Unplanned Interruptions Reporting
FY2023

29 August 2023

Contents

1. The Reason for Non-Compliance and Supporting Evidence

12.4(a) the reasons for not complying with the annual unplanned interruption's reliability assessment specified in clause 9.8 and supporting evidence for those reasons:

Reasons

1.1 Adverse weather is the primary reason for Top Energy's non-compliance.
1.2 The secondary reason for the non-compliance is vegetation damage beyond Top Energy's control.
1.3 Another contribution factor was the increase in distribution (11kV) related faults.

The aggregated SAIDI impact of these three measures was 380.7 minutes, 77% higher than the corresponding measure in FYE2022.

Supporting Evidence

1.1 Adverse weather is the primary reason for Top Energy's non-compliance.

The severe weather events recorded for FYE23 are listed in the following table:

Severe Weather	Date
Cyclone Gabrielle (National State of Emergency which was the 2nd State of Emergency in Northland FYE23)	12 February 2023
Storm (1st State of Emergency in Northland)	31 January 2023
Storm	27 January 2023
Cyclone Hale	10 January 2023
Storm	4 January 2023
Storms	10 and 23 November 2022
Storm	27 October 2022
Flooding	5 September 2022
Storm (Loss of State Highway 1 through Mangamuka Gorge)	18 August 2022
Storms	12 and 25 July 2022
Storm	28 May 2022
Cyclone Fili	12 April 2022

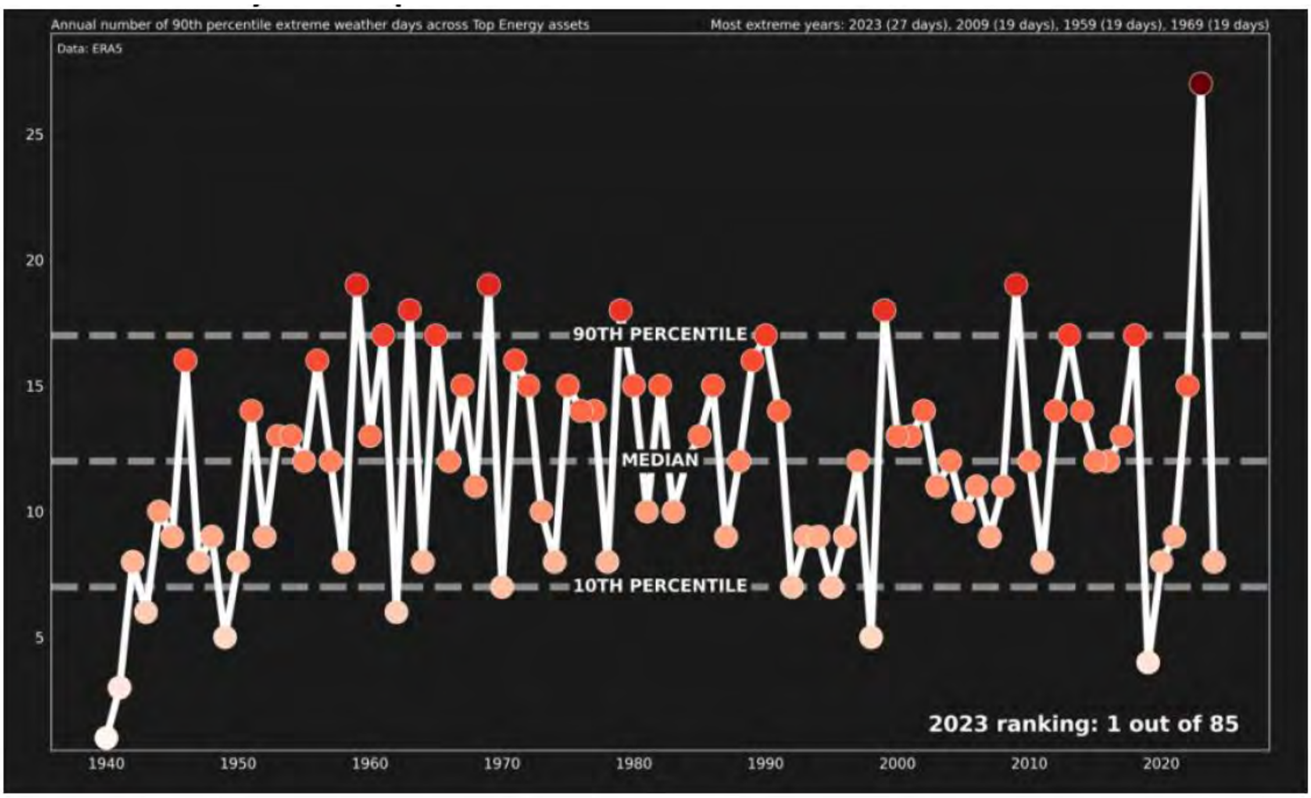
Source MetService

Significant adverse weather activity characterised the year, including two tropical cyclones and one ex-tropical cyclone. Adverse weather resulted in two states of emergency declared in Northland.

NIWA Analysis Report - Extreme Weather Days

Refer Appendix 1 – Niwa Extreme Weather Days

Last year was an exceptional year for extreme weather events. Analysis by NIWA determines that we had the most extreme weather days (27 days) since records began in 1940, far exceeding the previous record (19 days) as displayed in Graph 1 below. In addition, we had the 2nd most extreme precipitation days again since records began in 1940.



Graph 1. Extreme Weather Days

NIWA Analysis report – Complimentary Weather Analysis
Refer Appendix 1.1 – Niwa Complimentary Analysis

This report analyses severe wind days and coincident strong wind and heavy rain days for the regulatory years 1 April 2022 to 31 March 2023 over the Top Energy region of Northland in comparison to the previous 4-year regulatory years (1 April 2018 to 31 March 2022). The results are summarised in Table 1 below, which shows that the incidence of such days was around two-to-three times higher and up to ten times higher in the past regulatory year than in previous years.

Station (Thresholds) (Wind [km/h]/rain [mm])	Average past 4 years [max]	2022-2023	Ratio
Kerikeri (55/30)	**3.8[5]**	**14**	**373%**
Kaitaia EWS (70/30)	**11[13]**	**21**	**191%**
Kaitaia Aero (70/30)	**8.3[10]**	**22**	**267%**
Cape Reinga (80/20)[1]	*2.8[4.2]*	*5[7.8]*	*182%*
Russell (40/30)	**1.75[3]**	**5**	**286%**
Trounson (50/20)	**0.75[1]**	**8**	**1,067%**
Dargaville (60/30)	**1.25[2]**	**4**	**320%**

Table 1. Coincident Strong Wind and Very Wet Days

Note. Trounson and Dargaville are not within Top Energy's area of operations, however these stations were included as they are reasonably close to the area and observations there are likely to be more representative of conditions on the south western coast and hills of Top Energy's operating area.

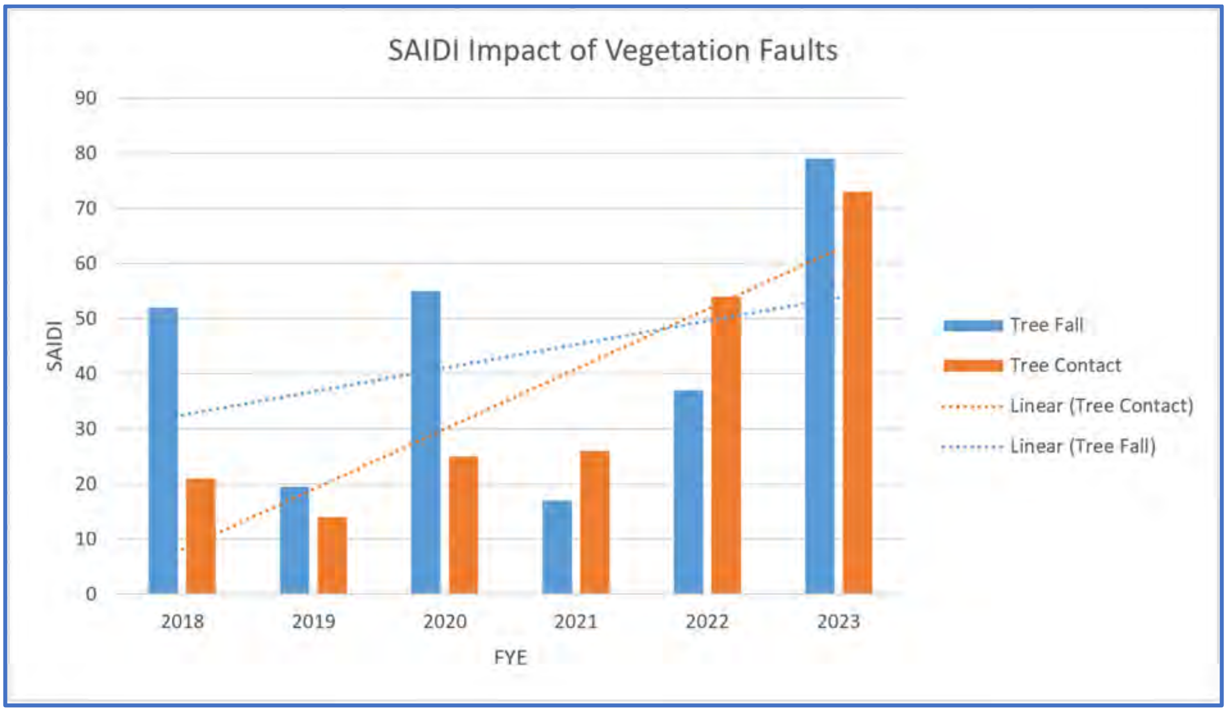
Harmonic Analytics Report

Harmonic Analytics were engaged in December 2022 to undertake an investigation into unplanned SAIDI. Refer to Harmonic Analytics Report (Appendix 6). Relevant findings included:

- *To date, YE2023 has the second most recorded weather events since YE2020, with more extreme weather events being recorded per month on average compared to previous years.*
- *More SAIDI has been generated in Summer and Autumn months in YE2023, compared to Summer and Autumn in previous years. This is consistent with the increased record count of extreme weather events observed in YE2023."*

1.2 Vegetation damage beyond Top Energy's control

The largest fault cause in FYE2023 was vegetation. Graph 2 below trends the SAIDI impact of vegetation faults on the network over FYE2018-23, further disaggregated into tree contact and tree fall impacts. We estimate that we experienced approximately 100 trees fall through or across our lines during Cyclone Gabrielle alone. Vegetation contributed 151 minutes compared to an average of 68 minutes over the last 5 years.

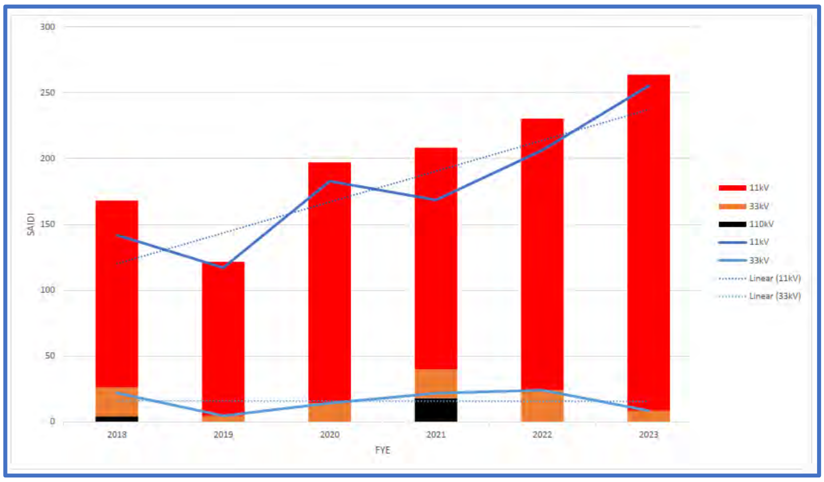


Graph 2. SAIDI Impact of Vegetation faults

Top Energy's vegetation management programme is regulated by the Electricity (Hazards from Trees) Regulations 2003. This outcome was significantly impacted by fall trees and tree contact, many of which are outside the regulatory limits and intensified due to the climatic conditions experienced through the financial year.

1.3 Rise in distribution (11kV) related faults.

Graph 3 below shows Unplanned SAIDI (normalised) across the 110kV transmission, 33kV sub transmission and 11kV distribution voltages.



Graph 3. Normalised Unplanned SAIDI Trends

Since 2010 Top Energy has embarked on a strategy of investing in network remediation and reinforcement in areas which provide the most performance improvement for the least expenditure.

The sub transmission system was prioritised, which has resulted in improved performance as shown with the sub transmission results for FY23 during the extreme weather experienced in FYE23 in Graph 3 above. During this period, distribution remediation was focused on worst performing feeders and assets. Refer Asset Management Plans – 2010 to 2023: Top Energy Website – Disclosures.

An internal 11kV feeder performance analysis (Analysis of SAIDI Impacts) was undertaken in 2022 and presented to the Board in November 2022.
Refer Appendix 2 - Analysis of SAIDI Impacts

2. Class C Interruption Data for FY23

12.4(b) for each Class C interruption for the assessment period:

- *(i) the start date (dd/mm/yyyy) of the Class C interruption;*
- *(ii) the start time (hh:mm am/pm) of the Class C interruption;*
- *(iii) the end date (dd/mm/yyyy) of the Class C interruption;*
- *(iv) the end time (hh:mm am/pm) of the Class C interruption;*
- *(v) SAIDI value of the Class C interruption;*
- *(vi) SAIFI value of the Class C interruption;*
- *(vii) the cause;*

Refer Appendix 3 – Unplanned SAIDI Data for FY23

3. Independent Reviews of the State of the Network and Operational Practices

12.4(c) any existing independent reviews of the state of the network or operational practices completed in the assessment period in which the non-exempt EDB failed to comply with the annual unplanned interruption's reliability assessment specified in clause 9.8 or in any of the three preceding assessment periods;

3.1 *Ergo Consulting - Network Reliability Unplanned SAIDI Review 15 November 2021*
Ergo Consulting was engaged to undertake a critical review of the past two full regulatory years YE2020 and YE2021 unplanned network outage performance, including the 6 months of the regulatory year YE2022 for findings and recommendations.
Refer Appendix 4 – Ergo - Network Reliability Unplanned SAIDI Review 15 November 2021

3.2 *Harmonic Analytics SAIDI Investigation Summary Report 18 February 2022*
Harmonic Analytics were engaged in February 2022 to undertake an investigation to identify and understand the reasons for the high SAIDI minute events Top Energy were experiencing due to unplanned outages on the network.
Refer Appendix 5 - Harmonic SAIDI Investigation Summary Report 18 February 2022

3.3 *Harmonic Analytics SAIDI Investigation Summary Report 5 December 2022*
In December 2022, Harmonic Analytics were engaged to refresh and re-examine our data to identify and understand the high unplanned SAIDI observed in YE2022 and YE2023 (partial) compared to previous years.
Refer Appendix 6 - Harmonic SAIDI Investigation Summary Report 5 December 2022

3.4 *Ergo Consulting - 21011 TOP 11kV Network Protection Settings Review 2 February 2023*
A complete review of the 11kV network protection settings was undertaken and presented to Top Energy for implementation to ensure optimal protection coordination would result in greater system performance.
Refer Appendix 7 - 21011 TOP 11kV Network Settings Review

4. Investigations into SAIDI or SAIFI Major Events

12.4(d) where there was a SAIDI major event or SAIFI major event during the assessment period in which the non-exempt EDB first failed to comply with the annual unplanned interruption's reliability assessment specified in clause 9.8, any investigations of that SAIDI major event or SAIFI major event;

There were 4 SAIDI major events and 1 SAIFI event.

- *10 – 15 February 2023. Cyclone Gabrielle (SAIDI & SAIFI event).*
- *25 – 27 August 2022. Tree fall 33kV single circuit line.*
- *17 – 19 August 2022. Storm*
- *24 – 26 July 2022 Storm*

4.1 Investigations into the 3 major events (excluding Cyclone Gabriel) were not undertaken through our standard events over 2 SAIDI minutes documented review process as each individual interruption within the major event was under our two-minute trigger in our review process. A formal review was not undertaken for the single tree across line event due to the nature of the fault. All other > 2 SAIDI minute events trigger an investigation.

4.2 A separate internal investigation was undertaken for Cyclone Gabrielle with opportunities for improvement logged in our database and assigned to parties for execution.
Refer Appendix 8 - Presentation Gabrielle OFI's

5. Investigations into why Top Energy Failed to Comply with the Annual Unplanned Interruptions Reliability Assessment

12.4(e) *any investigations into why the non-exempt EDB failed to comply with the annual unplanned interruption's reliability assessment specified in clause 9.8 for the assessment period;*

In order to investigate why this non-compliance has occurred there has been considerable thorough internal and external investigative work and analysis undertaken before and during the period of the non-compliance. Investigations included:

Internal

- Internal individual investigations - Over 2 Minutes Fault Audit Review.
  Refer Appendix 9 - Over 2 Minutes Fault Audit Review
- Internal review of Cyclone Gabrielle event. (Appendix 8).
- Analysis of SAIDI Impacts for FY23 (November 2022). (Appendix 2).

External

- Ergo Consulting - Network Reliability Unplanned SAIDI Review 15 November 2021. (Appendix 4)
- Harmonic Analytics SAIDI Investigation Summary Report 18 February 2022. (Appendix 5).
- Harmonic Analytics SAIDI Investigation Summary Report 5 December 2022. (Appendix 6).
- Harmonics Analytics SAIDI Deep Dive Summary Report 12 May 2023.
  Refer Appendix 10 -SAIDI Deep Dive Report 12-05-23
- NIWA Analysis report – Extreme Weather Days. (Appendix 1).
- NIWA Analysis report – Complimentary Weather Analysis. (Appendix 1.1)

6. Data Analysis Conducted into why Top Energy failed to Comply with the Annual Unplanned Interruptions Reliability Assessments

12.4(f) any analysis, conducted in the assessment period in which the non-exempt EDB failed to comply with the annual unplanned interruption reliability assessment specified in clause 9.8 or in any of the three preceding assessment periods of:

i) Any analysis conducted on trends in asset condition
ii) Any analysis conducted on the causes of Class C interruptions
iii) Any analysis conducted on asset replacement and renewal
iv) Any analysis conducted on vegetation management;

i) Any analysis conducted on trends in asset condition
- Analysis of SAIDI Impacts for FY23 (November 2022). (Appendix 2).
- Annual AMP Reporting

ii) Any analysis conducted on the causes of Class C interruptions
- Ergo Consulting - Network Reliability Unplanned SAIDI Review 15 November 2021. (Appendix 4).
- Harmonic Analytics SAIDI Investigation Summary Report 18 February 2022. (Appendix 5).
- Harmonic Analytics SAIDI Investigation Summary Report 5 December 2022. (Appendix 6).

- Harmonics Analytics SAIDI Deep Dive Summary Report 12 May 2023. (Appendix 10).
- Analysis of SAIDI Impacts for FY23 (November 2022). (Appendix 2).
- AMP Due Diligence Part 1 Asset Performance and Review – August 2022.
  Refer Appendix 11 – AMP Due Diligence Part 1 2022
- AMP Due Diligence Part 1 Asset Performance and Review – August 2023.
  Refer Appendix 12 - AMP Due Diligence Part 1 2023
  NIWA Analysis report - Wind: hi-resolution & wind and rainfall trends. (Appendix 1).
- NIWA Analysis report – Complimentary Weather Analysis. (Appendix 1.1)

iii) Any analysis conducted on asset replacement and renewal
- Ergo Consulting - Network Reliability Unplanned SAIDI Review 15 November 2021. (Appendix 4).
- Internal paper entitled Management of Distribution Network Reliability was undertaken and presented to the Board in April 2022.
  Refer Appendix 13 - Management of Distribution Network Reliability

iv) Any analysis conducted on vegetation management
- Analysis of SAIDI Impacts for FY23 (November 2022). (Appendix 2).
- Ergo Consulting - Network Reliability Unplanned SAIDI Review 15 November 2021. (Appendix 4).

7. Intended Reviews, Analysis, or Investigation currently in Progress

12.4(g) an outline of any intended reviews, intended analysis, or intended investigation that would meet the categories specified in clause 12.4(c)-(f), which is planned, but not yet completed;

7.1 Harmonics Analytics SAIDI Analytics Deep Dive Summary Report
This report has been undertaken to address the relationship between weather conditions and the high unplanned SAIDI.

7.2 Harmonic Analytics Staff Modelling Feasibility Investigation
Harmonic Analytics have been commissioned to understand staffing number impacts on service delivery.

8. Directors Certification

A certificate in the form set out in Schedule 14 of the 2020 DPP Determination is included as Appendix 14, signed by at least one director of the non-exempt EDB.
Refer Appendix 14 – Directors Certificate

Appendix 1

Memo

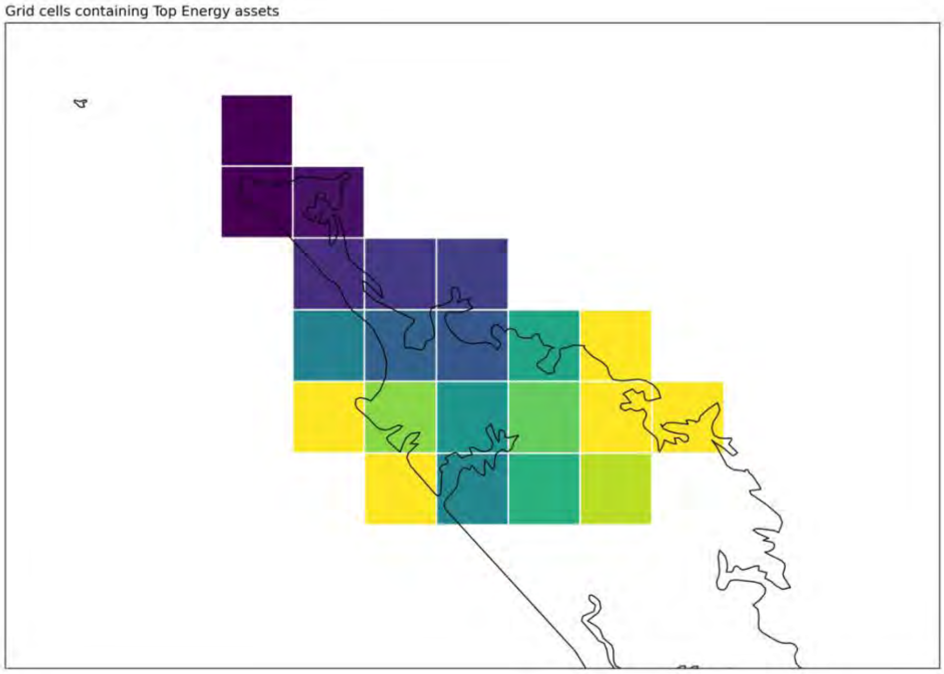
From	**Ben Noll, NIWA meteorologist** **ben.noll@niwa.co.nz**
To	Ian Robertson Top Energy Ltd John Butler Centre, Level 2, 60 Kerikeri Road, Kerikeri Ian.Robertson@topenergy .co.nz
CC	Mark Bojesen-Trepka Richard Turner
Date	18 August 2023
Subject	Extreme weather days

The following information provides a high-level overview of extreme precipitation, wind, and weather days from January 1940 through early August 2023 across Top Energy assets. The dataset used was ECMWF-ERA5, *an atmospheric reanalysis that combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics*. The dataset has an approximate horizontal resolution of 30 km. This makes it useful for assessing regional trends, but not location specifics.

The attached folder "outputs" contains the spreadsheets described below and images in this report. Inside the folder, there are sub-folders which classify extreme weather upon the 90th and 95th percentile, with respect to the regulatory year (1 April to 31 March).

- Extreme precipitation is defined as average total daily precipitation exceeding the 90th - 95th percentile across Top Energy assets.
    - The days on which extreme precipitation occurred are contained in "very_wet_days.csv". A value of "1" means extreme precipitation occurred, while "0" means it did not.
    - The annual number of days that featured extreme precipitation are contained in "annual_very_wet_days.csv".
- Extreme wind is defined as the average daily wind gust exceeding the 90th - 95th percentile across Top Energy assets.
    - The days on which extreme wind gusts occurred are contained in "high_wind_days.csv". A value of "1" means extreme wind occurred, while "0" means it did not.
    - The annual number of days that featured extreme wind gusts are contained in "annual_high_wind_days.csv".
- An extreme weather day is defined as having both extreme rainfall and extreme wind.
    - The days on which extreme weather occurred are contained in "extreme_weather_days.csv". A value of "1" means extreme weather occurred, while "0" means it did not.
    - The annual number of days that featured extreme weather are contained in "annual_extreme_weather_days.csv".

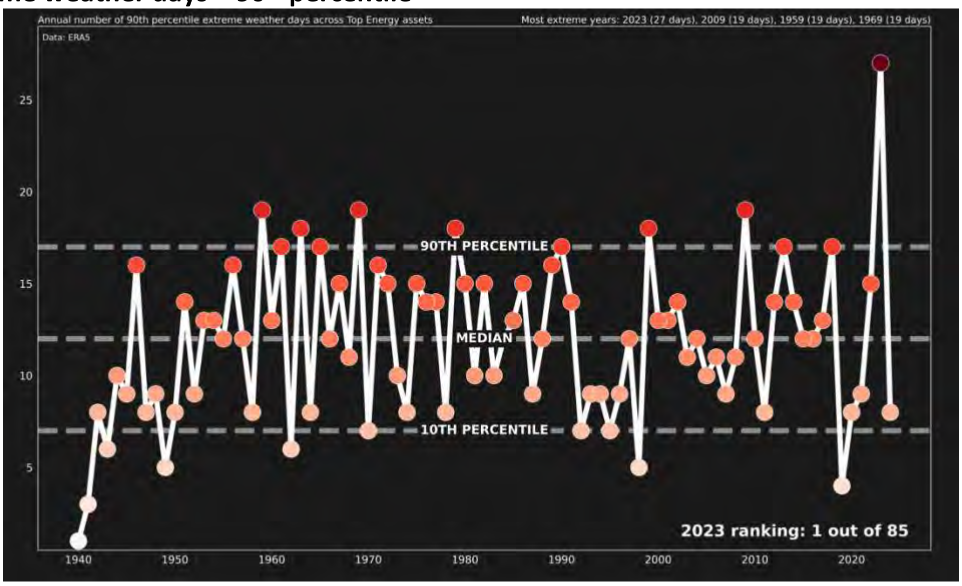
The image below shows the region for which historical data was extracted in order to complete this analysis (inclusive of assets belonging to Top Energy).



The information below is reflective of the regulatory year (1 April to 31 March).

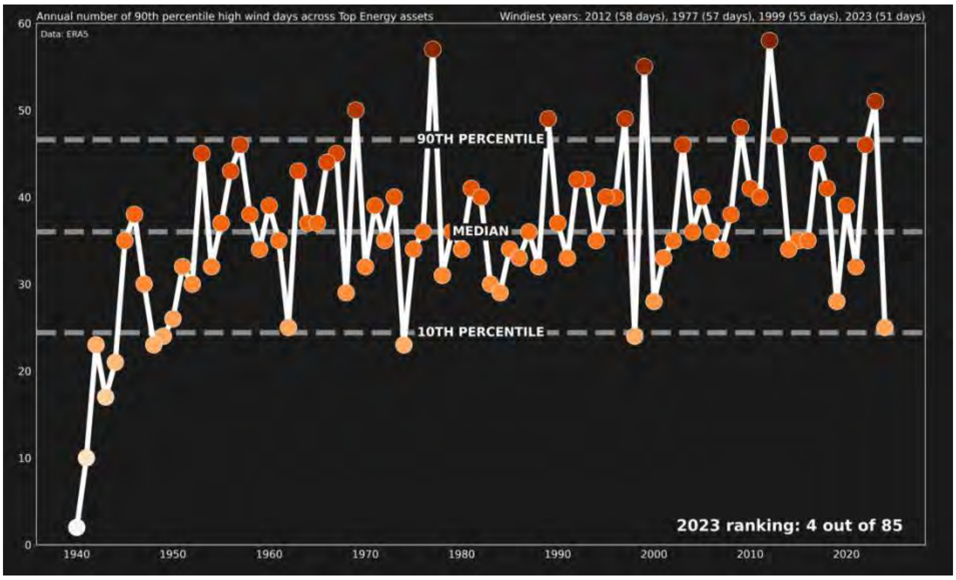
The following sections provide a brief overview of the findings for extreme weather, wind, and precipitation days. The data is presented for both the 90th and 95th percentile.

