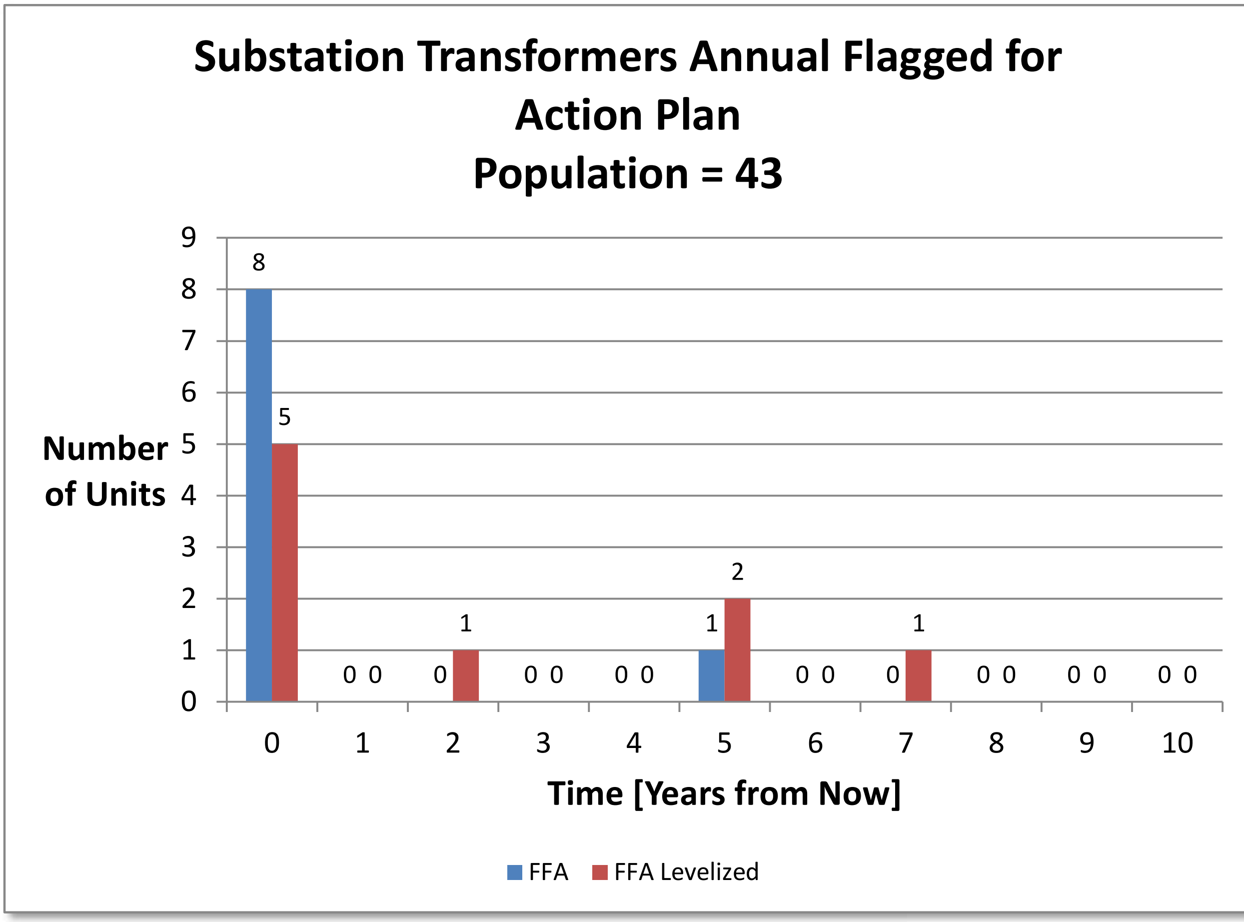

Figure A 1-4 Substation Transformers FFA

1.6 Risk Based Prioritized List

The following table shows the risk based prioritization lists for this asset category. The results are sorted by highest to lowest Risk Index.

Table A 1-10 Substation Transformers Risk Based Priortized List

Index	ID	Element Name	Common Name	Serial Number	Size (MVA)	Voltage (kV)	Year	Age	DAI	HI Calculated	Age Limited		De-Rating Multipliers			Final HI		Criticality Index 0% = least critical 100% = most critical	Risk Index 100% = Most Risk 0% = Least Risk	FFA	FFA Levelized
											Age Limit	Age Limited	De-Rating Multiplier	DGA Trend (TDGC)	Oil Quality	HI	HI Category				
1	2530	3T3	CRESSEY	290754	5	44	1958	61	59%	92.5%	26.0%	Y	1	1	1	26.0%	Poor	25.00%	84.0%	0	0
2	4521	38T1	THIRD	C10111	5	44	1994	25	51%	29.3%	99.3%	N	0.4	1	0.4	29.3%	Poor	25.00%	83.4%	0	0
3	4368	32T1	CAPREOL	282072	6	44	1957	62	49%	97.4%	22.7%	Y	1	1	1	22.7%	Very Poor	5.00%	80.0%	0	0
4	2520	3T1	CRESSEY	0	5.001	44	1951	68	52%	63.2%	7.8%	Y	1	1		7.8%	Very Poor	0.00%	78.9%	0	0
5	2519	3T2	CRESSEY	0	5.001	44	1951	68	54%	68.3%	7.8%	Y	1	1		7.8%	Very Poor	0.00%	78.9%	0	0
6	2515	9T1	REGENT	291983	5	44	1962	57	67%	91.8%	40.6%	Y	1	1	1	40.6%	Poor	40.00%	72.4%	0	2
7	152	18T1	MOONLIGHT	214436	5	44	1962	57	52%	98.3%	40.6%	Y	1	1	1	40.6%	Poor	5.00%	66.3%	0	5
8	2524	8T1	MARTTILA	291966	5	44	1962	57	52%	99.5%	40.6%	Y	1	1	1	40.6%	Poor	5.00%	66.3%	0	5
9	2521	10T1	RAMSEY LAKE	285187	5	44	1963	56	52%	96.1%	44.4%	Y	1	1	1	44.4%	Poor	30.00%	57.4%	5	7
10	169	11T1	GEMMELL	238850	5	44	1967	52	53%	57.6%	59.2%	N	0.65	1	0.65	57.6%	Fair	5.00%	9.2%	>10	>10
11	2518	14T1	CENTENNIAL	293695	5	44	1967	52	79%	96.2%	59.2%	Y	1	1	1	59.2%	Fair	40.00%	5.8%	>10	>10
12	153	21T1	RICHARD LAKE	293655	6	44	1967	52	52%	96.9%	59.2%	Y	1	1	1	59.2%	Fair	25.00%	5.6%	>10	>10
13	161	13T1	PARIS	286651	5	44	1967	52	46%	93.8%	59.2%	Y	1	1	1	59.2%	Fair	5.00%	5.3%	>10	>10
14	2522	10T2	RAMSEY LAKE	3442	5	44	1970	49	52%	100.0%	69.1%	Y	1	1	1	69.1%	Fair	30.00%	0.3%	>10	>10
15	4238	31T1	UPPER CONISTON	0	3	22	1971	48	60%	69.3%	72.1%	N	1	1		69.3%	Fair	0.00%	0.2%	>10	>10
16	160	19T2	DASH	69708	20	44	1977	42	51%	70.4%	86.2%	N	1	1	1	70.4%	Good	5.00%	0.1%	>10	>10
17	157	19T1	DASH	65050	20	44	1977	42	46%	73.4%	86.2%	N	1	1	1	73.4%	Good	5.00%	0.0%	>10	>10
18	2352	29T1	Mansour Mining	238849	5	44	1972	47	56%	90.9%	74.9%	Y	1	1	1	74.9%	Good	5.00%	0.0%	>10	>10
19	166	6T1	LEVERT	13710	7.5	44	1972	47	52%	95.2%	74.9%	Y	1	1	1	74.9%	Good	5.00%	0.0%	>10	>10
20	154	7T1	LASALLE	13669	7.5	44	1972	47	52%	98.2%	74.9%	Y	1	1	1	74.9%	Good	5.00%	0.0%	>10	>10
21	2525	25T1	COPPER CLIFF	T55101	5	44	1974	45	62%	85.3%	80.0%	Y	1	1	1	80.0%	Good	50.00%	0.0%	>10	>10
22	2535	12T1	TEDMAN	293694	5	44	1975	44	55%	96.4%	82.2%	Y	1	1	1	82.2%	Good	15.00%	0.0%	>10	>10
23	155	7T2	LASALLE	T602231	7.5	44	1976	43	54%	96.1%	84.3%	Y	1	1	1	84.3%	Good	5.00%	0.0%	>10	>10
24	4522	35T1	CACHE BAY	112427	6	44	1977	42	49%	98.5%	86.2%	Y	1	1	1	86.2%	Very Good	25.00%	0.0%	>10	>10
25	4520	37T1	RAILWAY	991541	5	44	2000	19	54%	87.7%	99.9%	N	1	1	1	87.7%	Very Good	25.00%	0.0%	>10	>10
26	4519	36T1	ETHEL	UO138001	5	44	1990	29	49%	89.4%	98.3%	N	1	1	1	89.4%	Very Good	25.00%	0.0%	>10	>10
27	164	17T2	MAIN	1829610101	10	44	1997	22	53%	90.3%	99.7%	N	1	1	1	90.3%	Very Good	15.00%	0.0%	>10	>10
28	2532	15T1	ROBINSON	S1388301	10	44	1989	30	63%	92.6%	98.0%	N	1	1	1	92.6%	Very Good	15.00%	0.0%	>10	>10
29	4241	30T1	LOWER CONISTON	91811	5	44	1991	28	50%	93.3%	98.6%	N	1	1	1	93.3%	Very Good	35.00%	0.0%	>10	>10
30	2534	17T1	MAIN	1829510101	10	44	1997	22	53%	94.1%	99.7%	N	1	1	1	94.1%	Very Good	15.00%	0.0%	>10	>10
31	172	24T1	BRODER	A356923	10	44	1987	32	53%	94.5%	97.1%	N	1	1	1	94.5%	Very Good	15.00%	0.0%	>10	>10
32	171	11T2	GEMMELL	S1418601	10	44	1989	30	59%	98.3%	98.0%	Y	1	1	1	98.0%	Very Good	15.00%	0.0%	>10	>10
33	2538	20T1	LONG LAKE	1721410101	10	44	1995	24	58%	98.1%	99.5%	N	1	1	1	98.1%	Very Good	10.00%	0.0%	>10	>10
34	163	16T1	BARRYDOWNE	A3S6153	7.5	44	2007	12	54%	97.5%	100.0%	N	1	1	1	97.5%	Very Good	5.00%	0.0%	>10	>10

Index	ID	Element Name	Common Name	Serial Number	Size (MVA)	Voltage (kV)	Year	Age	DAI	HI Calculated	Age Limited		De-Rating Multipliers			Final HI		Criticality Index 0% = least critical 100% = most critical	Risk Index 100% = Most Risk 0% = Least Risk	FFA	FFA Levelized
											Age Limit	Age Limited	De-Rating Multiplier	DGA Trend (TDGC)	Oil Quality	HI	HI Category				
35	2360	33T1	FALCONBRIDGE	TAG6235298	1	44	2016	3	5%		100.0%	Y	1	1		100.0%	Very Good	50.00%	0.0%	>10	>10
36	2528	2T1	KATHLEEN	165308	7.5	44	2018	1	9%	100.0%	100.0%	Y	1	1		100.0%	Very Good	15.00%	0.0%	>10	>10
37	2529	2T2	KATHLEEN	166016	7.5	44	2018	1	9%	100.0%	100.0%	Y	1	1		100.0%	Very Good	15.00%	0.0%	>10	>10
38	2392	33T2		0	1	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10
39	2542	26T1	DATA CENTRE	unknown	2	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10
40	2451	22T1	LAURENTIAN HOSPITAL	unknown	3.75	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10
41	2480	22T2	LAURENTIAN HOSPITAL	unknown	3.75	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10
42	2527	23T1-F	SEWAGE PLANT	T-4518-1	3.75	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10
43	2526	23T2	SEWAGE PLANT	T-4518-2	3.75	44			0%		100.0%	Y	1	1		100.0%	Very Good	0.00%	0.0%	>10	>10

1.7 Data Assessment

The Substation Transformers Substation Transformers data included nameplate information, oil test results (DGA, GOQ), and non-conformance logs.

The majority of transformers have DGA and GOQ tests. For Substation Transformers, there are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown

Nearly all transformers had DGA and GOQ tests. However, many did not have non-conformance based parameters. Additionally, power factor tests and loading information were not available. As such, the average DAI for this asset group is 44%.

While many general asset components have already been incorporated into the Health Index formula it can be improved by adding detailed information listed in the table below can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

Additional transformer test can also be added to the HI formula.

Table A 1-11 Substation Transformers Substation Transformers Data Gaps

Data Gap	Priority	Description	Source
Auxiliary components	L	Pad Heater Thermostat Vent Temp Gauge Alarms Oil Gauge Wires	Visual inspection
Turns ratio tests	M	Turns ratio test records	Test
Winding resistance	M	Winding resistance test records	Test
Power Factor	H	Power factor tests	Test
Furaninc Compound	M	Furan tests (2FAL)	Test
Insulation Resistance	L	Megger tests	Test
Bushing power factor	M	Bushing power factor tests	Test

LTC oil tests	M	LTC DGA and GOQ	Test
Loading	M	Loading profile (e.g. monthly 15 minute peaks)	Loading Data

It was also noted that the GOQ tests currently being conducted by GSHI for dielectric breakdown uses ASTM D877. ASTM is not recommended for in-service transformers; consider using ASTM D1816. As well, power dissipation factor ASTM D924 is not currently being conducted as part of the GOQ. This test should also be considered as a test for oil deterioration and contamination.

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2 Pad Mounted Transformers

There are a total of 1440 Pad Mounted Transformers at GSHI. Of these, 1418 had sufficient data for Health Indexing.

2.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 2-1 Pad Mounted Transformers Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Main Tank	7	Tank Corrosion	8	Table A 2-2
		Oil Leak	6	Table A 2-2
		Door	2	Table A 2-2
		Paint	3	Table A 2-2
Connections	4	Connections	4	Table A 2-2
		Grounding	1	Table A 2-2
Base / Foundation	2	Base/Foundation	1	Table A 2-2
Access	1	Access	1	Table A 2-2
Service Record	6	Loading	3	Table A 2-3
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 2-1	

Multiple Years Non-Conformance

Table A 2-2 Multiple Years Non-Conformance Criteria

Score	Non-Conformance Count (NC) Value
4	NC < 3
3	3 ≤ NC < 6
2	6 ≤ NC < 9
1	9 ≤ NC < 12
0	NC ≥ 12

Where "Non-Conformance Count" is a function of the number and severity of non-conformances in a given year, calculated as below:

Non-Conformance Count (NC) = $\sum_i \left(\sum_j N_{ij} \times TW_j \right) \times YW_i$

Nij = Number of problems/issues reported in the year "i" that are classified as type "j"
YWi = Weight of problems/issues that occurred in year "i"
TWj = Weight of problems/issues that are classified as having a type "j"

i	Year	Year Weight (YW_i)
1	2017	1
2	2016	0.9
3	2015	0.8
4	2014	0.7
5	2013	0.6
6	2012	0.5
7	2011	0.4
8	2010	0.3
9	2009	0.2
10	2008	0.1
11	2007	0

j	Corrective Type	Type Weight (TW_j)
1	1 - Immediate	4
2	3 - Within 7 Days of Start	3.5
3	4 - Within 1 Month of Start	3
4	6 - Within One Year	2
5	7 - Next Maintenance	1.5
6	0 - None	0

Example: Sample Data set = { 2017: 1 – type "Within 1 Month of Start", 1 type "Next Maintenance"; 2015: 2 – type "Within One Year"}

Corrective Maintenance Count = (1*3 + 1*1.5)*1 + (2*2)*0.8 = 7.7

Loading History

Table A 2-3 Loading History

Score	% of Time Above Operating Band
4	Percent < 1%
3	1% ≤ Percent < 5%
2	5% ≤ Percent < 10%
1	10% ≤ Percent < 15%
0	Percent ≥ 15%

Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

Based on GSHI's removal statistics, it was determined that the likelihood of removal at 20 years is 20% and that at 50 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

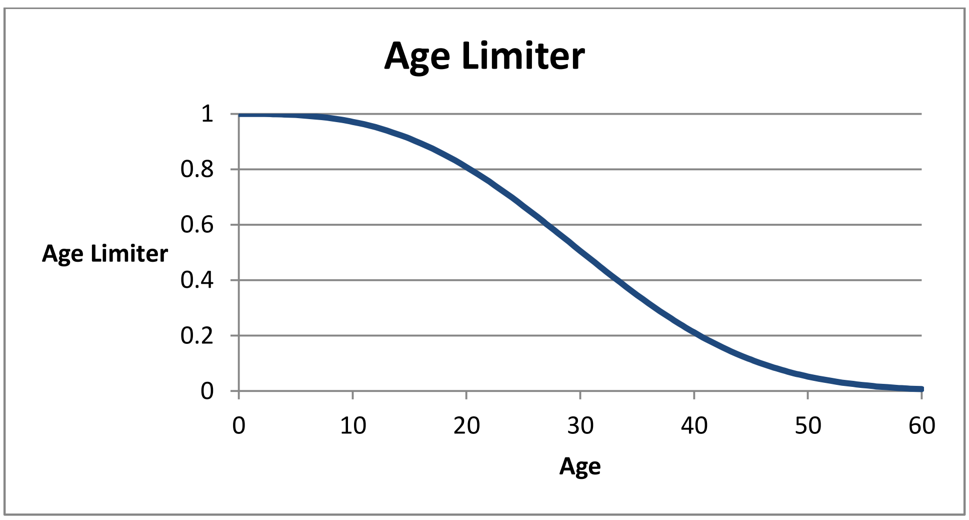

Figure A 2-1 Pad Mounted Transformers Age Limiter

De-Rating Multiplier

The de-rating multiplier is based on the overall non-conformance count as shown in the following table.

Table A 2-4 De-Rating Multiplier

DR	Non-Conformance (NC) Value
1	NC = 0
0.95	$0 \le NC < 0.2$
0.9	$0.2 \le NC < 0.25$
0.8	$0.25 \le NC < 0.5$
0.7	$0.5 \le NC < 0.75$
0.6	$0.75 \le NC < 1$

Where "Non-Conformance Count" is a function of the number and severity of non-conformances in a given year, calculated as below:

Non-Conformance Count (CM) = $\sum_i \left(\sum_j N_{ij} \times TW_j \right) \times YW_i$

- Nij = Number of problems/issues reported in the year "i" that are classified as type "j"
- YWi = Weight of problems/issues that occurred in year "i"
- TWj = Weight of problems/issues that are classified as having a type "j"

i	Year	Year Weight (YW_i)
1	2019	1
2	2018	0.9
3	2017	0.8
4	2016	0.7
5	2015	0.6
6	2014	0.5
7	2013	0.4
8	2012	0.3
9	2011	0.2
10	2010	0.1
11	2009	0

j	Corrective Type	Type Weight (TW_j)
1	1 - Immediate	4
2	3 - Within 7 Days of Start	3.5
3	4 - Within 1 Month of Start	3
4	6 - Within One Year	2
5	7 - Next Maintenance	1.5
6	0 - None	0

Example: Sample Data set = { 2017: 1 – type “Within 1 Month of Start”, 1 type “Next Maintenance”;
2015: 2 – type “Within One Year”}

Corrective Maintenance Count = (1*3 + 1*1.5)*1 + (2*2)*0.8 = 7.7

2.2 Age

The average age of all in-service Pad Mounted Transformers units was 18 years.

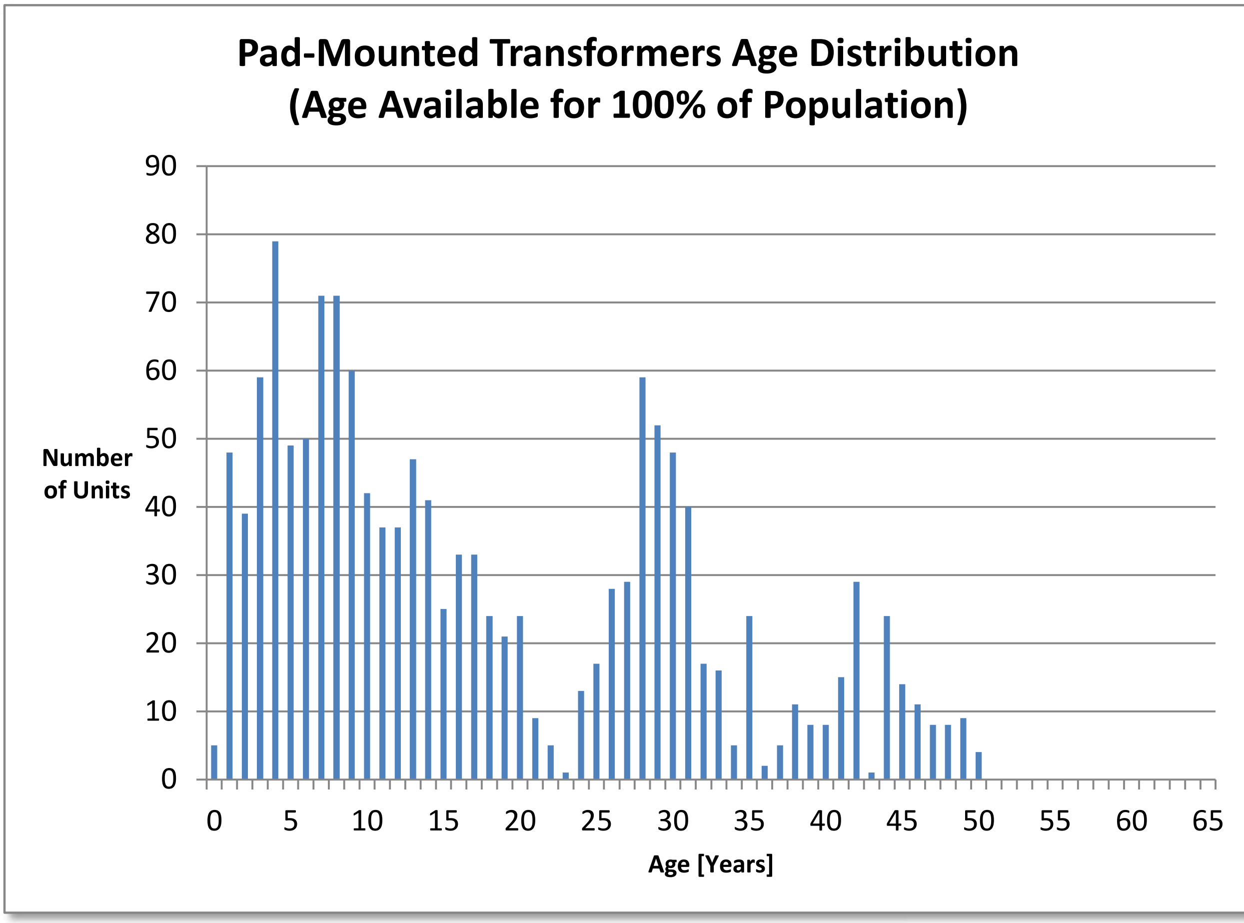

Figure A 2-2 Pad Mounted Transformers Age Distribution

2.3 Health Index Results

The average Health Index for this asset group was 76%. Approximately 18% were found to be in “poor” or “very poor” condition.