1. **Extreme weather days – 90th percentile**



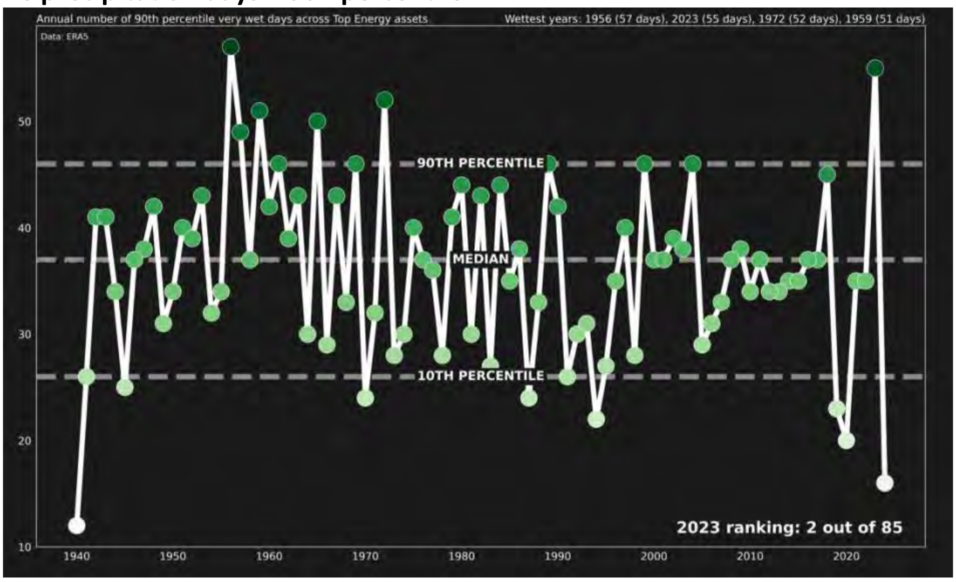
- Regulatory year 2023 had the most extreme weather days (27 days) since records began in 1940 according to the 90th percentile, far exceeding the previous record (19 days)

2. **Extreme wind days – 90th percentile**



- Regulatory year 2023 had the 4th most extreme wind days since records began in 1940 according to the 90th percentile

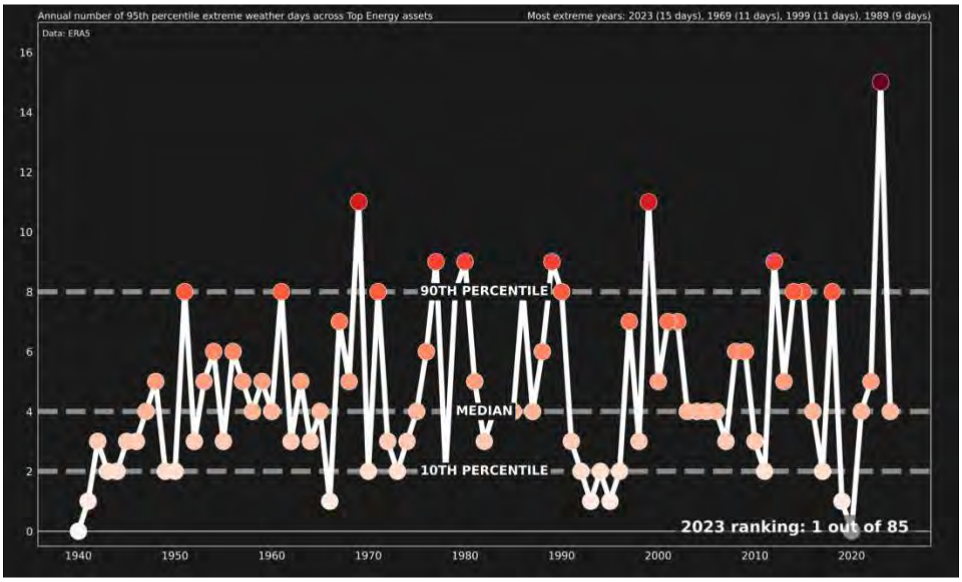
3. Extreme precipitation days – 90th percentile



- Regulatory year 2023 had the 2nd most extreme precipitation days since records began in 1940 according to the 90th percentile

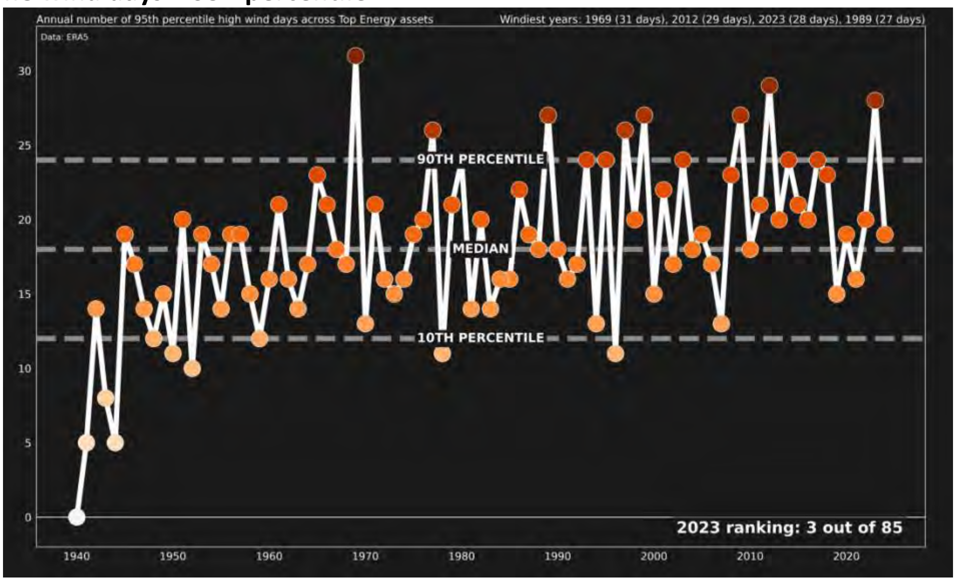
---

4. Extreme weather days – 95th percentile



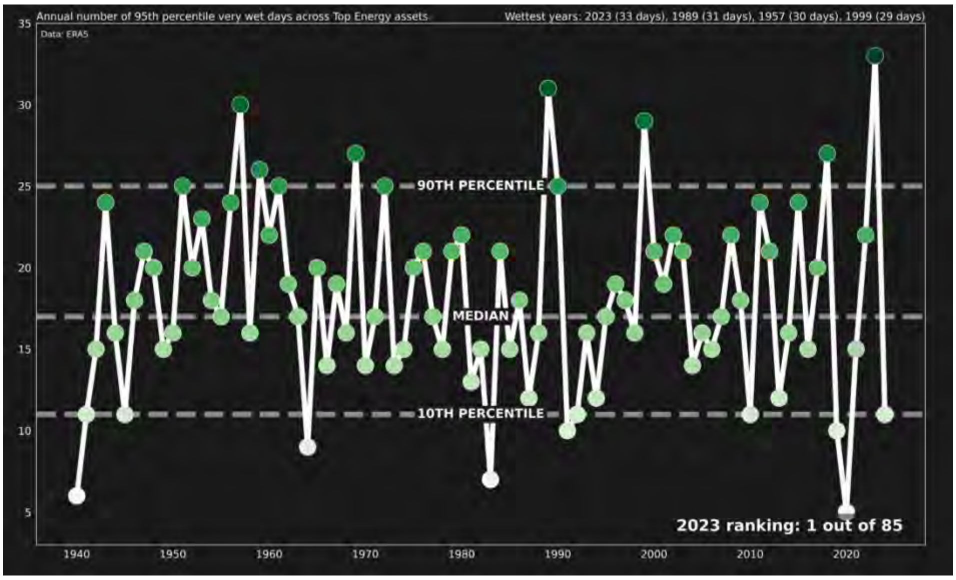
- Regulatory year 2023 had the most extreme weather days since records began in 1940 according to the 95th percentile

5. Extreme wind days – 95th percentile



- Regulatory year 2023 had the 3rd most extreme wind days since records began in 1940 according to the 95th percentile

6. Extreme precipitation days – 95th percentile



- Regulatory year 2023 had the most extreme precipitation days since records began in 1940 according to the 95th percentile

For queries regarding this analysis, please contact Ben Noll (ben.noll@niwa.co.nz).

The other component of this analysis involves a higher-resolution review of weather conditions across Top Energy's area of interest, carried out by Dr Richard Turner (richard.turner@niwa.co.nz).

Appendix 1.1

Memo

From	**Richard Turner**
To	Top Energy
CC	Mark Bojesen-Trepka Ben Noll
Date	17 August 2023
Subject	Extreme weather days – wind in Regulatory Year 2022-2023
File path *(right click to update)*	*https://niwa-my.sharepoint.com/personal/richard_turner_niwa_co_nz/Documents/Documents/Memo-Winds-Northland-Top-Lines-Company-2022-2023-NIWA.docx*

This is and analysis of severe wind days and coincident strong wind and heavy rain days for the regulatory year April 1, 2022 to March 31, 2023 over the Top Energy region of Northland in comparison to the previous 4-year regulatory years (April 1, 2018 to March 31, 2022). This is complementary to an analysis done by Ben Noll supplied separately.

Stations

The analysis examined wind and rainfall records for several stations in the region, these being;

- Kaikohe
- Kaitaia
- Kerikeri Aero
- Russell
- Cape Reinga
- Trounson(*)
- Dargaville(*)

(*) *Trounson and Dargaville are not within Top Energy's area of operations, however these stations were included as they are reasonably close to the area and observations there are likely to be more representative of conditions on the south western coast and hills of the Top operating area*.

The locations of the stations are marked in Figure 2.

The analysis also makes use of gust wind estimates from the archive of NIWA's high resolution Numerical Weather Model output (the 1.5 km grid spaced New Zealand Convective Scale Model) for the period from Apr 1, 2018 through Mar 31, 2013 including results from simulations of the passage of ex-Tropical Cyclone Gabrielle on 13 and 14 Feb 2023.

Winds:

In Table 1 are shown the number of exceedances of strong wind thresholds in the regulatory year 2022-2023 and how that compares with the average over the previous four regulatory years, (2018/19, 2019/20, 2021/21, 2021/22)

This shows that 5 of the 7 sites had below average number (around 50-90% the number) of strong wind episodes in the 2022/23 year, and 2 sites had above average number of incidences.

Note; due to differences in exposure and the complex terrain of the Northland region, different thresholds of exposure were chosen to identify dates in which winds over a wider area may have been strong – around the 90 – 95th percentile. For example, the Cape Reinga site has steep surrounding slopes and its elevation and far more exposed than the site at Russell – where 95% winds are just under 40 km/h and near 100 km/h at the (See Figure 1)

Table 1: The average number of exceedances of the average over the four regulatory years (2018/19, 2019/20, 2021/21, 2021/22) of strong wind thresholds (in brackets) and those in the regulatory year 2022-2023 and the ratio of last year to the previous 4. The numbers in orange brackets are scaled to the full year for Cape Reinga where there were many missing records – and while consistent are much more uncertain.

Station	Average past 4 years	2022-2023	Ratio
Kerikeri (55)	**15.5**	**25**	**161%**
Kaitaia EWS (80)	**10.0**	**13**	**130%**
Kaitaia Aero (80)	**12.3**	**16**	**131%**
Cape Reinga (100)[1]	*9(14.8)*	*16(24.8)*	*168%*
Russell (40)	**3.5**	**6**	**171%**
Trounson (70)	**0.5**	**24**	**4,800%**
Dargaville (80)	**19.3**	**25**	**130%**

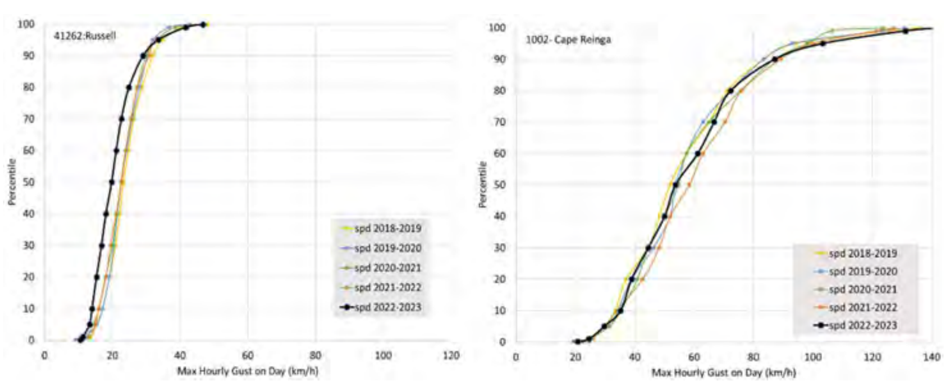


Figure 1: Cumulative distribution of observed gust exceedances at Russell and Cape Reinga over the past 5 regulatory years.

[1] Cape Reinga had 30% missing days of records in 2022/2023

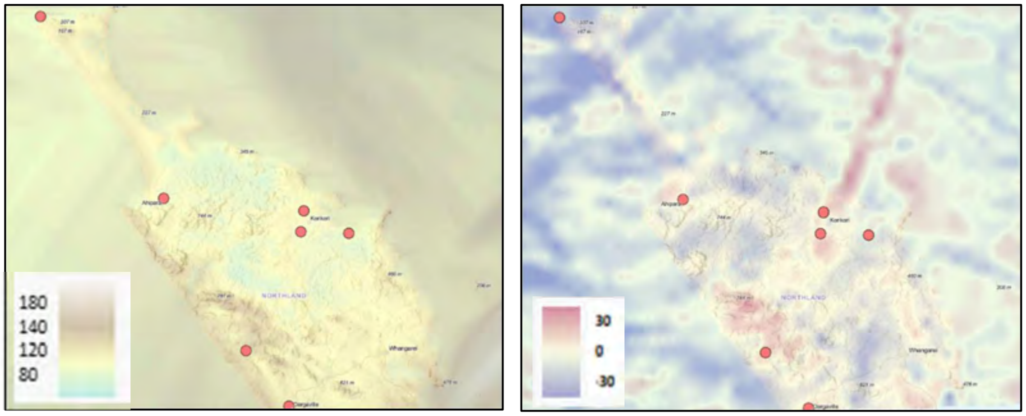


Figure 2: NZCSM (New Zealand Convective Scale Model) estimated maximum 3-s gusts (km/h) during the passage of ex-Tropical cyclone Gabrielle (left) and the difference (km/h) between maximum NZCSM gusts in 2022/23 against the average for the 5-year period Apr 1, 2018, to Mar 31, 2023 (right).

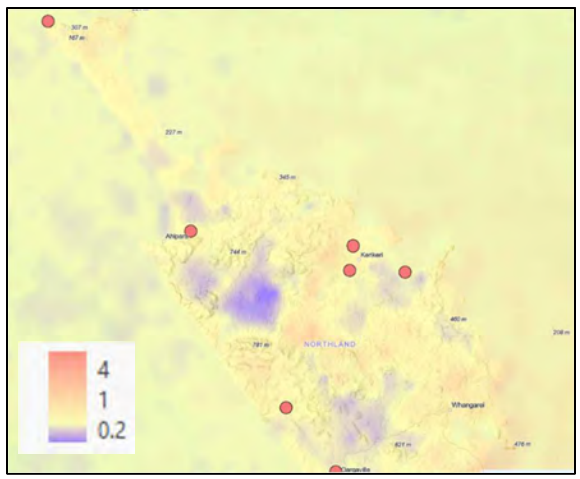


Figure 3: The ratio of days in regulatory year Apr 2022 to Mar 2023 with NZCSM wind gusts exceeding 80 km/h compared to the average over the four regulatory years prior. Red markers indicate location of weather observing stations, showing that many of the observing stations were in relatively less windy locations in 2022/23.

Rainfall

Observed rainfall across the region was abnormally high at all observing sites, being 120-150% above the average of the Apr 2018- Mar 2023. This is shown in Figure 4 and reinforced by the number of very wet days that occurred in 2022/23 - see Table 2.

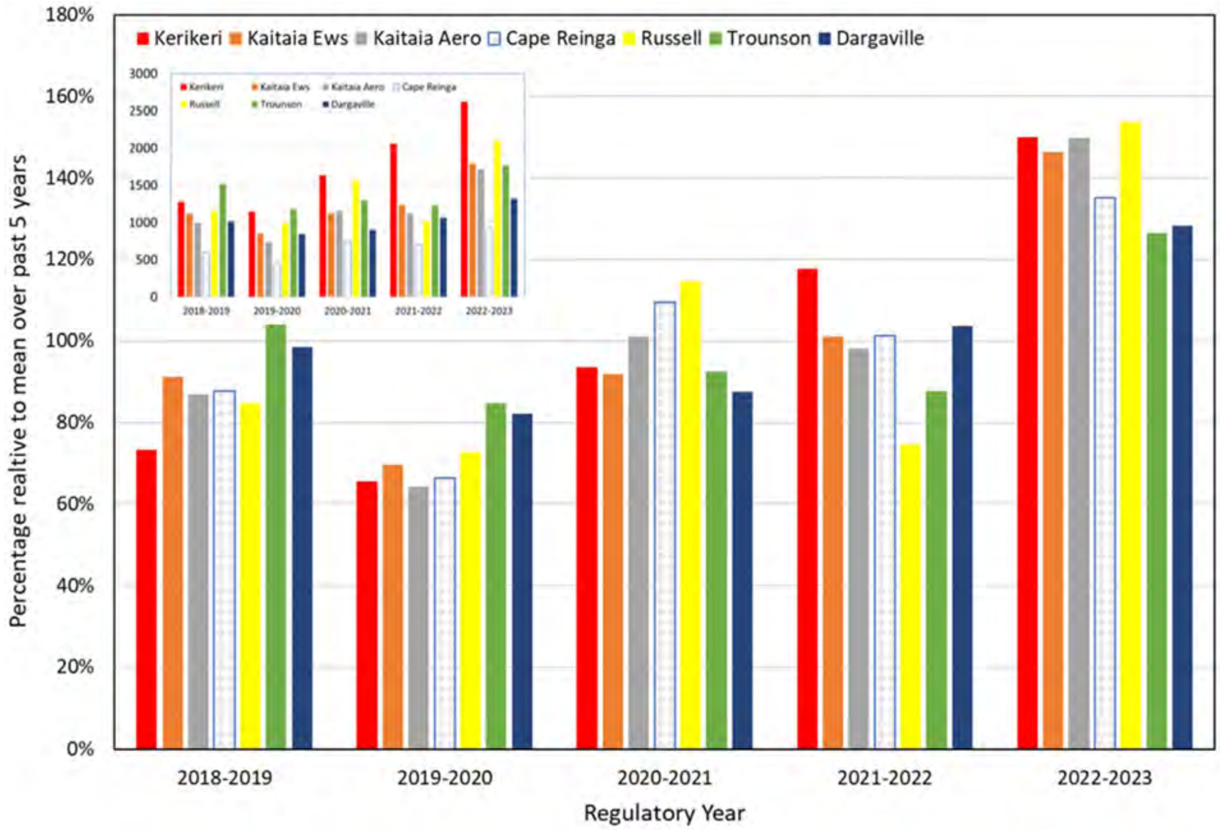


Figure 4: Regulatory Year annual percent of normal of accumulated rainfall at the 7 observing sites. The inset shows the actual totals in mm.

Table 2: The average number of exceedances of the average over the four regulatory years (2018/19, 2019/20, 2021/21, 2021/22) of very wet day thresholds (in brackets) and those in the regulatory year 2022-2023 and the ratio of last year to the previous 4 years.

Station	Average past 4 years	2022-2023	Ratio
Kerikeri (30)	13.3	**30**	**226%**
Kaitaia EWS (30)	**6.8**	**17**	**252%**
Kaitaia Aero (30)	**6.3**	**14**	**224%**
Cape Reinga (30)[1]	2	4	200%
Russell (30)	**9.3**	**22**	**238%**
Trounson (30)	**7.3**	**11**	**152%**
Dargaville (30)	**2.8**	**5**	**182%**

Coincident High Wind and Heavy Rain Events (Observed)

From above it appears that (i) the exceedances for strong wind events were relatively more than the average over the past 4 years, and (ii) there were an abnormal number of rainfall events, and (ii) high winds from those associated with Gabrielle were the strongest that many parts of the region had experienced for several years. Weather impacts from these factors taken separately over the past regulatory year would have been more likely. An additional compounding factor is that in times of prolonged wet and high soil-moisture – winds that would not otherwise cause issues can be damaging due to a higher risk of treefall. Thus, an analysis of the number of coincident strong wind and very wet days is also instructive. The results are summarised in Table 3, which shows that the incidence of such days was around two-to-three times higher and up to ten times higher in the past regulatory year than over the previous years.

Table 3: The average number of coincident high wind and very wet days average over the four regulatory years (2018/19, 2019/20, 2021/21, 2021/22) of very wet day thresholds (in brackets) and those in the regulatory year 2022-2023 and the ratio of last year to the previous 4 years.

Station (Thresholds) (Wind [km/h]/rain [mm])	**Average past 4 years [max]**	**2022-2023**	**Ratio**
Kerikeri (55/30)	**3.8[5]**	**14**	**373%**
Kaitaia EWS (70/30)	**11[13]**	**21**	**191%**
Kaitaia Aero (70/30)	**8.3[10]**	**22**	**267%**
Cape Reinga (80/20)[1]	*2.8[4.2]*	*5[7.8]*	*182%*
Russell (40/30)	**1.75[3]**	**5**	**286%**
Trounson (50/20)	**0.75[1]**	**8**	**1,067%**
Dargaville (60/30)	**1.25[2]**	**4**	**320%**

Appendix 2

TOP ENERGY®
Te Puna Hihiko
www.topenergy.co.nz

Top Energy Limited
Level 2, John Butler Centre
60 Kerikeri Road
P O Box 43
Kerikeri 0245
New Zealand
PH +64 (0)9 401 5440
FAX +64 (0)9 407 0611

Memo to	**David Sullivan** **Nicole Anderson** **Jon Nichols** **Steve Sanderson** **Simon Young**
From	**Russell Shaw**
Date	
Subject	**Analysis of SAIDI Impacts**

Purpose

This is an information paper. Top Energy's network reliability has deteriorated to the point where there is a high risk that in the current year we will breach the quality threshold, which is a component of the price-quality path set by the Commerce Commission for the current regulatory control period (RCP3). Furthermore, as at the end of October, the fault response expenditure we have incurred was 69% above the year-to date budget. This paper analyses the underlying drivers that are causing these deviations from our expected performance, to assist management in the development of effective responses.

This analysis is generally based on faults that occurred over the first seven months (April-October) of each financial year over the period FYE2018-23. A six-year time frame is considered sufficient to make valid comparisons without being unduly distorted by year-on-year volatility, and considering only the first seven months of each year has allowed us to directly compare the current year's performance with that of earlier years.

Executive Summary

- Approximately 90% of our normalised unplanned network SAIDI is now due to the impact of faults on the 11kV distribution network. Going forward, any programme designed to stabilise the current deterioration in network reliability must focus on this part of the network. Our 11kV reliability improvement plan does this.
- The fault causes that have the most significant impact on network SAIDI are defective equipment (35%) and vegetation (25%). Other significant contributors are third party interference (19%) and faults with an unknown cause (10%).
- There was a significant step increase between FYE 2019 and FYE 2020 in the SAIDI impact of defective equipment faults. While this has trended downwards slightly since FYE 2020, it remains 80% higher than the average in FYE 2018-19, the first two years of the review period.
- We categorise vegetation faults into tree fall and tree contact events. Tree fall events are difficult to actively manage due to limitations in the Electricity (Hazards from Trees) Regulation 2003, but their SAIDI impact has changed little over the review period. Only the SAIDI impact of tree contact events can be managed by our vegetation management programme. However, the SAIDI impact of tree fall events is currently increasing at an estimated rate of 4 minutes per year.

- The average time consumers are off supply due to a SAIDI interruption has increased by 25% between FYE 2018-20 and FYE FY21-23. This could be because more faults are occurring on our worst served rural feeders. These faults take longer to repair due primarily to the longer travel times required to locate the fault and then return to base after the fault is repaired.
- The rate at which the reliability of the ten worst served feeders is deteriorating is significantly greater than the deterioration in the reliability of the overall network. Our 11kV reliability improvement plan is targeting these worst-served feeders.
- Expenditure on fault and emergency response has increased over the review period due to both an increase in the number of events each year and an increase in the average cost of responding to a single event. The number of events requiring a response increased by 12% between FYE2018 and 2022, while the average cost of responding to a single event has increased by 49% between FYE2018 and 2023.
- Less than 20% of fault and emergency response events have a SAIDI impact. The bulk of the fault and emergency response budget is spent on faults that do not cause a SAIDI interruption and addressing safety and other issues that require an immediate response.
- We estimate the annual cost of responding to SAIDI impact events has increased by 50% between FYE 2018 and FYE 2013 due to the increase in the number of faults. The average cost of responding to an event has also increased by 49% over the same period, with much of this impact occurring over the last two years, presumably due to the high level of inflation. When this inflationary impact is included, the estimated cost of responding to SAIDI events has increased by 123% over the period. We estimate the increase in cost between FYE2022 and FYE 2023 to be 31%.

SAIDI Impact by Voltage

Figure 1 shows the normalised unplanned SAIDI impact of each of the three network voltage levels for the first seven months of each year from FYE2018-23[1]. Superimposed on this plot is a line graph showing the SAIDI impact of 11kV and 33kV faults together with their associated trend lines. The figure shows that:

- The SAIDI impact of faults on the 110kV transmission network is not significant.
- Faults on the 33kV subtransmission network contribute around 8% of the total normalised unplanned SAIDI. This is because most 33kV subtransmission lines are now operated in parallel and most 33kV faults do no result in a supply interruption. When lines are operated in parallel, the load is automatically taken up by the parallel line whenever a fault occurs.
- Approximately 90% of the normalised unplanned SAIDI across the network is due to faults on the 11kV distribution system. The trend line shows that the unplanned SAIDI impact of these faults has almost doubled over the five years from FYE 2018 to FYE 2023.

1

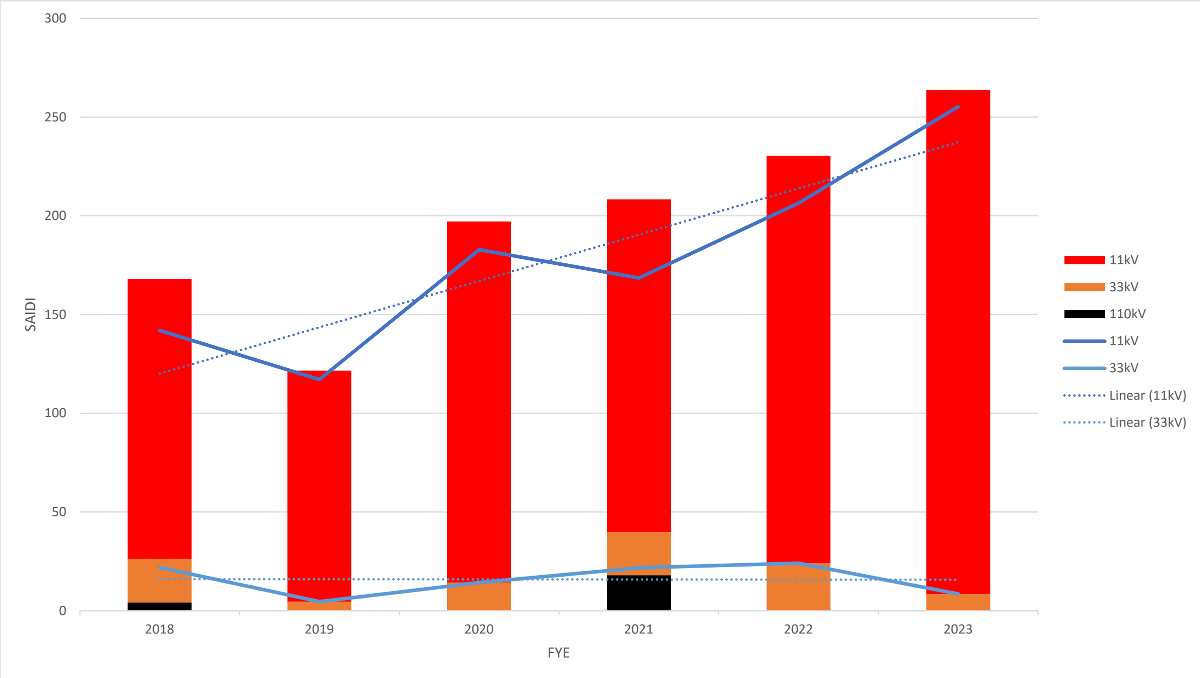


Fig 1: Unplanned SAIDI Impact by Voltage (Apr-Oct FYE 2018-23)

Given that our total network SAIDI is dominated by faults on the 11kV distribution system, unless otherwise stated, the analysis in the rest of this paper only considers the SAIDI impact of 11kV faults.

Fault Cause

Figure 2 shows the normalised SAIDI impact of all unplanned interruptions on the 11kV network during FYE 2018-23, disaggregated by the fault causes used by the Commerce Commission for information disclosure. The two most significant causes are defective equipment and vegetation, which account for 35% and 25% of the SAIDI impact respectively. Third party interference (mainly vehicle vs pole incidents) (19%) and unknown (10%) were also significant causes, but it is difficult to design a mitigation strategy to effectively target these causes.

The analysis shows that adverse weather contributed 6% of the normalised network SAIDI over the review period. From a consumer perspective the impact of adverse weather on minutes off supply would have been substantially higher as the normalised SAIDI measure used by the Commission reduces the impact of faults that occur during storm conditions. There also appears to be an anomaly in the analysis dataset in the 38 of the 53 (72%) SAIDI minutes attributed to adverse weather occurred in FYE 2023.[2] For these reasons, the adverse weather fault cause is not considered in this paper.

The other causes monitored by the Commission have collectively contributed only 5% of the SAIDI impact over the review period and are not considered material.

[2] The reason for this is not clear but it could be due to a change in the way fault causes are attributed. We have removed all normalised SAIDI and SAIFI events from the database used for the analysis in this paper, to avoid any distortion form the normalisation process.

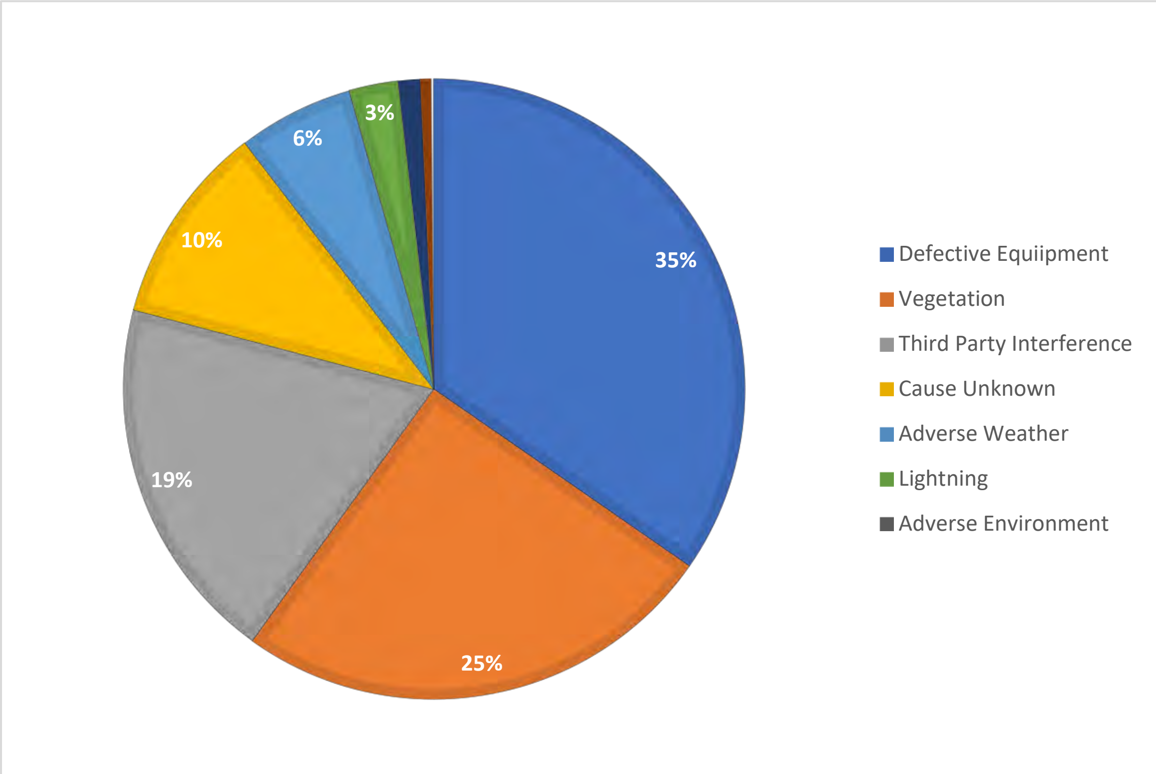


Fig 2: SAIDI Impact of 11kV Faults by Cause (Apr-Oct FYE 2018-23)

As this paper is primarily concerned with identifying the drivers for the recent **increase** in the network SAIDI, we have looked at the four main fault causes shown in Figure 3 and, for each cause, compared the average SAIDI impact over April-Oct FYE 2021-23 with the corresponding impact over the same period in FYE 2018-20. This analysis is shown in Table 1 below.

Cause	**Average SAIDI (April-October)**		**Increase**
	FYE 2018-20	**FYE 2021-23**	
Defective Equipment	53.03	78.85	49%
Vegetation	43.81	54.03	23%
Third Party	38.52	29.99	(22%)
Unknown	16.73	20.66	24%

Table 1: Change in 11kV SAIDI by Cause. April-October FYE2018-23

It can be seen from Table 1 that the increases in normalised SAIDI currently being experienced across the network are due primarily to increases in defective equipment and vegetation faults. These faults will therefore be the focus of the analysis in the remainder of this paper.

Defective Equipment Faults

Figure 3 shows the number and normalised SAIDI impact of defective equipment faults on the 11kV network over the first seven months of each year FYE 2018-23. While there was a step increase between FYE 2019 and FYE 2020, there has been little change in since FYE 2020. Hence the 49% increase in the defective equipment SAIDI impact is primarily due to the step increase in the SAIDI impact between FYE 2019 and 2020. The reason for this is not clear.

We note that the 49% increase shown in Table 1 is based on a comparison of two three-year averages. It can be seen from Figure 3 that, notwithstanding the slight downward trend in the SAIDI impact of defective equipment faults between FYE2021 and FYE 2023, the impact in the current year was still approximately 80% greater than in FYE 2018-19.

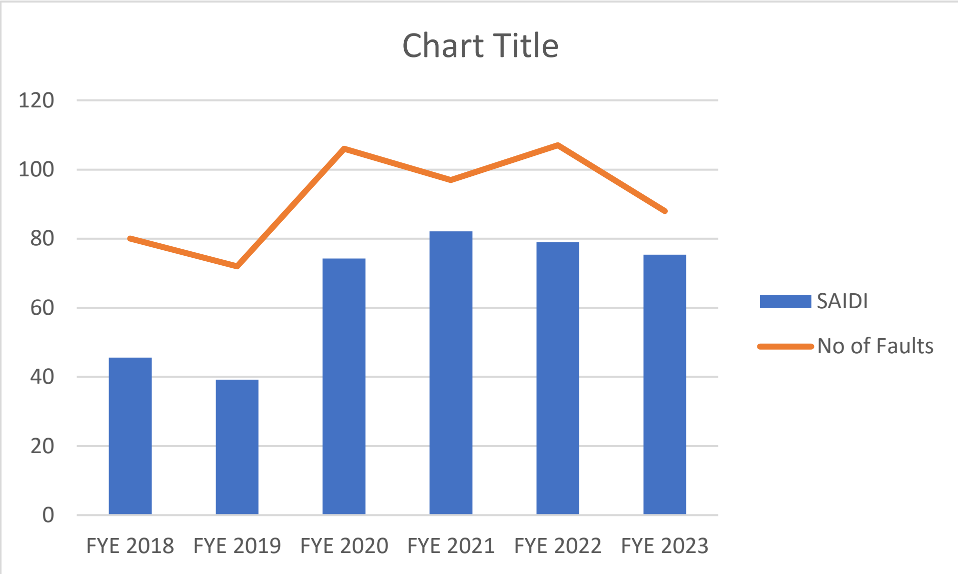


Fig 3: 11kV Defective Equipment Faults, Apr-Oct FYE 2018-23

Vegetation Faults

Top Energy's vegetation management programme is regulated by the Electricity (Hazards from Trees) Regulations 2003. These prescribe the minimum distance that any part of a tree must be from a line before it can be compulsorily trimmed, and the maximum extent to which a tree may be trimmed without the consent of the tree owner. Unless the owner agrees, Top Energy cannot trim trees within falling distance of a line unless they encroach the minimum clearance distance. Under the current regulations there is therefore little we can do to mitigate the risk of trees falling into a line. A review of the regulations has been on MBIE's work programme for several years but there has been little progress.

Top Energy categorises vegetation faults into tree fall and tree contact events. There are treated separately in this paper since only tree contact events cannot be effectively targeted by our vegetation management programme.

Table 2 provides an indication of the change in the average number and SAIDI impact of both tree fall and tree contact events over the period FYE 2021-23 compared to the previous three years. It shows that the impact of tree fall events was significantly higher than tree contact events. However the SAIDI impact of tree contact events more than doubled in the FYE 2021-23 period and we are now at the point where the two types of vegetation faults have a comparable SAIDI impact.

Cause	Average (April-October)		Increase
	FYE 2018-20	FYE 2021-23	

Tree Fall Events			
SAIDI	25.72	26.52	3%
No of Events	29	24	(18%)
Tree Contact Events			
SAIDI	11.55	26.08	126%
No of Events	18	27	50%

Table 2: Change in Impact of Tree Fall and Tree contact Events (FYE2018-23)

Figure 4 shows the SAIDI impact of tree contact events for each year of the review period. While there has been a steady upward trend, this has not been uniform across the period. There was a step increase between FYE 2021and 2022, when the tree contact SAIDI almost doubled, and this higher SAIDI was increased even further in FYE 2023. The average annual tree contact SAIDI over four-year FYE2018-21 period was 11.55, which in FYE 2022-23 the average was 26.08, an increase of 126%. The trendline indicates that the tree contact SAIDI has increased on average by approximately 4 SAIDI minutes per year over the period.

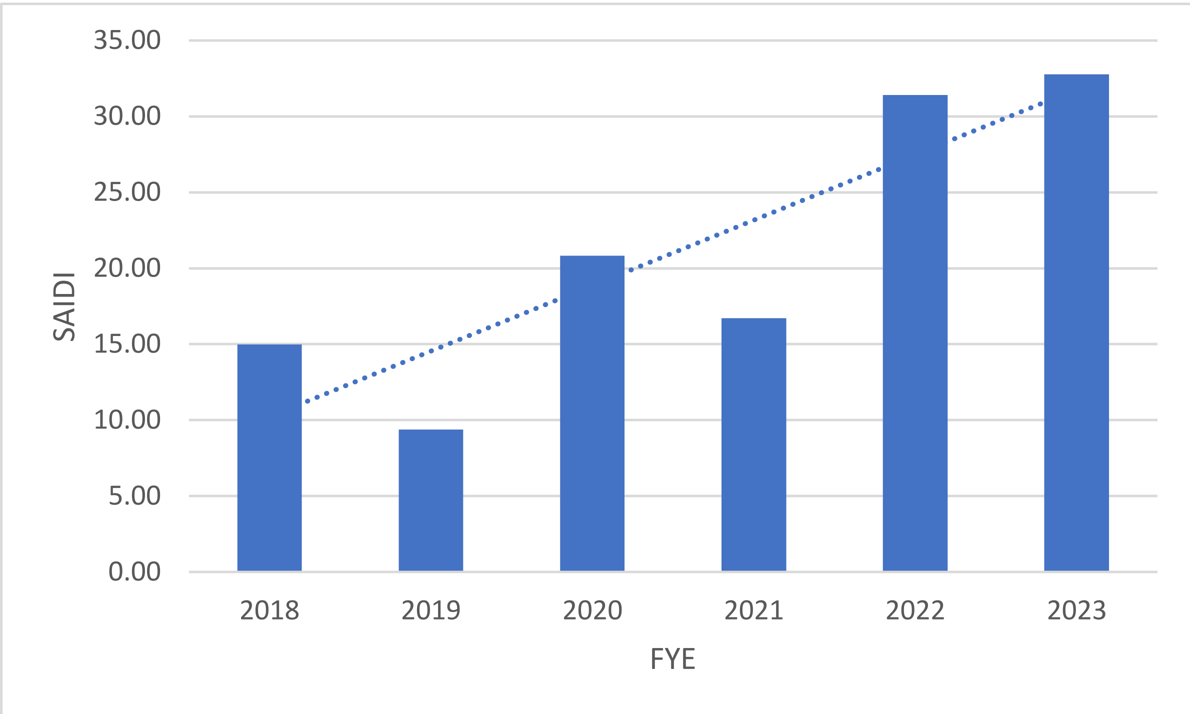


Fig 4: Tree Contact SAIDI FYE 2018-23

Average Time off Supply

A measure of the average time affected consumers are without supply as a result of network faults is the Customer Average Interruption Duration Index (CAIDI), which is the ratio of

SAIDI/SAIFI.[3] The average time off supply is an indicator of the repair time, since if a fault takes longer to repair, then affected consumers are without supply for longer.[4]

Cause	Average CAIDI (April-October) (hours)		Increase
	FYE 2018-20	FYE 2021-23	
All Causes	1.32	1.66	25%
Defective Equipment	1.38	1.86	35%
Tree Contact	1.16	1.78	53%

Table 3: Change in Average CAIDI by Fault Cause (Apr-Oct FYE 2018-23)

Table 3 shows that the average time that affected consumers are off supply following a fault is increasing. While this is true for all fault causes, it is particularly true of tree contact faults, where the average length of consumer interruptions has increased by 53% since the beginning of the review period.

Worst Served Feeders

This analysis examines the deterioration in performance of the ten worst served feeders on the network relative to the average deterioration across the whole network, using a range of measures. We speculated that the reliability of our long rural feeders, which already have the poorest performance, is deteriorating faster than other parts of the network.

For this study feeders were ranked by total SAIDI due to all fault causes over the April-October months of the FYE2018-23 review period. Normalised faults were not included in the analysis.[5] The worst served feeders based on this criterion are shown in Figure 5, with the feeders included in the analysis highlighted in red. For clarity, only those feeders with a total SAIDI higher than 12 (two minutes per year) are shown.

The analysis compared the average performance over the months of April-October in each year from over the period FYE2021-23 with the performance over the corresponding period in the previous three years (FYE 2018-20) across a range of measures. It also compared the performance in the current year to the average performance over the FYE2021-23 period. The results are shown in Tables 4 and 5. It found that:

- The reliability of the network has deteriorated over the review period irrespective of how reliability is measured. When measured across the network the deterioration in average performance over the three-year period FYE2021-23 has ranged from a 12% increase in the number of faults to a 126% increase in tree contact SAIDI, when compared to the corresponding FYE2018-20 period.

[3] The ratio of SAIDI/SAIFI is measured in minutes. For this analysis we have used the expression SAIDI/SAIFI/60 to express the result in hours.

[4] This is not a direct relationship, since the CAIDI will be reduced if it is possible to restore supply to downstream consumers before a fault is repaired. However, the statement is broadly true when averaged across the network.

[5] Inclusion of normalised faults would distort the CAIDI measure since in most instances SAIDI is normalised and SAIFI is not. Furthermore, the normalisation process de-weights the SAIDI of faults that meet the normalisation threshold to the point where these faults are not a major contributor to the total normalised SAIDI measure.

- The deterioration in the performance of the worst served feeders over the same period has been even higher, ranging from a 14% increase in the number of faults to a 238% increase in tree contact SAIDI.
- The analysis confirmed that, while defective equipment faults have the highest SAIDI impact, the rate of deterioration in tree contact SAIDI is significantly higher.
- In FYE 2023 Top Energy has stabilised its CAIDI and defective equipment SAIDI performance. However, the number of faults has increased, as has the impact of tree contact events, and this has resulted in an increase in the total SAIDI impact. This increase has been higher across the worst-served feeders than across the network as a whole.

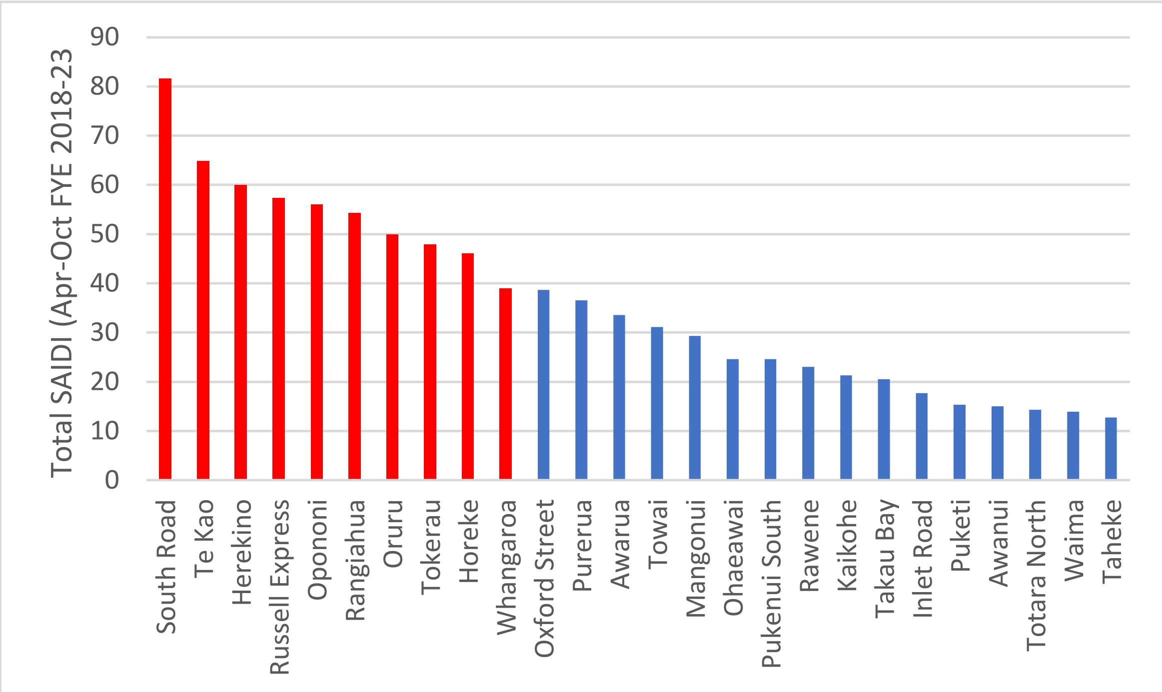


Figure 5: Worst Served Feeders Ranked by Total SAIDI (Apr-Oct FYE2018-23)

The results of this study are shown in Table 4.

	Worst Served Feeders			11kV Network		
	FYE 2018-20	FYE 2021-23	Change	FYE 2018-20	FYE 2021-23	Change
No. Faults (all causes)	94	107	14%	217	244	12%
Total SAIDI (all causes)	68	117	72%	146	201	37%
CAIDI (hrs, all causes)	1.45	2.04	40%	1.30	1.66	28%
Total SAIDI (Defective Equipment)	26	52	99%	53	79	49%
Total SAIDI (Tree Contact)	4	14	238%	12	26	126%

Table 4: Average Annual Reliability Performance (April-October only)

	Worst Served Feeders			11kV Network		
	FYE 2023	FYE 2021-23	Change	FYE 2023	FYE 2021-23	Change
No. Faults (all causes)	136	107	27%	283	244	16%
Total SAIDI (all causes)	145	117	24%	236	201	17%
CAIDI (hrs, all causes)	1.99	2.04	(2%)	1.69	1.66	2%
Total SAIDI (Defective Equipment)	51	52	(2%)	75	79	(5%)
Total SAIDI (Tree Contact)	22	14	57%	33	27	22%

Table 5: Comparison of FYE 2023 Reliability Performance with Average Annual Performance FYE 2021-23 (April-October only)

Expenditure on Fault and Emergency Response

Table 6 shows Top Energy's annual fault and emergency response expenditure from FYE 2018 to the end of October 2022 and the number of fault events responded to in that period.[6]

	No of Events	Expenditure ($000)	Expenditure per event	No of Events (Apr-Oct)
FYE 2018	2,296	1,371	$597	208
FYE 2019	2,213	1,192	$539	190
FYE 2020	2,287	1,706	$746	272
FYE 2021	2,274	1,706	$750	210
FYE 2022	2,573	2,082	$809	261
FYE 2023 (to date)	1,695	1,506	$888	312

Table 6: Expenditure on Service Interruptions and Emergencies

An analysis of Table 6 shows the following.

- Less than one fifth of fault and emergency events cause an interruption that contributes to the SAIDI reported to the Commission. Over the review period there were a total of 13,338 emergency responses but only 2,262 (17%) interruptions recorded in the unplanned SAIDI database. The remaining responses would have been for faults on the 33kV network that did not cause and interruption, faults on the low voltage network and reactive responses to safety and other issues that did not cause an interruption.
- Over the April-October period FYE 2018-23 the number of interruptions with a SAIDI impact has increased by 50%, and the cost of responding to each interruption has increased by 49%. Based on the expenditure per event shown in Table 6, the cost of responding to SAIDI interruptions over the seven-month period each year has increased by 31% between FYE2022 and 2023 alone. These trends can be shown in Figure 7, where the baseline assumes a unit response cost fixed the FYE2018 level of $597 per event and the actual line shows the impact of inflation in the unit response cost.

[6] We were not able to disaggregate all fault and emergency response events by month so the number of events and costs over the period FYE 2018-22 are for the whole year. Nevertheless, the cost per event for FYE 2023 is directly comparable with earlier years.

- The major expenditure components of fault and emergency response are labour and fuel both of which have been sensitive to the inflationary pressures in the economy. This impact is apparent in the unit response costs shown in Table 6.

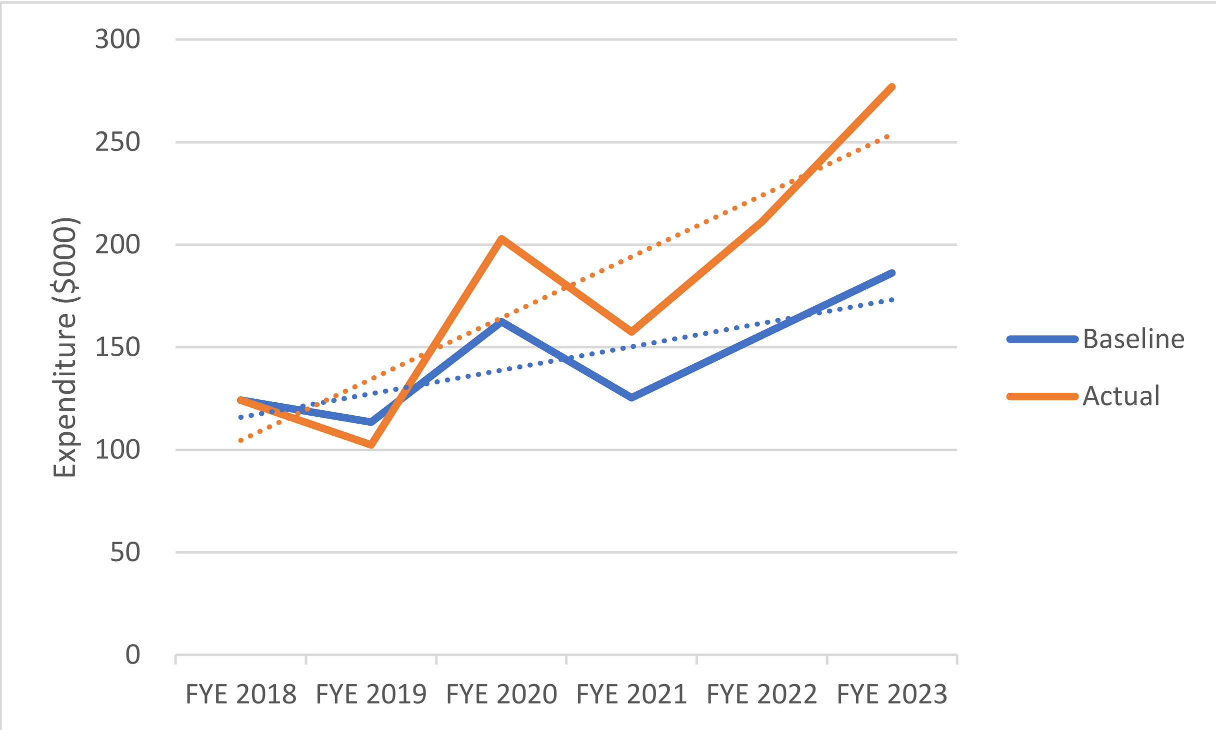


Figure 7: Relative Impact of Increased No. of Events and Inflation on SAIDI Response Expenditure (Apr-Oct FYE2018-2)

Recommendation
That the Directors receive this paper for information.