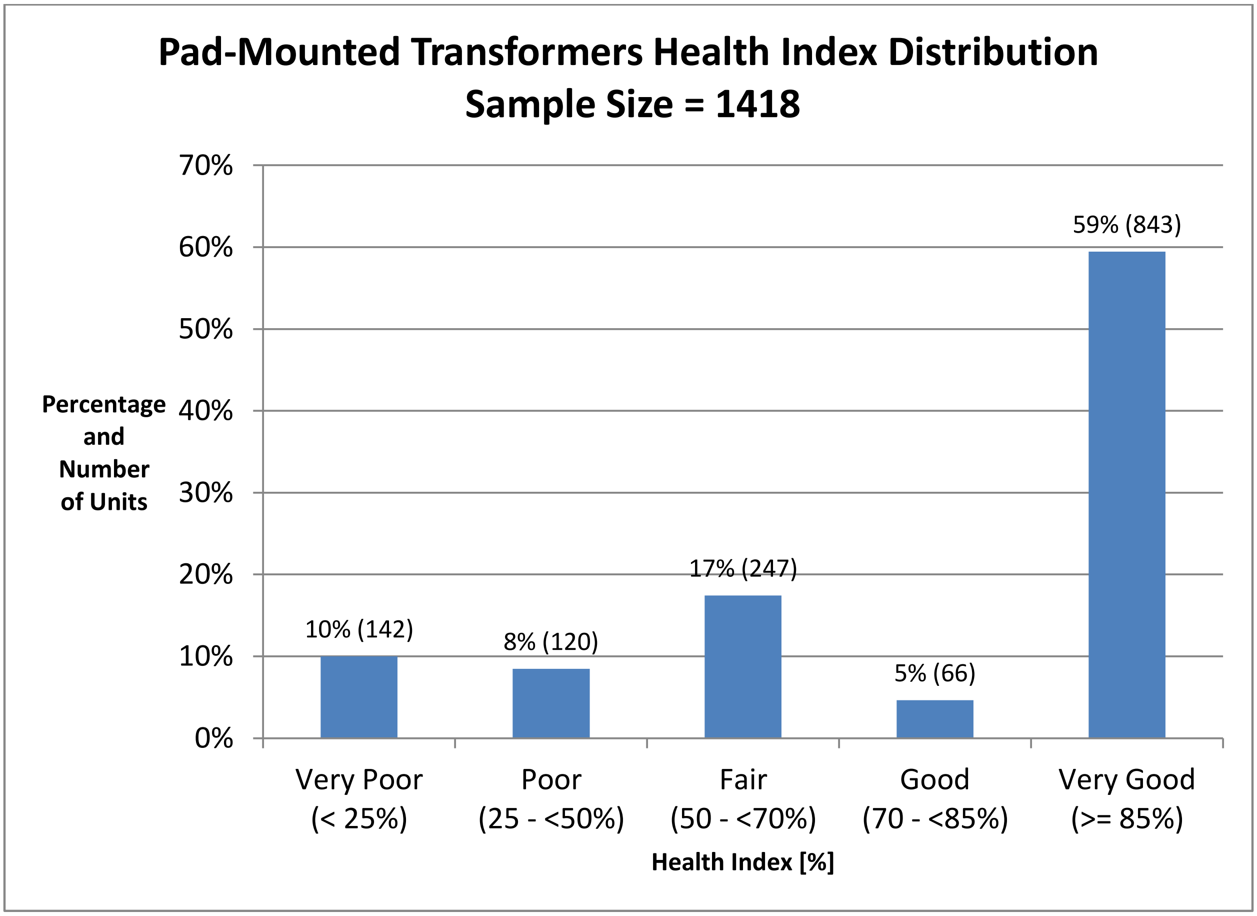

Figure A 2-3 Pad Mounted Transformers HI Distribution

2.4 Flagged for Action Plan

As it is assumed that Pad Mounted Transformers are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

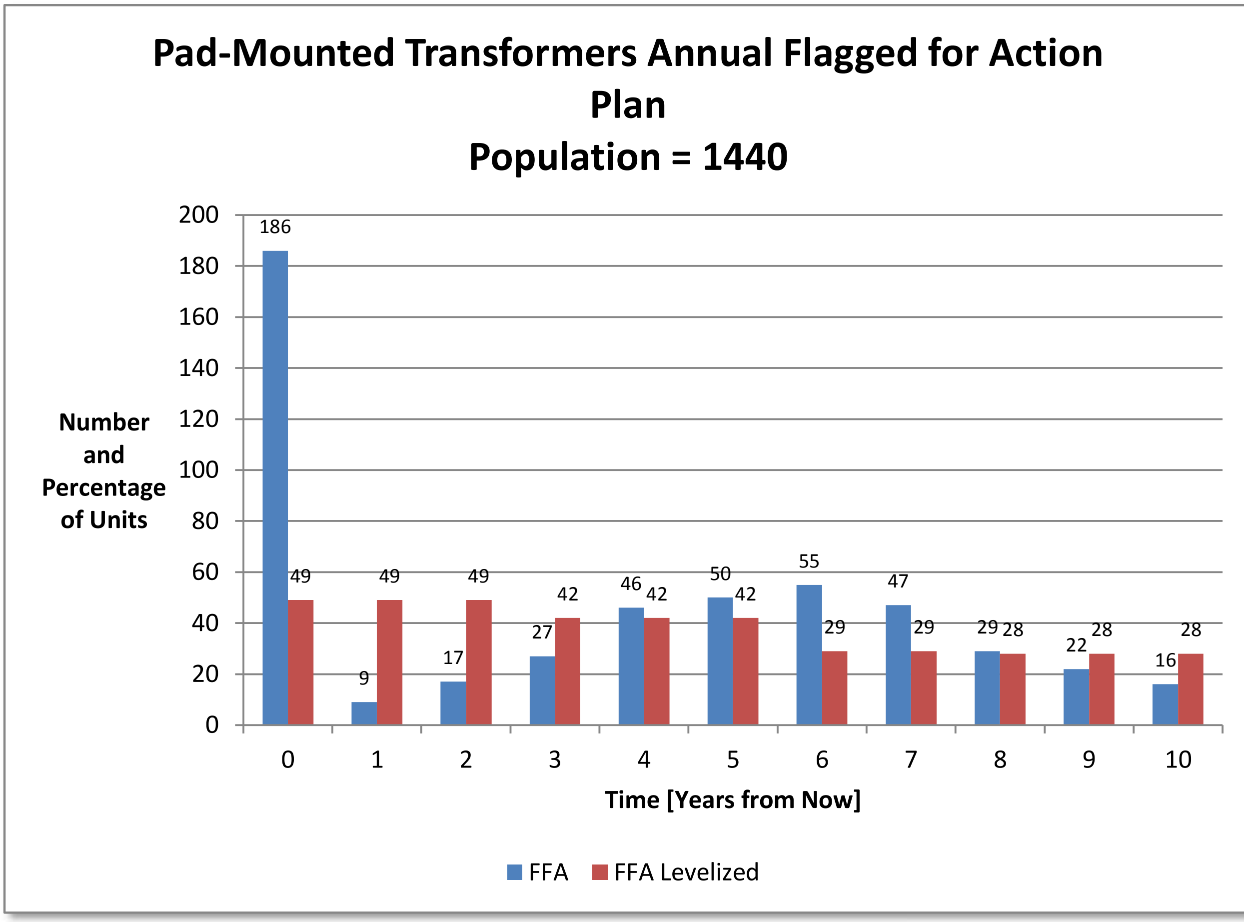

Figure A 2-4 Pad Mounted Transformers FFA

2.5 Data Assessment

The Pad Mounted Transformers data included nameplate information, loading, and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. only 45% had non-conformance records), the average DAI for this asset group was 51%.

For Pad Mounted Transformers, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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3 Pole Mounted Transformers

There are a total of 3232 Pole Mounted Transformers at GSHI. Of these, 3232 had sufficient data for Health Indexing.

3.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 3-1 Pole Mounted Transformers Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Main Tank	7	Tank Corrosion	8	Table A 2-2
		Oil Leak	6	Table A 2-2
Connections	4	Connections	4	Table A 2-2
		Grounding	1	Table A 2-2
Service Record	6	Loading	3	Table A 2-3
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 5-1	

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Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 40 years is 20% and that at 45 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

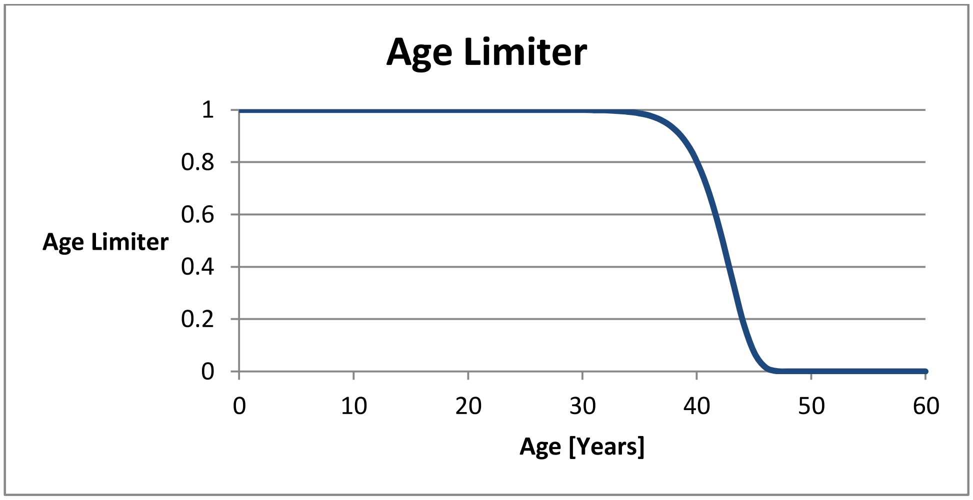

Figure A 3-1 Pole Mounted Transformers Age Limiter

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3.2 Age

The average age of all in-service Pole Mounted Transformers units was 14 years.

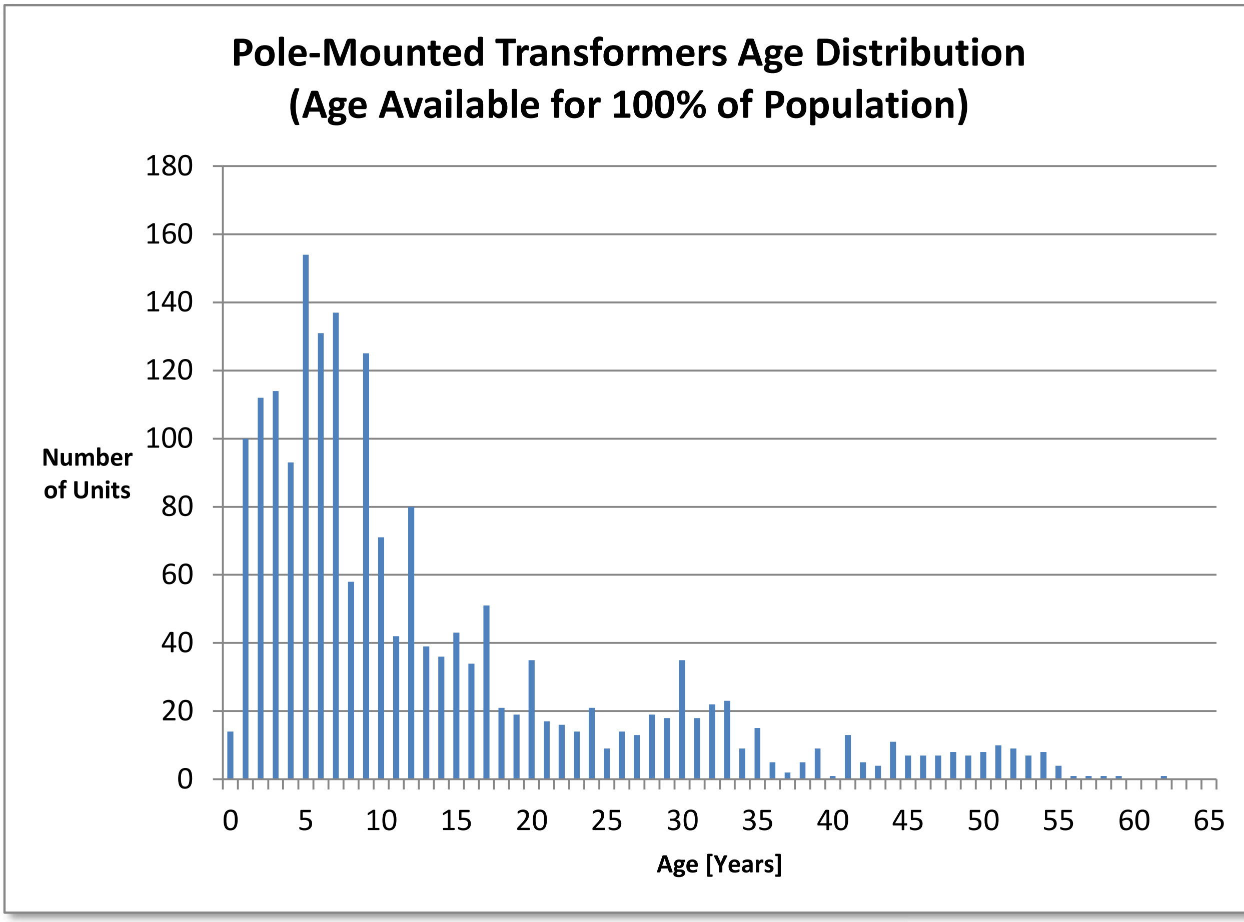

Figure A 3-2 Pole Mounted Transformers Age Distribution

3.3 Health Index Results

The average Health Index for this asset group was 94%. Approximately 4% were found to be in “poor” or “very poor” condition.

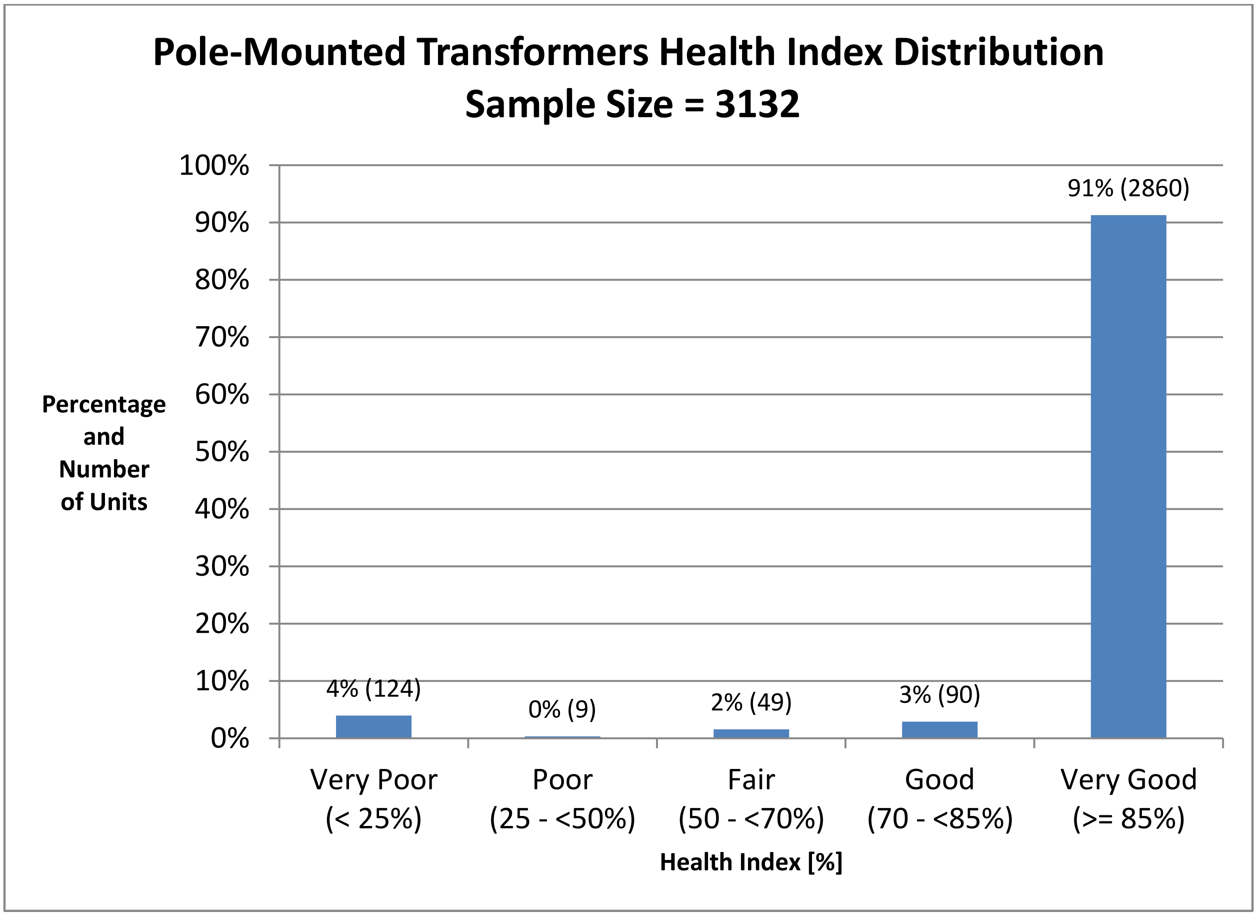

Figure A 3-3 Pole Mounted Transformers HI Distribution

3.4 Flagged for Action Plan

As it is assumed that Pole Mounted Transformers are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

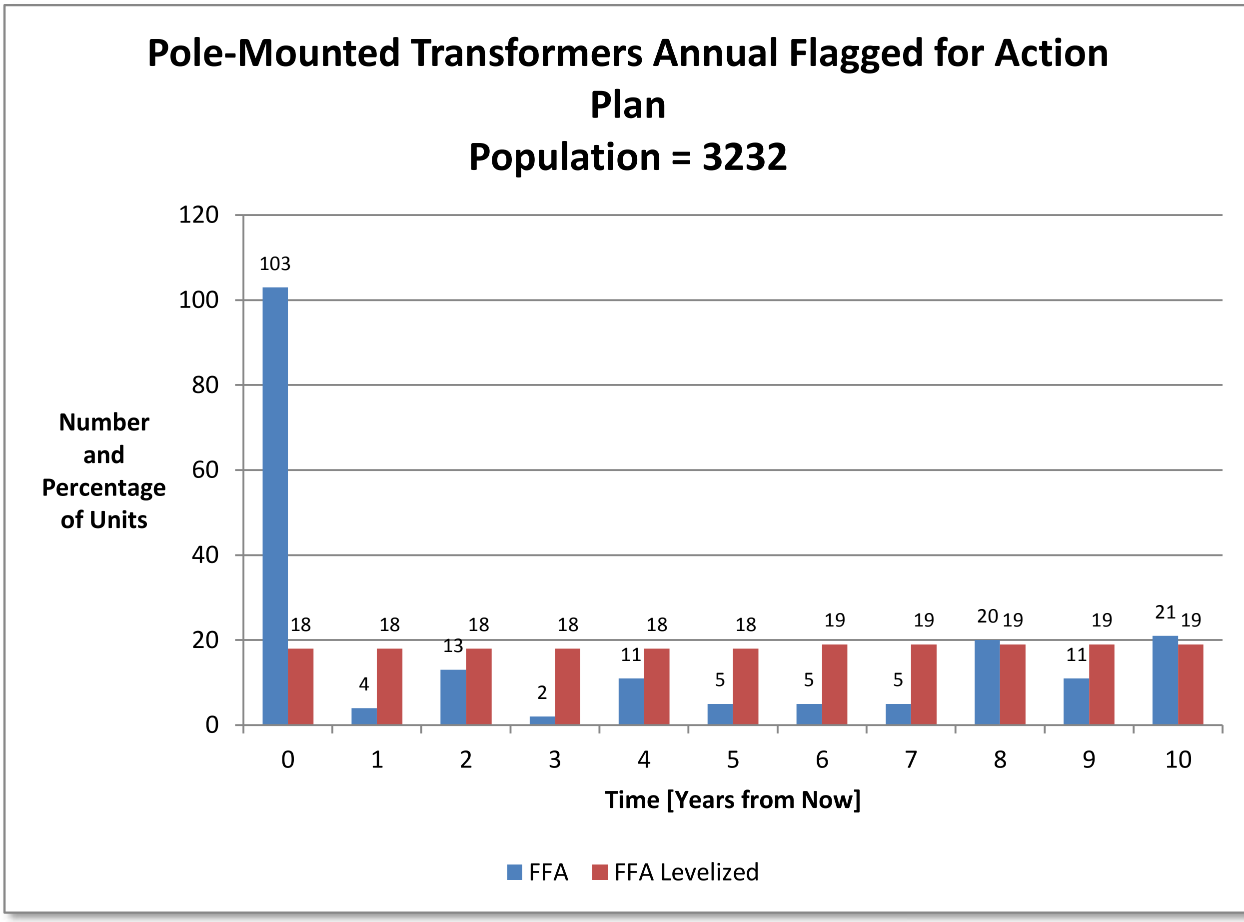

Figure A 3-4 Pole Mounted Transformers FFA

3.5 Data Assessment

The Pole Mounted Transformers data included nameplate information, loading, and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset in the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. only 1.5% had non-conformance records), the average DAI for this asset group was 34%.

For Pole Mounted Transformers, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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4 Submersible Transformers

There are a total of 16 Submersible Transformers at GSHI. Of these, 16 had sufficient data for Health Indexing.

4.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 4-1 Submersible Transformers Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Main Tank	7	Tank Corrosion	8	Table A 2-2
		Oil Leak	6	Table A 2-2
Connections	4	Connections	4	Table A 2-2
		Grounding	1	Table A 2-2
Access	1	Access	1	Table A 2-2
Service Record	6	Loading	3	Table A 2-3
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 4-2	

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Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 35 years is 20% and that at 45 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

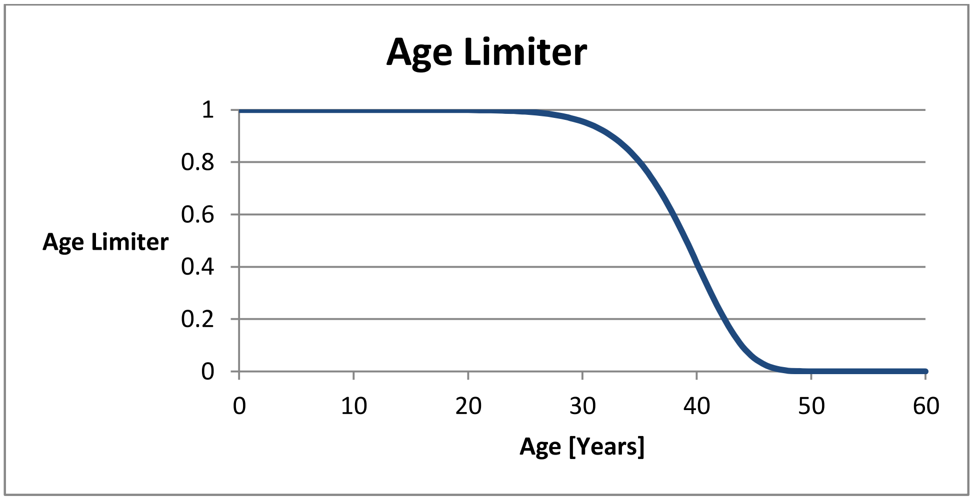

Figure A 4-1 Submersible Transformers Age Limiter

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4.2 Age

The average age of all in-service Submersible Transformers units was 43 years.