Russell Shaw
Chief Executive
Top Energy Group

Prepared by:
Name
Designation

Appendix 3

Start Date	Start Time	End Date	End Tme	Cause	SAIDI Value	SAIFI Value	Feeder	Voltage
01/04/2022	6:11:00 PM	02/04/2022	12:37:00 AM	Defective Equipment	0.088410444	0.000229043	CB0111	11kV
03/04/2022	8:46:49 AM	03/04/2022	3:12:00 PM	Third Party	0.782380898	0.028086349	CB0108	11kV
06/04/2022	11:16:00 AM	06/04/2022	1:53:48 PM	Defective Equipment	0.48505497	0.008388685	131142	11kV
07/04/2022	2:32:11 AM	07/04/2022	11:20:00 AM	Third Party	5.16817453	0.016634219	CB0407	11kV
07/04/2022	12:01:00 PM	07/04/2022	4:20:00 PM	Third Party	0.103813559	0.000400825	51762	6.35kV
11/04/2022	10:00:54 AM	11/04/2022	12:50:00 PM	Defective Equipment	0.764715987	0.00526798	CB1105	11kV
14/04/2022	11:00:19 AM	14/04/2022	11:39:50 AM	Defective Equipment	0.669348374	0.017435868	131142	11kV
14/04/2022	5:31:10 PM	14/04/2022	6:41:59 PM	Third Party	0.328447091	0.004638113	CB1205	11kV
15/04/2022	6:20:13 AM	15/04/2022	12:14:00 PM	Defective Equipment	1.427937471	0.012396931	51772	11kV
15/04/2022	7:02:00 AM	15/04/2022	6:59:00 PM	Defective Equipment	0.792773706	0.001202474	CB1109	11kV
15/04/2022	2:00:18 PM	15/04/2022	2:53:07 PM	Unknown	1.079678195	0.020442052	CB1109	11kV
16/04/2022	4:21:00 PM	16/04/2022	6:44:00 PM	Human Error	0.229414796	0.0034929	CB1732	11kV
16/04/2022	2:29:10 PM	17/04/2022	1:22:00 PM	Defective Equipment	1.011051306	0.008159643	CB0408	11kV
16/04/2022	9:16:00 PM	17/04/2022	7:10:00 AM	Defective Equipment	0.23591388	0.000944801	CB1105	11kV
17/04/2022	12:44:00 PM	17/04/2022	5:45:00 PM	Unknown	0.051706367	0.000171782	CB0105	11kV
17/04/2022	4:58:49 PM	17/04/2022	10:26:00 PM	Vegetation	2.710289739	0.043260421	CB0209	11kV
18/04/2022	12:32:37 AM	18/04/2022	3:08:00 AM	Unknown	3.547240037	0.024049473	CB0209	11kV
18/04/2022	1:09:11 AM	18/04/2022	10:50:00 AM	Vegetation	5.018724233	0.015202703	CB1105	11kV
18/04/2022	1:21:15 AM	18/04/2022	1:02:00 PM	Defective Equipment	3.961177279	0.009390747	131142	11kV
18/04/2022	1:27:28 AM	18/04/2022	3:38:35 AM	Vegetation	0.735770728	0.005611544	CB1112	11kV
18/04/2022	3:33:29 AM	18/04/2022	1:08:13 PM	Vegetation	4.485827989	0.04933005	CB1208	11kV
18/04/2022	5:29:24 AM	18/04/2022	8:13:27 AM	Unknown	2.120132845	0.014143381	CB0111	11kV
18/04/2022	5:29:24 AM	18/04/2022	9:56:00 AM	Unknown	0.54838525	0.002404947	CB1205	11kV
18/04/2022	5:29:23 AM	18/04/2022	11:00:03 AM	Vegetation	1.562070545	0.004724004	CB1206	11kV
18/04/2022	6:41:15 AM	18/04/2022	11:38:00 AM	Adverse Weather	0.380153459	0.001345625	51742	11kV
18/04/2022	6:41:16 AM	18/04/2022	6:43:27 AM	Adverse Weather	0.000314934	0.000143152	51742	11kV
18/04/2022	10:34:02 AM	18/04/2022	11:04:57 AM	Vegetation	0.753263857	0.024364407	18-1142	11kV
21/04/2022	12:08:00 AM	21/04/2022	2:45:00 AM	Defective Equipment	0.264257902	0.002032753	CB1206	11kV
21/04/2022	8:59:58 PM	21/04/2022	9:32:07 PM	Defective Equipment	0.333543289	0.010621851	CB0105	11kV
24/04/2022	5:37:57 AM	24/04/2022	12:07:00 PM	Adverse Environment	0.489492671	0.002404947	CB0108	11kV
26/04/2022	6:10:38 AM	26/04/2022	3:55:00 PM	Defective Equipment	1.166428081	0.010850893	CB1108	6.35kV
26/04/2022	10:01:13 AM	26/04/2022	1:57:25 PM	Defective Equipment	3.21217934	0.013599404	CB1208	11kV
27/04/2022	12:39:51 PM	27/04/2022	1:18:30 PM	Third Party	1.214040311	0.032352268	CB1109	11kV
28/04/2022	1:25:31 PM	28/04/2022	2:01:48 PM	Vegetation	0.08102382	0.002233165	CB1406	11kV
29/04/2022	2:54:04 PM	29/04/2022	3:36:00 PM	Third Party	0.074066651	0.006899908	131132	11kV
30/04/2022	6:13:00 AM	30/04/2022	7:15:00 AM	Unknown	0.015975721	0.000257673	CB0408	11kV
30/04/2022	5:49:00 PM	30/04/2022	9:37:00 PM	Defective Equipment	0.629552222	0.015431745	CB0405	11kV
01/05/2022	5:35:00 AM	01/05/2022	7:22:00 AM	Defective Equipment	0.039824782	0.000372194	CB0405	11kV
03/05/2022	6:16:51 AM	03/05/2022	9:52:00 AM	Defective Equipment	1.547784013	0.012253779	51772	11kV
05/05/2022	11:37:00 PM	06/05/2022	12:45:00 AM	Unknown	0.042830967	0.000629867	CB1108	6.35kV
05/05/2022	9:13:00 AM	05/05/2022	2:54:00 PM	Vegetation	0.068340586	0.000200412	CB1105	6.35kV
05/05/2022	12:00:33 PM	05/05/2022	3:26:34 PM	Defective Equipment	0.566250573	0.002748511	CB0111	11kV
06/05/2022	12:05:00 PM	06/05/2022	2:27:00 PM	Defective Equipment	0	0	CB0410	11kV
06/05/2022	2:44:35 AM	06/05/2022	3:15:12 AM	Unknown	0.246650252	0.008932661	CB0110	11kV
06/05/2022	5:14:00 AM	06/05/2022	6:27:00 AM	Wildlife	0.01672011	0.000229043	CB0111	11kV
06/05/2022	8:02:42 AM	06/05/2022	9:23:28 AM	Wildlife	0.600606963	0.008932661	CB0110	11kV
08/05/2022	9:50:21 AM	08/05/2022	2:56:00 PM	Vegetation	1.014630096	0.00707169	18-1142	11kV
11/05/2022	10:07:00 AM	11/05/2022	12:42:00 PM	Defective Equipment	0.044377004	0.000286303	CB1712	6.35kV
12/05/2022	3:07:00 PM	12/05/2022	6:01:00 PM	Defective Equipment	0.004981677	2.86303E-05	CB1109	11kV
14/05/2022	10:42:58 PM	15/05/2022	1:52:00 PM	Third Party	0.755038937	0.00526798	CB1105	11kV
17/05/2022	10:23:07 AM	18/05/2022	2:42:00 PM	Defective Equipment	3.965557719	0.036589556	CB1208	11kV
18/05/2022	9:21:00 AM	18/05/2022	10:29:00 AM	Vegetation	0.009734311	0.000143152	CB0407	11kV
18/05/2022	11:30:30 PM	19/05/2022	3:24:53 AM	Vegetation	5.441508246	0.024049473	CB0209	11kV
19/05/2022	9:44:00 AM	19/05/2022	12:18:00 PM	Vegetation	0.198408154	0.001288365	CB0108	11kV
19/05/2022	1:15:44 AM	10/06/2022	4:22:16 PM	Defective Equipment	5.236944572	0.040826844	51762	11kV
19/05/2022	10:20:06 PM	20/05/2022	9:30:00 AM	Vegetation	0.603441365	0.007329363	31312	11kV
20/05/2022	10:01:15 AM	20/05/2022	1:36:00 PM	Unknown	1.878607421	0.009963353	CB1206	11kV
20/05/2022	2:03:00 PM	20/05/2022	3:56:00 PM	Vegetation	0.043689876	0.000400825	CB0406	11kV
20/05/2022	6:33:19 PM	20/05/2022	9:34:00 PM	Vegetation	0.655004581	0.025652771	CB1406	11kV
20/05/2022	6:39:00 PM	20/05/2022	8:49:00 PM	Unknown	0.465242785	0.003578791	CB1406	11kV
21/05/2022	12:44:15 PM	23/05/2022	9:40:48 AM	Vegetation	3.541313559	0.043833028	CB1108	11kV
22/05/2022	4:38:22 PM	23/05/2022	1:34:00 PM	Defective Equipment	0.92427279	0.00526798	CB1105	11kV
23/05/2022	6:26:00 PM	23/05/2022	8:05:00 PM	Unknown	0.022675218	0.000229043	CB0607	11kV
24/05/2022	10:00:38 AM	24/05/2022	11:36:01 AM	Defective Equipment	0.393237517	0.004122767	CB1205	11kV
26/05/2022	6:17:00 AM	26/05/2022	11:36:00 AM	Wildlife	0.040712322	0.000171782	CB0410	11kV
27/05/2022	9:28:00 PM	27/05/2022	10:21:00 PM	Defective Equipment	0.039452588	0.000744388	CB0206	11kV
28/05/2022	10:49:19 AM	28/05/2022	7:40:00 PM	Defective Equipment	1.570001145	0.021014659	CB1206	11kV
29/05/2022	2:31:32 PM	29/05/2022	7:15:00 PM	Vegetation	0.535129409	0.006756757	CB1109	11kV
29/05/2022	6:10:00 PM	30/05/2022	10:49:00 AM	Defective Equipment	0.143122996	0.001660559	CB1108	11kV
29/05/2022	8:58:00 PM	30/05/2022	12:02:00 PM	Defective Equipment	0.840357306	0.001231104	CB0209	11kV
30/05/2022	1:30:04 AM	30/05/2022	9:23:00 AM	Third Party	1.1840071	0.005668804	CB0105	11kV

31/05/2022	8:59:11 PM	01/06/2022	1:12:00 AM	Defective Equipment	1.398161933	0.01059322	CB1732	11kV
31/05/2022	10:12:40 PM	31/05/2022	11:41:00 PM	Adverse Weather	0.386852955	0.005038937	CB0409	11kV
31/05/2022	10:12:43 PM	31/05/2022	10:42:24 PM	Adverse Weather	0.092619102	0.003120705	CB0608	11kV
31/05/2022	10:26:53 PM	01/06/2022	1:03:07 AM	Adverse Weather	0.67873912	0.00970568	CB0108	11kV
31/05/2022	10:30:20 PM	01/06/2022	10:47:00 AM	Vegetation	1.213095511	0.011366239	CB0207	11kV
31/05/2022	11:24:17 PM	01/06/2022	12:27:36 AM	Vegetation	0.511938846	0.008159643	CB0408	11kV
01/06/2022	12:02:14 AM	01/06/2022	12:35:04 AM	Adverse Weather	0.065792487	0.002004123	CB1105	11kV
01/06/2022	4:34:00 AM	01/06/2022	12:35:00 PM	Defective Equipment	0.402628264	0.001231104	CB0209	11kV
01/06/2022	7:05:00 AM	01/06/2022	8:56:00 AM	Vegetation	0.025423729	0.000229043	41692	11kV
01/06/2022	6:06:00 AM	01/06/2022	11:36:00 AM	Vegetation	0.330680257	0.001002061	CB1206	11kV
01/06/2022	12:25:00 PM	01/06/2022	3:28:00 PM	Vegetation	0.082827531	0.009619789	CB0108	11kV
01/06/2022	12:32:00 PM	01/06/2022	3:57:00 PM	Adverse Weather	0.051706367	0.000400825	CB0608	11kV
01/06/2022	1:01:12 PM	01/06/2022	1:39:07 PM	Vegetation	0.840443197	0.024049473	CB0209	11kV
01/06/2022	2:59:00 PM	01/06/2022	3:52:00 PM	Defective Equipment	0.013656665	0.000257673	41672	11kV
02/06/2022	12:51:00 PM	02/06/2022	5:40:00 PM	Defective Equipment	0.320087036	0.003407009	CB0108	11kV
03/06/2022	12:53:00 PM	03/06/2022	2:24:00 PM	Defective Equipment	0.026053596	0.000286303	CB0109	11kV
07/06/2022	9:30:39 AM	07/06/2022	12:31:47 PM	Defective Equipment	1.565706596	0.00876088	CB0209	11kV
07/06/2022	7:13:00 PM	07/06/2022	8:54:00 PM	Unknown	0.089641548	0.00088754	CB1205	11kV
09/06/2022	8:40:44 PM	09/06/2022	10:44:00 PM	Unknown	0.214899221	0.00263399	CB0206	11kV
09/06/2022	8:57:00 PM	10/06/2022	3:29:39 AM	Defective Equipment	2.59682776	0.006613605	CB1206	11kV
10/06/2022	8:22:17 AM	10/06/2022	6:17:00 PM	Lightning	0.31951443	0.006756757	CB1109	11kV
10/06/2022	9:46:07 AM	10/06/2022	2:07:12 PM	Vegetation	0.519010536	0.00263399	CB0206	11kV
10/06/2022	3:56:17 PM	10/06/2022	4:17:56 PM	Unknown	0.194743472	0.009390747	131142	11kV
11/06/2022	12:23:34 PM	11/06/2022	8:33:00 PM	Defective Equipment	3.325297755	0.032352268	CB1109	11kV
11/06/2022	4:05:00 PM	11/06/2022	6:06:00 PM	Adverse Weather	0.142035044	0.001173843	51742	11kV
11/06/2022	10:40:00 PM	12/06/2022	3:16:17 PM	Adverse Weather	0.640088181	0.032352268	CB1109	11kV
12/06/2022	6:22:00 AM	12/06/2022	9:42:00 AM	Lightning	0.073293633	0.000400825	CB1105	11kV
12/06/2022	8:27:00 AM	12/06/2022	11:47:00 AM	Lightning	0.177508016	0.00088754	CB0111	6.35kV
12/06/2022	12:33:00 PM	12/06/2022	2:50:00 PM	Defective Equipment	0.10475836	0.001316995	41692	11kV
12/06/2022	10:11:29 PM	13/06/2022	3:51:00 PM	Lightning	6.344279661	0.015202703	CB1105	11kV
13/06/2022	12:36:47 AM	13/06/2022	1:02:48 AM	Adverse Weather	0.73061727	0.033068026	CB1108	11kV
13/06/2022	1:07:19 AM	13/06/2022	3:42:18 AM	Vegetation	0.346112002	0.002233165	CB1406	11kV
13/06/2022	3:19:00 AM	13/06/2022	9:45:00 PM	Adverse Weather	0.654832799	0.003092075	CB1712	11kV
13/06/2022	6:14:00 AM	13/06/2022	7:47:00 AM	Adverse Weather	0.239635822	0.002576729	41692	11kV
13/06/2022	8:53:00 AM	13/06/2022	6:07:00 PM	Defective Equipment	0.78435639	0.001546038	CB0105	11kV
13/06/2022	9:52:39 AM	13/06/2022	2:00:00 PM	Adverse Weather	4.263685295	0.030691709	51762	11kV
13/06/2022	3:31:00 PM	13/06/2022	4:52:00 PM	Lightning	0.034785845	0.000429455	51762	11kV
13/06/2022	6:11:00 PM	13/06/2022	9:45:00 PM	Adverse Weather	0	0	CB1712	11kV
15/06/2022	7:40:09 AM	15/06/2022	9:05:02 AM	Vegetation	2.567052222	0.053624599	CB3582	33kV
15/06/2022	7:03:46 PM	15/06/2022	8:42:13 PM	Wildlife	0.854443426	0.010450069	CB1108	11kV
15/06/2022	10:35:00 PM	16/06/2022	2:05:00 AM	Third Party	1.725549702	0.008216903	CB1722	11kV
17/06/2022	12:49:16 AM	17/06/2022	2:48:00 AM	Wildlife	0.9568541	0.010450069	CB1108	11kV
18/06/2022	5:10:55 PM	18/06/2022	9:23:54 PM	Third Party	2.770871507	0.013313101	CB0105	11kV
20/06/2022	5:21:31 AM	20/06/2022	11:18:38 AM	Adverse Weather	1.303796381	0.008073752	CB0105	11kV
20/06/2022	11:38:00 AM	21/06/2022	2:14:47 PM	Vegetation	0.759562529	0.031035273	CB1105	11kV
23/06/2022	7:36:58 AM	23/06/2022	9:55:00 AM	Unknown	0.228699038	0.002347687	CB0109	11kV
23/06/2022	9:44:00 AM	23/06/2022	2:19:00 PM	Third Party	0.722972973	0.006069629	41672	11kV
24/06/2022	10:52:00 PM	25/06/2022	9:57:00 AM	Defective Equipment	0.361744159	0.000543976	CB0206	6.35kV
27/06/2022	3:01:30 PM	27/06/2022	4:45:00 PM	Third Party	0.253177966	0.010450069	CB1108	11kV
27/06/2022	9:15:00 PM	27/06/2022	10:05:00 PM	Adverse Environment	0.047240037	0.000944801	CB1105	11kV
29/06/2022	6:55:10 AM	30/06/2022	12:21:00 PM	Defective Equipment	2.18397847	0.009362116	131142	11kV
29/06/2022	9:17:24 AM	29/06/2022	11:46:01 AM	Third Party	2.057432432	0.032352268	CB1109	11kV
30/06/2022	3:36:08 PM	30/06/2022	5:51:00 PM	Vegetation	1.693054283	0.012654604	41632	11kV
03/07/2022	9:05:00 AM	03/07/2022	11:56:00 AM	Defective Equipment	2.330021759	0.033068026	CB1205	11kV
04/07/2022	4:37:07 AM	04/07/2022	5:11:38 AM	Unknown	0.18578218	0.005382501	CB1206	11kV
04/07/2022	9:49:00 AM	04/07/2022	2:56:00 PM	Third Party	0.226923958	0.001288365	CB1105	6.35kV
04/07/2022	2:08:57 PM	04/07/2022	8:50:00 PM	Defective Equipment	0.680628722	0.024278516	CB1782	11kV
05/07/2022	3:28:00 PM	05/07/2022	4:30:00 PM	Unknown	0.127805772	0.002061383	CB1109	11kV
06/07/2022	2:16:13 PM	06/07/2022	9:05:00 PM	Vegetation	1.246363949	0.013628035	CB1722	11kV
07/07/2022	1:35:09 AM	07/07/2022	3:19:02 AM	Wildlife	2.583571919	0.028286761	CB0108	11kV
08/07/2022	9:55:00 AM	08/07/2022	12:30:00 PM	Defective Equipment	0.759133074	0.012425561	CB1722	11kV
08/07/2022	10:37:00 AM	08/07/2022	2:45:00 PM	Defective Equipment	0	0	CB1108	11kV
08/07/2022	11:46:46 AM	08/07/2022	9:26:00 PM	Vegetation	0.747595053	0.009877462	CB1206	11kV
08/07/2022	2:04:58 PM	08/07/2022	4:04:57 PM	Defective Equipment	0.793518094	0.006613605	CB1782	11kV
08/07/2022	7:32:40 PM	09/07/2022	5:30:00 PM	Adverse Weather	1.178166514	0.00701443	CB0206	11kV
11/07/2022	9:01:46 PM	12/07/2022	1:42:00 AM	Adverse Weather	2.112803481	0.020442052	CB1109	11kV
11/07/2022	9:51:18 PM	12/07/2022	2:27:52 PM	Adverse Weather	0.516806001	0.015231333	CB1105	11kV
11/07/2022	10:20:02 PM	12/07/2022	10:36:00 AM	Adverse Weather	2.624398763	0.009390747	131142	11kV

12/07/2022	12:40:00 AM	12/07/2022	10:11:00 AM	Adverse Weather	0.081596427	0.001316995	41692	11kV
12/07/2022	1:36:15 AM	12/07/2022	1:04:00 PM	Vegetation	1.51674874	0.00964842	CB0108	11kV
12/07/2022	3:28:00 AM	13/07/2022	3:00:00 PM	Adverse Weather	0.210261109	0.000515346	CB1206	11kV
12/07/2022	3:28:14 AM	12/07/2022	9:33:51 PM	Adverse Weather	1.796896473	0.009362116	CB1206	11kV
12/07/2022	3:31:00 AM	12/07/2022	5:32:00 AM	Adverse Weather	0.315248511	0.00260536	41692	11kV
12/07/2022	4:15:13 AM	12/07/2022	6:42:32 AM	Vegetation	0.238834173	0.002261796	CB1406	11kV
12/07/2022	5:16:00 AM	12/07/2022	10:48:00 AM	Adverse Weather	0.408726523	0.001231104	CB0209	11kV
12/07/2022	6:34:17 AM	12/07/2022	9:29:14 AM	Adverse Weather	2.300045809	0.01319858	CB0206	11kV
12/07/2022	7:03:16 AM	12/07/2022	12:27:00 PM	Adverse Weather	1.508531837	0.012711864	CB1206	11kV
12/07/2022	7:09:00 AM	12/07/2022	10:04:00 AM	Adverse Weather	0.070144297	0.000400825	CB0608	11kV
12/07/2022	9:08:00 AM	12/07/2022	1:32:00 PM	Adverse Weather	0.090042373	0.000372194	41632	11kV
12/07/2022	12:26:00 PM	12/07/2022	12:43:00 PM	Adverse Weather	0.003893724	0.000229043	171112	11kV
12/07/2022	12:56:45 PM	12/07/2022	3:45:00 PM	Defective Equipment	1.743443656	0.024135364	CB0209	11kV
13/07/2022	3:01:00 PM	13/07/2022	5:51:00 PM	Unknown	0.384505268	0.002261796	CB0209	11kV
13/07/2022	6:23:00 PM	13/07/2022	7:39:00 PM	Defective Equipment	0.108795236	0.001431516	CB1108	11kV
14/07/2022	6:43:00 PM	15/07/2022	12:52:00 AM	Third Party	0.746993816	0.007243472	51762	11kV
14/07/2022	6:50:00 PM	15/07/2022	1:40:00 PM	Vegetation	1.195001145	0.01674874	41672	11kV
14/07/2022	7:03:25 PM	15/07/2022	11:43:00 AM	Defective Equipment	1.606705222	0.009276225	131142	11kV
14/07/2022	10:14:20 PM	15/07/2022	2:22:00 PM	Vegetation	2.233652084	0.013628035	CB1722	11kV
15/07/2022	9:33:42 AM	15/07/2022	10:35:45 AM	Defective Equipment	0.214956482	0.003464269	CB1732	11kV
18/07/2022	1:40:08 PM	18/07/2022	3:39:43 PM	Defective Equipment	0.280748969	0.002347687	CB0109	11kV
19/07/2022	5:35:29 PM	20/07/2022	10:38:00 AM	Wildlife	1.131499084	0.022303023	CB0105	11kV
20/07/2022	8:02:00 PM	21/07/2022	12:23:00 PM	Defective Equipment	0.040196977	0.000314934	CB1105	11kV
22/07/2022	6:38:00 AM	22/07/2022	10:44:00 AM	Defective Equipment	0.05634448	0.000229043	CB1722	11kV
23/07/2022	1:41:00 PM	23/07/2022	3:24:00 PM	Defective Equipment	0.05016033	0.000572607	CB1782	11kV
23/07/2022	4:36:00 PM	23/07/2022	6:55:00 PM	Defective Equipment	0.039423958	0.00085891	CB1782	11kV
23/07/2022	11:08:30 PM	23/07/2022	11:48:03 PM	Unknown	0.401969766	0.010163765	181112	11kV
24/07/2022	4:37:00 AM	24/07/2022	6:44:00 AM	Unknown	0.065849748	0.000687128	CB1108	6.35kV
24/07/2022	8:17:00 AM	24/07/2022	11:28:00 AM	Defective Equipment	0.104500687	0.000629867	CB1108	6.35kV
24/07/2022	2:21:00 PM	26/07/2022	2:55:00 PM	Adverse Weather	6.079993129	0.045006871	CB1105	11kV
24/07/2022	5:47:58 PM	26/07/2022	12:24:00 PM	Adverse Weather	0.9647847	0.00174645	51742	11kV
24/07/2022	5:49:00 PM	25/07/2022	7:11:00 PM	Adverse Weather	0.26145213	0.000171782	51762	6.35kV
24/07/2022	6:52:13 PM	25/07/2022	5:12:40 PM	Adverse Weather	3.394268209	0.029517865	CB1206	11kV
24/07/2022	9:38:00 PM	25/07/2022	4:07:00 PM	Adverse Weather	0.430886395	0.001002061	CB1206	11kV
25/07/2022	1:09:34 AM	25/07/2022	10:21:00 AM	Adverse Weather	0.258188273	0.014229272	CB1406	11kV
25/07/2022	2:07:53 AM	25/07/2022	1:14:00 PM	Adverse Weather	5.08892579	0.019754924	CB1108	11kV
25/07/2022	2:09:00 AM	25/07/2022	12:58:00 PM	Adverse Weather	0.456195602	0.002691251	CB1722	11kV
25/07/2022	6:02:00 AM	25/07/2022	7:10:00 PM	Adverse Weather	3.781951443	0.005153459	51762	11kV
25/07/2022	8:45:00 AM	26/07/2022	12:27:00 PM	Adverse Weather	0.446489922	0.008417316	131142	11kV
25/07/2022	8:59:20 AM	25/07/2022	4:25:00 PM	Adverse Weather	15.01958314	0.05989464	33882	33kV
25/07/2022	9:04:00 AM	25/07/2022	3:07:00 PM	Adverse Weather	0.05196404	0.000143152	41672	11kV
25/07/2022	9:24:00 AM	25/07/2022	11:20:00 AM	Adverse Weather	0.026568942	0.000229043	CB1722	11kV
25/07/2022	9:31:00 AM	25/07/2022	5:25:00 PM	Adverse Weather	0.583543289	0.001231104	CB0209	11kV
25/07/2022	9:35:00 AM	25/07/2022	2:07:00 PM	Adverse Weather	0.241410902	0.00088754	CB1108	11kV
25/07/2022	10:29:00 AM	25/07/2022	3:52:00 PM	Vegetation	0.092475951	0.000286303	CB0110	11kV
25/07/2022	10:46:00 AM	25/07/2022	1:03:00 PM	Adverse Weather	0.007844709	5.72607E-05	CB1205	11kV
25/07/2022	11:06:00 AM	25/07/2022	2:12:00 PM	Adverse Weather	0.585776454	0.003149336	131132	11kV
25/07/2022	12:00:15 PM	26/07/2022	6:45:00 PM	Adverse Weather	2.036789968	0.013341732	CB1206	11kV
25/07/2022	1:03:56 PM	25/07/2022	2:21:50 PM	Adverse Weather	1.231132616	0.01580394	181182	11kV
25/07/2022	3:43:03 PM	25/07/2022	4:36:33 PM	Adverse Weather	0.940477554	0.01757902	171122	11kV
25/07/2022	5:51:00 PM	26/07/2022	1:05:00 PM	Adverse Weather	0.48505497	0.001231104	CB0209	11kV
25/07/2022	7:28:00 PM	26/07/2022	11:14:00 AM	Adverse Weather	0.131355932	0.001030692	CB1108	11kV
25/07/2022	8:00:00 PM	26/07/2022	2:51:00 PM	Lightning	0.615237059	0.000543976	51762	11kV
26/07/2022	8:34:00 AM	26/07/2022	12:49:00 PM	Vegetation	0.002805772	0.000200412	CB0209	11kV
26/07/2022	9:43:01 AM	26/07/2022	1:26:00 PM	Adverse Weather	4.390489006	0.05989464	33882	33kV
26/07/2022	1:41:00 PM	26/07/2022	6:08:00 PM	Lightning	0.015288594	5.72607E-05	51762	11kV
26/07/2022	4:14:34 PM	26/07/2022	9:29:00 PM	Defective Equipment	1.945545121	0.022303023	CB0105	11kV
26/07/2022	4:34:00 PM	26/07/2022	8:43:00 PM	Vegetation	0.049902657	0.000200412	CB0209	11kV
27/07/2022	8:53:00 AM	05/08/2022	5:25:00 PM	Third Party	0.58454535	0.031464727	CB1322	11kV
27/07/2022	2:43:39 PM	28/07/2022	12:40:00 PM	Vegetation	0.075383646	5.72607E-05	CB1772	11kV
27/07/2022	4:25:35 PM	28/07/2022	3:22:00 PM	Third Party	0.641462437	0.008016491	CB1322	11kV
28/07/2022	4:37:41 AM	28/07/2022	5:12:44 AM	Vegetation	0.254065506	0.008989922	CB0110	11kV
28/07/2022	4:59:49 AM	28/07/2022	5:24:54 AM	Vegetation	0.127118644	0.005067568	41622	11kV
28/07/2022	3:42:59 PM	28/07/2022	6:53:11 PM	Defective Equipment	0.534155978	0.002376317	CB1206	11kV
30/07/2022	8:17:00 AM	30/07/2022	9:48:00 AM	Defective Equipment	0.013026798	0.000143152	CB1206	11kV
30/07/2022	9:53:00 AM	30/07/2022	10:38:00 AM	Defective Equipment	0.083743701	0.001860971	CB0108	11kV
01/08/2022	10:13:00 AM	01/08/2022	2:02:00 PM	Unknown	0.163908612	0.000715758	CB0206	11kV
01/08/2022	2:20:00 PM	01/08/2022	3:54:00 PM	Defective Equipment	0.005382501	5.72607E-05	CB0109	11kV
02/08/2022	6:34:00 AM	02/08/2022	3:03:00 PM	Defective Equipment	0.1215071	0.000343564	CB0111	11kV
02/08/2022	2:44:00 PM	02/08/2022	3:14:00 PM	Defective Equipment	0.134848832	0.004494961	131142	11kV