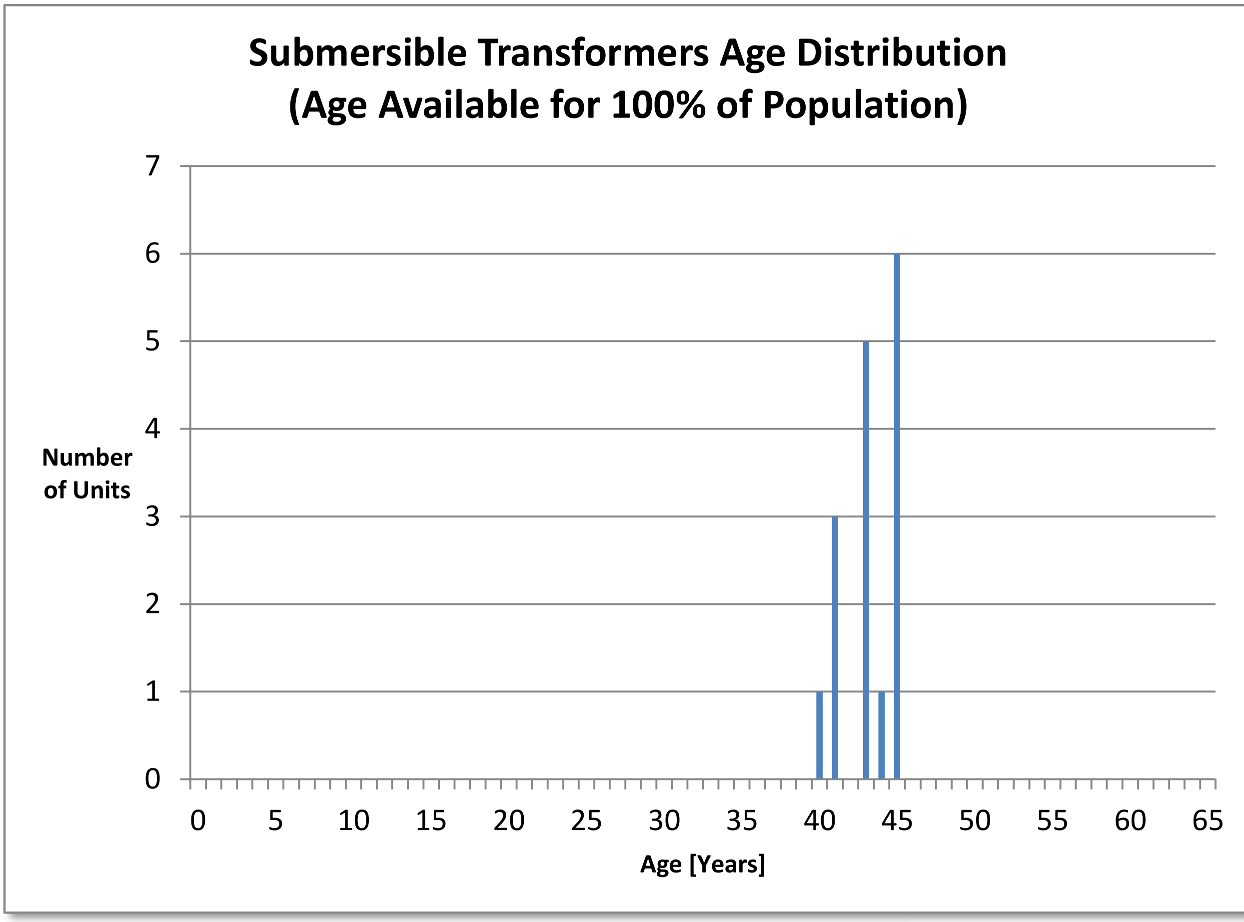

Figure A 4-2 Submersible Transformers Age Distribution

4.3 Health Index Results

The average Health Index for this asset group was 16%. The entire population was found to be in “poor” or “very poor” condition.

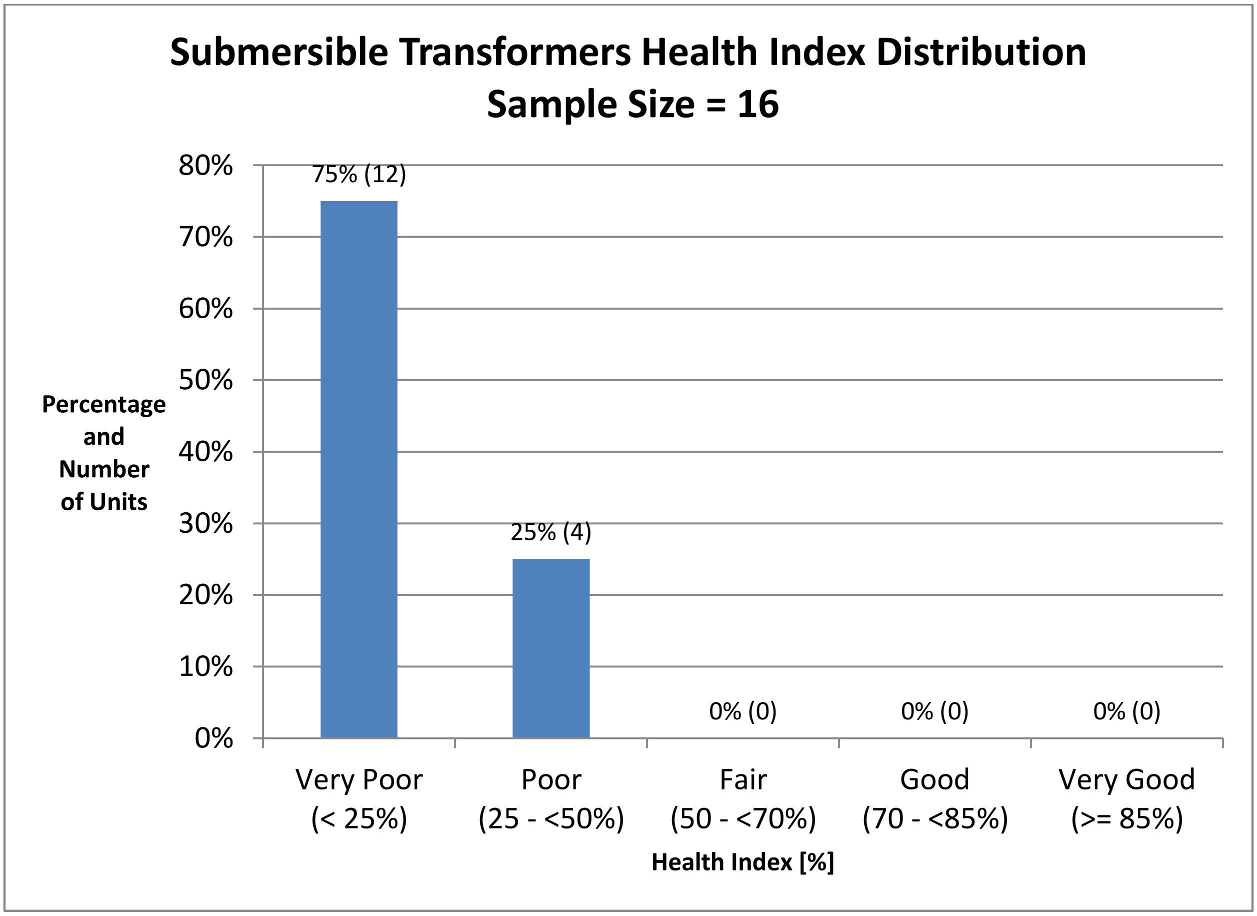

Figure A 4-3 Submersible Transformers HI Distribution

4.4 Flagged for Action Plan

As it is assumed that Submersible Transformers are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

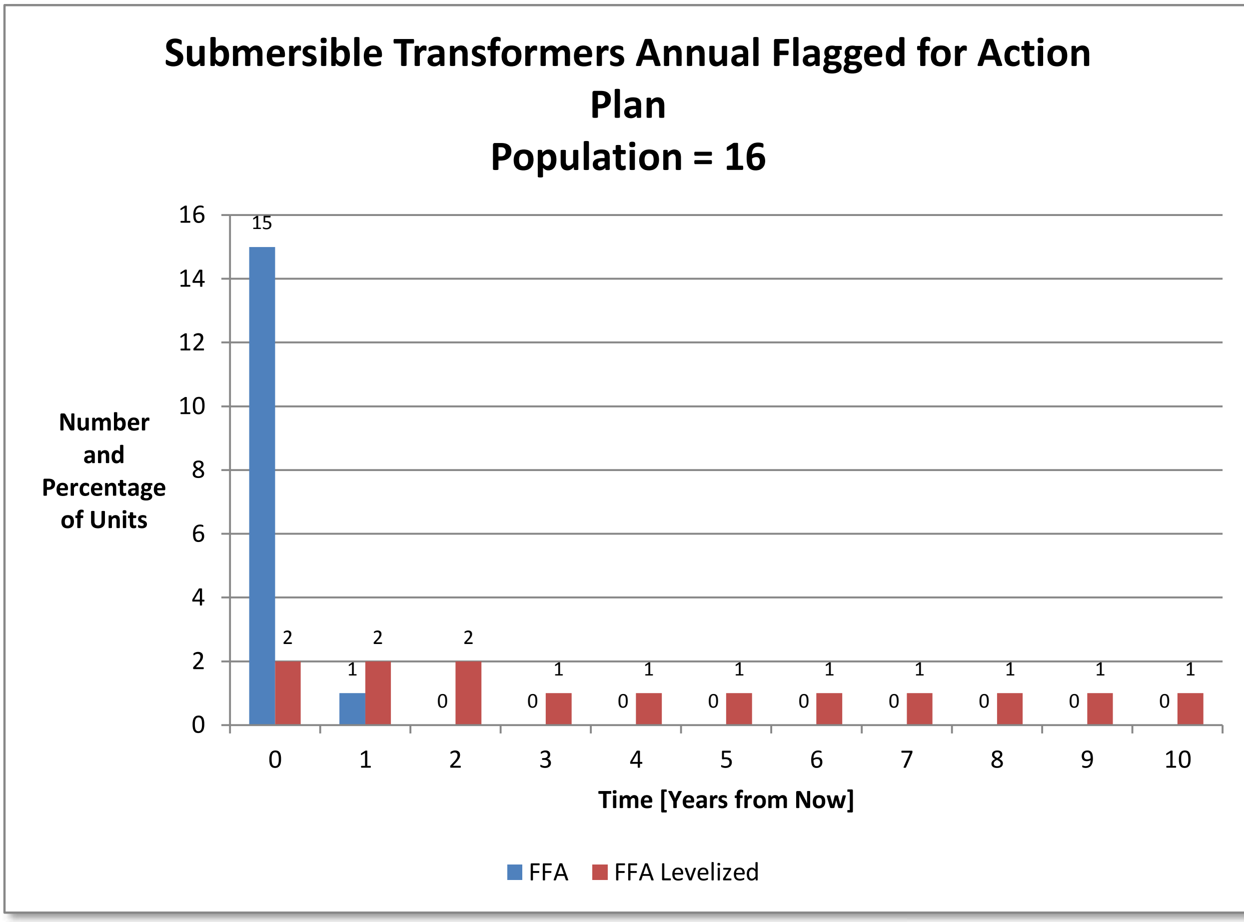

Figure A 4-4 Submersible Transformers FFA

4.5 Data Assessment

The Submersible Transformers data included nameplate information, loading, and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. only 6% had non-conformance records), the average DAI for this asset group was 34%.

For Submersible Transformers, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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5 Vault Transformers

There are a total of 131 Vault Transformers at GSHI. Of these, 116 had sufficient data for Health Indexing.

5.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 5-1 Vault Transformers Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Main Tank	7	Tank Corrosion	8	Table A 2-2
		Oil Leak	6	Table A 2-2
Connections	4	Connections	4	Table A 2-2
		Grounding	1	Table A 2-2
Access	1	Access	1	Table A 2-2
Service Record	6	Loading	3	Table A 2-3
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 5-1	

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Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 35 years is 20% and that at 45 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

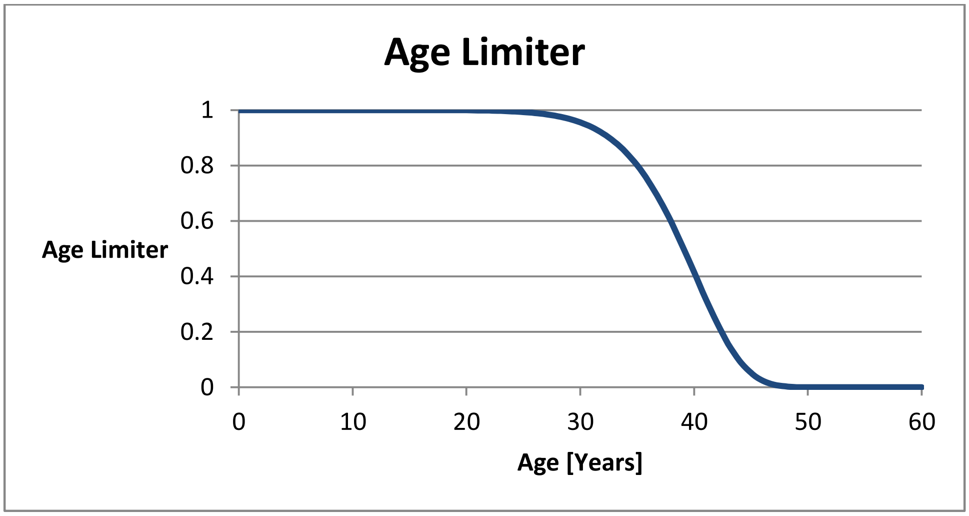

Figure A 5-1 Vault Transformers Age Limiter

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5.2 Age

The average age of all in-service Vault Transformers units was 30 years.

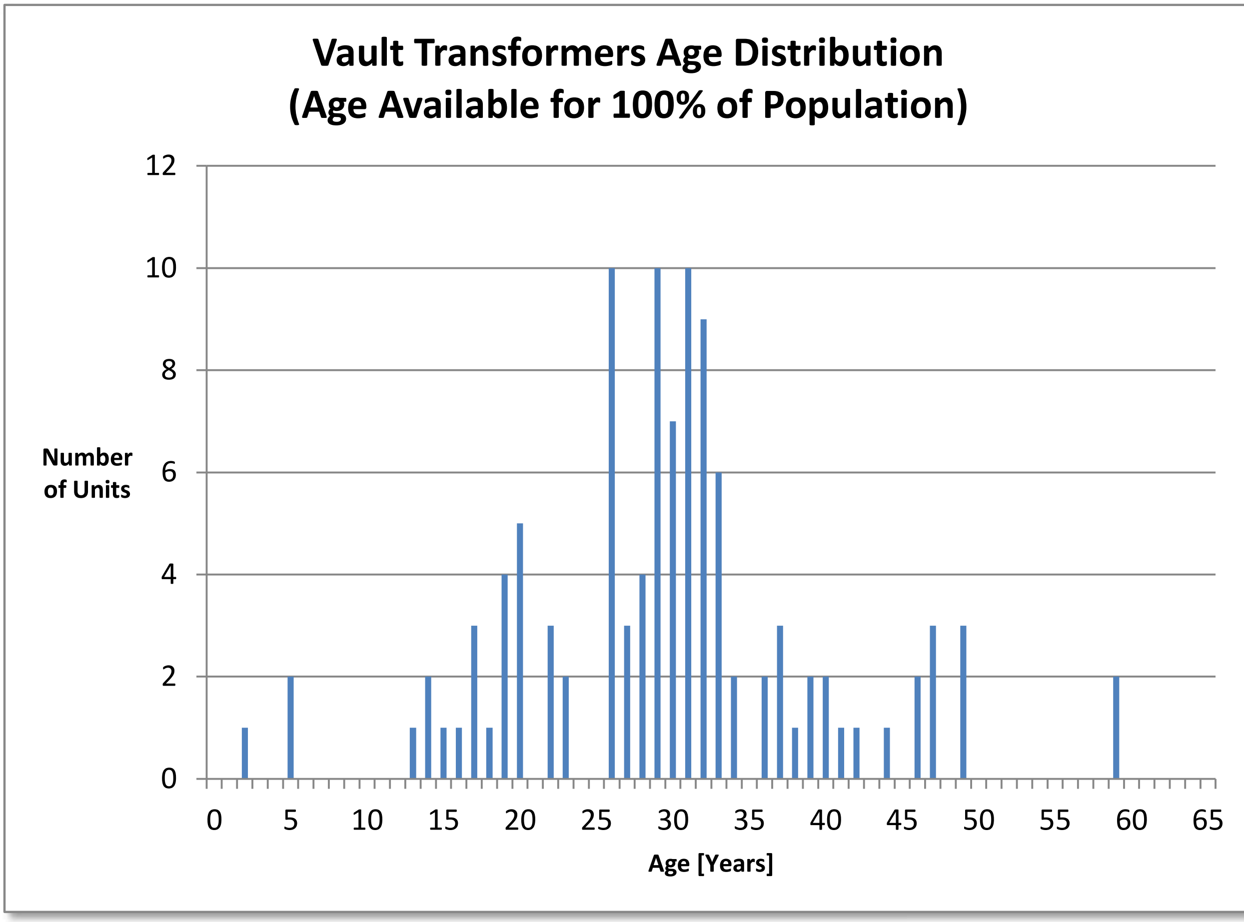
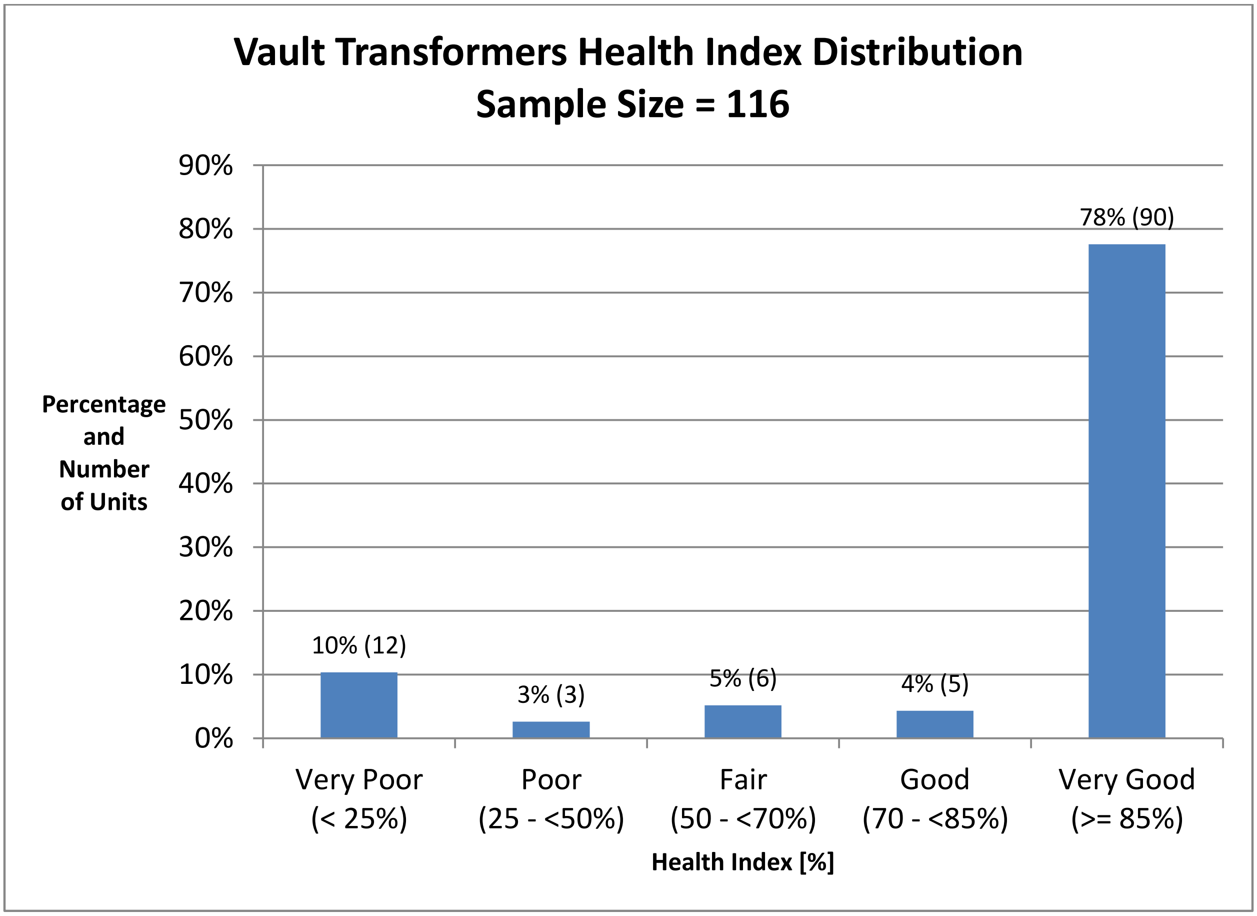


Figure A 5-2 Vault Transformers Age Distribution

5.3 Health Index Results

The average Health Index for this asset group was 83%. Approximately 13% were found to be in “poor” or “very poor” condition.



5.4 Flagged for Action Plan

As it is assumed that Vault Transformers are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a “levelized” plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

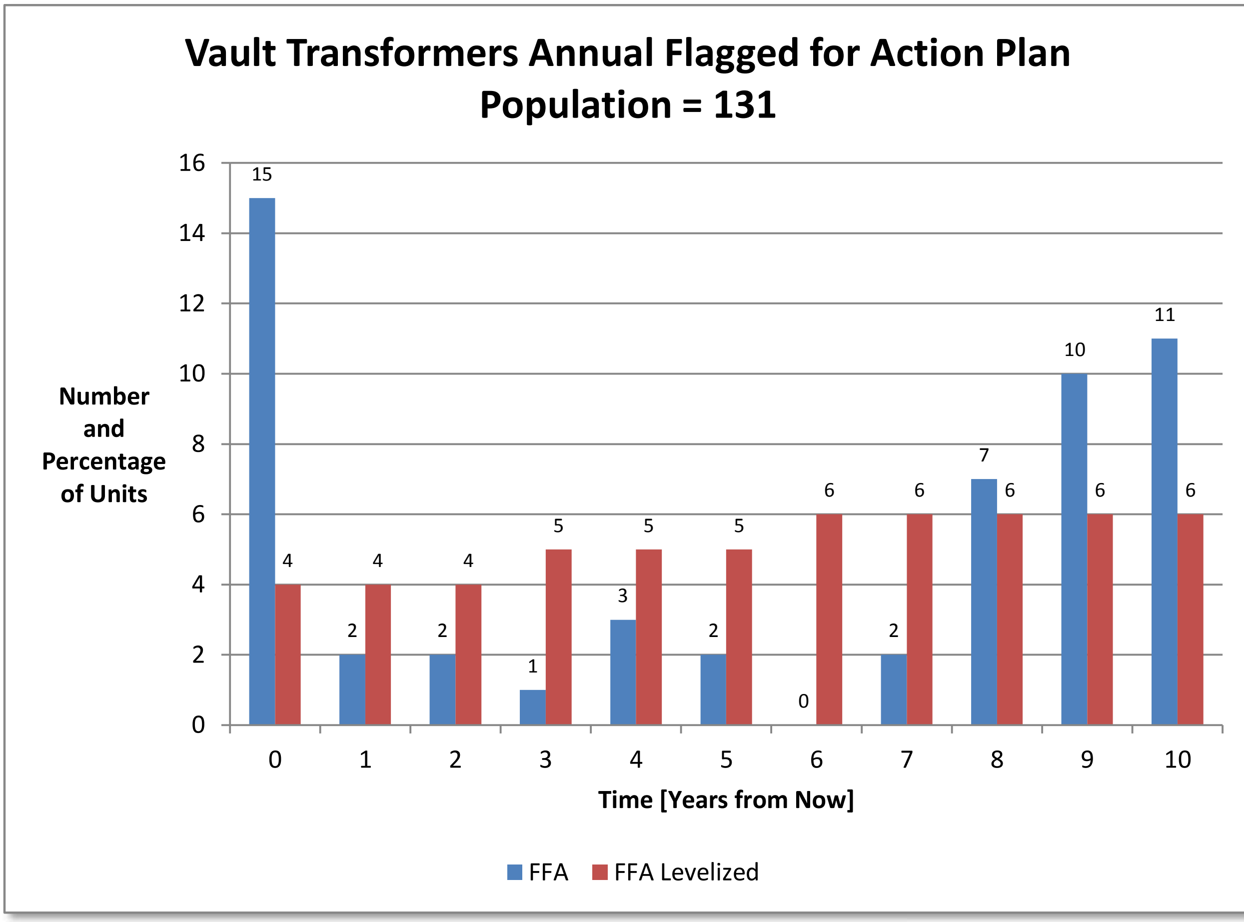


Figure A 5-3 Vault Transformers FFA

5.5 Data Assessment

The Vault Transformers data included nameplate information, loading, and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. <1% had non-conformance records), the average DAI for this asset group was 28%.

For Vault Transformers, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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6 Overhead Switches

There are a total of 2173 Overhead Switches at GSHI. Of these, 2016 had sufficient data for Health Indexing.