02/08/2022	4:57:00 PM	02/08/2022	6:07:00 PM	Defective Equipment	0.064131929	0.00091617	CB1782	11kV
03/08/2022	8:38:00 AM	03/08/2022	4:18:00 PM	Vegetation	0.192481677	0.001116583	CB1206	11kV
05/08/2022	10:43:24 AM	19/08/2022	5:16:00 PM	Adverse Weather	1.99561956	0.001231104	CB1782	11kV
07/08/2022	11:58:00 PM	08/08/2022	3:11:00 AM	Adverse Environment	0.077359139	0.000400825	CB0105	11kV
08/08/2022	12:28:00 PM	08/08/2022	6:10:00 PM	Third Party	0.166972057	0.000715758	CB0206	11kV
08/08/2022	2:30:23 PM	08/08/2022	2:31:51 PM	Human Error	0.019783555	0.013484883	CB1722	11kV
08/08/2022	7:36:29 PM	09/08/2022	3:32:00 PM	Defective Equipment	1.629265918	0.022217132	CB0209	11kV
09/08/2022	6:53:00 AM	09/08/2022	8:06:00 AM	Defective Equipment	0.075240495	0.001030692	CB1108	11kV
10/08/2022	4:52:03 AM	10/08/2022	6:37:00 AM	Third Party	0.338295923	0.003464269	CB1732	11kV
11/08/2022	7:33:00 AM	11/08/2022	9:01:00 AM	Wildlife	0.060581768	0.000715758	CB0105	11kV
12/08/2022	5:03:27 AM	12/08/2022	6:45:00 AM	Vegetation	0.295493587	0.005067568	41622	11kV
12/08/2022	6:24:00 AM	12/08/2022	8:21:00 AM	Vegetation	0.450526798	0.005096198	CB0210	11kV
13/08/2022	7:56:00 AM	13/08/2022	7:58:00 AM	Defective Equipment	5.72607E-05	2.86303E-05	CB0206	11kV
16/08/2022	10:32:00 AM	16/08/2022	3:44:00 PM	Defective Equipment	0.008932661	2.86303E-05	CB1782	11kV
17/08/2022	9:41:00 AM	17/08/2022	10:36:00 AM	Adverse Weather	0.173213468	0.003149336	131132	11kV
17/08/2022	3:15:00 PM	17/08/2022	4:41:00 PM	Adverse Weather	0.004924416	5.72607E-05	171122	11kV
17/08/2022	4:29:00 PM	17/08/2022	7:01:00 PM	Adverse Weather	0.026110857	0.000171782	CB0105	11kV
17/08/2022	8:35:00 PM	18/08/2022	3:40:25 AM	Adverse Weather	2.35830852	0.011681173	CB1208	11kV
17/08/2022	10:12:00 PM	19/08/2022	2:27:00 PM	Adverse Weather	0.556201328	0.00171782	CB1108	6.35kV
17/08/2022	11:02:48 PM	17/08/2022	11:22:20 PM	Adverse Weather	0.686183005	0.035129409	273332	33kV
17/08/2022	11:32:12 PM	18/08/2022	10:14:09 AM	Adverse Weather	4.163450527	0.006642235	CB1109	11kV
18/08/2022	12:12:41 AM	21/08/2022	1:05:34 AM	Adverse Weather	5.550647045	0.016806001	131142	11kV
18/08/2022	2:59:11 AM	20/08/2022	3:35:00 PM	Adverse Weather	5.439504123	0.009848832	CB1206	11kV
18/08/2022	3:34:17 AM	18/08/2022	5:33:00 PM	Adverse Weather	3.826643381	0.010936784	CB1108	11kV
18/08/2022	5:17:00 AM	18/08/2022	11:34:00 AM	Adverse Weather	0.293088639	0.00091617	CB0110	11kV
18/08/2022	5:43:00 AM	18/08/2022	9:24:00 AM	Adverse Weather	0.269669033	0.001231104	CB0209	11kV
18/08/2022	6:55:54 AM	18/08/2022	11:14:00 AM	Adverse Weather	1.618157352	0.01231104	51772	11kV
18/08/2022	8:04:21 AM	18/08/2022	3:11:00 PM	Adverse Weather	4.683377233	0.041170408	CB0208	11kV
18/08/2022	8:42:00 AM	18/08/2022	6:34:00 PM	Adverse Weather	0.033898305	5.72607E-05	131132	11kV
18/08/2022	9:17:13 AM	18/08/2022	6:33:00 PM	Adverse Weather	1.095739808	0.00263399	CB0206	11kV
18/08/2022	9:46:34 AM	18/08/2022	2:15:00 PM	Adverse Weather	0.843907467	0.003721942	CB1712	11kV
18/08/2022	10:36:35 AM	18/08/2022	4:16:00 PM	Adverse Weather	1.154231562	0.00964842	CB0108	11kV
18/08/2022	11:16:42 AM	18/08/2022	1:05:00 PM	Adverse Weather	1.324152542	0.013484883	CB1722	11kV
18/08/2022	11:17:00 AM	18/08/2022	3:18:00 PM	Adverse Weather	0.096598717	0.000400825	CB0608	11kV
18/08/2022	11:50:49 AM	19/08/2022	1:57:00 PM	Adverse Weather	3.857879066	0.007214842	CB0206	11kV
18/08/2022	12:16:00 PM	20/08/2022	6:49:00 PM	Adverse Weather	0.094938158	5.72607E-05	CB1406	11kV
18/08/2022	2:02:47 PM	18/08/2022	3:19:34 PM	Adverse Weather	0.252805772	0.003292487	CB0110	11kV
18/08/2022	2:48:10 PM	22/08/2022	12:27:00 PM	Adverse Weather	0.661245992	0.00091617	CB1105	11kV
18/08/2022	3:19:00 PM	20/08/2022	2:50:00 PM	Adverse Weather	0.271959459	0.000400825	CB1722	11kV
18/08/2022	4:16:00 PM	18/08/2022	7:41:00 PM	Adverse Weather	1.055142006	0.011509391	CB0208	11kV
18/08/2022	5:02:08 PM	21/08/2022	12:29:00 PM	Adverse Weather	0.292487403	0.004208658	CB1712	11kV
18/08/2022	5:20:06 PM	19/08/2022	7:19:00 PM	Adverse Weather	1.054855703	0.002404947	CB0108	11kV
18/08/2022	5:31:00 PM	18/08/2022	8:25:00 PM	Adverse Weather	0.348717361	0.002004123	131132	11kV
18/08/2022	7:30:00 PM	19/08/2022	1:32:00 PM	Adverse Weather	0.079706825	0.00091617	CB0111	6.35kV
19/08/2022	3:32:56 AM	19/08/2022	5:38:44 AM	Adverse Weather	3.518008475	0.02820087	CB0108	11kV
19/08/2022	7:11:05 AM	19/08/2022	8:48:32 AM	Adverse Weather	1.314103298	0.013484883	CB1722	11kV
19/08/2022	9:20:12 AM	19/08/2022	1:40:00 PM	Adverse Weather	0.32747366	0.001345625	51742	11kV
19/08/2022	10:12:00 AM	19/08/2022	11:09:00 AM	Adverse Weather	0.013055428	0.000229043	CB1112	11kV
19/08/2022	10:35:00 AM	20/08/2022	9:26:00 AM	Adverse Weather	1.529632387	0.001116583	CB1206	6.35kV
19/08/2022	12:18:00 PM	19/08/2022	4:51:00 PM	Adverse Weather	0.099175447	0.000372194	41632	11kV
19/08/2022	1:32:00 PM	19/08/2022	4:28:00 PM	Adverse Weather	0.010077874	5.72607E-05	CB0108	11kV
19/08/2022	1:46:00 PM	19/08/2022	7:02:00 PM	Adverse Weather	0.528830738	0.004781264	CB1109	11kV
19/08/2022	4:47:13 PM	20/08/2022	11:03:00 AM	Adverse Weather	1.143896015	0.008073752	CB0105	11kV
21/08/2022	8:51:00 AM	21/08/2022	11:26:00 AM	Unknown	0.142006413	0.00091617	131142	11kV
23/08/2022	5:14:00 AM	23/08/2022	12:14:00 PM	Vegetation	0.107191938	0.000572607	CB1782	11kV
23/08/2022	6:54:22 PM	23/08/2022	10:03:00 PM	Defective Equipment	0.653057719	0.01056459	CB1732	11kV
24/08/2022	2:49:00 AM	24/08/2022	1:14:00 PM	Defective Equipment	0.004466331	5.72607E-05	CB0105	22kV
25/08/2022	2:02:11 PM	25/08/2022	4:57:00 PM	Lightning	2.165368759	0.012654604	41632	11kV
25/08/2022	6:32:51 PM	27/08/2022	11:35:00 AM	Vegetation	1.410959689	0.009848832	CB1206	11kV
26/08/2022	11:07:21 AM	26/08/2022	10:13:00 PM	Vegetation	49.8083486	0.15841159	151162	33kV
27/08/2022	9:02:00 AM	27/08/2022	3:21:00 PM	Vegetation	0.445774164	0.001288365	CB1105	6.35kV
27/08/2022	3:49:32 PM	27/08/2022	4:13:04 PM	Defective Equipment	0.492527485	0.022818369	CB1205	11kV
01/09/2022	9:31:00 AM	01/09/2022	2:24:00 PM	Defective Equipment	0.184551077	0.000629867	CB1732	11kV
03/09/2022	5:34:00 AM	03/09/2022	8:57:00 AM	Unknown	0.185982593	0.00091617	131142	11kV
04/09/2022	7:46:22 AM	04/09/2022	9:30:00 AM	Wildlife	1.638112689	0.034671324	41682	11kV
05/09/2022	1:04:00 PM	05/09/2022	3:32:00 PM	Unknown	0.237603069	0.002548099	41632	11kV
05/09/2022	3:14:00 PM	05/09/2022	6:23:00 PM	Defective Equipment	0.150309208	0.00085891	191782	11kV
05/09/2022	10:53:19 PM	06/09/2022	9:29:00 AM	Defective Equipment	0.789882043	0.003206596	CB1406	11kV
06/09/2022	1:17:18 AM	06/09/2022	2:26:00 PM	Vegetation	2.538965873	0.014229272	CB0105	11kV
06/09/2022	1:48:28 AM	06/09/2022	12:58:00 PM	Vegetation	7.029288823	0.046037563	CB1105	11kV

06/09/2022	1:52:00 AM	06/09/2022	3:27:17 AM	Vegetation	0.35736372	0.003750573	CB0206	11kV
06/09/2022	2:15:20 AM	06/09/2022	10:11:00 AM	Vegetation	1.279861429	0.01583257	CB1408	11kV
06/09/2022	5:13:12 AM	07/09/2022	2:16:00 PM	Vegetation	2.739578562	0.013742556	CB1722	11kV
06/09/2022	6:01:00 AM	06/09/2022	12:47:00 PM	Vegetation	0.05811956	0.000143152	41672	11kV
06/09/2022	7:41:00 AM	06/09/2022	10:57:00 AM	Defective Equipment	0.132873339	0.000744388	CB1108	11kV
06/09/2022	10:32:00 AM	06/09/2022	10:37:00 PM	Defective Equipment	0.082083142	0.000543976	CB1406	11kV
06/09/2022	8:28:00 AM	06/09/2022	1:36:00 PM	Adverse Weather	0.01763628	5.72607E-05	CB1205	11kV
06/09/2022	3:49:58 PM	07/09/2022	12:04:17 AM	Defective Equipment	5.166914796	0.01233967	CB0209	11kV
08/09/2022	7:59:00 AM	08/09/2022	8:10:00 AM	Human Error	0.000314934	2.86303E-05	41692	11kV
12/09/2022	6:06:29 AM	12/09/2022	7:29:17 AM	Defective Equipment	0.773133303	0.023305085	CB1206	11kV
12/09/2022	12:58:00 AM	12/09/2022	11:03:00 AM	Defective Equipment	0.081166972	0.000944801	51762	11kV
12/09/2022	5:47:41 PM	12/09/2022	6:48:00 PM	Defective Equipment	0.054139945	0.00088754	CB1205	11kV
16/09/2022	2:55:38 PM	16/09/2022	2:57:39 PM	Unknown	0.006069629	0.003006184	CB1105	6.35kV
19/09/2022	8:56:47 AM	19/09/2022	1:37:00 PM	Defective Equipment	1.305628722	0.009419377	131142	11kV
19/09/2022	8:55:00 AM	19/09/2022	11:05:00 AM	Unknown	1.197577874	0.010192396	181112	11kV
19/09/2022	1:23:00 PM	19/09/2022	8:02:00 PM	Defective Equipment	0.201872423	0.000944801	CB1105	11kV
23/09/2022	9:09:45 AM	23/09/2022	10:16:43 AM	Defective Equipment	0.442882501	0.006613605	CB1206	11kV
23/09/2022	1:49:48 PM	23/09/2022	2:21:21 PM	Lightning	0.14000229	0.0044377	41612	11kV
28/09/2022	2:37:00 PM	28/09/2022	6:22:00 PM	Defective Equipment	0.830279432	0.00523935	51762	11kV
30/09/2022	11:39:56 AM	30/09/2022	11:54:00 PM	Unknown	0.78258131	0.004924416	CB1782	11kV
01/10/2022	7:05:33 AM	01/10/2022	9:35:00 AM	Vegetation	0.914223546	0.013341732	CB0105	11kV
01/10/2022	8:37:05 AM	01/10/2022	2:21:00 PM	Unknown	1.251202474	0.009419377	131142	11kV
01/10/2022	10:30:05 AM	01/10/2022	2:14:00 PM	Defective Equipment	2.501488777	0.012654604	41632	11kV
01/10/2022	10:32:47 AM	02/10/2022	2:55:32 PM	Adverse Environment	0.787677508	0.00091617	CB1105	11kV
01/10/2022	10:46:32 AM	01/10/2022	12:24:43 PM	Vegetation	0.497537792	0.005067568	41622	11kV
04/10/2022	9:08:35 AM	04/10/2022	2:46:00 PM	Defective Equipment	0.589097572	0.00180371	CB1206	11kV
06/10/2022	1:49:36 PM	06/10/2022	5:25:00 PM	Vegetation	1.948494045	0.010707742	51742	11kV
06/10/2022	2:46:00 PM	06/10/2022	3:42:00 PM	Defective Equipment	0.046495648	0.000830279	CB0110	11kV
06/10/2022	2:54:55 PM	06/10/2022	2:59:14 PM	Unknown	0.034843106	0.008073752	CB0105	11kV
09/10/2022	11:13:59 AM	09/10/2022	4:40:00 PM	Third Party	0.738061154	0.010879524	CB1108	11kV
11/10/2022	9:06:11 AM	11/10/2022	1:16:15 PM	Wildlife	2.661818598	0.070172927	51762	11kV
14/10/2022	12:15:12 PM	14/10/2022	4:48:00 PM	Vegetation	0.606418919	0.009848832	CB1206	11kV
14/10/2022	12:01:00 PM	14/10/2022	2:32:00 PM	Unknown	0.043231791	0.000286303	CB0108	11kV
14/10/2022	2:53:00 PM	14/10/2022	5:47:00 PM	Unknown	0.084688502	0.000715758	CB0206	11kV
15/10/2022	1:37:00 AM	15/10/2022	3:05:00 AM	Vegetation	0.020155749	0.000229043	CB1782	11kV
15/10/2022	6:58:00 AM	15/10/2022	10:25:00 AM	Unknown	0.064990838	0.000372194	41632	11kV
15/10/2022	6:05:16 PM	15/10/2022	10:58:00 PM	Vegetation	1.47363147	0.01233967	51772	11kV
16/10/2022	8:06:57 AM	16/10/2022	12:04:00 PM	Defective Equipment	0.300418003	0.018208887	131142	11kV
16/10/2022	8:15:00 AM	19/10/2022	5:35:00 PM	Defective Equipment	0.554426248	0.000114521	CB1406	11kV
17/10/2022	9:35:00 AM	17/10/2022	3:33:00 PM	Defective Equipment	0.040998626	0.000114521	CB1109	11kV
17/10/2022	2:41:00 PM	17/10/2022	9:17:00 PM	Defective Equipment	0.351465873	0.00088754	CB0111	6.35kV
19/10/2022	6:31:00 PM	20/10/2022	11:56:00 AM	Vegetation	0.528229501	0.001288365	CB1105	6.35kV
20/10/2022	11:05:00 AM	20/10/2022	1:46:00 PM	Unknown	0.322663765	0.002004123	131132	11kV
21/10/2022	8:22:00 AM	21/10/2022	9:06:00 AM	Third Party	0.054168575	0.001231104	CB1782	11kV
23/10/2022	11:15:59 PM	24/10/2022	6:43:00 AM	Third Party	1.294548786	0.008102382	CB0105	11kV
26/10/2022	1:16:00 PM	26/10/2022	6:20:00 PM	Defective Equipment	0.272847	0.003435639	CB0108	11kV
27/10/2022	1:07:00 PM	27/10/2022	6:01:00 PM	Unknown	0.350606963	0.001288365	CB1105	6.35kV
28/10/2022	5:17:47 PM	28/10/2022	8:37:00 PM	Defective Equipment	2.495333257	0.035415712	CB0107	11kV
29/10/2022	11:21:53 AM	29/10/2022	4:14:00 PM	Third Party	0.436154375	0.003636051	41692	11kV
29/10/2022	2:22:58 PM	29/10/2022	7:11:00 PM	Defective Equipment	2.183262712	0.009047183	CB0110	11kV
30/10/2022	4:40:54 AM	30/10/2022	11:22:00 AM	Vegetation	4.682604214	0.014229272	CB0111	11kV
30/10/2022	11:50:14 AM	30/10/2022	1:22:23 PM	Vegetation	1.229443426	0.013341732	CB1722	11kV
31/10/2022	12:00:00 PM	31/10/2022	1:44:00 PM	Defective Equipment	0.087837838	0.000944801	CB1105	11kV
31/10/2022	1:52:00 PM	31/10/2022	7:46:00 PM	Defective Equipment	0.293918919	0.000830279	CB0209	11kV
01/11/2022	12:09:43 AM	01/11/2022	12:50:00 PM	Defective Equipment	0.272073981	0.001603298	CB0105	11kV
05/11/2022	7:57:01 AM	05/11/2022	8:27:36 AM	Wildlife	1.074381585	0.035129409	41682	11kV
07/11/2022	11:41:57 PM	08/11/2022	2:03:00 AM	Vegetation	0.782982135	0.007157581	181142	11kV
08/11/2022	6:12:14 AM	08/11/2022	11:48:00 AM	Third Party	1.19809322	0.01672011	41672	11kV
08/11/2022	8:53:00 AM	08/11/2022	1:13:47 PM	Vegetation	0.970625286	0.003721942	CB1712	11kV
10/11/2022	8:06:12 PM	11/11/2022	12:45:00 AM	Vegetation	2.871907925	0.019611773	CB0208	11kV
10/11/2022	11:02:55 PM	11/11/2022	1:50:54 AM	Lightning	6.937986716	0.042172469	CB0209	11kV
11/11/2022	12:19:30 AM	11/11/2022	3:21:00 PM	Vegetation	8.338410444	0.041513972	51762	11kV
14/11/2022	9:33:00 AM	14/11/2022	3:48:00 PM	Vegetation	0.246936555	0.000658497	51762	11kV
14/11/2022	6:53:00 PM	14/11/2022	7:39:00 PM	Defective Equipment	0.030290884	0.000658497	51762	11kV
17/11/2022	9:05:50 AM	17/11/2022	9:27:03 AM	Unknown	0.556058177	0.035158039	CB1142	33kV
17/11/2022	10:31:31 AM	17/11/2022	11:53:00 AM	Vegetation	3.551878149	0.076786532	CB1406	33kV
19/11/2022	6:41:46 AM	19/11/2022	7:29:22 AM	Unknown	0.590385937	0.023448236	173352	33kV
19/11/2022	10:57:36 AM	19/11/2022	11:07:12 AM	Unknown	0.322577874	0.035158039	CB1142	33kV
19/11/2022	2:18:28 PM	19/11/2022	2:53:54 PM	Vegetation	0.681888456	0.018953275	CB1105	11kV
22/11/2022	3:50:45 AM	22/11/2022	10:02:00 AM	Adverse Weather	5.290082455	0.05631585	51772	11kV

22/11/2022	5:48:00 AM	22/11/2022	1:33:00 PM	Unknown	0.10650481	0.000229043	CB1105	11kV
22/11/2022	2:20:06 PM	22/11/2022	5:23:00 PM	Vegetation	0.326901054	0.005067568	41622	11kV
22/11/2022	2:29:45 PM	22/11/2022	6:59:00 PM	Vegetation	3.276254008	0.014343793	CB1722	11kV
22/11/2022	2:42:08 PM	22/11/2022	4:40:00 PM	Vegetation	0.681659414	0.009047183	CB0110	11kV
22/11/2022	2:23:00 PM	23/11/2022	2:19:00 PM	Lightning	0.228269583	0.000515346	51762	11kV
22/11/2022	4:24:00 PM	22/11/2022	6:54:00 PM	Lightning	0.150309208	0.001002061	CB1206	11kV
22/11/2022	2:07:00 PM	23/11/2022	2:50:00 PM	Defective Equipment	1.443054283	0.001889601	CB0105	11kV
22/11/2022	2:41:00 PM	23/11/2022	10:25:00 AM	Defective Equipment	0.305084746	0.000257673	CB0111	6.35kV
22/11/2022	7:55:49 PM	23/11/2022	11:42:00 AM	Vegetation	1.042859597	0.018323408	51772	11kV
22/11/2022	8:11:23 PM	23/11/2022	11:15:00 AM	Vegetation	2.60561727	0.009047183	CB0110	11kV
22/11/2022	8:15:27 PM	23/11/2022	3:08:00 PM	Vegetation	1.384791571	0.015975721	CB1782	11kV
22/11/2022	9:04:11 PM	23/11/2022	3:20:38 PM	Vegetation	1.415998626	0.014315163	CB0111	11kV
22/11/2022	8:34:00 PM	23/11/2022	7:40:00 PM	Vegetation	0.396816308	0.000286303	CB0110	11kV
23/11/2022	2:26:12 AM	23/11/2022	2:27:56 AM	Unknown	0.086205909	0.049730875	CB1208	11kV
23/11/2022	7:36:18 AM	23/11/2022	9:50:32 AM	Vegetation	1.258188273	0.009848832	CB1206	11kV
23/11/2022	11:03:00 AM	23/11/2022	3:00:00 PM	Third Party	1.517321347	0.006613605	CB1110	11kV
23/11/2022	6:38:00 AM	23/11/2022	11:21:00 AM	Lightning	0.567166743	0.002004123	131132	11kV
23/11/2022	7:12:00 AM	23/11/2022	3:27:00 PM	Defective Equipment	0.506670866	0.001488777	51762	11kV
23/11/2022	10:16:00 AM	24/11/2022	3:23:00 PM	Vegetation	0.215185525	0.011165827	CB0105	11kV
24/11/2022	12:30:06 PM	24/11/2022	6:10:00 PM	Vegetation	0.457569858	0.004008246	CB1312	11kV
26/11/2022	10:50:00 AM	26/11/2022	11:55:00 AM	Defective Equipment	0.100492442	0.001546038	CB1105	11kV
28/11/2022	10:12:00 AM	28/11/2022	1:13:00 PM	Defective Equipment	0.098459689	0.000543976	31312	11kV
29/11/2022	12:02:12 AM	29/11/2022	2:43:00 AM	Wildlife	0.788794091	0.013771186	CB0105	11kV
01/12/2022	10:12:00 AM	01/12/2022	12:23:00 PM	Defective Equipment	0.123768896	0.000944801	CB1105	6.35kV
01/12/2022	11:10:30 AM	01/12/2022	4:15:00 PM	Unknown	0.593821576	0.010850893	CB1108	11kV
01/12/2022	3:32:00 PM	01/12/2022	6:53:00 PM	Unknown	0.166027256	0.00088754	CB0108	11kV
05/12/2022	1:21:19 PM	05/12/2022	2:32:00 PM	Vegetation	0.991382272	0.015030921	41692	11kV
06/12/2022	9:00:31 AM	06/12/2022	2:41:00 PM	Defective Equipment	0.356304398	0.003950985	131142	11kV
06/12/2022	9:02:00 AM	06/12/2022	1:17:00 PM	Vegetation	0.12411246	0.000486716	131132	11kV
06/12/2022	9:05:00 AM	06/12/2022	1:23:00 PM	Defective Equipment	0.125572607	0.000486716	CB0108	11kV
06/12/2022	10:02:00 AM	06/12/2022	12:23:00 PM	Defective Equipment	0.016032982	0.000114521	CB0105	11kV
06/12/2022	3:41:55 PM	06/12/2022	4:24:00 PM	Vegetation	0.090385937	0.002261796	CB1406	11kV
06/12/2022	6:29:00 PM	06/12/2022	9:27:58 PM	Vegetation	0.404775538	0.002261796	CB1406	11kV
07/12/2022	7:47:14 AM	07/12/2022	11:21:00 AM	Unknown	3.94276798	0.029117041	51762	11kV
07/12/2022	12:16:43 PM	07/12/2022	3:13:00 PM	Unknown	0.368930371	0.003292487	CB0110	11kV
07/12/2022	2:35:51 PM	07/12/2022	4:35:52 PM	Vegetation	0.659528172	0.008589098	CB0111	11kV
07/12/2022	2:19:00 PM	07/12/2022	3:27:00 PM	Unknown	0.017521759	0.000257673	41672	11kV
07/12/2022	3:04:56 PM	12/10/202	2 12:14:00 PM	Defective Equipment	1.478498626	0.003578791	CB1732	11kV
07/12/2022	5:57:11 PM	07/12/2022	7:28:00 PM	Vegetation	0.317997022	0.014229272	CB1406	11kV
07/12/2022	8:14:00 PM	08/12/2022	9:05:00 AM	Vegetation	0.706367384	0.00091617	51762	6.35kV
08/12/2022	9:12:00 AM	08/12/2022	9:56:00 AM	Defective Equipment	0.036532295	0.000830279	CB1105	11kV
08/12/2022	11:09:00 AM	08/12/2022	12:43:00 PM	Vegetation	0.18838754	0.002004123	CB1105	11kV
08/12/2022	1:01:46 PM	08/12/2022	2:21:54 PM	Vegetation	0.220253092	0.002748511	CB0111	11kV
09/12/2022	3:45:20 AM	09/12/2022	3:52:11 AM	Unknown	0.0114235	0.004724004	CB1772	11kV
09/12/2022	4:56:32 AM	09/12/2022	5:03:59 AM	Vegetation	0.03518667	0.004724004	CB1772	11kV
09/12/2022	9:07:00 PM	09/12/2022	11:53:00 PM	Unknown	0.152084288	0.00091617	131142	11kV
11/12/2022	7:54:02 PM	11/12/2022	10:12:29 PM	Third Party	0.221970912	0.001603298	CB0105	22kV
13/12/2022	1:32:58 PM	16/12/2022	9:53:00 PM	Unknown	0.603326844	0.006785387	CB1109	11kV
15/12/2022	7:37:00 AM	15/12/2022	11:05:00 AM	Defective Equipment	0.038192854	0.000830279	CB0105	11kV
16/12/2022	8:32:02 PM	16/12/2022	8:33:34 PM	Unknown	0.013570774	0.00884677	CB1105	11kV
17/12/2022	12:51:44 AM	17/12/2022	4:16:00 AM	Vegetation	1.002032753	0.007100321	CB0206	11kV
19/12/2022	10:02:16 AM	19/12/2022	12:17:08 PM	Defective Equipment	1.183377233	0.03346885	CB1207	11kV
19/12/2022	10:02:00 AM	19/12/2022	11:43:00 AM	Defective Equipment	0.326757902	0.003235227	CB0109	11kV
21/12/2022	7:16:31 PM	21/12/2022	8:18:05 PM	Defective Equipment	0.634562529	0.010306917	CB0209	11kV
22/12/2022	8:43:00 AM	22/12/2022	10:40:00 AM	Unknown	0.573007329	0.00523935	51762	11kV
22/12/2022	7:48:00 PM	23/12/2022	1:57:00 PM	Defective Equipment	0.093535273	8.5891E-05	CB0209	11kV
24/12/2022	5:46:00 AM	24/12/2022	8:16:00 AM	Wildlife	0.022331654	0.000400825	41632	11kV
24/12/2022	12:31:00 PM	24/12/2022	2:07:00 PM	Defective Equipment	0.005497022	5.72607E-05	CB1406	11kV
28/12/2022	8:15:56 PM	28/12/2022	11:42:00 PM	Wildlife	0.822835547	0.028916628	CB1110	11kV
30/12/2022	10:51:00 AM	30/12/2022	3:52:00 PM	Defective Equipment	0.025853184	8.5891E-05	CB0209	11kV
30/12/2022	11:46:33 PM	31/12/2022	9:37:00 AM	Wildlife	0.963524966	0.028916628	CB1110	11kV
01/01/2023	10:18:50 AM	01/01/2023	1:29:00 PM	Third Party	0.459860284	0.002891663	CB1406	11kV
02/01/2023	10:58:26 AM	02/01/2023	2:25:00 PM	Unknown	1.400194686	0.01674874	41672	11kV
02/01/2023	7:22:00 PM	03/01/2023	12:55:00 PM	Vegetation	0.078704764	0.000257673	41632	11kV
02/01/2023	6:45:00 PM	02/01/2023	10:18:00 PM	Defective Equipment	0.020785616	0.000229043	181192	11kV
03/01/2023	1:50:00 PM	03/01/2023	4:20:00 PM	Vegetation	0.154603756	0.001030692	CB1108	11kV
03/01/2023	6:41:57 PM	03/01/2023	8:21:28 PM	Defective Equipment	0.096885021	0.000973431	CB1406	11kV
03/01/2023	11:44:13 PM	04/01/2023	4:34:00 AM	Vegetation	2.988461979	0.032524049	CB1109	11kV
04/01/2023	12:25:00 PM	04/01/2023	3:22:00 PM	Unknown	0.040540541	0.000229043	CB1722	11kV
04/01/2023	3:11:00 PM	04/01/2023	7:49:00 PM	Unknown	0.38204306	0.001374256	51762	11kV

04/01/2023	6:08:42 PM	04/01/2023	6:11:05 PM	Human Error	0.119817911	0.050274851	CB1108	11kV
04/01/2023	8:07:23 PM	04/01/2023	8:28:54 PM	Vegetation	0.109024279	0.005067568	41622	11kV
04/01/2023	8:14:00 PM	04/01/2023	11:16:00 PM	Unknown	4.985455795	0.035415712	CB0107	11kV
04/01/2023	12:44:12 AM	04/01/2023	3:53:00 AM	Defective Equipment	0.644010536	0.010478699	CB1108	11kV
04/01/2023	3:08:09 AM	04/01/2023	11:23:53 AM	Adverse Environment	4.344079249	0.009419377	131142	11kV
04/01/2023	4:09:43 AM	04/01/2023	5:09:00 PM	Defective Equipment	1.789395328	0.003206596	CB1406	11kV
04/01/2023	5:38:48 AM	04/01/2023	12:31:00 PM	Adverse Environment	1.829935868	0.007157581	181142	11kV
04/01/2023	6:37:00 AM	04/01/2023	11:44:00 AM	Adverse Environment	0.366095969	0.001231104	CB0209	11kV
04/01/2023	8:18:00 AM	04/01/2023	6:31:00 PM	Vegetation	0.036732707	0.000229043	181192	11kV
04/01/2023	9:06:29 AM	04/01/2023	5:47:29 PM	Defective Equipment	8.698436784	0.024335776	CB1105	11kV
04/01/2023	7:44:00 AM	04/01/2023	10:11:00 AM	Unknown	0.025251947	0.000171782	CB0105	11kV
05/01/2023	6:03:00 AM	05/01/2023	8:24:00 AM	Vegetation	0.040368759	0.000286303	CB0110	11kV
05/01/2023	2:08:35 PM	05/01/2023	2:52:32 PM	Defective Equipment	1.423127577	0.032380898	CB1109	11kV
07/01/2023	4:03:37 AM	07/01/2023	10:47:00 AM	Lightning	0.715529088	0.002204535	CB1406	11kV
07/01/2023	10:57:00 AM	07/01/2023	12:06:00 PM	Vegetation	0.700927623	0.010278287	CB0108	11kV
07/01/2023	10:51:00 PM	08/01/2023	1:22:00 AM	Unknown	0.673642923	0.00523935	51762	11kV
08/01/2023	7:32:00 AM	08/01/2023	9:08:00 AM	Wildlife	0.002748511	2.86303E-05	CB0111	11kV
11/01/2023	3:06:00 PM	11/01/2023	4:50:00 PM	Vegetation	0.056573523	0.000543976	CB0110	11kV
11/01/2023	4:46:33 PM	11/01/2023	5:57:00 PM	Vegetation	0.945144297	0.019640403	CB0208	11kV
11/01/2023	6:31:00 PM	12/01/2023	12:37:00 PM	Unknown	0.201471599	0.000744388	CB1105	11kV
11/01/2023	9:41:44 PM	12/01/2023	10:38:00 AM	Vegetation	0.886967476	0.0079306	CB0105	11kV
12/01/2023	1:41:03 AM	12/01/2023	5:12:00 AM	Wildlife	1.136652542	0.008102382	CB0105	11kV
13/01/2023	10:13:32 PM	14/01/2023	4:06:00 AM	Third Party	1.101609024	0.0044377	41612	11kV
16/01/2023	10:42:45 PM	16/01/2023	11:25:22 PM	Wildlife	0.554912964	0.019640403	CB0208	11kV
23/01/2023	8:39:00 PM	24/01/2023	1:03:00 AM	Defective Equipment	0.075584059	0.000286303	191712	11kV
24/01/2023	12:13:00 PM	24/01/2023	3:10:00 PM	Defective Equipment	0.025337838	0.000143152	CB1206	11kV
25/01/2023	9:27:46 AM	25/01/2023	2:33:00 PM	Unknown	1.105359597	0.011079936	CB0605	11kV
25/01/2023	12:31:00 PM	25/01/2023	6:19:00 PM	Unknown	0.411389143	0.001345625	51742	11kV
26/01/2023	4:26:00 AM	26/01/2023	9:03:00 AM	Defective Equipment	0.371621622	0.002548099	CB1205	11kV
26/01/2023	4:28:21 AM	26/01/2023	6:11:00 AM	Vegetation	0.971140632	0.019926706	CB0208	11kV
26/01/2023	8:20:00 AM	26/01/2023	12:05:51 PM	Defective Equipment	3.119273935	0.044606047	CB1205	11kV
26/01/2023	11:11:15 AM	26/01/2023	11:13:34 AM	Unknown	0.159814475	0.069027714	CB1108	11kV
26/01/2023	3:11:10 PM	26/01/2023	3:30:10 PM	Vegetation	0.096283784	0.005067568	41622	11kV
26/01/2023	7:51:41 PM	26/01/2023	9:40:00 PM	Unknown	0.179111315	0.002548099	CB1205	11kV
26/01/2023	9:19:49 PM	26/01/2023	10:16:37 PM	Unknown	1.909012826	0.0352153	273312	33kV
26/01/2023	8:59:00 PM	28/01/2023	7:32:00 PM	Lightning	0.758703619	0.00085891	CB1108	11kV
26/01/2023	11:10:00 PM	29/01/2023	11:08:00 AM	Lightning	0.815935639	0.001231104	CB1109	11kV
27/01/2023	1:38:48 AM	27/01/2023	3:33:00 AM	Vegetation	1.106361658	0.017865323	CB1122	11kV
27/01/2023	3:55:24 AM	27/01/2023	2:07:00 PM	Vegetation	1.269754924	0.003149336	CB0608	11kV
27/01/2023	9:02:20 AM	27/01/2023	1:25:00 PM	Defective Equipment	2.766491067	0.029231562	51762	11kV
27/01/2023	2:29:42 PM	27/01/2023	2:33:16 PM	Unknown	0.001374256	0.002462208	223392	33kV
27/01/2023	1:27:00 PM	27/01/2023	4:50:00 PM	Defective Equipment	0.639315163	0.003149336	51762	11kV
27/01/2023	5:11:00 PM	28/01/2023	12:07:00 PM	Vegetation	0.130096198	0.000114521	131142	11kV
30/01/2023	3:25:00 PM	30/01/2023	8:45:00 PM	Vegetation	0.438559322	0.005382501	CB1322	11kV
31/01/2023	5:36:47 AM	31/01/2023	7:49:00 AM	Unknown	1.020356161	0.01231104	51772	11kV
31/01/2023	7:12:00 AM	31/01/2023	11:49:00 AM	Vegetation	0.0158612	5.72607E-05	CB1206	11kV
31/01/2023	12:29:26 PM	31/01/2023	3:35:00 PM	Defective Equipment	0.491496793	0.007100321	CB0206	11kV
31/01/2023	1:23:08 PM	31/01/2023	4:56:00 PM	Defective Equipment	0.977725607	0.017035044	131132	11kV
31/01/2023	1:43:00 PM	31/01/2023	4:01:00 PM	Defective Equipment	0.659814475	0.004781264	CB1112	11kV
31/01/2023	2:25:51 PM	01/02/2023	12:58:00 PM	Defective Equipment	3.038937242	0.01228241	51772	11kV
31/01/2023	2:28:42 PM	31/01/2023	2:30:33 PM	Adverse Weather	0.020069858	0.010908154	CB1108	11kV
31/01/2023	2:51:42 PM	31/01/2023	5:44:06 PM	Unknown	2.254008246	0.018094366	CB1406	11kV
31/01/2023	3:57:46 PM	01/02/2023	2:07:00 PM	Adverse Weather	0.818913193	0.004809895	CB1109	11kV
31/01/2023	5:31:52 PM	31/01/2023	6:57:22 PM	Vegetation	1.527485112	0.017865323	CB1122	11kV
01/02/2023	9:30:23 AM	01/02/2023	4:20:00 PM	Adverse Weather	1.127576729	0.014200641	CB1406	11kV
01/02/2023	2:26:00 PM	03/02/2023	2:59:00 PM	Adverse Weather	0.280233623	0.000715758	CB0206	11kV
02/02/2023	9:23:11 AM	02/02/2023	9:40:07 AM	Third Party	0.268581081	0.0158612	CB1322	11kV
02/02/2023	4:46:00 PM	02/02/2023	4:47:00 PM	Defective Equipment	0.000143152	0.000143152	CB0109	11kV
03/02/2023	10:09:19 AM	03/02/2023	12:21:35 PM	Third Party	0.212064819	0.001603298	CB1322	11kV
03/02/2023	10:07:07 AM	07/02/2023	2:01:03 PM	Adverse Weather	2.059293404	0.000343564	51772	11kV
05/02/2023	11:57:29 PM	06/02/2023	6:36:00 AM	Third Party	5.057403802	0.026969766	CB1722	11kV
06/02/2023	6:53:55 AM	06/02/2023	7:46:42 AM	Third Party	0.693054283	0.013456253	CB1722	11kV
07/02/2023	2:22:01 AM	07/02/2023	4:52:00 AM	Wildlife	1.915712322	0.022331654	CB0105	11kV
07/02/2023	6:44:00 AM	07/02/2023	7:24:00 AM	Wildlife	0.028630325	0.000715758	CB0105	11kV
09/02/2023	3:29:11 AM	09/02/2023	5:05:09 AM	Unknown	2.603183692	0.03524393	273312	33kV
09/02/2023	2:16:00 PM	09/02/2023	4:27:00 PM	Third Party	0.611343335	0.004666743	CB1205	11kV
10/02/2023	12:07:28 AM	10/02/2023	12:11:28 AM	Unknown	0.000801649	0.000200412	CB0105	11kV
10/02/2023	10:44:00 AM	10/02/2023	2:20:00 PM	Defective Equipment	0.185524508	0.00085891	CB1112	11kV
11/02/2023	7:06:00 AM	11/02/2023	8:54:00 AM	Unknown	0.003092075	2.86303E-05	CB0111	11kV
11/02/2023	4:29:00 PM	11/02/2023	5:15:00 PM	Vegetation	0.019754924	0.000429455	CB0209	11kV

11/02/2023	6:15:00 PM	27/02/2023	3:10:00 PM	Adverse Weather	83.01832341	0.019669033	CB0208	11kV
12/02/2023	3:08:01 AM	22/02/2023	2:54:37 PM	Adverse Weather	5.811984654	0.009333486	131142	11kV
12/02/2023	3:18:07 AM	12/02/2023	4:33:00 AM	Adverse Weather	0.536331883	0.009877462	CB1206	11kV
12/02/2023	5:58:16 AM	12/02/2023	8:32:00 AM	Vegetation	0.318340586	0.002548099	41632	11kV
12/02/2023	7:34:31 AM	21/02/2023	11:19:00 AM	Vegetation	57.33110971	0.043718507	CB0209	11kV
12/02/2023	7:46:30 AM	21/02/2023	4:36:00 PM	Vegetation	15.48940678	0.012683234	41632	11kV
12/02/2023	8:17:00 AM	16/02/2023	2:17:00 PM	Adverse Weather	85.94030577	0.02550962	131142	11kV
12/02/2023	8:17:49 AM	16/02/2023	4:47:00 PM	Vegetation	1.704849977	0.006842648	131132	11kV
12/02/2023	8:21:00 AM	12/02/2023	10:11:31 AM	Vegetation	2.107564132	0.032867613	CB1108	11kV
12/02/2023	8:48:00 AM	21/02/2023	1:09:00 PM	Vegetation	14.54243014	0.015975721	191782	11kV
12/02/2023	8:59:24 AM	12/02/2023	9:15:37 AM	Adverse Weather	0.081224233	0.021186441	CB0609	11kV
12/02/2023	9:28:04 AM	12/02/2023	9:32:04 AM	Adverse Weather	0.000458085	0.000114521	CB1109	11kV
12/02/2023	9:28:38 AM	22/02/2023	3:30:00 PM	Vegetation	62.45943083	0.012167888	51772	11kV
12/02/2023	9:38:00 AM	16/02/2023	1:09:19 PM	Adverse Weather	2.61887311	0.000687128	131142	11kV
12/02/2023	9:53:04 AM	12/02/2023	12:41:52 PM	Vegetation	1.123912048	0.021329592	CB1206	11kV
12/02/2023	10:01:42 AM	12/02/2023	10:02:51 AM	Adverse Weather	0.017493129	0.015202703	CB1105	11kV
12/02/2023	10:07:00 AM	13/02/2023	1:08:00 PM	Unknown	0.361142923	0.000400825	CB0608	11kV
12/02/2023	10:11:08 AM	12/02/2023	10:22:58 AM	Adverse Weather	0.028973889	0.021186441	CB0609	11kV
12/02/2023	10:33:00 AM	21/02/2023	12:27:00 PM	Vegetation	29.97257215	0.029174301	51762	11kV
12/02/2023	10:39:00 AM	12/02/2023	3:06:00 PM	Defective Equipment	7.430800504	0.032753092	CB1108	11kV
12/02/2023	10:56:00 AM	12/02/2023	11:42:00 AM	Defective Equipment	0.003950985	8.5891E-05	131142	11kV
12/02/2023	11:02:29 AM	18/02/2023	4:03:00 PM	Vegetation	22.90145442	0.009877462	CB1206	11kV
12/02/2023	11:45:45 AM	12/02/2023	4:51:00 PM	Vegetation	0.863834173	0.024249885	CB1105	11kV
12/02/2023	12:08:00 PM	12/02/2023	3:51:00 PM	Adverse Weather	0.587379753	0.00263399	41692	11kV
12/02/2023	12:20:00 PM	13/02/2023	12:15:00 PM	Vegetation	0.395442052	0.000687128	CB1105	11kV
12/02/2023	12:24:35 PM	12/02/2023	10:40:21 PM	Vegetation	4.143781493	0.011366239	CB0207	11kV
12/02/2023	1:05:35 PM	12/02/2023	4:26:06 PM	Vegetation	4.374341503	0.022446175	CB0105	22kV
12/02/2023	1:40:00 PM	12/02/2023	7:13:00 PM	Vegetation	3.583142464	0.013656665	191722	11kV
12/02/2023	2:12:45 PM	12/02/2023	7:12:48 PM	Adverse Weather	0.789023133	0.00263399	CB0206	11kV
12/02/2023	2:23:00 PM	21/02/2023	7:47:00 PM	Vegetation	1.147131241	0.000114521	51762	11kV
12/02/2023	2:25:33 PM	24/02/2023	5:27:00 PM	Vegetation	33.25363605	0.00701443	CB0206	11kV
12/02/2023	3:25:00 PM	17/02/2023	12:00:00 PM	Adverse Weather	44.5795923	0.032753092	CB1108	11kV
12/02/2023	3:53:29 PM	15/02/2023	7:18:00 PM	Adverse Weather	39.63493472	0.033554741	CB1205	11kV
12/02/2023	4:24:00 PM	13/02/2023	8:57:00 AM	Adverse Weather	15.9194629	0.020384792	CB0605	11kV
12/02/2023	4:34:21 PM	15/02/2023	4:22:00 PM	Adverse Weather	13.89011681	0.016777371	41672	11kV
12/02/2023	4:45:00 PM	13/02/2023	5:25:00 PM	Adverse Weather	2.594537334	0.007243472	181142	11kV
12/02/2023	4:58:26 PM	28/02/2023	3:25:00 PM	Vegetation	17.95115667	0.008188273	41632	11kV
12/02/2023	6:07:00 PM	16/02/2023	5:30:00 PM	Vegetation	6.677679798	0.006069629	CB0210	11kV
12/02/2023	6:47:00 PM	17/02/2023	4:54:00 PM	Vegetation	0.282123225	5.72607E-05	CB1205	11kV
12/02/2023	6:52:52 PM	23/02/2023	1:37:00 PM	Vegetation	2.794405634	0.000257673	CB0206	11kV
12/02/2023	6:56:00 PM	12/02/2023	7:06:00 PM	Adverse Weather	0.001145213	0.000114521	CB1109	11kV
12/02/2023	8:53:00 PM	13/02/2023	4:36:00 PM	Adverse Weather	0.518065735	0.001002061	131132	11kV
12/02/2023	9:29:00 PM	13/02/2023	12:28:00 PM	Third Party	1.047411819	0.003893724	131132	11kV
12/02/2023	9:34:00 PM	12/02/2023	10:38:00 PM	Vegetation	0.025652771	0.000400825	CB0108	11kV
12/02/2023	11:08:16 PM	24/02/2023	3:46:00 PM	Vegetation	27.22560696	0.013456253	CB1722	11kV
12/02/2023	11:33:41 PM	16/02/2023	12:05:00 PM	Vegetation	10.56650825	0.015059551	41692	11kV
12/02/2023	11:34:35 PM	16/02/2023	5:32:00 PM	Adverse Weather	23.56075355	0.038307375	CB3322	33kV
12/02/2023	11:40:13 PM	02/03/2023	2:33:00 PM	Vegetation	45.91505383	0.00967705	CB0108	11kV
12/02/2023	11:40:13 PM	23/02/2023	12:40:00 PM	Vegetation	3.026883875	0.000200412	CB0108	6.35kV
12/02/2023	11:40:13 PM	24/02/2023	4:50:00 PM	Vegetation	2.210203848	0.000143152	CB0108	11kV
13/02/2023	12:09:20 AM	13/02/2023	2:16:59 PM	Adverse Weather	5.378378378	0.024078104	CB1105	11kV
13/02/2023	12:37:33 AM	17/02/2023	1:57:00 PM	Adverse Weather	4.869961063	0.003292487	CB0110	11kV
13/02/2023	12:52:27 AM	23/02/2023	9:18:00 AM	Adverse Weather	7.452931745	0.004008246	CB1312	11kV
13/02/2023	2:05:35 AM	13/02/2023	2:09:57 AM	Adverse Weather	0.081138342	0.018581081	CB0108	11kV
13/02/2023	4:57:18 AM	23/02/2023	4:58:00 PM	Defective Equipment	12.10447206	0.003721942	CB0109	11kV
13/02/2023	4:57:18 AM	22/02/2023	2:48:00 PM	Adverse Weather	5.511079936	0.000515346	CB0109	6.35kV
13/02/2023	4:57:18 AM	24/02/2023	12:18:00 PM	Vegetation	0.465529088	2.86303E-05	CB0109	11kV
13/02/2023	4:57:18 AM	23/02/2023	4:29:59 PM	Vegetation	0.922268667	0.00177508	CB0109	11kV
13/02/2023	4:57:18 AM	24/02/2023	11:44:00 AM	Adverse Weather	2.19362689	0.000143152	CB0109	11kV
13/02/2023	6:11:28 AM	13/02/2023	5:39:58 PM	Vegetation	12.13356047	0.021329592	CB1206	11kV
13/02/2023	6:15:04 AM	14/02/2023	10:29:51 AM	Vegetation	6.337494274	0.023505497	173352	33kV
13/02/2023	7:49:00 AM	24/02/2023	5:21:00 PM	Adverse Weather	8.53607421	0.000543976	CB1372	11kV
13/02/2023	9:01:00 AM	13/02/2023	9:45:00 AM	Adverse Weather	0.023934952	0.000543976	CB1406	11kV
13/02/2023	9:09:00 AM	25/02/2023	1:47:00 PM	Vegetation	9.757329363	0.003149336	CB0608	11kV
13/02/2023	10:25:43 AM	21/02/2023	5:14:00 PM	Vegetation	160.1058749	0.032266377	51762	11kV
13/02/2023	11:25:16 AM	13/02/2023	3:22:00 PM	Adverse Weather	0.451729272	0.004065506	CB1106	11kV
13/02/2023	12:40:32 PM	21/02/2023	6:20:00 PM	Adverse Weather	35.7239464	0.015288594	CB1105	11kV
13/02/2023	12:56:41 PM	15/02/2023	8:57:20 AM	Adverse Weather	13.01981219	0.02024164	CB0110	11kV
13/02/2023	1:44:00 PM	14/02/2023	8:50:00 PM	Adverse Weather	2.920121393	0.002548099	CB1205	11kV
13/02/2023	3:16:15 PM	16/02/2023	10:26:00 AM	Vegetation	4.880726065	0.005411131	CB1322	11kV

13/02/2023	3:16:45 PM	13/02/2023	3:20:45 PM	Adverse Weather	0.001488777	0.000372194	CB1109	11kV
13/02/2023	3:29:01 PM	13/02/2023	7:54:00 PM	Adverse Weather	5.918231791	0.035387082	41682	11kV
13/02/2023	3:32:00 PM	21/02/2023	2:08:00 PM	Vegetation	18.65016606	0.009562529	CB0206	11kV
13/02/2023	4:38:00 PM	14/02/2023	8:43:00 PM	Vegetation	13.63327416	0.020642464	CB1109	11kV
13/02/2023	4:53:54 PM	21/02/2023	3:59:00 PM	Vegetation	42.04861429	0.022245763	CB0105	11kV
13/02/2023	5:08:55 PM	14/02/2023	6:12:12 PM	Vegetation	0.018151626	0.003693312	CB0109	11kV
13/02/2023	5:58:06 PM	14/02/2023	5:38:00 PM	Adverse Weather	7.502748511	0.010736372	CB3582	33kV
13/02/2023	6:30:20 PM	13/02/2023	6:34:20 PM	Adverse Weather	0.000458085	0.000114521	CB1109	11kV
13/02/2023	6:46:21 PM	16/02/2023	7:40:00 PM	Adverse Weather	12.57309322	0.006785387	CB1109	11kV
13/02/2023	6:51:51 PM	13/02/2023	7:31:00 PM	Vegetation	0.130153459	0.005067568	41622	11kV
13/02/2023	7:29:00 PM	23/02/2023	11:38:00 AM	Vegetation	5.015116812	0.000400825	41632	11kV
13/02/2023	8:56:13 PM	15/02/2023	10:03:00 AM	Adverse Weather	0.347486257	0.006670866	41692	11kV
13/02/2023	10:20:00 PM	14/02/2023	8:17:00 PM	Vegetation	0.929683921	0.001259734	41672	11kV
13/02/2023	11:36:19 PM	23/02/2023	4:13:00 PM	Vegetation	43.65603527	0.008589098	CB0111	11kV
13/02/2023	11:41:32 PM	14/02/2023	10:22:20 AM	Vegetation	0.855130554	0.008961292	CB1105	11kV
14/02/2023	1:07:59 AM	17/02/2023	2:10:00 PM	Adverse Weather	8.272503436	0.011996106	CB1406	11kV
14/02/2023	7:54:32 AM	14/02/2023	7:55:00 PM	Adverse Weather	7.656407467	0.01319858	CB0110	11kV
14/02/2023	11:26:01 AM	14/02/2023	2:09:00 PM	Vegetation	1.255067568	0.008961292	CB1105	11kV
14/02/2023	11:27:55 AM	16/02/2023	8:40:00 PM	Adverse Weather	5.151998397	0.004724004	CB1772	11kV
14/02/2023	11:27:55 AM	14/02/2023	6:23:00 PM	Adverse Weather	1.639744617	0.004008246	191772	11kV
14/02/2023	12:40:50 PM	14/02/2023	1:13:10 PM	Unknown	1.343707055	0.042659185	63322	33kV
14/02/2023	12:50:29 PM	14/02/2023	2:42:02 PM	Vegetation	2.072721026	0.018581081	CB0108	11kV
14/02/2023	4:03:00 PM	14/02/2023	5:34:00 PM	Adverse Weather	0.977009849	0.010736372	51742	11kV
14/02/2023	4:10:00 PM	14/02/2023	5:35:00 PM	Adverse Weather	0.046237975	0.000543976	CB1406	11kV
14/02/2023	4:58:00 PM	15/02/2023	3:32:00 PM	Unknown	2.946174989	0.002175905	171122	11kV
14/02/2023	6:49:00 PM	19/02/2023	6:53:00 PM	Vegetation	2.500171782	0.000400825	CB1105	11kV
15/02/2023	8:48:17 AM	15/02/2023	4:48:00 PM	Adverse Weather	11.47532066	0.027513743	CB1109	11kV
15/02/2023	10:10:00 AM	16/02/2023	1:12:00 PM	Adverse Weather	0.046438388	2.86303E-05	CB0206	6.35kV
15/02/2023	4:42:00 PM	15/02/2023	5:28:00 PM	Adverse Weather	0.005582913	0.000143152	41692	11kV
15/02/2023	6:42:00 PM	01/03/2023	6:05:00 PM	Vegetation	1.219737746	0.001231104	CB1105	11kV
15/02/2023	6:42:00 PM	19/02/2023	6:45:00 PM	Vegetation	7.424845396	0.001288365	CB1105	6.35kV
15/02/2023	8:44:00 PM	15/02/2023	10:27:00 PM	Adverse Weather	0.162190792	0.001574668	CB1205	11kV
15/02/2023	8:53:00 PM	15/02/2023	9:12:00 PM	Adverse Weather	0.002175905	0.000114521	CB0607	11kV
16/02/2023	11:04:22 AM	16/02/2023	2:16:09 PM	Vegetation	2.026225378	0.011366239	CB1105	11kV
16/02/2023	6:40:00 PM	23/02/2023	12:34:00 PM	Adverse Weather	0.748139029	0.006069629	CB0210	11kV
16/02/2023	5:53:00 PM	19/02/2023	1:30:00 PM	Adverse Weather	1.297955795	0.000658497	CB0111	11kV
16/02/2023	8:22:00 PM	16/02/2023	10:27:00 PM	Adverse Weather	0.028630325	0.000229043	CB1112	11kV
16/02/2023	10:59:00 AM	20/02/2023	2:38:00 PM	Vegetation	0.886223087	0.000744388	51772	11kV
16/02/2023	12:58:00 PM	16/02/2023	5:14:00 PM	Vegetation	0.014658727	5.72607E-05	CB1206	11kV
16/02/2023	8:34:00 PM	16/02/2023	9:29:00 PM	Adverse Weather	0.001574668	2.86303E-05	CB0111	11kV
16/02/2023	8:35:00 PM	21/02/2023	2:20:00 PM	Adverse Weather	2.540225607	0.000372194	181142	11kV
17/02/2023	6:38:00 AM	17/02/2023	7:03:00 AM	Adverse Weather	0.001431516	5.72607E-05	CB1406	11kV
17/02/2023	9:30:00 AM	17/02/2023	12:22:00 PM	Adverse Weather	0.054225836	0.000629867	CB1108	11kV
17/02/2023	1:40:00 PM	19/02/2023	2:47:05 PM	Vegetation	0.75707169	0.000314934	51742	11kV
17/02/2023	2:59:00 PM	17/02/2023	3:54:00 PM	Unknown	0.001574668	2.86303E-05	CB0111	11kV
17/02/2023	2:47:00 PM	17/02/2023	4:27:33 PM	Adverse Weather	0.064933578	0.000944801	CB0609	11kV
17/02/2023	4:03:00 PM	17/02/2023	6:30:00 PM	Vegetation	0.084230417	0.000744388	CB1206	11kV
17/02/2023	6:48:00 PM	18/02/2023	11:41:00 AM	Vegetation	0.203017636	0.000200412	CB0609	11kV
18/02/2023	10:07:00 AM	19/02/2023	1:08:00 PM	Defective Equipment	0.817138113	0.018180257	131142	11kV
18/02/2023	10:25:00 AM	18/02/2023	12:44:00 PM	Adverse Weather	0.082913422	0.001145213	131142	11kV