6.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 6-1 Overhead Switches Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Operating Mechanism	8	Operating Mechanism	1	Table A 2-2
Switch Contact	4	Switch Contact	1	Table A 2-2
Arc Extinction	3	Arc Extinction	1	Table A 2-2
Insulation	1	Insulation	1	Table A 2-2
Service Record	4*	Age	1*	N/A
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 5-1	
*weight only applies to DAI calculation; weight set to 0 for HI calculation				

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Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 45 years is 20% and that at 55 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

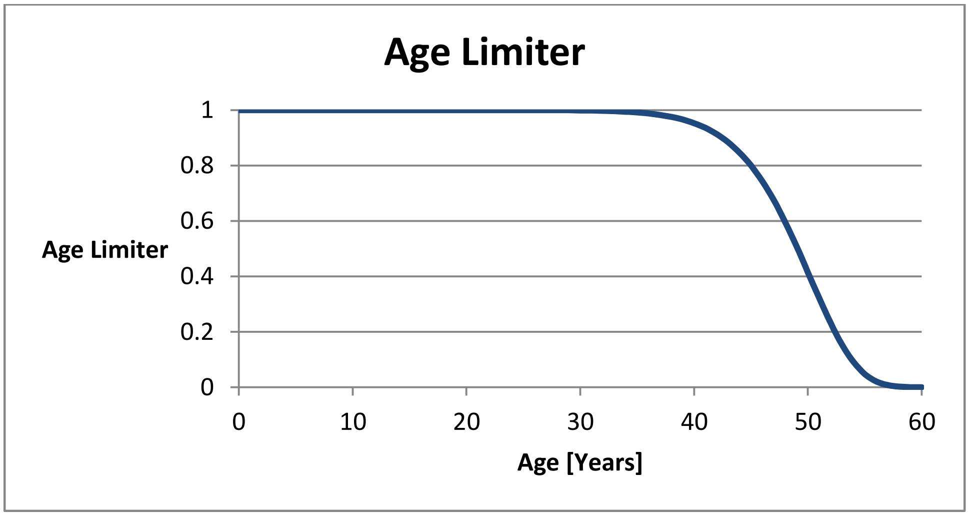

Figure A 6-1 Overhead Switches Age Limiter

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6.2 Age

The average age of all in-service Overhead Switches units was 19 years.

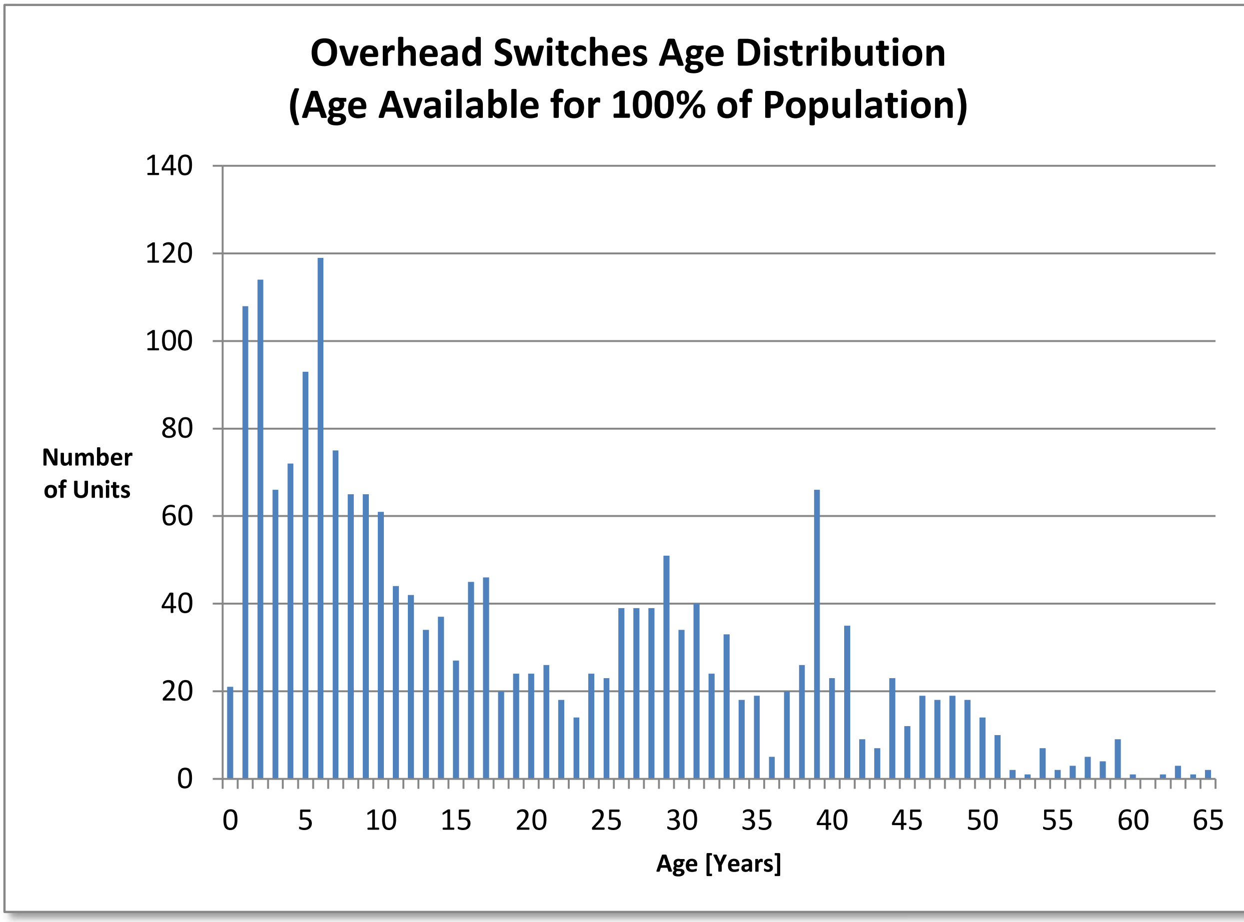

Figure A 6-2 Overhead Switches Age Distribution

6.3 Health Index Results

The average Health Index for this asset group was 95%. More than 3% were found to be in "poor" or "very poor" condition.

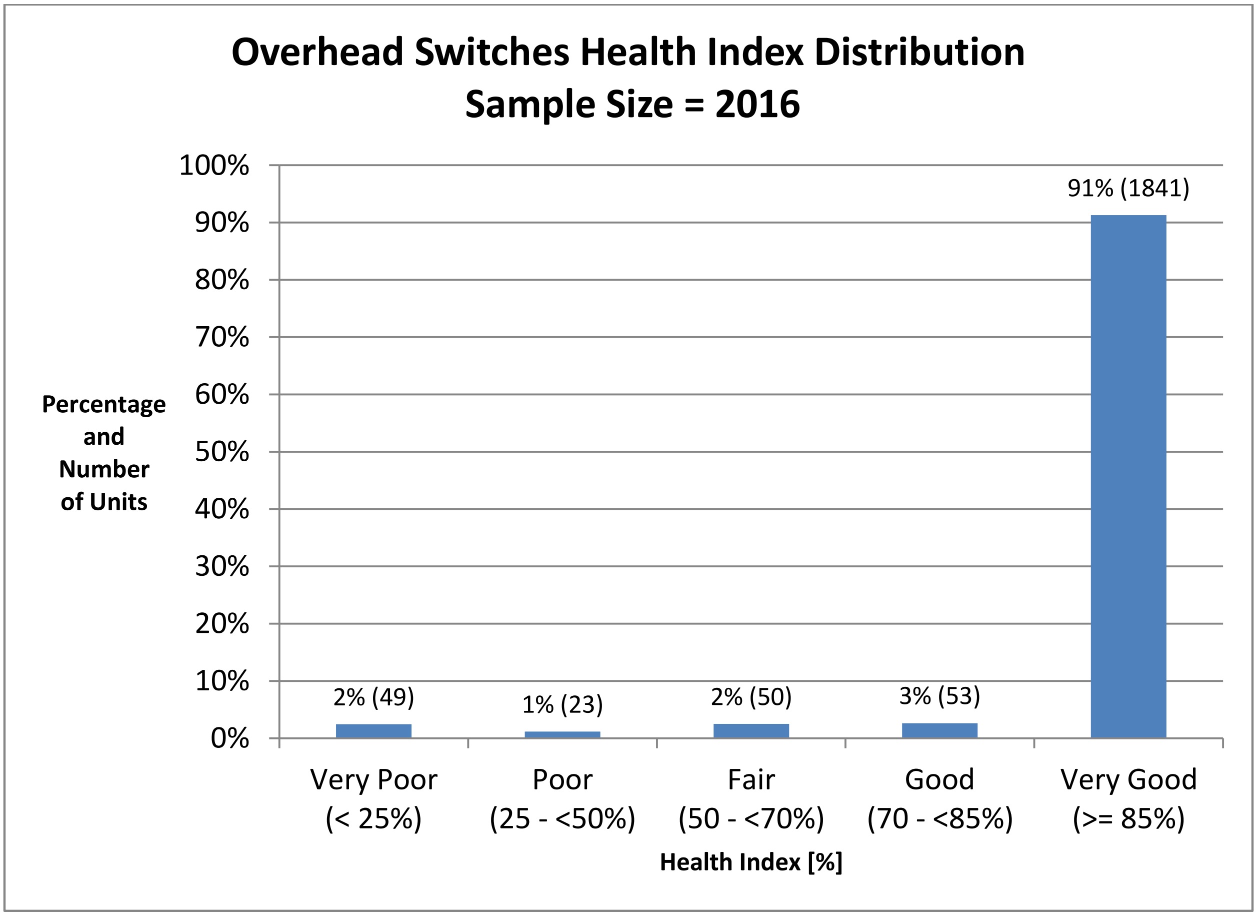

Figure A 6-3 Overhead Switches HI Distribution

6.4 Flagged for Action Plan

As it is assumed that Overhead Switches are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

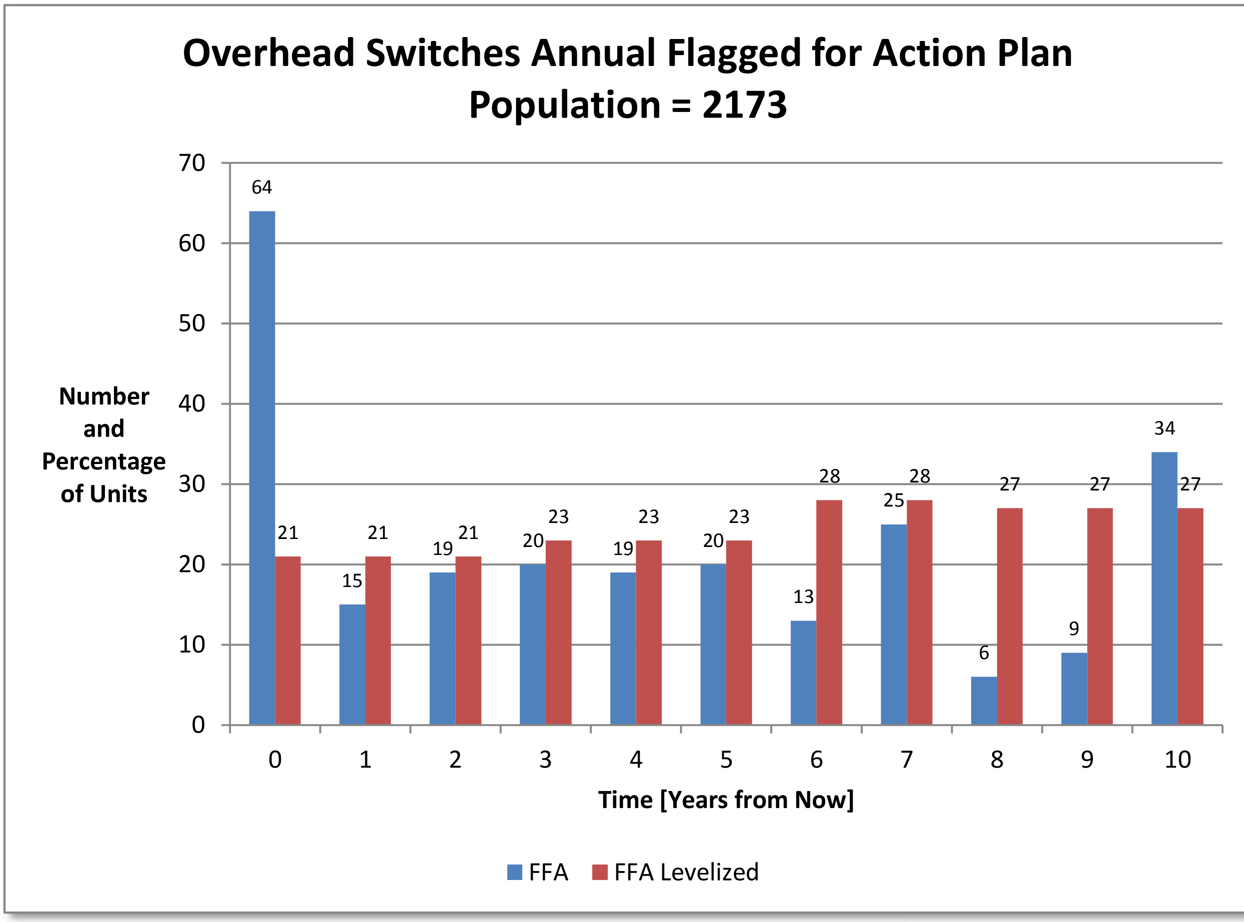

Figure A 6-4 Overhead Switches FFA

6.5 Data Assessment

The Overhead Switches data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. Only 3% had non-conformance records), the assessment was primarily age-based and the average DAI for this asset group was 10%.

For Overhead Switches, general components of the asset have incorporated into the Health Index formula. To improve the HI formula, more detailed information listed in the table below can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

Table A 6-2 Overhead Switches Data Gaps

Data Gap	Priority	Description	Source
Operating Mechanism	H	Mechanical part Linkage	On-site manual inspection
Switch Blade	L	Contact, alignment	On-site visual inspection
Arc Extinction	L	Arc horns Interrupters/suppressors	On-site visual inspection
Mechanical Support	L	Loose installation	On-site visual inspection
Insulators	L	Condition of insulators	On-site visual inspection
Operation History	M	Last time switch was operated; number of times operated in past year or recent years. Periodic exercising of switches is recommended.	Operation record

7 Pad Mounted Switchgear

There are a total of 80 Pad Mounted Switchgear at GSHI. Of these, 80 had sufficient data for Health Indexing.

7.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 7-1 Pad Mounted Switchgear Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Enclosure	3	Enclosure Corrosion	8	Table A 2-2
		Door	1	Table A 2-2
		Paint	1	Table A 2-2
Connections	5	Connections	3	Table A 2-2
		Grounding	1	Table A 2-2
Fuse / Switch	3 0[1,2,3]	Fuse	1 0[1,2,3]	Table A 2-2
		Switch	1 0[1,2,3]	Table A 2-2
Insulation	5 0[1,2,3]	Insulation	1 0[1,2,3]	Table A 2-2
		Barrier Boards	1 0[1,2,3]	Table A 2-2
Base / Foundation	2	Base/Foundation	1	Table A 2-2
Access	1	Access	1	Table A 2-2
Service Record	4	Age	1*	N/A
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 7-1	
*weight only applies to DAI calculation; weight set to 0 for HI calculation				
[1] Deadfront [2] SF6 [3] Solid Dielctric Unspecified - Livefront				

Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 34 years is 20% and that at 45 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

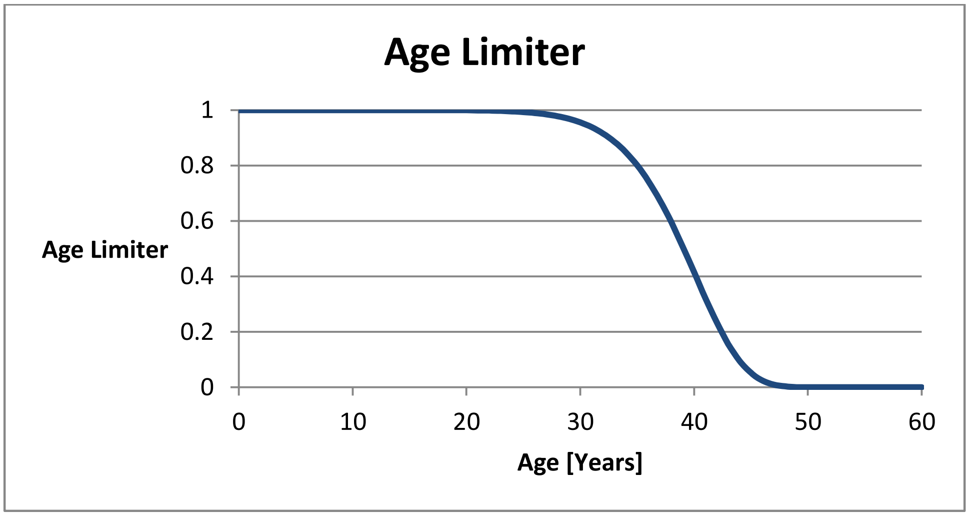

Figure A 7-1 Pad Mounted Switchgear Age Limiter

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7.2 Age

The average age of all in-service Pad Mounted Switchgear units was 18 years.

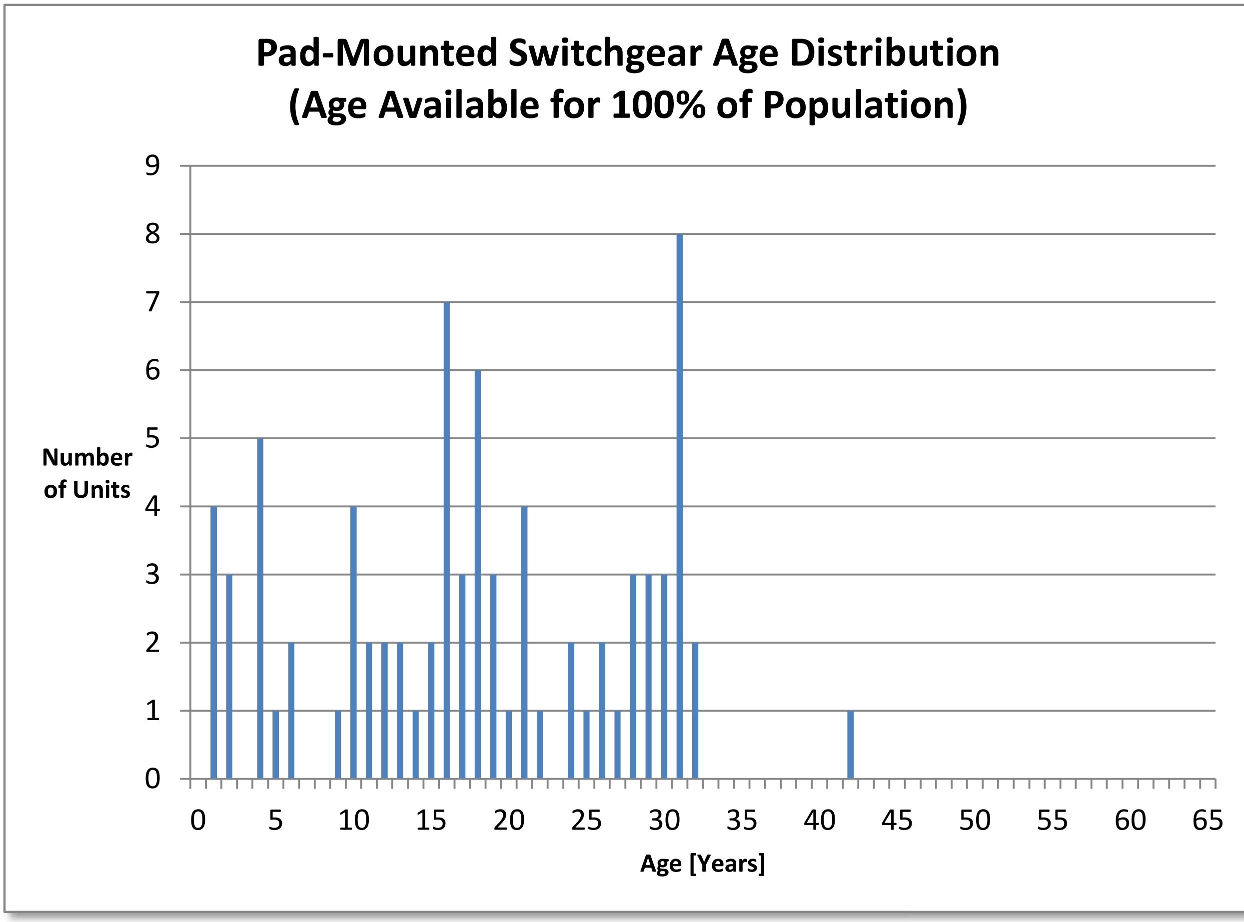

Figure A 7-2 Pad Mounted Switchgear Age Distribution

7.3 Health Index Results

The average Health Index for this asset group was 96%. Approximately 1% were found to be in "poor" or "very poor" condition.

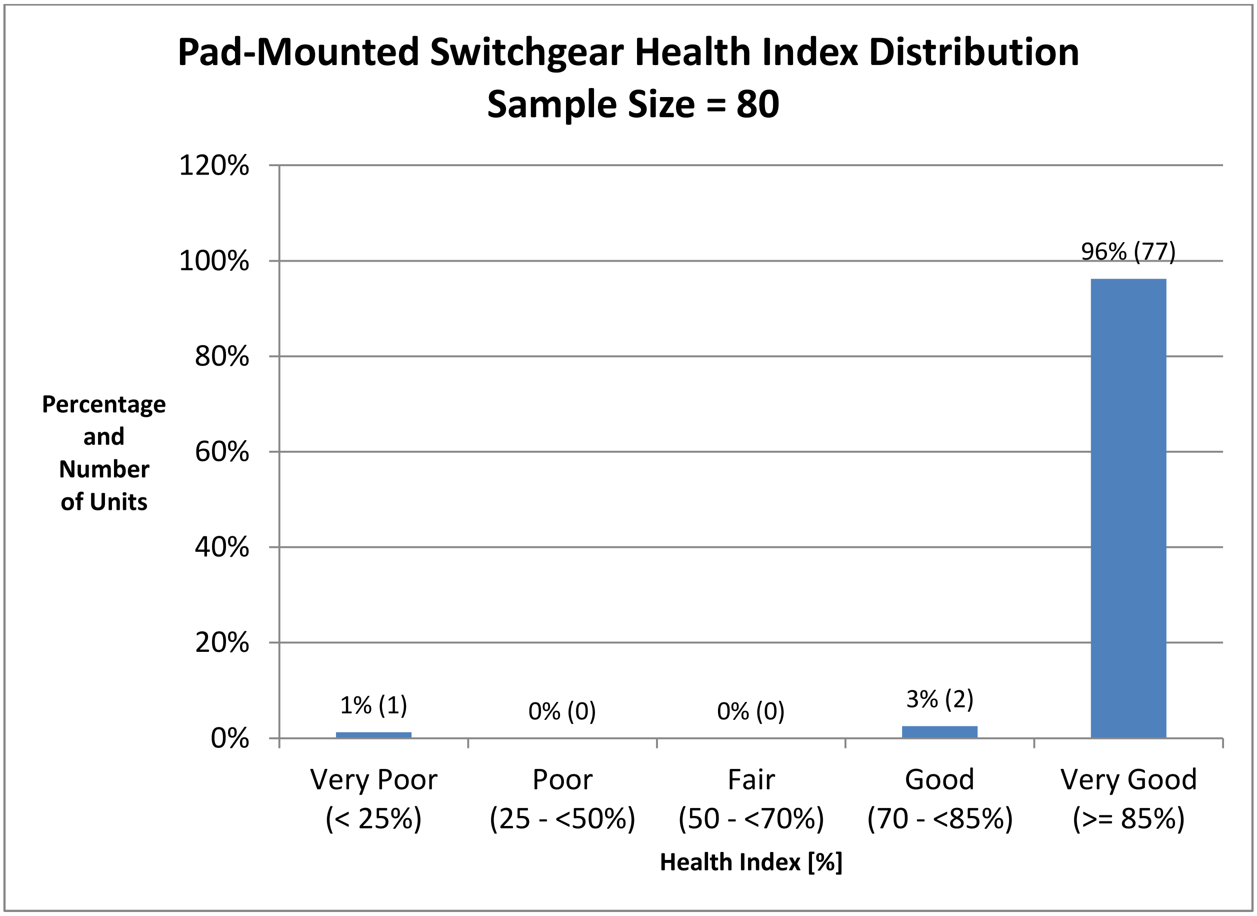

Figure A 7-3 Pad Mounted Switchgear HI Distribution

7.4 Flagged for Action Plan

As it is assumed that Pad Mounted Switchgear are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

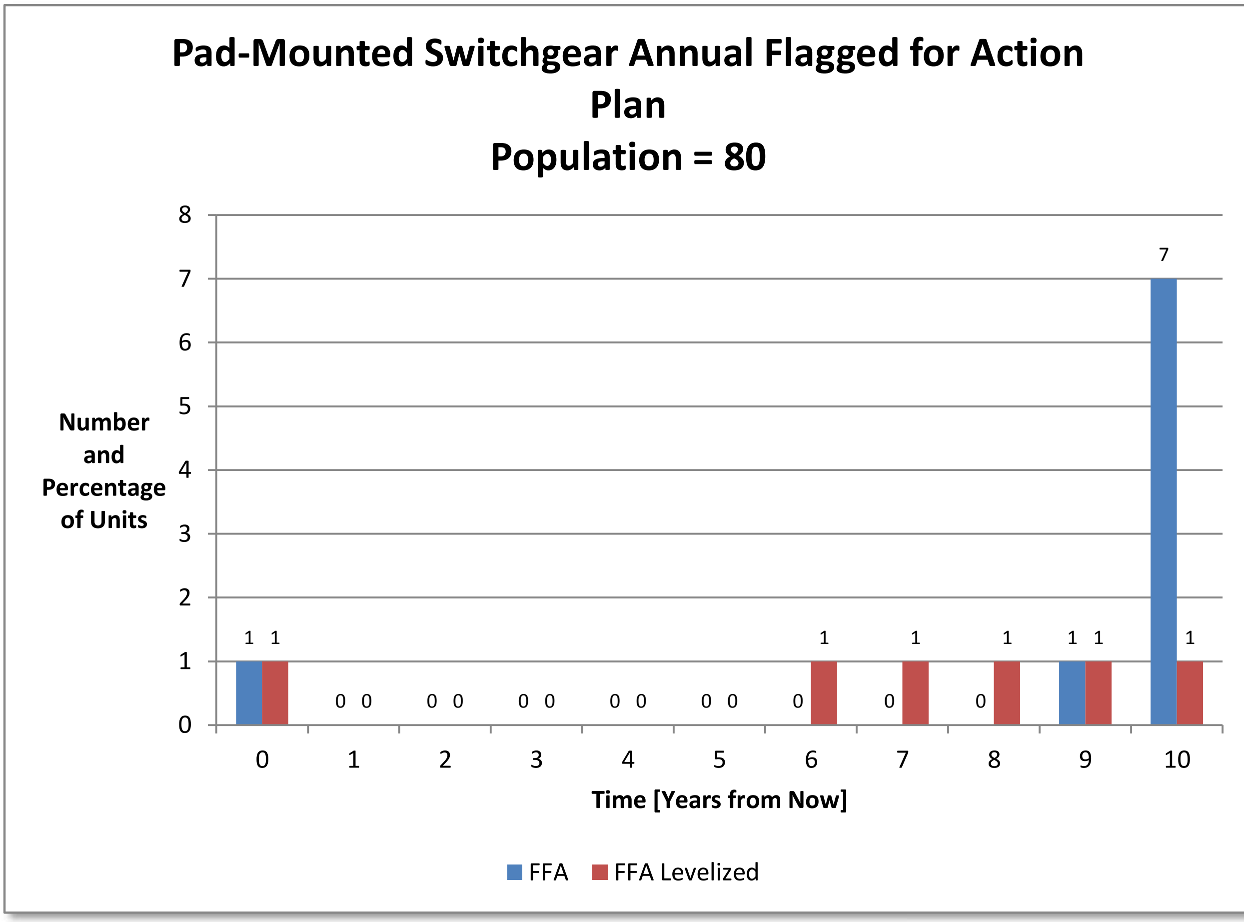

Figure A 7-4 Pad Mounted Switchgear FFA

7.5 Data Assessment

The Pad Mounted Switchgear data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. Approximately 41% had non-conformance records), the average DAI for this asset group was 42%.