18/02/2023	3:21:00 PM	18/02/2023	4:13:00 PM	Adverse Weather	0.022331654	0.000429455	CB1406	11kV
18/02/2023	6:40:00 PM	18/02/2023	8:48:00 PM	Defective Equipment	0.083829592	0.000773019	CB1206	11kV
18/02/2023	10:15:00 AM	19/02/2023	10:32:00 AM	Vegetation	0.54228699	0.000372194	41692	11kV
19/02/2023	8:58:00 PM	23/02/2023	5:37:00 PM	Vegetation	1.087809208	0.001002061	CB0105	11kV
19/02/2023	3:51:13 PM	19/02/2023	4:29:23 PM	Vegetation	0.052221713	0.001488777	51742	11kV
19/02/2023	4:49:00 PM	20/02/2023	11:29:00 AM	Vegetation	0.249055199	0.001488777	51742	11kV
19/02/2023	5:10:00 AM	19/02/2023	9:11:00 PM	Adverse Weather	4.361371965	0.005611544	CB1112	11kV
20/02/2023	12:23:00 PM	23/02/2023	12:41:00 PM	Defective Equipment	0.901769354	0.000458085	CB1782	11kV
20/02/2023	5:58:00 PM	20/02/2023	6:17:00 PM	Adverse Weather	0.002719881	0.000143152	CB1108	11kV
20/02/2023	3:50:00 PM	24/02/2023	12:21:00 PM	Adverse Weather	1.062442739	0.000658497	CB0105	11kV
22/02/2023	8:17:00 AM	22/02/2023	12:56:00 PM	Lightning	0.007987861	2.86303E-05	171122	11kV
22/02/2023	4:37:00 PM	22/02/2023	8:16:46 PM	Third Party	0.528515804	0.002404947	CB0108	11kV
22/02/2023	10:14:00 PM	22/02/2023	11:40:00 PM	Defective Equipment	0.179741182	0.002090014	CB1106	11kV
23/02/2023	10:33:00 AM	23/02/2023	1:37:00 PM	Vegetation	0.047411819	0.000257673	CB0206	11kV
23/02/2023	10:03:00 AM	23/02/2023	11:09:00 AM	Vegetation	0.011337609	0.000171782	CB0206	11kV
23/02/2023	12:52:00 PM	25/02/2023	12:24:00 PM	Adverse Weather	0.928309666	0.000515346	CB0209	11kV
24/02/2023	10:19:00 AM	24/02/2023	11:13:00 AM	Adverse Weather	0.162419835	0.003063445	51762	11kV
24/02/2023	10:22:51 AM	24/02/2023	11:50:00 AM	Unknown	2.150853184	0.129809895	33882	33kV
24/02/2023	11:55:00 AM	24/02/2023	12:51:00 PM	Third Party	0.014429684	0.000257673	CB0108	11kV
24/02/2023	1:21:00 PM	25/02/2023	1:11:00 PM	Adverse Weather	1.175360742	0.007844709	CB1722	11kV
24/02/2023	4:43:00 PM	24/02/2023	6:12:00 PM	Adverse Weather	0.36088525	0.005497022	41632	11kV
25/02/2023	11:17:05 AM	25/02/2023	11:50:33 AM	Unknown	0.067080852	0.002004123	CB1105	11kV
26/02/2023	6:45:00 AM	26/02/2023	7:28:00 AM	Wildlife	0.001231104	2.86303E-05	CB0111	11kV
26/02/2023	4:41:21 PM	27/02/2023	11:50:00 AM	Defective Equipment	0.756670866	0.00529661	CB1105	11kV
26/02/2023	10:11:18 PM	27/02/2023	2:04:38 AM	Vegetation	0.554483509	0.002376317	CB0109	11kV
27/02/2023	12:29:44 AM	27/02/2023	10:14:44 AM	Vegetation	1.170006871	0.003721942	CB0109	11kV
27/02/2023	8:42:49 AM	27/02/2023	8:46:49 AM	Unknown	0.000458085	0.000114521	151162	33kV
27/02/2023	11:02:17 PM	28/02/2023	12:41:54 AM	Defective Equipment	4.120848603	0.042401512	CB0609	11kV
28/02/2023	6:35:00 AM	28/02/2023	8:57:00 AM	Unknown	0.121965186	0.00085891	CB1108	11kV
28/02/2023	10:54:00 AM	28/02/2023	2:30:00 PM	Third Party	0.519468621	0.002404947	CB0108	11kV
01/03/2023	5:53:23 PM	01/03/2023	6:33:50 PM	Defective Equipment	0.934579707	0.023104672	CB1205	11kV
03/03/2023	11:03:00 AM	03/03/2023	3:18:00 PM	Defective Equipment	0.576013514	0.002404947	CB0108	11kV
03/03/2023	11:51:15 PM	03/03/2023	11:55:15 PM	Unknown	0.000343564	8.5891E-05	51762	11kV
05/03/2023	6:23:00 AM	05/03/2023	10:05:00 AM	Defective Equipment	0.108852497	0.000543976	51772	11kV
06/03/2023	7:30:00 AM	06/03/2023	11:59:00 AM	Defective Equipment	0.069314017	0.000257673	CB0111	6.35kV
07/03/2023	9:07:13 AM	07/03/2023	11:04:00 AM	Defective Equipment	3.392779432	0.03255268	CB1109	11kV
07/03/2023	3:17:27 PM	07/03/2023	4:06:00 PM	Unknown	0.307346541	0.009047183	CB0110	11kV
07/03/2023	7:39:44 PM	07/03/2023	11:15:00 PM	Vegetation	0.900710032	0.016806001	41672	11kV
08/03/2023	4:42:00 AM	08/03/2023	6:45:00 AM	Wildlife	0.00352153	2.86303E-05	CB0111	11kV
08/03/2023	10:03:00 AM	08/03/2023	11:03:00 AM	Vegetation	0.024049473	0.000400825	CB0105	11kV
08/03/2023	10:06:00 PM	08/03/2023	11:12:00 PM	Wildlife	0.001889601	2.86303E-05	CB0111	11kV
10/03/2023	3:30:34 PM	10/03/2023	3:32:43 PM	Unknown	0.09416514	0.04403344	CB0209	11kV
10/03/2023	6:07:55 AM	10/03/2023	12:24:00 PM	Defective Equipment	3.303223775	0.015288594	CB1105	11kV
10/03/2023	9:07:20 AM	10/03/2023	12:40:00 PM	Defective Equipment	3.814561383	0.035472973	CB0107	11kV
11/03/2023	5:36:00 AM	11/03/2023	8:24:00 AM	Vegetation	0.336692625	0.002004123	131132	11kV
13/03/2023	11:20:00 AM	13/03/2023	12:30:00 PM	Defective Equipment	0.004008246	5.72607E-05	51762	11kV
14/03/2023	2:58:00 PM	14/03/2023	2:59:50 PM	Unknown	5.72607E-05	2.86303E-05	CB0106	11kV
14/03/2023	8:04:47 PM	14/03/2023	11:07:00 PM	Defective Equipment	5.555714613	0.033669262	CB1205	11kV
15/03/2023	11:22:00 AM	15/03/2023	12:39:00 PM	Defective Equipment	0.030863491	0.000400825	CB1722	11kV
15/03/2023	12:11:27 PM	15/03/2023	1:56:50 PM	Defective Equipment	0.371106276	0.00352153	CB1205	11kV
15/03/2023	4:57:00 PM	15/03/2023	5:56:00 PM	Defective Equipment	0.200813101	0.003435639	CB1406	11kV
16/03/2023	5:38:00 PM	16/03/2023	7:12:00 PM	Vegetation	0.002691251	2.86303E-05	41622	11kV
17/03/2023	6:57:00 AM	20/03/2023	10:44:00 AM	Third Party	0.525939075	0.000200412	41632	11kV
17/03/2023	8:13:00 AM	17/03/2023	11:01:00 AM	Vegetation	0.019239579	0.000114521	51762	11kV
17/03/2023	11:17:15 AM	17/03/2023	2:18:22 PM	Unknown	0.366496793	0.00529661	CB1105	11kV
17/03/2023	2:26:00 PM	17/03/2023	2:34:00 PM	Defective Equipment	0.003893724	0.000486716	41692	11kV
17/03/2023	5:45:51 AM	17/03/2023	10:20:00 AM	Defective Equipment	0.931831196	0.010965415	CB1108	11kV
18/03/2023	2:27:25 AM	18/03/2023	3:38:00 AM	Unknown	0.528315392	0.010478699	CB1108	11kV
18/03/2023	6:04:00 AM	18/03/2023	9:35:00 AM	Unknown	0.972600779	0.004609482	CB1110	11kV
21/03/2023	4:54:00 PM	21/03/2023	10:08:00 PM	Defective Equipment	0.606619331	0.00964842	51762	11kV
22/03/2023	9:37:00 AM	22/03/2023	10:46:00 AM	Defective Equipment	0.233108108	0.003378378	41682	33kV
25/03/2023	11:38:00 AM	25/03/2023	3:09:00 PM	Defective Equipment	0.151024966	0.000715758	CB1322	11kV
27/03/2023	4:32:13 PM	28/03/2023	2:40:00 PM	Third Party	0.668403573	0.007128951	CB0206	11kV
28/03/2023	6:41:00 AM	28/03/2023	10:15:00 AM	Wildlife	0.016376546	8.5891E-05	41692	11kV
29/03/2023	3:18:13 AM	29/03/2023	5:55:00 AM	Defective Equipment	1.02024164	0.022388914	CB0105	22kV
29/03/2023	6:24:00 AM	29/03/2023	9:34:00 AM	Unknown	0.114234998	0.000601237	51762	11kV
29/03/2023	7:46:00 AM	29/03/2023	2:38:00 PM	Wildlife	0.023591388	5.72607E-05	CB0108	11kV
29/03/2023	6:12:00 PM	29/03/2023	7:01:02 PM	Defective Equipment	0.25970568	0.00529661	CB1108	11kV
30/03/2023	10:02:00 AM	30/03/2023	12:30:00 PM	Unknown	0.631355932	0.004265918	131142	11kV

Appendix 4

Network Reliability

Unplanned SAIDI Review

Top Energy

21139 / 21139-RPT-0001 / Revision D / 15-Nov-2021

ERGO CONSULTING

Document history and status

Revision	Date	Author	Reviewed by	Approved by	Status
A	20-10-2021	Richard Fairbairn	Unreviewed	Alistair Williams	Draft
B	28-10-2021	Richard Fairbairn	Chris Turney	Alistair Williams	Draft
C	29-10-2021	Richard Fairbairn	Chris Turney	Alistair Williams	Draft
D	15-11-2021	Richard Fairbairn	Chris Turney	Alistair Williams	Final

Revision details

Revision	Details
A	Issued for client comment
B	Draft report issued to client for final review/comment
C	Further draft after client discussion
D	Final document

Table of Contents

List of Tables

List of Figures

1. Executive Summary

Top Energy Ltd (TEN) owns and operates the electricity network in the northern most part of New Zealand's North Island. The network comprises some 4,500 kilometres of overhead and underground lines and cables, which services over 31,500 power consumers in an area that covers some 6,822 square kilometres throughout the Far North region.

Over the period 1999 through 2020 TEN's reported SAIDI has varied significantly, with its annual SAIDI (planned and unplanned) varying from 329 minutes (2001) to 1,838 minutes (2015) with an average of 575 minutes. In the last decade, in an effort to stabilize its SAIDI performance, TEN has invested a significant amount of capital on its network. This expenditure was formulated in its TE2020 Project that has mostly focused on its sub-transmission network. The TE2020 Project has yet to be completed.

TEN's year ending SAIDI results for 2021 (YE2021) came in just under the Regulatory Target of 302 minutes, and although April of the current year (YE2022) started out well the SAIDI results for the ensuing 6 months to September have well exceeded the budgeted values. If the present trend continues there is a possibility TEN will breach its Regulatory Cap of 380 minutes for YE2022.

Given the above backdrop, TEN engaged Ergo Consulting (Ergo) to undertake a critical review of its unplanned network outage performance over the past two full regulatory years (YE2020 and YE2021), including the six months of this regulatory year (YE2022) which includes the period 1st April 2019 to 30th September 2021. This report documents Ergo's findings and recommendations.

1.1 Findings

The following summarises Ergo's investigations of TEN's YE2020/YE2021/YE2022 unplanned SAIDI data:

- TEN's sub-transmission network[1] has contributed ≈15% to its unplanned SAIDI performance. There is evidence that sub-transmission SAIDI has trended downwards during the period, which infers that the TE2020 Project is delivering value.
- TEN's distribution network[2] has contributed the vast majority of ≈85% to its unplanned SAIDI performance.
- The unplanned SAIDI in TEN's network during YE2020 and YE2021 was of a similar magnitude.
- The April-September YE2022 data infers that the final year-end unplanned SAIDI could be higher than the unplanned SAIDI recorded in YE2020 and YE2021.[3]
- Over the period YE2020/YE2021/YE2022 the following are the outage types that have contributed to TEN's unplanned SAIDI:
    - *Defective equipment* (39%).
    - *Vegetation* (22%).
    - *Third Party* (18%).
    - *Unknown* (12%).
    - *Weather* (3%).
    - *Human Error* (2%).
    - *Wildlife* (2%)

[1] 110kV and 33kV.
[2] 6.35kV, 11kV and 22kV.
[3] This view is based on doubling the six months of YE2022 SAIDI and the fact that the unplanned SAIDI over the months of April-September in YE2020 and YE2021 contributed 38% and 49% respectively to the year-end totals.

  - *Lightning* (2%).
  - *Environment* (0%).
- Over the entire YE2020/YE2021/YE2022 period the five worst performing sections of TEN's network have been associated with the following substations (in order of poor performance):
  - Kaikohe.
  - Okahu Rd.
  - Taipa.
  - Pukenui.
  - Omanaia.
- Over the entire YE2020/YE2021/YE2022 period the five worst performing feeders on TEN's network have been (in order of poor performance):
  - **Tokerau feeder** (CB1205) fed from the Taipa zone substation. A high proportion of unplanned SAIDI on this feeder has been due to *defective equipment*.
  - **South Road feeder** (CB1105) fed from the Okahu zone substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *vegetation* and the unplanned SAIDI is trending upwards.
  - **Te Kao feeder** (131142) fed from the Pukenui zone substation. A high proportion of unplanned SAIDI on this feeder has been due to *defective equipment* and the unplanned SAIDI is trending upwards.
  - **Horeke feeder** (CB0111) fed from the Kaikohe zone substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *defective equipment* and the unplanned SAIDI is trending upwards.
  - **Oruru feeder** (CB1206) fed from the Taipa substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *vegetation* and *third party* and the unplanned SAIDI is trending upwards.

  Collectively the above five feeders contributed 36% of TEN's unplanned SAIDI.
- Over the entire YE2020/YE2021/YE2022 period the top five equipment categories that have contributed to 71% of TEN's unplanned SAIDI are (in order of magnitude):
  - **Conductor span (28%)**. The major causes of outages in this category (70%) relate to vegetation *Tree (Fall on Line)* and *Tree Contact*. The SAIDI minute contributions of this category appears to be trending upwards due to the number of events and the time to restore.
  - **Pole (17%).** The major cause of outages in this category (88%) related to *Vehicle-vs-Pole*. This category appears to be trending downwards.
  - **Unknown (11%).** As the category name indicates the cause of the SAIDI events is unknown. The SAIDI minutes due to this category appears to be trending upwards, although the number of events has trended downwards.
  - **X-arm (10%).** The major causes of this category are *X-arm Failure* and *Corrosion/Rot.* The SAIDI minutes appears to be trending upwards. The time to restore has trended downwards, but the number of failures appears to be increasing.
  - **Tail/Lead/Jumper (5%)**. The major causes of outages in this category are *Conductor Tail Blown Off*, *Conductor Failure* and *Joint Failure*. This category appears to be trending downwards.

- There is clear evidence that the SAIDI contributions of the higher value unplanned SAIDI events (i.e. 0.5 minutes to 5 minutes) have been larger in YE2022 than in the previous YE2020 and YE2021 periods. This is demonstrated by the fact that the 90th percentile YE2022 SAIDI event contributed 2.7 minutes as opposed to 2.0 minutes in YE2020 and 1.6 minutes in YE2021. We note that this increase is not clearly demonstrated in the event restoration/repair times and the data indicates that the majority of outage types that have contributing to the increase in the higher value SAIDI events during YE2022 are as follows:
  - *Weather*.
  - *Unknown*.
  - *Vegetation*.

1.2 Recommendations

Ergo recommends that TEN consider the following actions:

- Initiating a project/programme that focuses on the worst SAIDI performing distribution feeders (for example, the five feeders discussed above), which could include the following initiatives:
  - The installation of additional line fault indicators (LFIs) to assist with the identification of fault locations and reduce restoration/repair times.
  - The installation of reclosers and/or sectionalisers to reduce the number of consumers exposed to faults and to improve restoration times. This should involve targeting the number of ICPs to be sectionalised by the devices.
  - Higher levels of and/or more focused vegetation management.
  - Targeted replacement of equipment reaching end-of-life, particularly cross-arms as the number of failures appears to be increasing.
  - Installation of additional feeders in order to reduce the number of ICP's supplied by individual feeders.[4]
  - Upgrading existing lines or installing new lines in order to improve feeder back-feed options and reduce consumer restoration times.
  - Ongoing use/expansion of TEN's ADMS[5] to improve information management and implementation of distribution automation.
- Investigate the underlying reason for the increasing unplanned SAIDI minutes that have been reported against the outage type of *Unknown*. There is not sufficient information in the SAIDI database for Ergo to determine the underlying reasons for the increase, but we note that the number of the *Unknown* events has been decreasing.
- Investigate the underlying reason for the increasing unplanned SAIDI minutes that have been reported against the outage type of *Vegetation*. This category is a major contributor to TEN's unplanned SAIDI reported in the *Device Affected* category of *Conductor Span* and the data infers that restoration/repair times associated with *Conductor Span* related *vegetation* outages are increasing.
- Detailed investigation and reporting of all unplanned SAIDI events that exceed, say, 1 minute, which would typically involve investigating ≈120 events/annum. A less onerous regime could involve SAIDI events that exceed 2 minutes and ≈50 events/annum. The output from these investigations should inform TEN's future SAIDI initiatives.

---

[4] For example, the Tokerau feeder supplies the highest number of ICPs (≈1500) and was the worst performing feeder over the 2020/2021/2022 period.

[5] Advanced Distribution Management System.

Given the size of the distribution network Ergo is of the view that TEN needs to initially focus its efforts on the worst performing sections/feeders. Furthermore, based on our previous experiences, we recommend that TEN ensure that any initiatives (and expenditure) are closely tracked and reported against to ensure that they are delivering benefit (i.e. SAIDI reductions). We expect that the benefits will not be immediate and only become evident over the long term, in the same manner as the benefits associated with TEN's TE2020 Project.

2. Introduction

Top Energy Ltd (Top Energy) owns and operates the electricity network in the northern most part of New Zealand's North Island. The network comprises some 4,500 kilometres of overhead and underground lines and cables, which services over 31,500 power consumers throughout the Far North region. Figure 1 and Figure 2 illustrate Top Energy's Northern and Southern sub-transmission networks that deliver electrical supply to an area that covers some 6,822 square kilometres.

Over the last decade TEN has invested a significant amount of capital on its network in an effort to stabilize its SAIDI performance. This expenditure was formulated in a project referred to as the TE2020 Project and which included the following:

- Installation of unit/differential protection across all sub-transmission lines.
- The construction of a new 110kV double circuit line between Kaikohe and Wiroa, and a new 33kV switching station at Wiroa.
- The construction of a new 33/11kV zone substation at Kerikeri.
- The construction of a new 33/11kV zone substation at Kaeo.
- The installation of 14 diesel generator units with a rated capacity of 16.2MW.
- Refurbishment of the 33kV lines supplying the Pukenui and Taipa 33/11kV zone substations.
- Replacement of one of the 110/33kV transformers at the Kaitaia substation.
- Replacement of Kaikohe outdoor 33kV switchyard with an indoor switchboard/switchroom.

TEN's year ending SAIDI results for 2021 (YE2021) came in just under the Regulatory Target of 302 minutes, and although April of the current year (YE2022) started out well the SAIDI results for the ensuing 6 months to September have well exceeded the budgeted values. If the present trend continues there is a possibility Top Energy will breach its Regulatory Cap of 380 minutes for YE2022.

Given the above backdrop, Top Energy engaged Ergo Consulting (Ergo) to undertake a critical review of the past two full regulatory years (YE2020 and YE2021) unplanned network outage performance, including the six months of this regulatory year (YE2022) which includes the period 1st April 2019 to 30th September 2021. This report documents Ergo's findings and recommendations.

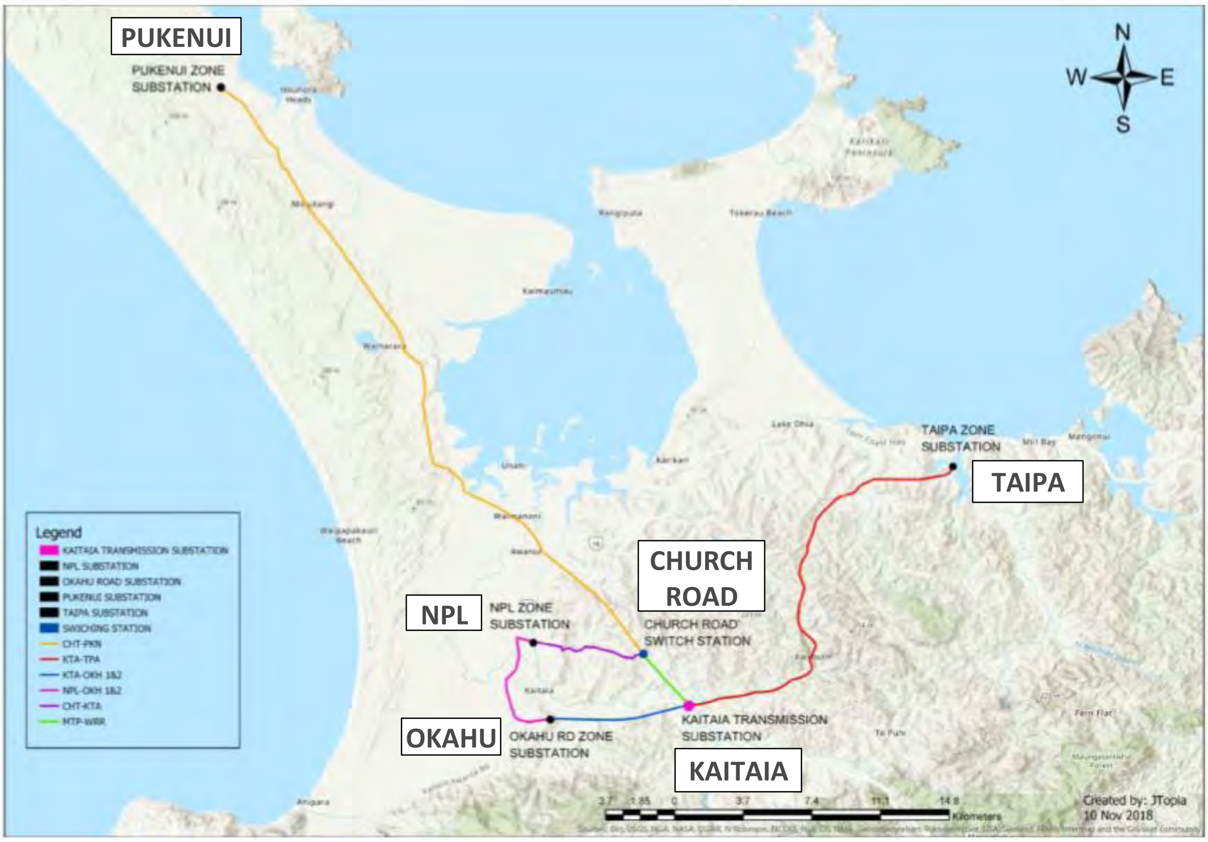


Figure 1 Northern sub-transmission network

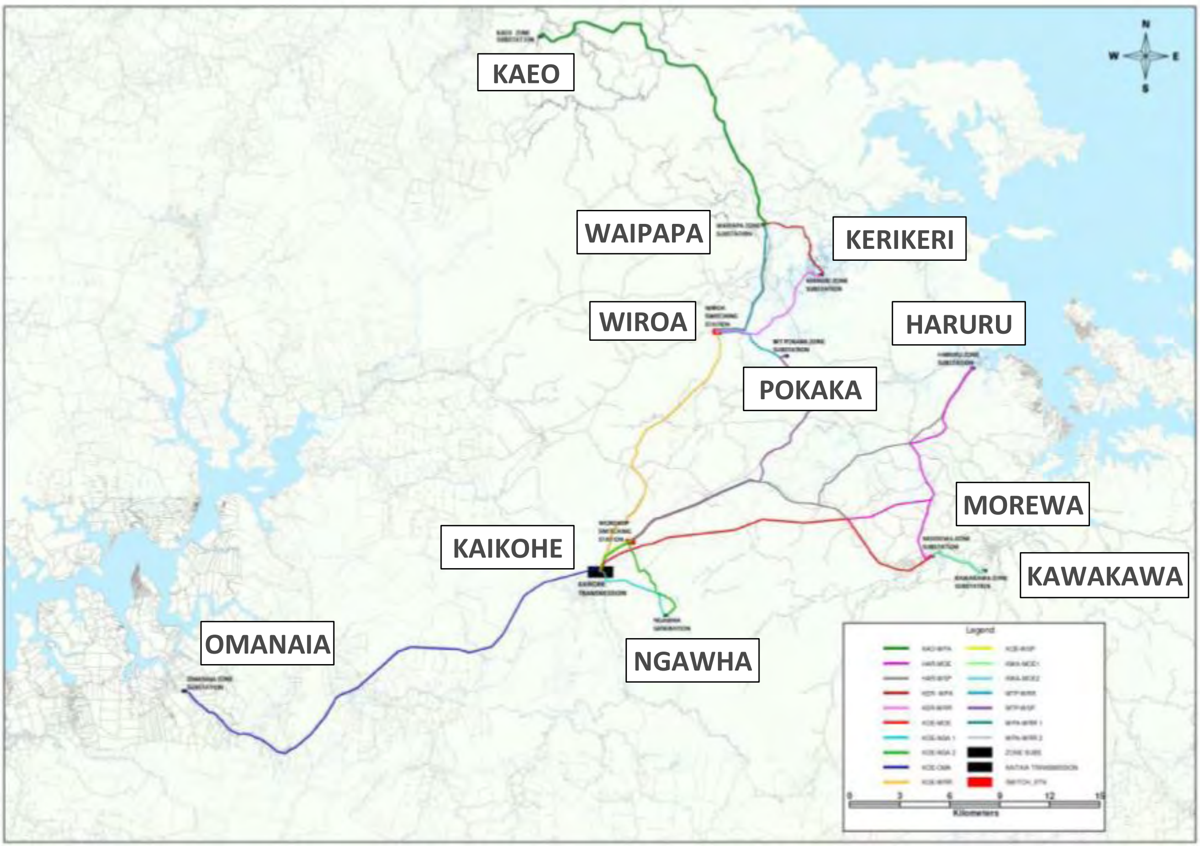


Figure 2 Southern sub-transmission network

3. Scope of the Work

The following is Top Energy's requested scope of work:

> Undertake a critical review of the past 2 full financial years unplanned network outage performance, including the six months of this financial year (1 April 2019 to 30 September 2021).
>
> Top Energy will provide the fault data for analysis and review to provide recommendations on:
>
> 1. What is driving the high unplanned SAIDI figures compared to the declining trend in previous years (e.g. is this more faults, more customers affected, longer repair time, failure of automation, network design)?
> 2. Has faults > 2 SAIDI minutes changed?
> 3. What are the root or common causes to the faults and/or high SAIDI impact?
> 4. What actions should be implemented to rectify the situation, immediately and in the future?