For Pad Mounted Switchgear, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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8 Junction Enclosures

There are a total of 70 Junction Enclosures at GSHI. Of these, 70 had sufficient data for Health Indexing.

8.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 8-1 Junction Enclosures Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Enclosure	3	Enclosure Corrosion	8	Table A 2-2
		Door	1	Table A 2-2
		Paint	1	Table A 2-2
Connections	5	Connections	3	Table A 2-2
		Grounding	1	Table A 2-2
Base / Foundation	2	Base/Foundation	1	Table A 2-2
Access	1	Access	1	Table A 2-2
Service Record	4	Age	1*	N/A
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 8-1	
*weight only applies to DAI calculation; weight set to 0 for HI calculation				

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Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 34 years is 20% and that at 45 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

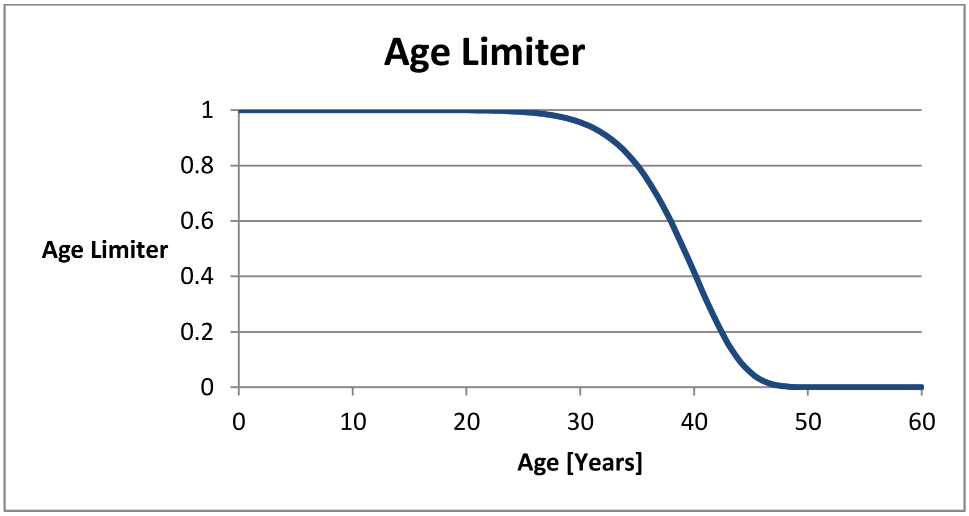

Figure A 8-1 Junction Enclosures Age Limiter

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8.2 Age

The average age of all in-service Junction Enclosures units was 17 years.

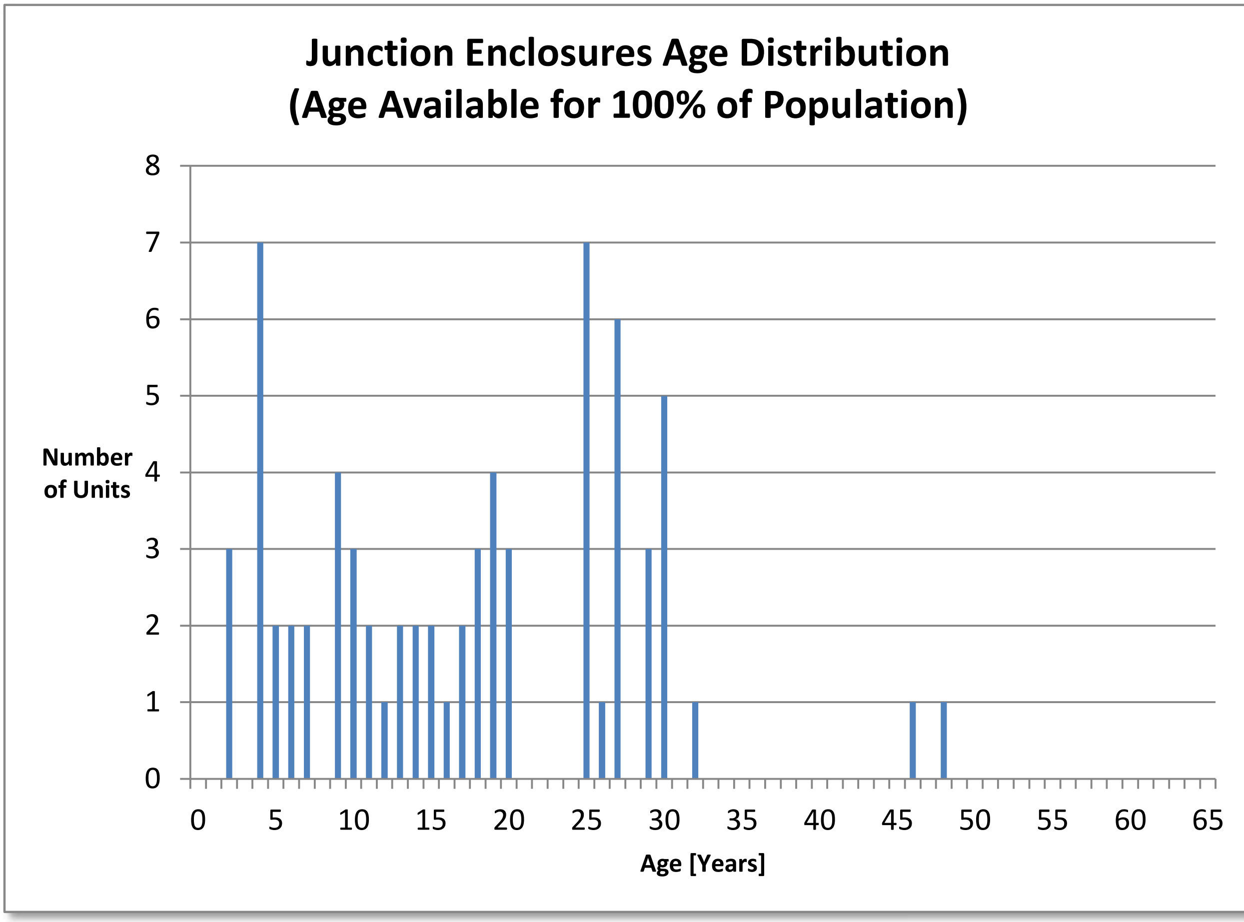

Figure A 8-2 Junction Enclosures Age Distribution

8.3 Health Index Results

The average Health Index for this asset group was 95%. Approximately 3% were found to be in "poor" or "very poor" condition.

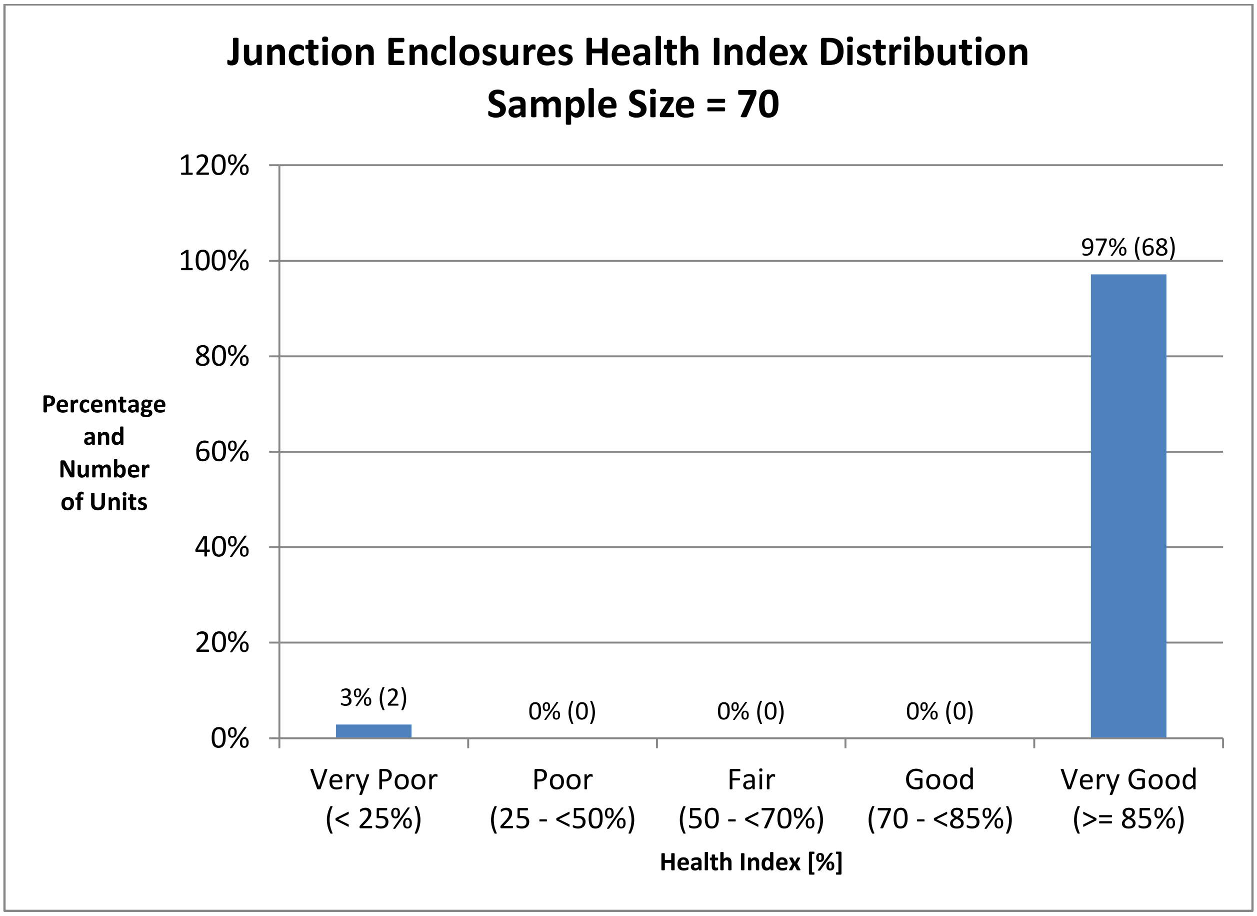

Figure A 8-3 Junction Enclosures HI Distribution

8.4 Flagged for Action Plan

As it is assumed that Junction Enclosures are reactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

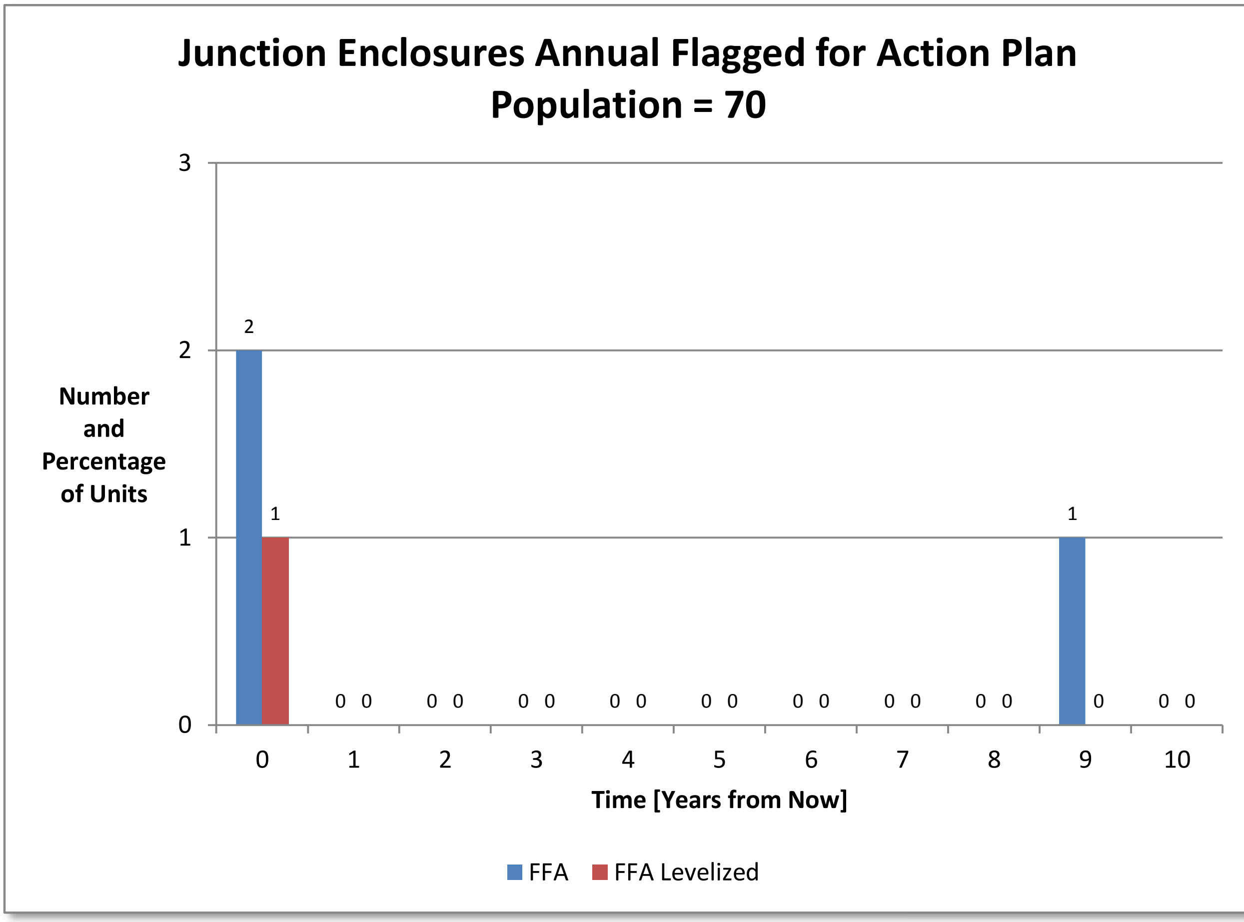

Figure A 8-4 Junction Enclosures FFA

8.5 Data Assessment

The Junction Enclosures data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. Approximately 43% had non-conformance records), the average DAI for this asset group was 51%.

For Junction Enclosures, much of the required data has been incorporated into the Health Index formula. Instead of using non-conformance logs however, GSHI should consider using more detailed inspection records, gathered by way of comprehensive inspection forms. No data gaps are noted because the non-conformance records for distribution transformers account for the condition parameters listed in the HI formula.

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9 Sudbury Wood Poles

There are a total of 11755 Sudbury Wood Poles. Of these, 11755 had sufficient data for Health Indexing.

9.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 9-1 Sudbury Wood Poles Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Pole	10	Pole Strength	8	Table A 2-2
		Pole Appearance	1	Table A 2-2
Support and Assemblies	8	Crossarm	4	Table A 2-2
		Guy Assembly	2	Table A 2-2
		Hardware and Connection	2	Table A 2-2
		Insulators	2	Table A 2-2
		Other Components	1	Table A 2-2
Environment	1	Vegetation	1	Table A 2-2
Encroachment and Clearance	1	Encroachment and Clearance	1	Table A 2-2
Service Record	10	Age	1*	N/A
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 9-1	
*weight only applies to DAI calculation; weight set to 0 for HI calculation				

Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 45 years is 20% and that at 75 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

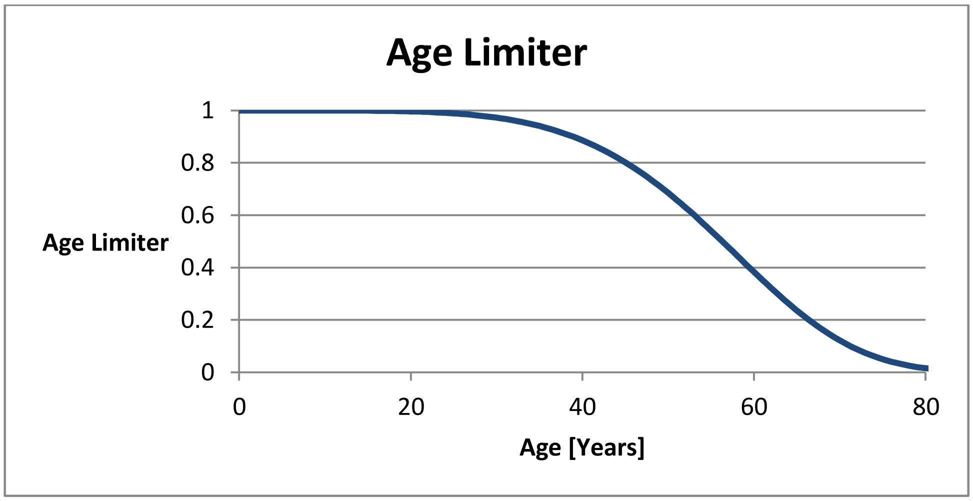

Figure A 9-1 Sudbury Wood Poles Age Limiter

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9.2 Age

The average age of all in-service Sudbury Wood Poles units was 31 years.

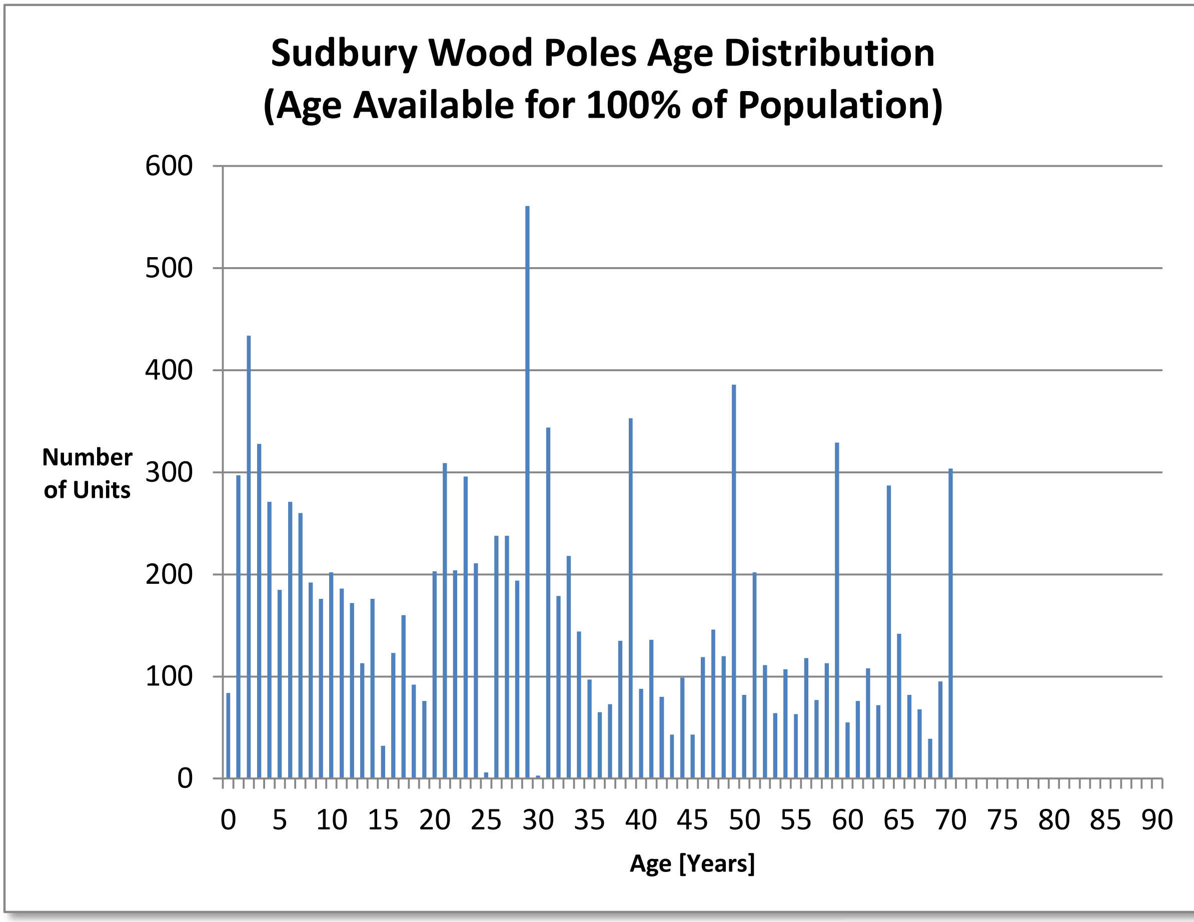

Figure A 9-2 Sudbury Wood Poles Age Distribution

9.3 Health Index Results

The average Health Index for this asset group was 83%. Approximately 16% were found to be in “poor” or “very poor” condition.

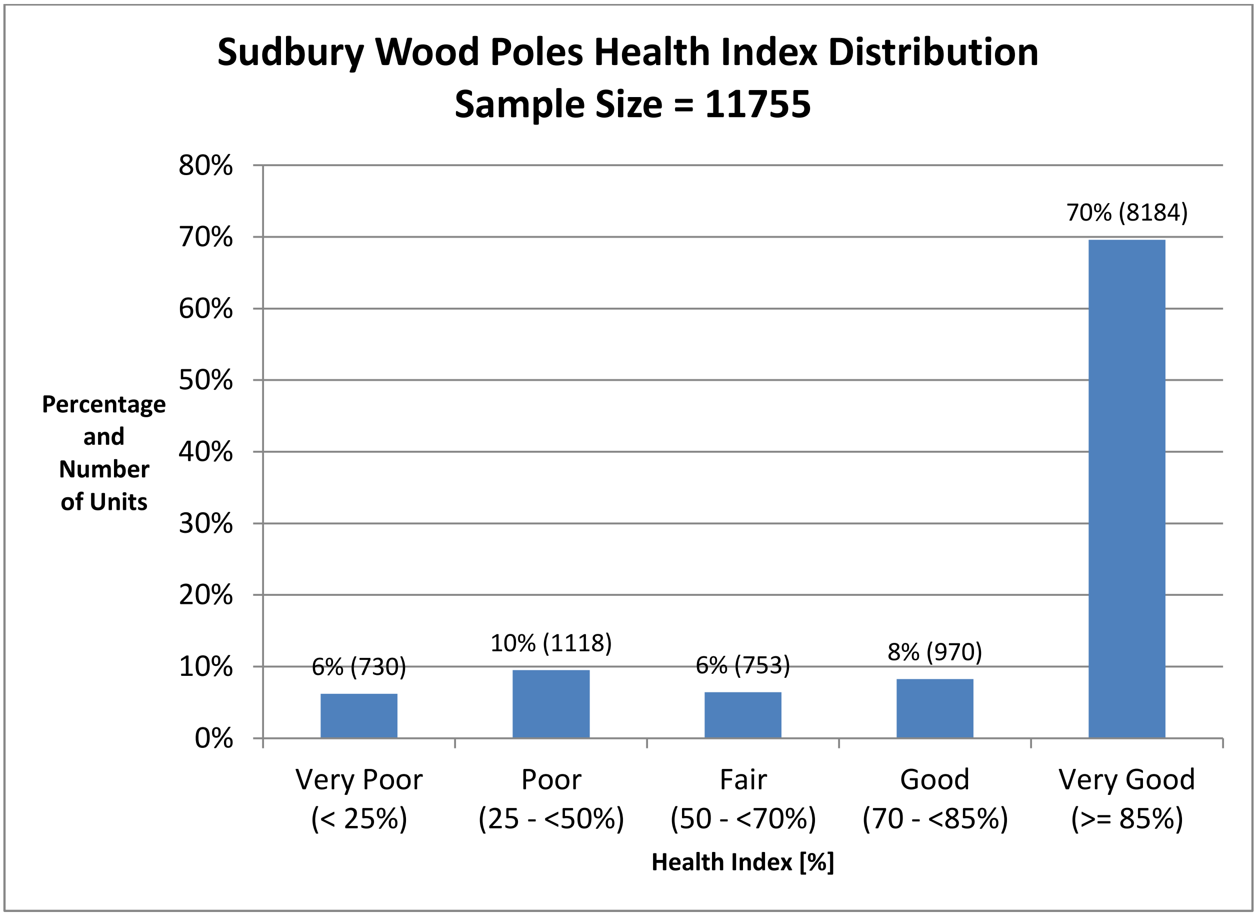

Figure A 9-3 Sudbury Wood Poles HI Distribution

9.4 Flagged for Action Plan

Although poles are proactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

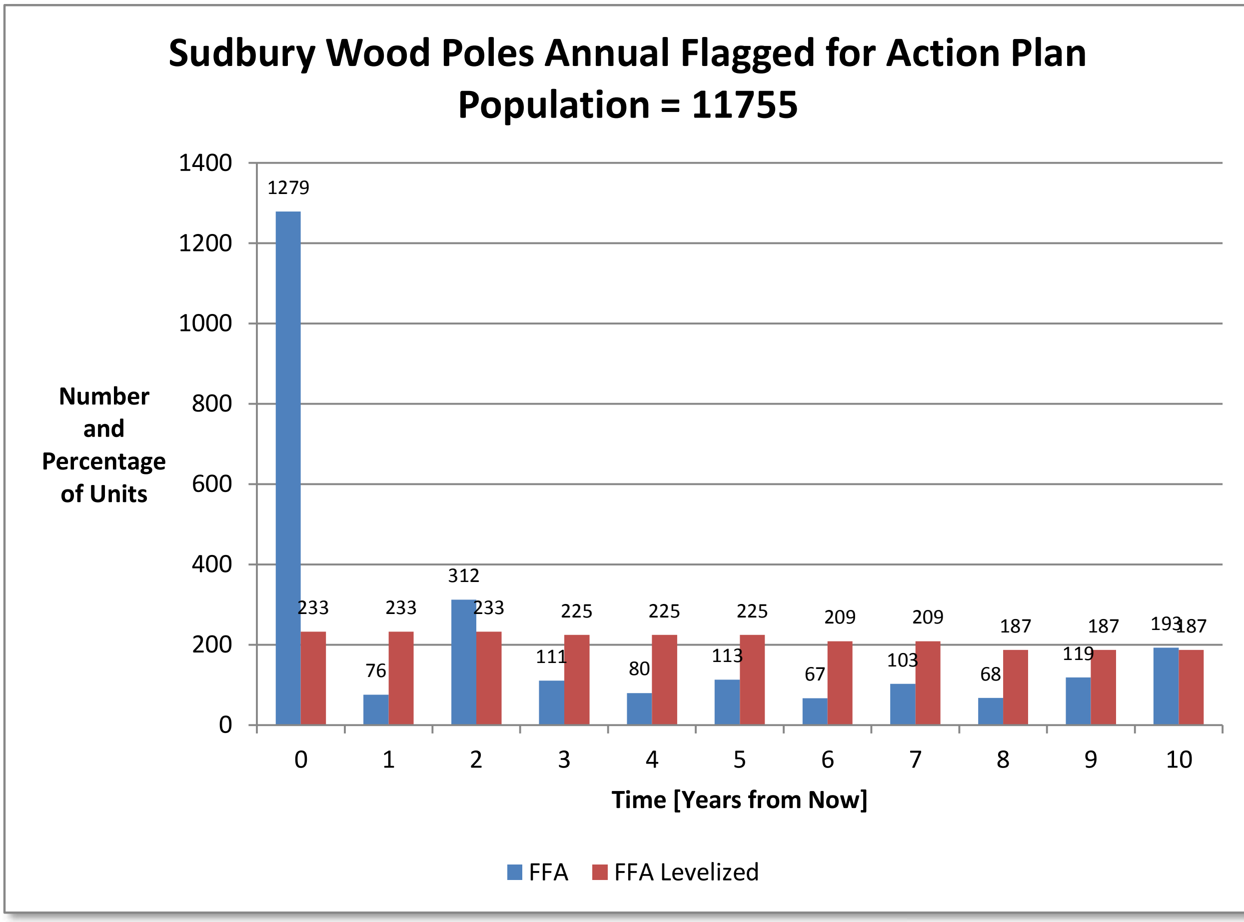

Figure A 9-4 Sudbury Wood Poles FFA

9.5 Data Assessment

The Sudbury Wood Poles data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. <6% had non-conformance records), the HI was primarily age-based and average DAI for this asset group was 37%.

For Sudbury Wood Poles, general components of the asset have incorporated into the Health Index formula. To improve the HI formula, more detailed information listed in the table below can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

Pole strength test provide subjective information about the pole. No poles currently have strength tests available so it is included as a data gap.

Table A 9-2 Sudbury Wood Poles Data Gaps

Data Gap	Priority	Description	Source
Pole Strength	H	Ratio of actual strength (psi) over the design strength (psi) Primarily used for wood poles, however core sample tests may be possible for concrete poles	Testing
Pole Appearance	H	Mechanical damage Burn damage Fracture Buckling Top split Top rot Pole split Pole rot Animal damage Pole leaning	On-site visual inspection
Crossarm	M	Damage	On-site visual inspection
Insulator Condition	M	Damage Tracking	On-site visual inspection

Guy Assembly	M	Anchor Guy line damage Guy attachment damage Ground rod damage	On-site visual inspection
Hardware and Conductor	L	Missing Broken Loose Corrosion	On-site visual inspection
Foundation	L	Damage Erosion	On-site visual inspection
Vegetation	L	Encroachment In Water	On-site visual inspection

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10 Sudbury Concrete Poles

There are a total of 120 Sudbury Concrete Poles. Of these, 120 had sufficient data for Health Indexing.

10.1 Health Index Formula

HI is a function of scores and weights of condition and sub-condition parameters and is calculated using Equation 1 and Equation 2. This section defines the condition and sub-condition parameters.

The condition parameters for the transformer are as follows:

Table A 10-1 Sudbury Concrete Poles Health Index Formula

Condition Parameter (CP)		Sub-Condition Parameter (SCP)		
Description	**Weight (WCP)**	**Description**	**Weight (WSCP)**	**Criteria**
Pole	13	Pole Appearance	1	Table A 2-2
Support and Assemblies	5	Crossarm	4	Table A 2-2
		Guy Assembly	2	Table A 2-2
		Hardware and Connection	2	Table A 2-2
		Insulators	2	Table A 2-2
		Other Components	1	Table A 2-2
Environment	1	Vegetation	1	Table A 2-2
Encroachment and Clearance	1	Encroachment and Clearance	1	Table A 2-2
Service Record	10	Age	1*	N/A
HI De-Rating Multiplier (DR)		Unit-specific Non-Conformances	Table A 2-4	
Age Limiter (AL)		Based on typical life curve	Figure A 9-1	
*weight only applies to DAI calculation; weight set to 0 for HI calculation				

Age Limiter

The Age Limiter used is equivalent to the survival function of the asset group. As described in Asset removal rate is assumed to increase exponentially with age. In this project the removal rate is modeled by the Weibull curve. The cumulative distribution function is per Equation 5.

It was assumed that the likelihood of removal at 60 years is 20% and that at 80 years the likelihood of removal is 95%. The resultant survival curve (1 – likelihood of removals) is shown in below. This survival curve was used as the Age Limiter.

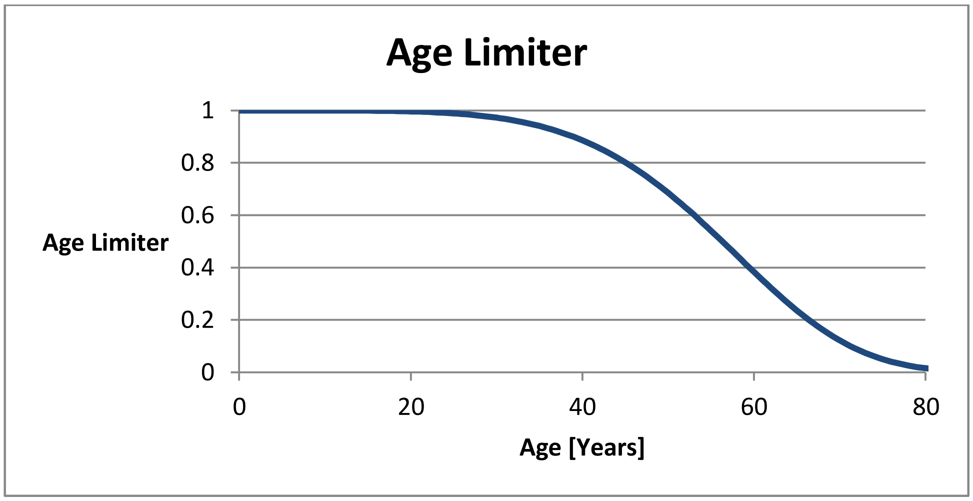

Figure A 10-1 Sudbury Concrete Poles Age Limiter

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10.2 Age

The average age of all in-service Sudbury Concrete Poles units was 46 years.

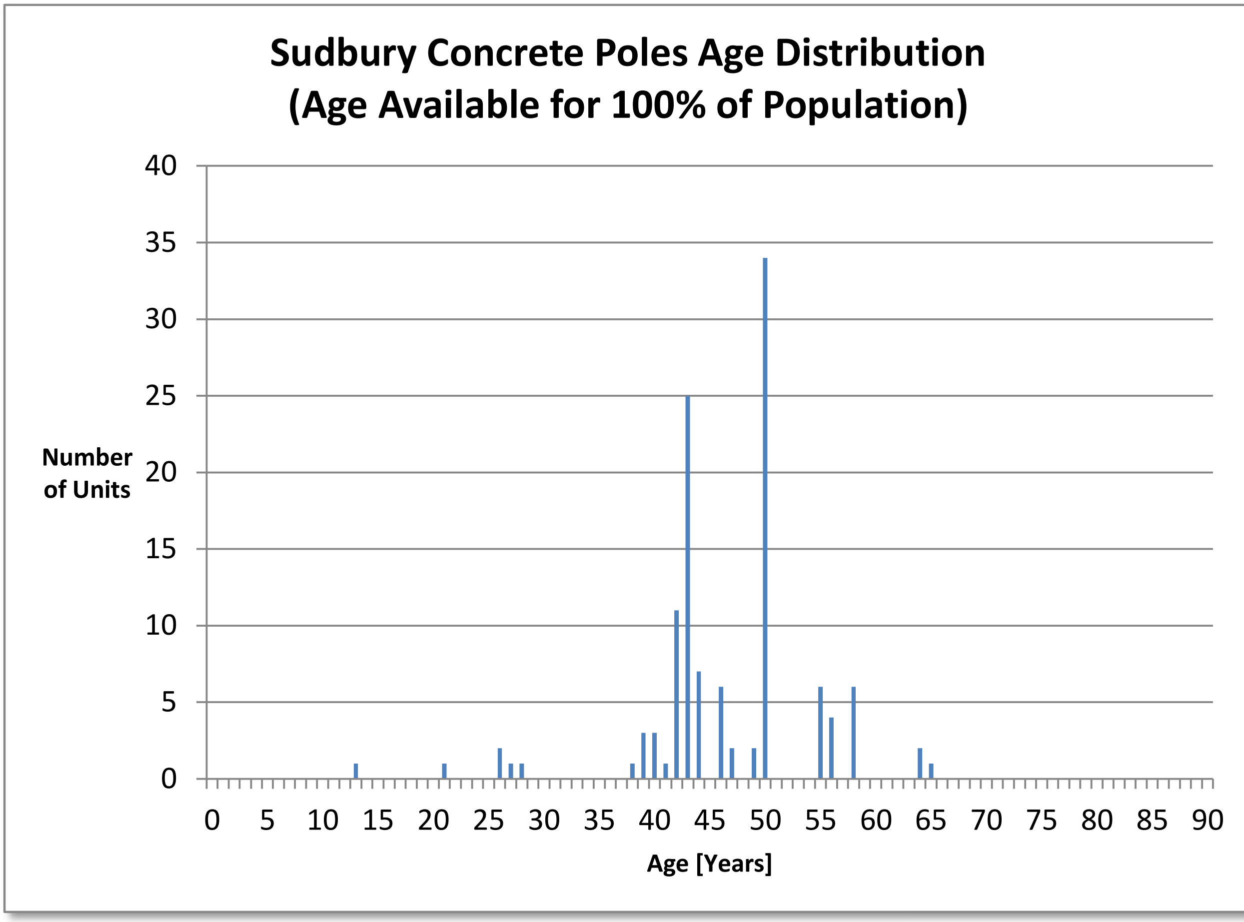

Figure A 10-2 Sudbury Concrete Poles Age Distribution

10.3 Health Index Results

The average Health Index for this asset group was 96%. None were found to be in “poor” or “very poor” condition.

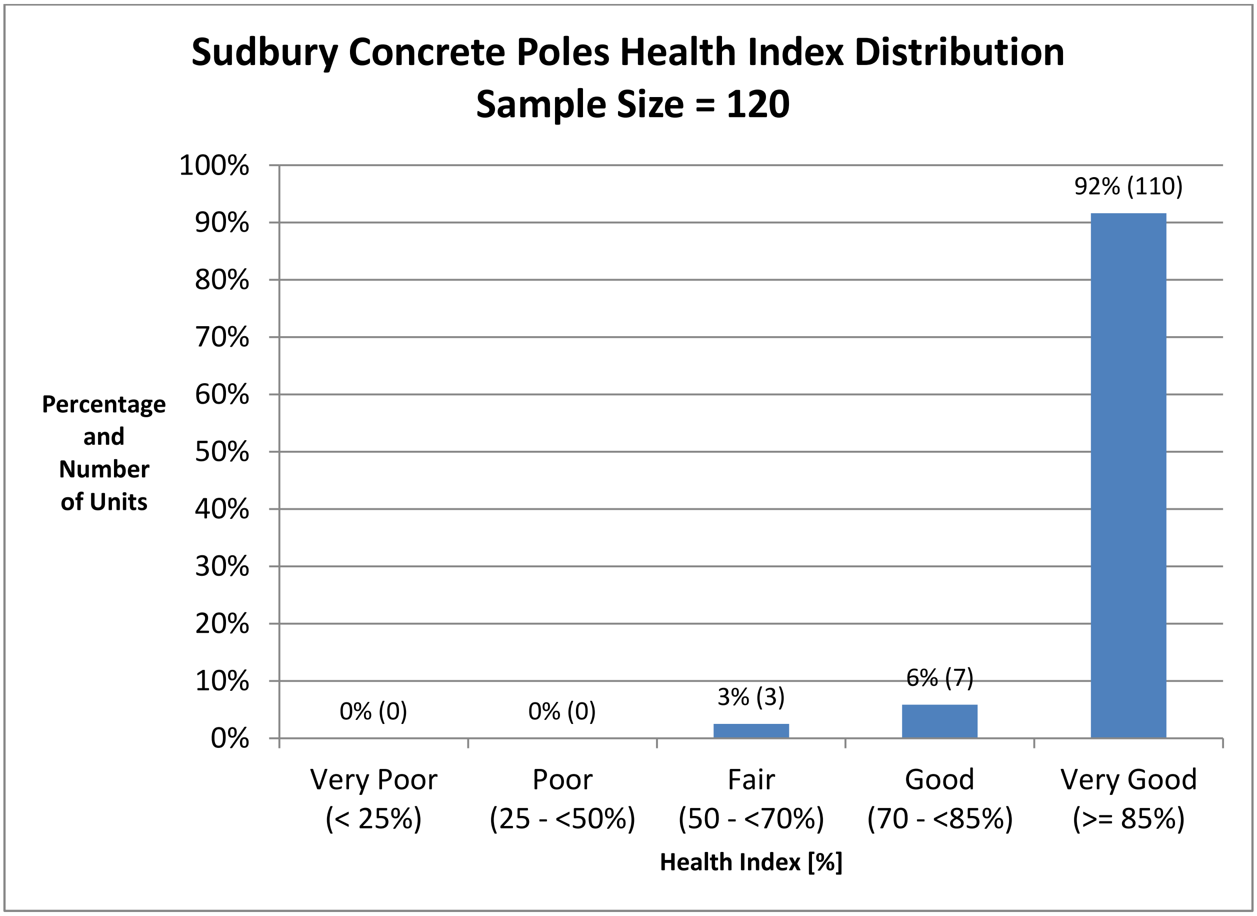

Figure A 10-3 Sudbury Concrete Poles HI Distribution

10.4 Flagged for Action Plan

Although poles are proactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

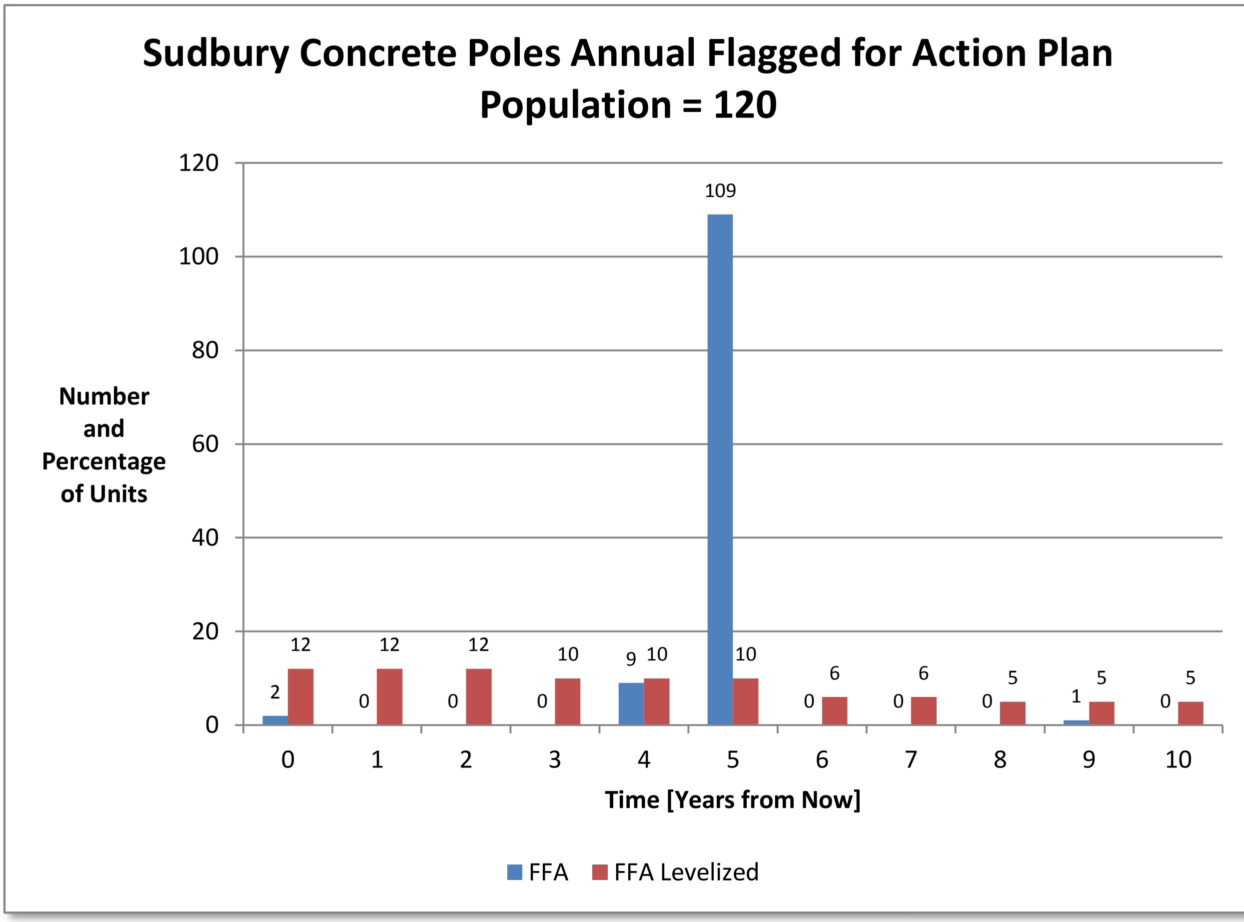

Figure A 10-4 Sudbury Concrete Poles FFA

10.5 Data Assessment

The Sudbury Concrete Poles data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. Approximately <1% had non-conformance records), the HI was primarily age-based and the average DAI for this asset group was 35%.

For Sudbury Concrete Poles, general components of the asset have incorporated into the Health Index formula. To improve the HI formula, more detailed information listed in the table below can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

Pole strength test provide subjective information about the pole. No poles have strength tests and this is less common for concrete poles so the priority is low.

Table A 10-2 Sudbury Concrete Poles Data Gaps

Data Gap	Priority	Description	Source
Pole Strength	L	Ratio of actual strength (psi) over the design strength (psi) Primarily used for wood poles, however core sample tests may be possible for concrete poles	Testing
Pole Appearance	H	Mechanical damage Burn damage Rebar exposed Rebar corrosion Fracture Cracks Spalling Pole leaning	On-site visual inspection
Crossarm	M	Damage	On-site visual inspection
Insulator Condition	M	Damage Tracking	On-site visual inspection

Guy Assembly	M	Anchor Guy line damage Guy attachment damage Ground rod damage	On-site visual inspection
Hardware and Conductor	L	Missing Broken Loose Corrosion	On-site visual inspection
Foundation	L	Damage Erosion	On-site visual inspection
Vegetation	L	Encroachment In Water	On-site visual inspection

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11 Bell Wood Poles

There are a total of 2695 Bell Wood Poles. Of these, 2693 had sufficient data for Health Indexing.

11.1 Health Index Formula

Please refer to Section 9.1.

11.2 Age

The average age of all in-service Bell Wood Poles units was 40 years.

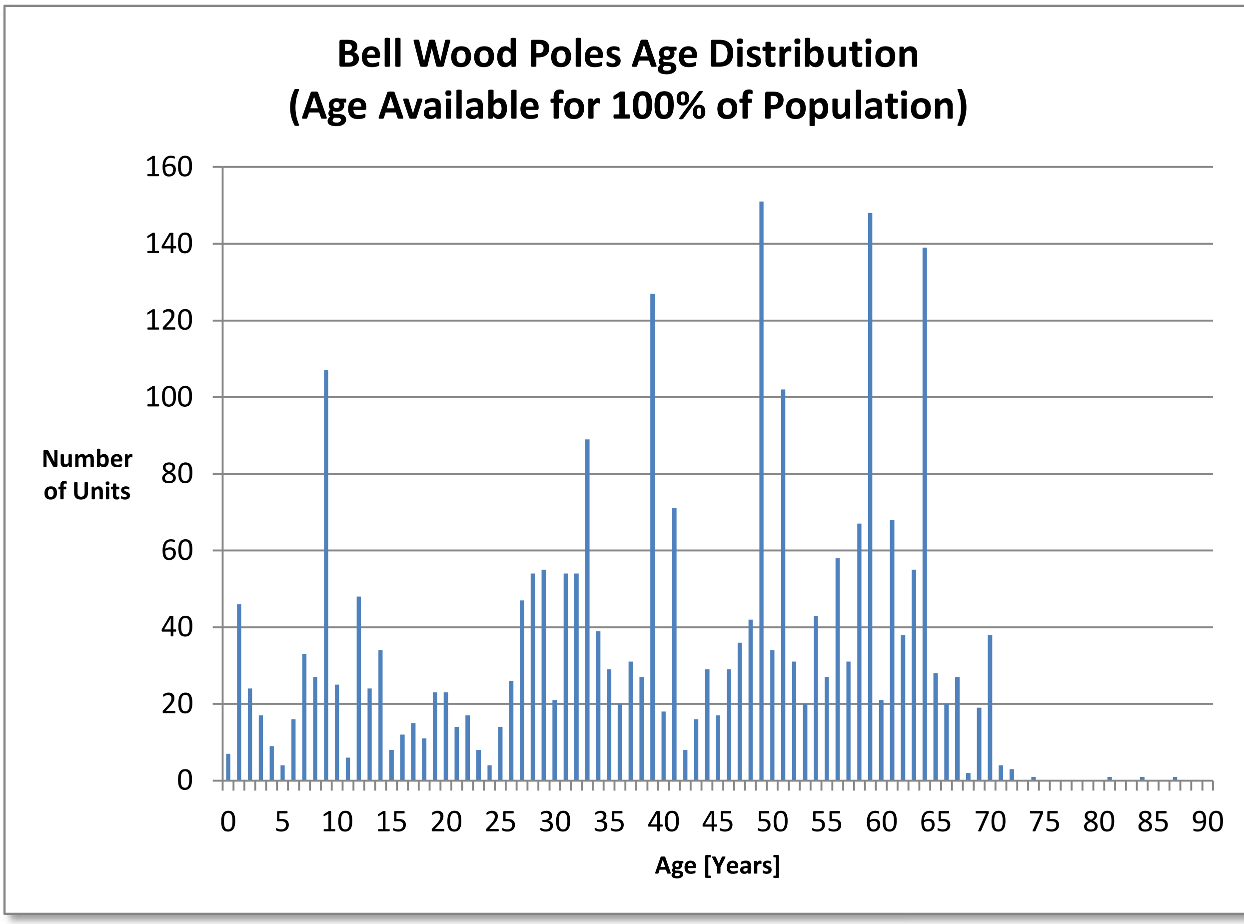

Figure A 11-1 Bell Wood Poles Age Distribution

11.3 Health Index Results

The average Health Index for this asset group was 73%. Approximately 26% were found to be in "poor" or "very poor" condition.

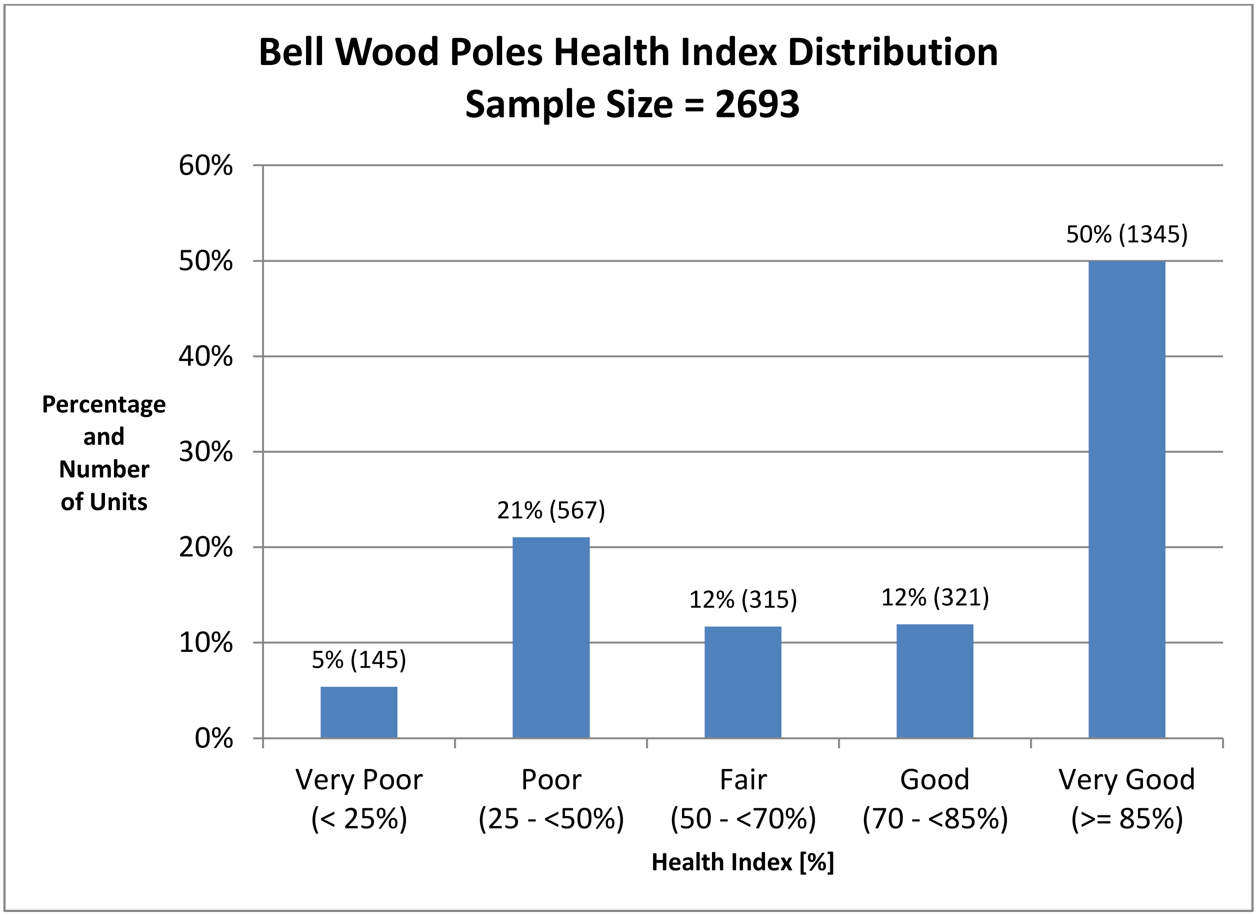

Figure A 11-2 Bell Wood Poles HI Distribution

11.4 Flagged for Action Plan

Although poles are proactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

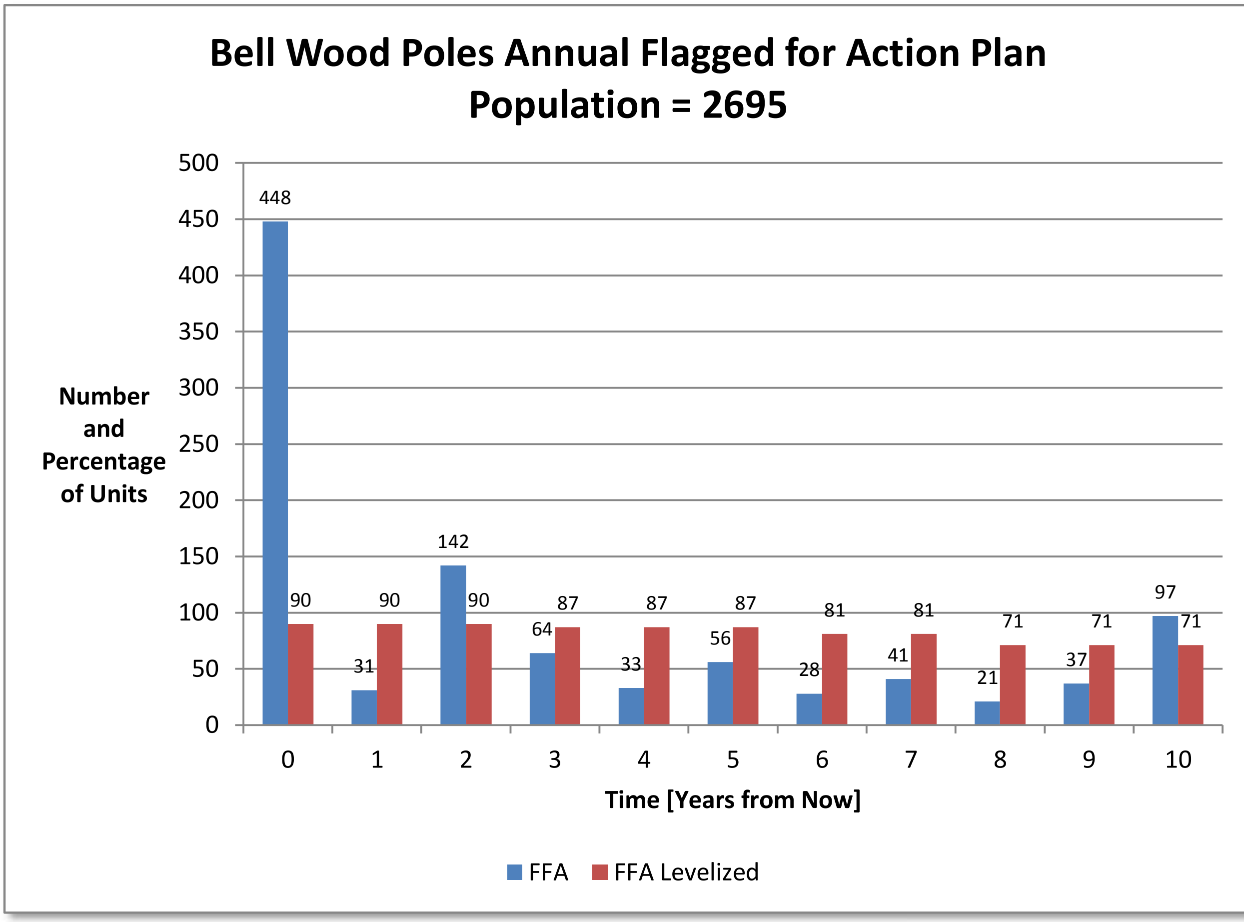

Figure A 11-3 Bell Wood Poles FFA

11.5 Data Assessment

The Bell Wood Poles data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. <1% had non-conformance records), the HI was primarily age-based and the average DAI for this asset group was 36%.

For Bell Wood Poles, general components of the asset have incorporated into the Health Index formula. To improve the HI formula, more detailed information listed in Table A 9-2 can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

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12 Hydro One Wood Poles

There are a total of 349 Hydro One Wood Poles. Of these, 339 had sufficient data for Health Indexing.

12.1 Health Index Formula

Please refer to Section 9.1.

12.2 Age

The average age of all in-service Hydro One Wood Poles units was 19 years.

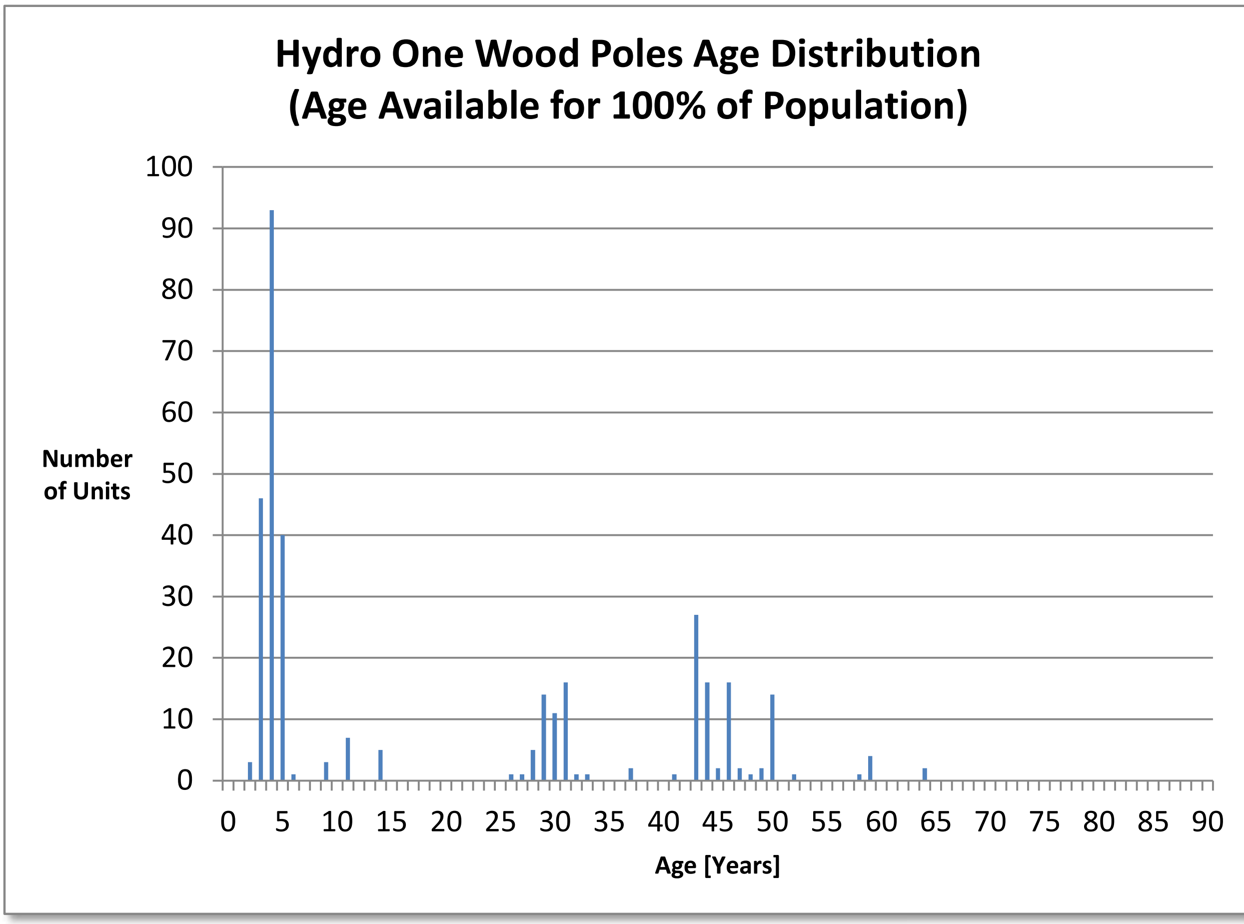

Figure A 12-1 Hydro One Wood Poles Age Distribution

12.3 Health Index Results

The average Health Index for this asset group was 93%. Approximately 2% were found to be in “poor” or “very poor” condition.

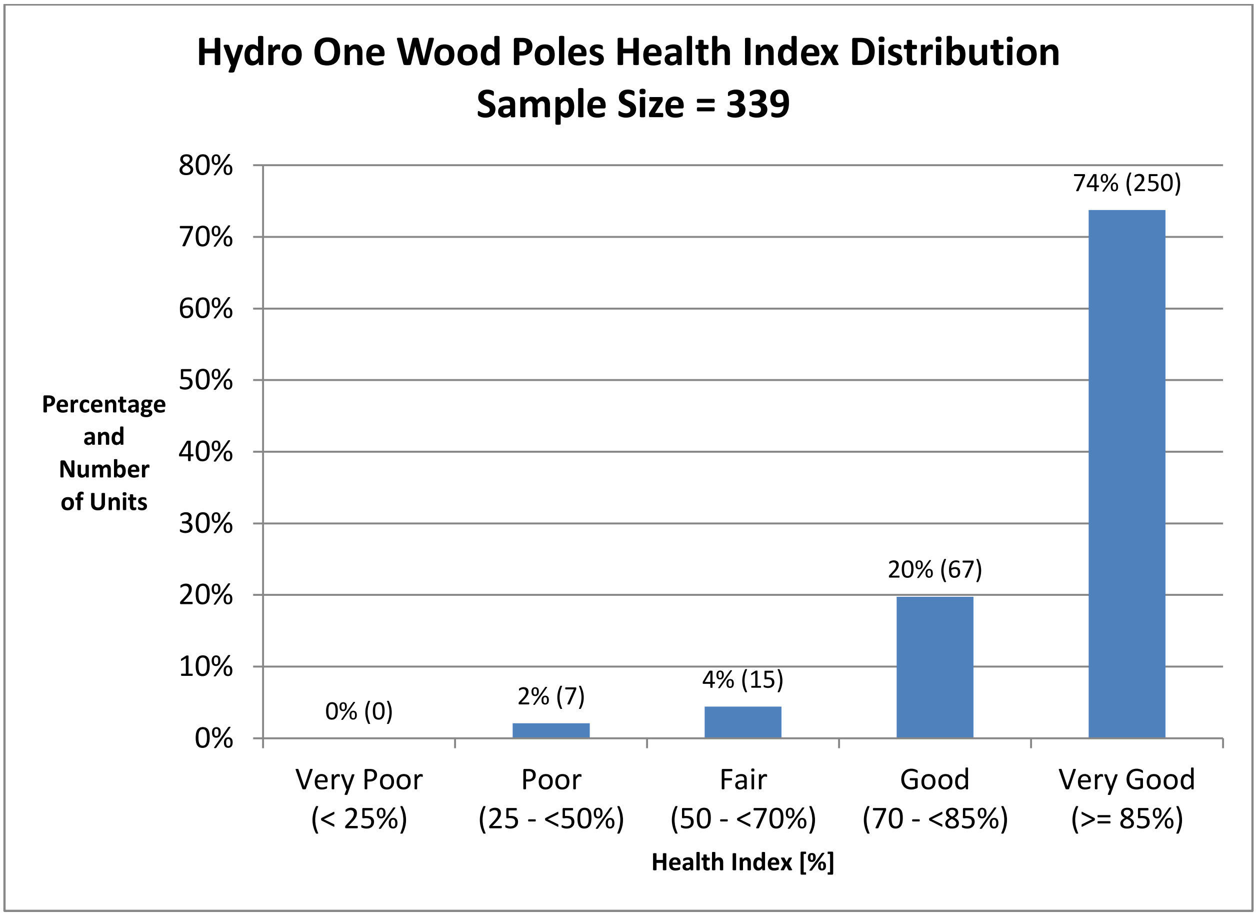

Figure A 12-2 Hydro One Wood Poles HI Distribution

12.4 Flagged for Action Plan

Although poles are proactively addressed, the 10 Year flagged for action plan was based on the asset failure rate. The flagged for action plan is based on the number of expected units to be addressed in a given year. As it may not always be feasible to address assets per this plan, a "levelized" plan, based on smoothing out the number of units to be addressed in the next 10 years, is also given.

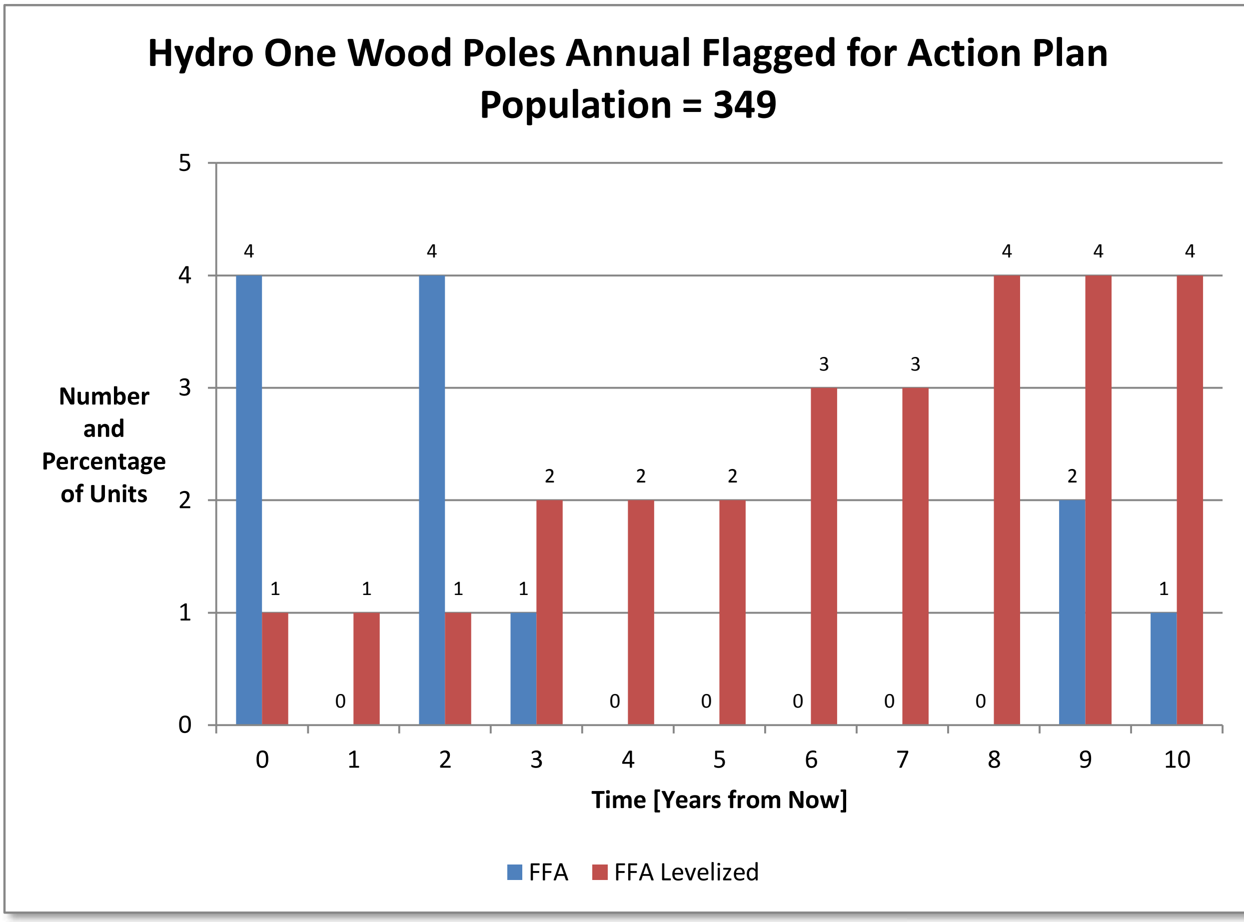

Figure A 12-3 Hydro One Wood Poles FFA

12.5 Data Assessment

The Hydro One Wood Poles data included nameplate information and non-conformance logs.

There are numerous condition parameters that are based on non-conformance records. If an asset has an entry in the non-conformance log but a specific problem attributed to one of the above parameters is not specifically noted, it is assumed that the condition of that parameter is good (i.e. it will receive a perfect score). If there is no entry for the asset is the log, the condition/status of the aforementioned parameters is assumed unknown.

Since many units did not have non-conformance based parameters (i.e. <1% had non-conformance records), the HI was primarily age-based and the average DAI for this asset group was 34%.

For Hydro One Wood Poles, general components of the asset have incorporated into the Health Index formula. To improve the HI formula, more detailed information listed in Table A 9-2 can be added. Instead of using non-conformance logs however, these should come from detailed inspection records, gathered by way of comprehensive inspection forms.

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2-AMPCO-29 GSHI's Response to Kinetrics Recommendation

Question:

With respect to Kinectrics' Conclusions and Recommendations, Kinectrics states "The data used in this assessment was from different locations within GSHI (e.g. numerous spreadsheets or PDF files). For more efficient record keeping and ease of future assessments, GSHI may wish to consider implementing Asset Performance Management (APM) platform that consolidates asset information and condition data (e.g. nameplate information, test results, operational information, inspection records, etc.) and that can perform required asset analytics, such as HI calculations and developing FFA plans.

Please provide GHSI's response to this recommendation.

Response:

GSHi accepts and plans on implementing the Kinectrics recommendation. Specifically, Section 5.4.2.1.3.5, p. 285 of the DSP outlines an investment entitled 'General Plant – Asset Management Software'. Section B.1a describes how the recommendation from the 2024 Kinectrics ACA report is the primary basis (driver) for the project.

2-AMPCO-30 Vehicles Replaced in 2020-2023

Question:

Ref 1: 2-9 Attachment #1 DSP Appendix C

Please provide the vehicles replaced in each of the years 2020 to 2023.

Response:

Please see table below for a listing of fleet assets that were disposed as well as purchased in each of the years 2020 to 2023.

YEAR	Vehicle (Disposed)	YEAR	Vehicle (Purchased)
2020	921-2005 Chev Express	2020	957- 2008 Ford Escape
	911- 2008 Splicing Trailer (AG)		984 - 2020 GMC
	926- 1989 Bucket Truck 65'		940- 2007 Ford Pick Up F150
	926A - 1989 Bucket Truck 65' Addition		995- 2004 Chev 4WD Half Ton
			993 - 2020 Ford (Agilis bucket
			907 - 1969 King Cable Trailer
2021	937- 2009 Dodge 3/4 Ton Pickup	2021	922 - 1997 International Truck
	959 - 2011 Ford F250		997 - 2022 F250
	966- 2011 Freightliner FM2		956 - 2007 Ford Pickup F150
2022	933- 2014 Freightlines Step-Van	2022	979 - 2021 Freight FM2
	948 - 2010 Dodge Ram 2500		9602 -2023 Freight FM2 (double)
	948A 2010 Dodge Ram 2500 Addition		985A 2012 Freight FM2 Double
	980- 2008 Dodge Dakota Pickup		905 - 2022 Solar Arrowboard
	915- 2006 Durabody Pole Trailer		989A - 2017 Freight FM2 (RBD)
	915A 2006 Durabody Pole Trailer Additio		
	928 - 1995 Freightliner FL-80		
	903 - 1996 Solar Arrowboard Trailer		
2023	941 - 2009 INTL Single Bucket	2023	614 - 2022 Pole Trailer (Big)
	961 - 2003 Freightliner SB		762 -2023 Highlander (Travel)
	954- 2009 Ford Escape		766 - 2023 F-250 Pick up
	974 - 2006 Ford F150		796 -2022 Dodge Ram(Meetering)

4-AMPCO-31 OMA Cost Drivers

Question:

Ref: 4-1-1 p.3

Table 3 provides the OMA Cost Drivers.

a) Please provide a breakdown of all Contract Labour activities and costs in 2020 compared to 2025.

b) Please provide a breakdown of all Vegetation Management Contract Labour activities and costs in 2020 compared to 2025.

c) Please explain the increase in IT costs allocated from Affiliate in 2025.

d) Please explain the increase in Insurance costs in 2025.

Response:

a) GSHi provides the table below.

Contract Labour Activities	**2020**	**2025**
Answering Service	18,000.00	21,000.00
Station Building Maintenance (Grass cutting, snow removal, pest control etc)	71,920.00	96,170.00
Oil Testing	29,600.00	27,500.00
Transformer Maintenance	27,500.00	28,000.00
Meter Sampling	8,000.00	44,000.00
Locates	10,000.00	12,000.00
Meter Reading	-	10,000.00
Collections	-	83,546.00
Meter Service Provider Services	12,800.00	13,560.00
General Assistance (Moving handholes, etc)	65,000.00	55,000.00
Power System Inspection and Miscellaneous Inspections	-	64,000.00
Overhead and Underground Maintenance (burn offs, lines and feeders, snow removal, etc)	129,000.00	110,000.00
Cable Removal Assistance		39,000.00
Miscellaneous	28,500.00	27,500.00
Total	**400,320.00**	**631,276.00**

b) GSHi provides the following breakdown of the Vegetation Management contract labour costs included in Table 3 – OM&A Cost Drivers.

	2020 Board Approved	2025 Budget
Spot Tree Trimming - Sudbury	200,000	208,000
Spot Tree Trimming - West Nipissing	40,000	41,600
Tree Trimming by Area (Planned)	249,851	450,400
	489,851	700,000

c) The increase in IT costs allocated from GSHPi to GSHi is driven by necessary improvements and changes in IT operations. Between the 2020 and 2025 budgets, these costs have grown due to the addition of an IT Service Desk Support position, general wage increases, the adoption of offsite cloud backups, higher costs for network security testing and monitoring, and the shift to subscription-based software.

d) The increase in insurance costs is primarily driven by a significant rise in property insurance premiums, which have more than doubled since 2020. This increase is attributed to the higher replacement value of assets at GSHi's facilities, resulting in higher associated premiums.

4-AMPCO-32 Position Vacancies by Position by Year 2020-2024

Question:

Ref: Ex. 4

a) Please provide a schedule that sets out the vacancies by position by year for each of the years 2020-2024 and provide the associated vacancy dollars by year.

b) Please provide the vacancy assumption for 2025.

Response:

a) GSHi is unable to provide a detailed schedule setting out vacancies by position and associated vacancy dollars for each of the years 2020–2024 within the time allotted for interrogatories. However, GSHi has conducted an analysis comparing its budgeted labor costs to actual labor costs incurred for each year from 2020 to 2024. This analysis serves as a proxy for calculating the vacancy rate experienced during this period. The results of this analysis are presented in Table 1 below.

For a schedule that sets out the position status for 2020 and 2025 FTEs, please refer to 3-VECC-29. Note that this schedule provides position counts but does not include associated dollars.

Table 1: Vacancy Rate Analysis

	2020	2021	2022	2023	2024
	Actual	Actual	Actual	Actual	Actual
Vacancy Rate	1.36%	5.82%	5.12%	4.03%	5.02%

Note: Vacancy rate is calculated as (Budgeted Labor Cost – Actual Labor Cost Incurred) ÷ Total Budgeted Labor Cost.

b) GSHi has filled most vacancies and budgeted for a full staff complement in 2025, consistent with expectations at the time of budget preparation. For further details on current vacancies and the anticipated timeline for filling these positions, please refer to 3-VECC-29.

4-AMPCO-33 Total Overtime Variances

Question:

4-2-1 p.6

Table 5 provides the overtime costs in OM&A.

Please provide Table 5 on the basis of total overtime costs.

Response:

GSHi has provided the requested table below.

	Total Overtime	Variance (over prior year)
2020 Board Approved	$ 550,648	
2020 Actuals	$ 724,155	$ 173,507
2021 Actuals	$ 810,182	$ 86,027
2022 Actuals	$ 780,491	-$ 29,691
2023 Actuals	$ 875,553	$ 95,062
2024 Projection	$ 762,986	-$ 112,567
2025 Budget	$ 713,957	-$ 49,029
2025 Budget vs 2020 Board Approved		**$ 163,309**

4-AMPCO-34 Vegetation Management

Question:

Ref: 4-2-1 p.10 & Appendix 2-JC

a) Please provide a breakdown of the 2025 Vegetation Management budget by activity.
b) Please describe GHSI's 2025 Vegetation Management Strategy and cycle compared to 2020 and explain any changes.
c) Please provide the vegetation management unit accomplishments for each of the years 2020 to 2024.
d) Please provide the forecast vegetation management unit accomplishments for each of the years 2025 to 2029.

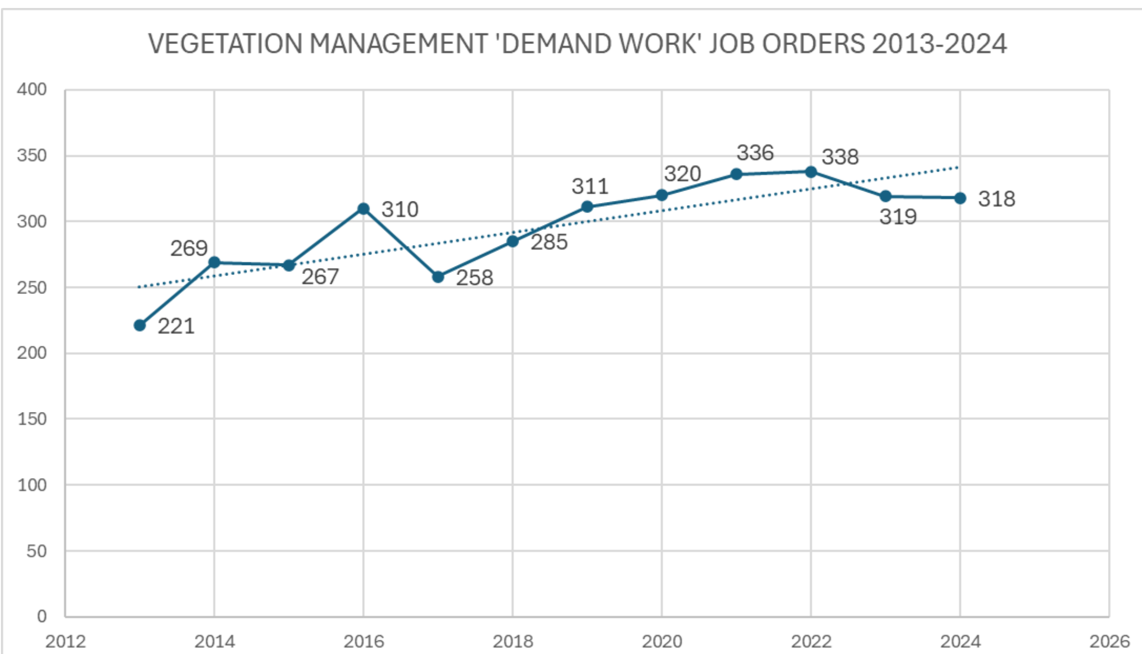
Response:

a) The table below shows the 2025 Vegetation Management budget by activity:

2025 Budget	
Labour and Burden	55,518
Vehicle Charges	8,709
Materials	2,500
Contract Labour - Spot Improvements Sudbury	208,000
Contract Labour - Areas West Nipissing	41,600
Tree Trimming by Area (Cycle)	450,400
Total	**766,727**

b) The 2025 vegetation management strategy and cycle are focused on maintaining the reliability and safety of the distribution system. GSHi must consistently address critical vegetation management needs to reduce power outages caused by overgrowth. By investing in this area, GSHi aims to enhance operational efficiency, minimize service interruptions, and deliver superior service to customers. Compared to 2020, the increased budget for 2025 will enable GSHi to allocate more resources and expedite essential work, ensuring regulatory compliance and preserving the integrity of the system infrastructure.

c) The chart below illustrates the number of vegetation management 'demand work' job orders from 2013 to 2024. Over this period, the average number of job orders per year was 296, totaling 3,552 job orders. However, for the five-year span from 2020 to 2024, the average number of job orders per year increased by approximately 10%, reaching 326 job orders annually, for a total of 1,631 job orders.



Additionally, between 2020 and 2024, GSHi completed 445 km of line clearing as part of its cycle-based vegetation management program. It's important to note that cycle trimming was postponed in 2020 due to the onset of the COVID-19 pandemic, and only demand-based work was carried out that year.

YEAR	KM
2020	0
2021	173
2022	142
2023	100
2024	30
Total	445

d) Considering the upward trend shown in the chart from the response to **c),** GSHi's expectation is that the number of vegetation management 'demand work' job orders will remain elevated into the forecast period 2025-2029, with approximately 320-340 job orders expected per year during this period,

For cycle-based vegetation management, GSHi is forecasting to complete 629km of work during the forecast period, which is 41% more than during the historical period 2020-2024.

YEAR	KM
2025	62
2026	106
2027	134
2028	207
2029	120
Total	629

4-AMPCO-35 Appendix 2-K FTE's for 2020-2025

Question:

Ref: Appendix 2-K

Please provide the number of FTE's on the basis of Executive, Management, Union and Non-Union for each of the years 2020 to 2025.

Response:

GSHi provides the table below. Please also see attachment 1 to this interrogatory for an updated version of Appendix 2K.

	2020 Actual	2021 Actual	2022 Actual	2023 Actual	2024 Projection	2025 Budget
GSHi						
Executive	1.59	1.00	1.00	0.92	1.00	1.00
Management	6.11	6.12	6.14	6.31	7.78	8.00
Union	51.49	50.92	51.07	48.09	46.93	54.92
Non-Union	1.00	1.00	1.00	1.05	1.00	1.00
Total	**60.19**	**59.03**	**59.20**	**56.37**	**56.71**	**64.92**
GSHPi						
Executive	2.40	2.40	2.34	2.35	2.98	3.09
Management	7.27	8.55	7.87	8.28	7.87	7.69
Union	23.59	23.78	24.51	25.47	25.97	27.69
Non-Union	2.65	3.76	3.38	3.36	3.22	4.28
Total	**35.92**	**38.49**	**38.10**	**39.47**	**40.04**	**42.74**
Combined						
Executive	3.99	3.40	3.34	3.28	3.98	4.09
Management	13.38	14.66	14.01	14.59	15.65	15.69
Union	75.08	74.70	75.57	73.56	72.89	82.60
Non-Union	3.65	4.75	4.38	4.41	4.22	5.28
Total	**96.10**	**97.51**	**97.31**	**95.83**	**96.75**	**107.66**

Please note: GSHi has corrected for a small error in the 2020 – 2023 actual FTE's submitted in the initial application.

Attachment 1 (of 1):

4-AMPCO-35 Attachment 1: Appendix 2-K by Company

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TO BE UPDATED AT THE DRAFT RATE ORDER STAGE

Appendix 2-K
Employee Costs - Combined GSHi & GSHPi

	Last Rebasing Year 2020 - OEB Approved	Last Rebasing Year (2020 Actuals)	2021 Actuals	2022 Actuals	2023 Actuals	2024 Bridge Year	2025 Test Year
Number of Employees (FTEs including Part-Time)[1]							
Management (including executive)	17.5	17.6	18.1	17.4	18.0	19.6	19.8
Non-Management (union and non-union)	85.4	78.6	79.4	79.9	77.8	77.1	87.9
Total	102.9	96.1	97.5	97.3	95.8	96.7	107.7
Total Salary and Wages including ovetime and incentive pay							
Management (including executive)	$ 2,398,316	$ 2,481,824	$ 2,550,294	$ 2,546,584	$ 2,792,157	$ 3,157,522	$ 3,181,226
Non-Management (union and non-union)	$ 7,403,141	$ 7,269,645	$ 7,270,989	$ 7,447,174	$ 7,440,082	$ 7,735,340	$ 8,820,921
Total	$ 9,801,457	$ 9,751,469	$ 9,821,283	$ 9,993,758	$ 10,232,239	$ 10,892,862	$ 12,002,146
Total Benefits (Current + Accrued)							
Management (including executive)	$ 735,220	$ 634,402	$ 736,709	$ 742,278	$ 767,437	$ 871,470	$ 894,408
Non-Management (union and non-union)	$ 2,259,846	$ 1,784,452	$ 2,325,505	$ 2,382,475	$ 2,239,559	$ 2,010,627	$ 2,365,467
Total	$ 2,995,066	$ 2,418,855	$ 3,062,214	$ 3,124,753	$ 3,006,995	$ 2,882,098	$ 3,259,875
Total Compensation (Salary, Wages, & Benefits)							
Management (including executive)	$ 3,133,536	$ 3,116,226	$ 3,287,003	$ 3,288,862	$ 3,559,594	$ 4,028,992	$ 4,075,633
Non-Management (union and non-union)	$ 9,662,986	$ 9,054,098	$ 9,596,494	$ 9,829,649	$ 9,679,641	$ 9,745,967	$ 11,186,388
Total	$ 12,796,523	$ 12,170,324	$ 12,883,497	$ 13,118,511	$ 13,239,235	$ 13,774,959	$ 15,262,021
Total Compensation Breakdown (Capital, OM&A)							
OM&A	$ 10,067,874	$ 9,412,507	$ 9,749,070	$ 10,286,633	$ 10,148,841	$ 10,471,741	$ 12,176,241
Capital	$ 2,728,649	$ 2,757,817	$ 3,134,427	$ 2,831,878	$ 3,090,393	$ 3,303,219	$ 3,085,780
Total	$ 12,796,523	$ 12,170,324	$ 12,883,497	$ 13,118,511	$ 13,239,235	$ 13,774,959	$ 15,262,021

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TO BE UPDATED AT THE DRAFT RATE ORDER STAGE

Appendix 2-K
Employee Costs - GSHi

	Last Rebasing Year 2020 - OEB Approved	Last Rebasing Year (2020 Actuals)	2021 Actuals	2022 Actuals	2023 Actuals	2024 Bridge Year	2025 Test Year
Number of Employees (FTEs including Part-Time)[1]							
Management (including executive)	8.0	7.7	7.1	7.0	7.4	8.8	9.0
Non-Management (union and non-union)	58.7	52.5	51.9	52.2	49.0	47.9	55.9
Total	66.7	60.2	59.0	59.2	56.4	56.7	64.9
Total Salary and Wages including ovetime and incentive pay							
Management (including executive)	$ 1,074,732	$ 1,037,174	$ 962,129	$ 983,961	$ 1,104,990	$ 1,382,112	$ 1,380,814
Non-Management (union and non-union)	$ 5,396,915	$ 5,382,631	$ 5,362,832	$ 5,467,975	$ 5,293,335	$ 5,495,467	$ 6,217,736
Total	$ 6,471,647	$ 6,419,805	$ 6,324,961	$ 6,451,936	$ 6,398,324	$ 6,877,579	$ 7,598,550
Total Benefits (Current + Accrued)							
Management (including executive)	$ 329,587	$ 258,814	$ 279,945	$ 285,396	$ 299,252	$ 355,316	$ 390,256
Non-Management (union and non-union)	$ 1,645,169	$ 1,291,763	$ 1,492,597	$ 1,520,351	$ 1,364,871	$ 1,393,055	$ 1,635,161
Total	$ 1,974,756	$ 1,550,577	$ 1,772,541	$ 1,805,747	$ 1,664,123	$ 1,748,371	$ 2,025,417
Total Compensation (Salary, Wages, & Benefits)							
Management (including executive)	$ 1,404,318	$ 1,295,987	$ 1,242,073	$ 1,269,357	$ 1,404,242	$ 1,737,428	$ 1,771,070
Non-Management (union and non-union)	$ 7,042,084	$ 6,674,395	$ 6,855,428	$ 6,988,326	$ 6,658,205	$ 6,888,522	$ 7,852,897
Total	$ 8,446,403	$ 7,970,382	$ 8,097,502	$ 8,257,683	$ 8,062,447	$ 8,625,950	$ 9,623,967
Total Compensation Breakdown (Capital, OM&A)							
OM&A	$ 5,820,976	$ 5,345,901	$ 5,108,024	$ 5,598,637	$ 5,184,087	$ 5,491,595	$ 6,698,631
Capital	$ 2,625,426	$ 2,624,481	$ 2,989,478	$ 2,659,046	$ 2,878,360	$ 3,134,355	$ 2,925,336
Total	$ 8,446,403	$ 7,970,382	$ 8,097,502	$ 8,257,683	$ 8,062,447	$ 8,625,950	$ 9,623,967

TO BE UPDATED AT THE DRAFT RATE ORDER STAGE

File Number:	EB-2024-0026
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Appendix 2-K
Employee Costs - GSHPi

	Last Rebasing Year 2020 - OEB Approved	Last Rebasing Year (2020 Actuals)	2021 Actuals	2022 Actuals	2023 Actuals	2024 Bridge Year	2025 Test Year
Number of Employees (FTEs including Part-Time)[1]							
Management (including executive)	9.5	9.9	10.9	10.5	10.6	10.9	10.8
Non-Management (union and non-union)	26.8	26.1	27.5	27.6	28.8	29.2	32.0
Total	36.2	35.9	38.5	38.1	39.5	40.0	42.7
Total Salary and Wages including ovetime and incentive pay							
Management (including executive)	$ 1,323,585	$ 1,444,650	$ 1,588,165	$ 1,562,622	$ 1,687,168	$ 1,775,409	$ 1,800,412
Non-Management (union and non-union)	$ 2,006,225	$ 1,887,014	$ 1,908,157	$ 1,979,199	$ 2,146,748	$ 2,239,873	$ 2,603,185
Total	$ 3,329,810	$ 3,331,664	$ 3,496,322	$ 3,541,822	$ 3,833,915	$ 4,015,282	$ 4,403,596
Total Benefits (Current + Accrued)							
Management (including executive)	$ 405,633	$ 375,589	$ 456,764	$ 456,882	$ 468,184	$ 516,155	$ 504,151
Non-Management (union and non-union)	$ 614,677	$ 492,689	$ 832,909	$ 862,124	$ 874,688	$ 617,572	$ 730,306
Total	$ 1,020,310	$ 868,278	$ 1,289,673	$ 1,319,006	$ 1,342,872	$ 1,133,727	$ 1,234,458
Total Compensation (Salary, Wages, & Benefits)							
Management (including executive)	$ 1,729,218	$ 1,820,239	$ 2,044,929	$ 2,019,505	$ 2,155,352	$ 2,291,564	$ 2,304,563
Non-Management (union and non-union)	$ 2,620,902	$ 2,379,703	$ 2,741,066	$ 2,841,324	$ 3,021,436	$ 2,857,445	$ 3,333,491
Total	$ 4,350,120	$ 4,199,942	$ 4,785,995	$ 4,860,828	$ 5,176,787	$ 5,149,009	$ 5,638,054
Total Compensation Breakdown (Capital, OM&A)							
OM&A	$ 4,246,897	$ 4,066,606	$ 4,641,046	$ 4,687,996	$ 4,964,754	$ 4,980,146	$ 5,477,610
Capital	$ 103,223	$ 133,336	$ 144,949	$ 172,832	$ 212,033	$ 168,863	$ 160,444
Total	$ 4,350,120	$ 4,199,942	$ 4,785,995	$ 4,860,828	$ 5,176,787	$ 5,149,009	$ 5,638,054

4-AMPCO-36 Calculation for the Administrative Cost Ratio for GSHI

Question:

Ref: 4-2-2 Appendix 2 p.5

Please provide the calculation for the Administrative Cost Ratio for GSHI.

Response:

As outlined in the KPMG report, the Administrative Cost Ratio is calculated by dividing GSHi's administrative costs by its total expenses as reported in the Ontario Energy Board (OEB) Yearbook. The administrative costs include all expenses associated with corporate support functions, such as human resources, IT, finance, regulatory, and customer service, which are allocated to GSHi from GSHP.

The OEB Yearbook's total expenses include all operating, maintenance, and administrative costs incurred by GSHi. By using this standardized data source, the Administrative Cost Ratio provides a consistent and comparable measure of GSHi's efficiency relative to peer Ontario LDCs.

This ratio was utilized in the benchmarking analysis performed by KPMG, which determined that GSHi's Administrative Cost Ratio is comparable to the median of its peer group, reflecting alignment with other similar LDCs.

A summary table of the inputs to GSHi's Administrative Cost Ratio used by KPMG from the OEB Yearbook is provided below:

Table 1: GSHi Administrative Ratio Calculation Summary Table

GSHi	Admin	Total Cost	Administrative Ratio
	a	b	a/b
2019	$ 7,660,525	$ 23,668,497	32.4%
2020	$ 7,411,808	$ 24,175,868	30.7%
2021	$ 7,776,096	$ 23,978,112	32.4%
		Average:	31.8%

4-AMPCO-37 2020 Consultant Costs Compared to Current Application

Question:

Ref: 4-4-5 Attachment #1

With respect to Appendix 2-M, please provide a breakdown of 2020 actual Consultant costs compared to the consultant costs for the current application.

Response:

Please see table below. GSHi has aligned similar activities from 2020 and 2025 on the same line in the table. For added clarity, GSHi has indicated the application it pertains to where the activities may have varied.

Type of Work Performed	Total 2020 COS	Total 2025 COS
Transfer Pricing (2020)/Report on Shared Services (2025)	8,700	70,000
OPEB Research and related evidence preparation	-	11,350
Distribution System Asset Condition Assessment	30,000	29,962
Substation Asset Condition Assessment	-	55,000
DSP Assistance (2020)/Review (2020 and 2025)	45,000	7,000
Polux Pole Condition Testing	-	63,231
Customer Consultation (2020)/DSP Survey (2025)	36,352	6,500
Prepare Load Forecast, Cost Allocation, Rate Design, Training and Evidence Review	68,324	78,006
Total	**188,377**	**321,049**