4. Methodology/Approach

Ergo has taken the following approach to its investigative review:

- Read the historical documents supplied by TEN, as noted in Section 5.
- Reviewed the YE2020/YE2021/YE2021 SAIDI data that TEN supplied (Item 1 in Section 5).
- Focused on the unplanned SAIDI as per the scope of work.
- Reviewed TEN's long-term historical disclosed SAIDI.
- Analysed the database supplied and summarised the short-term YE2020/YE2021/YE2021 SAIDI performance in terms of:
  - Zone substation
  - Feeder
  - Equipment
  - Cause

  This activity has helped Ergo develop a clear understanding of the factors that have contributing to TEN's recent SAIDI results.

- Focused in on the network equipment and causes that have made the highest contribution to TEN's SAIDI.
- Documented its findings.
- Made recommendations.

5. Background Information

The following documents/files/information was supplied to Ergo for its review.

Table 1: Input Data

No.	Document/File	Description	Source
1	Incidents by Date YE2020-2022.xlsx	MS-Excel file containing SAIDI & SAIFI records for the period April 2019 through to September 2022.	Top Energy
2	SAIDI Review 2020.pdf	SAIDI SAIFI Performance Review YE2021 to August.	Top Energy
3	SAIDI Review August 2021.docm	SAIDI SAIFI performance review YE2022 to 15 August.	Top Energy
4	Network Development Paper.docm	TEN paper discussing a 10 year Network Development Plan referred to as TE2020.	Top Energy
5	2021 Asset Management Plan.pdf	Top Energy’s 2021 Asset Management Plan	Internet

6. Long-term Historical SAIDI Performance

The following Figure 3 illustrates TEN's disclosed SAIDI (both planned and unplanned) for the last two decades. It shows that the company has experienced some significant variations in its reported SAIDI with a clear downward trend subsequent to the significant SAIDI result experienced in 2015 and the execution of its TE2020 Project. The downward trend in unplanned SAIDI is shown in the following Figure 4.

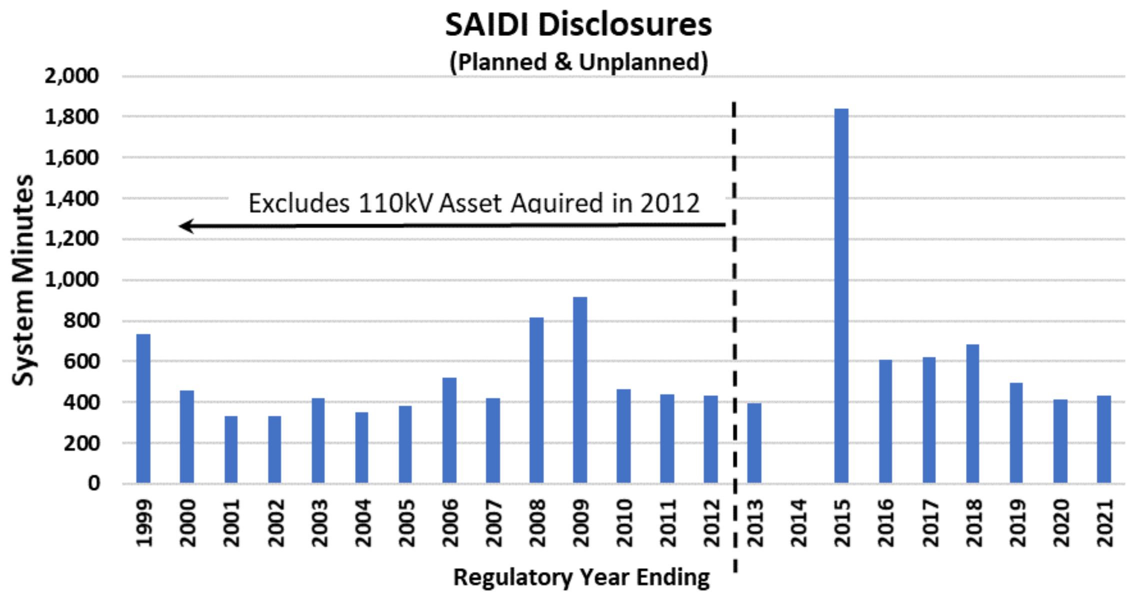


Figure 3 Historical disclosed SAIDI performance[6] (Source: PriceWaterhouseCooper's information disclosure compendiums[7]).

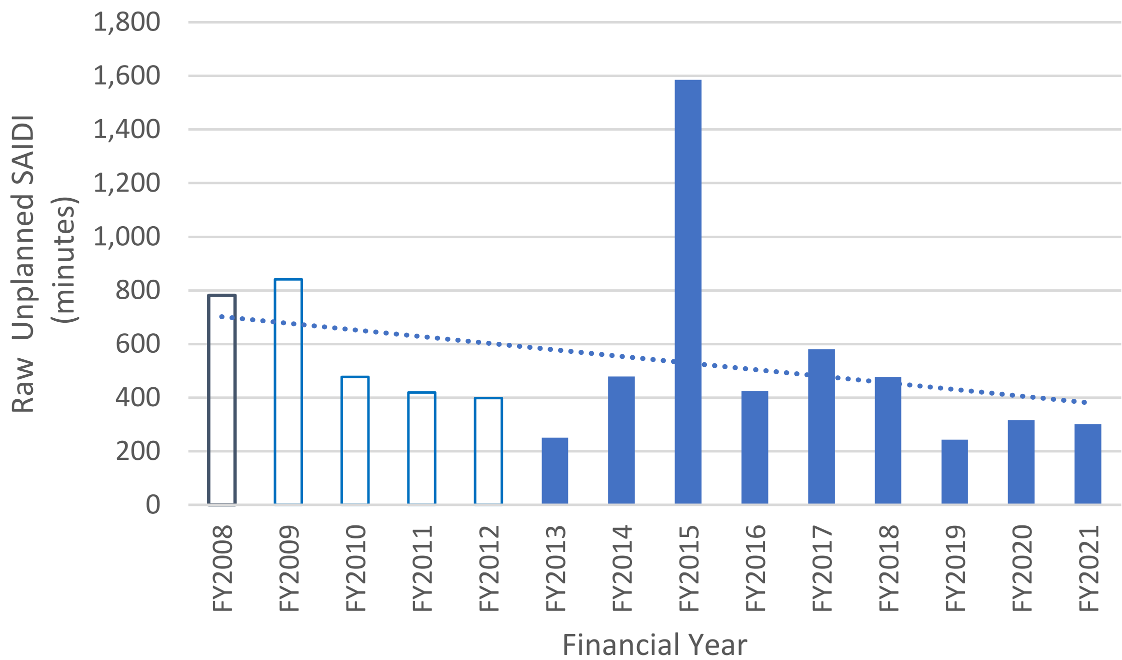


Figure 4 Historical unplanned SAIDI performance (Source: Item 4 in Section 5).

[6] Ergo does not have access to the 2014 SAIDI disclosure information.
[7] https://www.pwc.co.nz/insights-and-publications/2020-publications.

7. Short-term Historical Performance

The following Table 2 summarises TEN's recent unplanned SAIDI network performance (by substation) over the period YE2020, YE2021 and the first six months of YE2022six months of YE2022. Table 2 shows the following:

- Network performance in YE2020 and YE2021 was relatively similar.
- The first six months of YE2022 results clearly infer that the year-end unplanned SAIDI will be higher than YE2020 and YE2021. Although, we note that the set of data available includes the winter period which is typically subject to higher levels of rain/wind/etc.
- The sub-transmission network contributed a relatively small amount of ≈15% to TEN's SAIDI. Although, we note that sub-transmission SAIDI can vary significantly due to high-impact-low-probability (HILP) events. For example, TEN's Kaitaia 110/33kV substation supplies ≈30% of TEN's consumers and is supplied via a single 110kV line. Outages of this 110kV line has the potential to contribute significantly to TEN's SAIDI performance.
- The distribution network contributed a large amount (≈85%) of TEN's SAIDI.

Table 2: Summary: Unplanned SAIDI by substation for YE2021/YE2020/YE2022

	UNPLANNED SAIDI (minutes)						
YE2020	Network Voltage					Sub-Totals	
Substation	6.35kV	11kV	22kV	33kV	110kV	Totals	% of Total
CHURCH RD TEE							0%
HARURU		3.5		0.8		4.2	1%
KAEO		18.3		3.5		21.8	7%
KAIKOHE	0.6	55.5	0.1	33.3		89.4	28%
KAIKOHE 33kV							0%
KAITAIA 33KV							0%
KAWAKAWA	0.3	8.7		2.5		11.5	4%
KERIKERI		4.4		0.3		4.7	1%
MOEREWA		1.5		4.1		5.7	2%
MT POKAKA		1.1		0.0		1.2	0%
NPL		7.9				7.9	3%
OKAHU RD	0.8	38.5				39.2	12%
OMANAIA	0.4	28.1				28.5	9%
PUKENUI		22.2				22.2	7%
TAIPA	1.0	55.1				56.1	18%
WAIPAPA		23.6				23.6	7%
Grand Total	**3**	**268**	**0**	**44**	**0**	**315.9**	100%
% of Total	1%	85%	0%	14%	0%	100%	

	UNPLANNED SAIDI (minutes)						
YE2021	Network Voltage					Sub Total	
Substation	6.35kV	11kV	22kV	33kV	110kV	Grand Total	Percentage of Total
CHURCH RD TEE				0.8		0.8	0%
HARURU		3.3		0.1		3.4	1%
KAEO		9.4				9.4	3%
KAIKOHE	1.9	54.6	1.2			57.6	19%
KAIKOHE 33kV				24.1	18.0	42.2	14%
KAITAIA 33KV							0%
KAWAKAWA	1.9	28.8				30.8	10%
KERIKERI		3.2				3.2	1%
MOEREWA		5.4				5.4	2%
MT POKAKA		4.3				4.3	1%
NPL		7.9		0.5		8.4	3%
OKAHU RD	1.6	53.4				55.0	18%
OMANAIA	0.3	21.6				21.9	7%
PUKENUI		19.3				19.3	6%
TAIPA	0.4	29.5				30.0	10%
WAIPAPA		9.1				9.1	3%
Grand Total	**6**	**250**	**1**	**26**	**18**	**301**	100%
% of Total	2%	83%	0%	8%	6%	100%	

	UNPLANNED SAIDI (minutes)						
YE2022*	Network Voltage					Sub Total	
Substation	6.35kV	11kV	22kV	33kV	110kV	Grand Total	Percentage of Total
CHURCH RD TEE				8.3		8.3	4%
HARURU		0.2		0.1		0.3	0%
KAEO	0.7	23.8				24.5	11%
KAIKOHE	0.3	20.2	4.1			24.7	11%
KAIKOHE 33kV				7.7		7.7	3%
KAITAIA 33KV				11.4		11.4	5%
KAWAKAWA	2.5	12.3				14.8	7%
KERIKERI		2.9				2.9	1%
MOEREWA		1.1				1.1	0%
MT POKAKA		2.8				2.8	1%
NPL		5.8				5.8	3%
OKAHU RD	1.2	30.1				31.4	14%
OMANAIA		14.2				14.2	6%
PUKENUI		33.3		0.2		33.5	15%
TAIPA		32.2				32.2	14%
WAIPAPA	0.5	9.6				10.1	4%
Grand Total	**5**	**189**	**4**	**28**	**0**	**226**	100%
% of Total	2%	84%	2%	12%	0%	100%	

* The YE2022 summary table above is only for the six-month period April through September 2021.

7.1 Short-term Performance by Zone Substation

Figure 4 illustrates, graphically, the unplanned SAIDI performance (over the period YE2020, YE2021 and the first six months of YE2022) by substation, sorted from highest to lowest. The graphs show that, for the period considered, the five worst performing sections of TEN's network have been associated with the following substations (in order of performance):

- Kaikohe
- Okahu Rd
- Taipa
- Pukenui
- Omanaia

The networks associated with these substations include substantial rural distribution feeders. Also, the last three substations are supplied via single, overhead, 33kV lines. Having said this these lines did not contribute materially to the SAIDI performance, possibly due to the backup diesel generators that TEN has installed at these stations.

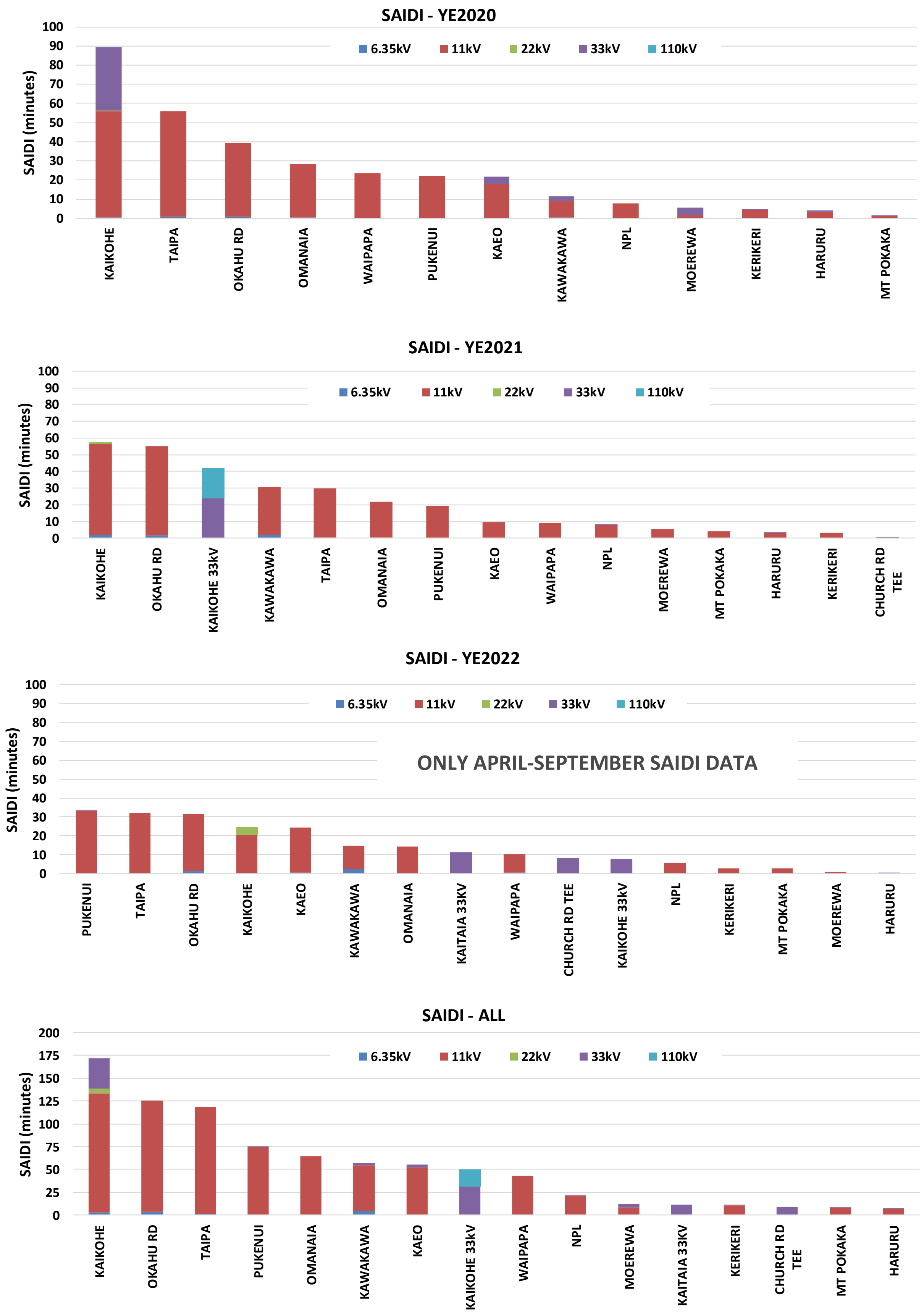


Figure 5 Unplanned SAIDI by substation for YE2021/YE2020/YE2022 and summarised for ALL three periods.

7.2 Short-term Performance by Cause

The following Table 3 summarises the sub-transmission, distribution and all unplanned SAIDI by the outage *cause*. The information in Table 3 is presented in terms of each of the YE2020, YE2021 and YE2022 periods, and is sorted from high to low in terms of the SAIDI contributions. Also included in Table 3 are the percentage SAIDI contributions, the cumulative percentage and a TREND column indicated whether the contribution is trending UP or DOWN. The trends have been established by calculating the SAIDI trend-line for each of the *causes* over the three periods (YE2020, YE2021 and YE2022) and if the slope is significantly positive or negative indicating the trend is UP or DOWN respectively. For the calculation we have doubled the YE2022 data because it only covers six months. This view is based on the fact that the unplanned SAIDI over the months of April-September in YE2020 and YE2021 contributed 38% and 49% respectively to the year-end totals.

Examination of Table 3 indicates the following:

- The top five causes of ALL unplanned SAIDI have been due to the following causes (in order of magnitude):
    - *Defective equipment*.
    - *Vegetation*.
    - *Third party*.
    - *Unknown*.
    - *Weather*.
- ALL unplanned SAIDI appears to be trending upwards due to the following causes:
    - *Defective equipment* on the distribution network. This is contrasted by the sub-transmission SAIDI due to *defective equipment* that appears to be trending downwards.
    - *Vegetation* related outages.
    - *Unknown events*.
    - *Weather*.
- There has been very little unplanned sub-transmission SAIDI due to the following:
    - *Lightning*.
    - *Wildlife*.
    - *Vegetation*.
    - *Third party*.

The information in Table 3 generally indicates that TEN's focus on its sub-transmission network (i.e. its TE2020 Project discussed in Section 2) is yielding benefits. However, the major contributor of its unplanned SAIDI, the distribution network, appears to be trending upwards.

Table 3 Unplanned SAIDI by Cause for YE2021/YE2020/YE2022

110kV / 33kV SUB-TRANSMISSION UNPLANNED SAIDI

		Unplanned SAIDI (minutes						
No.	**Cause**	**YE2020**	**YE2021**	**YE2022***	**Grand Total**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Defective Equipment	33.3	22.3	0.0	55.6	48%	48%	DOWN
2	Unknown	1.2	8.0	11.7	20.8	18%	66%	UP
3	Human Error	0.1	12.9	0.1	13.0	11%	77%	
4	Wildlife	9.2	0.0	2.7	11.9	10%	88%	
5	Weather	0.0	0.0	8.3	8.3	7%	95%	UP
6	Vegetation	0.0	0.0	5.0	5.0	4%	99%	UP
7	Lightning	0.5	0.4	0.0	0.9	1%	100%	
8	Third Party	0.2	0.0	0.0	0.2	0%	100%	
9	FOREIGN INTERFERENCE	0.0	0.0	0.0	0.0	0%	100%	
10	Environment	0.0	0.0	0.0	0.0	0%	100%	
	Grand Total	**44.5**	**43.5**	**27.7**	**115.8**	**100%**		UP

22kV / 11kV / 6.35kV DISTRIBUTION UNPLANNED SAIDI

		Unplanned SAIDI (minutes						
No.	**Cause**	**YE2020**	**YE2021**	**YE2022***	**Grand Total**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Defective Equipment	88.8	118.2	64.1	271.1	37%	37%	UP
2	Vegetation	81.2	44.4	54.9	180.6	25%	25%	UP
3	Third Party	59.5	56.8	28.9	145.1	20%	20%	
4	Unknown	20.6	32.1	27.2	79.9	11%	11%	UP
5	Weather	2.5	0.3	16.3	19.1	3%	3%	UP
6	Lightning	7.2	3.4	5.6	16.1	2%	2%	
7	Wildlife	4.1	1.4	1.0	6.5	1%	1%	
8	Human Error	4.2	0.7	0.0	4.9	1%	1%	
9	FOREIGN INTERFERENCE	3.3	0.0	0.0	3.3	0%	0%	
10	Environment	0.0	0.0	0.0	0.0	0%	0%	
	Grand Total	**271.4**	**257.3**	**198.0**	**726.7**	**100%**		UP

ALL UNPLANNED SAIDI (SUB-TRANSMISSION & DISTRIBUTION)

		Unplanned SAIDI (minutes						
No.	**Cause**	**YE2020**	**YE2021**	**YE2022***	**Grand Total**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Defective Equipment	122.1	140.5	64.1	326.7	39%	39%	UP
2	Vegetation	81.2	44.4	59.9	185.6	22%	22%	UP
3	Third Party	59.7	56.8	28.9	145.4	17%	17%	
4	Unknown	21.8	40.1	38.8	100.7	12%	12%	UP
5	Weather	2.5	0.3	24.6	27.4	3%	3%	UP
6	Wildlife	13.4	1.4	3.7	18.5	2%	2%	DOWN
7	Human Error	4.3	13.6	0.1	18.0	2%	2%	
8	Lightning	7.7	3.8	5.6	17.0	2%	2%	
9	FOREIGN INTERFERENCE	3.3	0.0	0.0	3.3	0%	0%	
10	Environment	0.0	0.0	0.0	0.0	0%	0%	
	Grand Total	**315.9**	**300.8**	**225.7**	**842.4**	**100%**		UP

* The YE2022 summary results above are only for the six-month period April through September 2021. Note that the trend has been established by doubling the YE2022 unplanned SAIDI.

7.3 Short-term Performance by Distribution Feeder

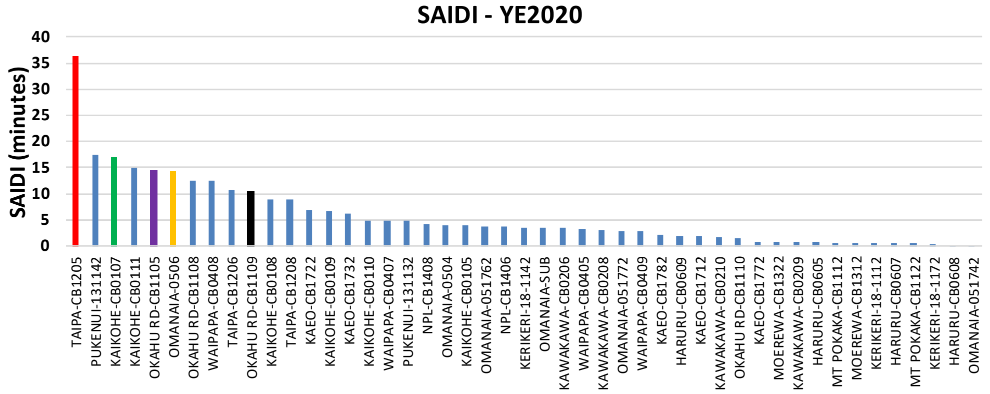
Figure 6 illustrates, graphically, the unplanned SAIDI performance (over the period YE2020, YE2021 and the first six months of YE2022) by feeder, sorted from highest to lowest. The graphs show that, for the period considered, the five worst performing feeders on TEN's (in order of performance):

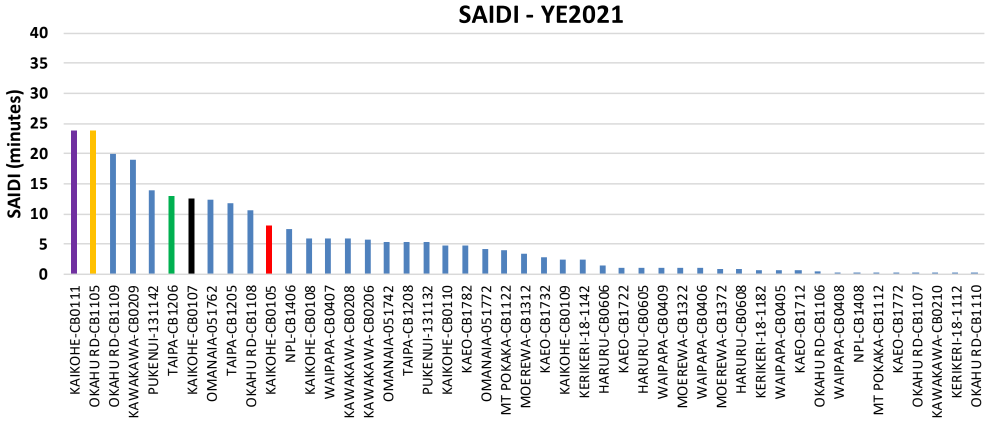
- Tokerau feeder (CB1205) fed from the Taipa zone substation (shaded red).
- South Road feeder (CB1105) fed from the Okahu zone substation (shaded yellow).
- Te Kao feeder (131142) fed from the Pukenui zone substation (shaded green).
- Horeke feeder (CB0111) fed from the Kaikohe zone substation (shaded purple).
- Oruru feeder (CB1206) fed from the Taipa substation (shaded black).

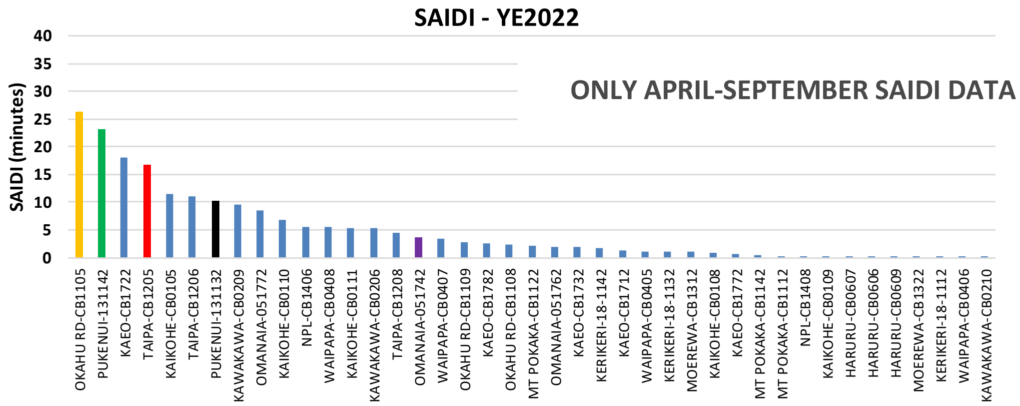
Ergo understands that these feeders are substantial overhead/rural and collectively they contributed 36% to TEN's SAIDI. In contrast, the top ten feeders contributed 56% to TEN's SAIDI.

Reducing the ICPs count on feeders has the potential to reduce unplanned SAIDI, for example, by installing new feeders, automated sectionalisers or distribution automation. For this reason Ergo has graphed, in Figure 7, unplanned SAIDI versus ICP number for TEN's distribution feeders. We have also coloured the five worst performing feeders red/yellow/green/purple/black.

Ergo have also looked at the unplanned SAIDI trends on each of the distribution feeders and the results are illustrated in Table 4, sorted from highest to lowest in terms of SAIDI contribution. Again, we have coloured the five worst performing feeders and they are thus at the top of the table. We have also included a TREND column using the methodology discussed in Section 7.2.







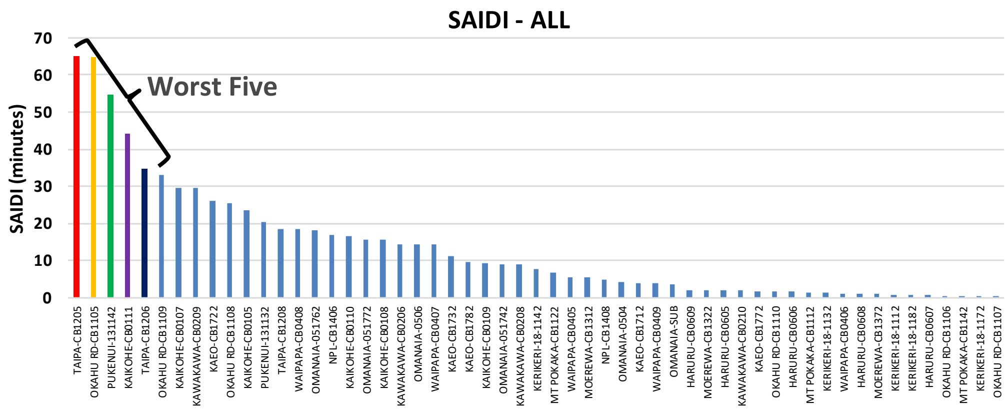


Figure 6 Unplanned SAIDI by distribution feeder for YE2021/YE2020/YE2022.

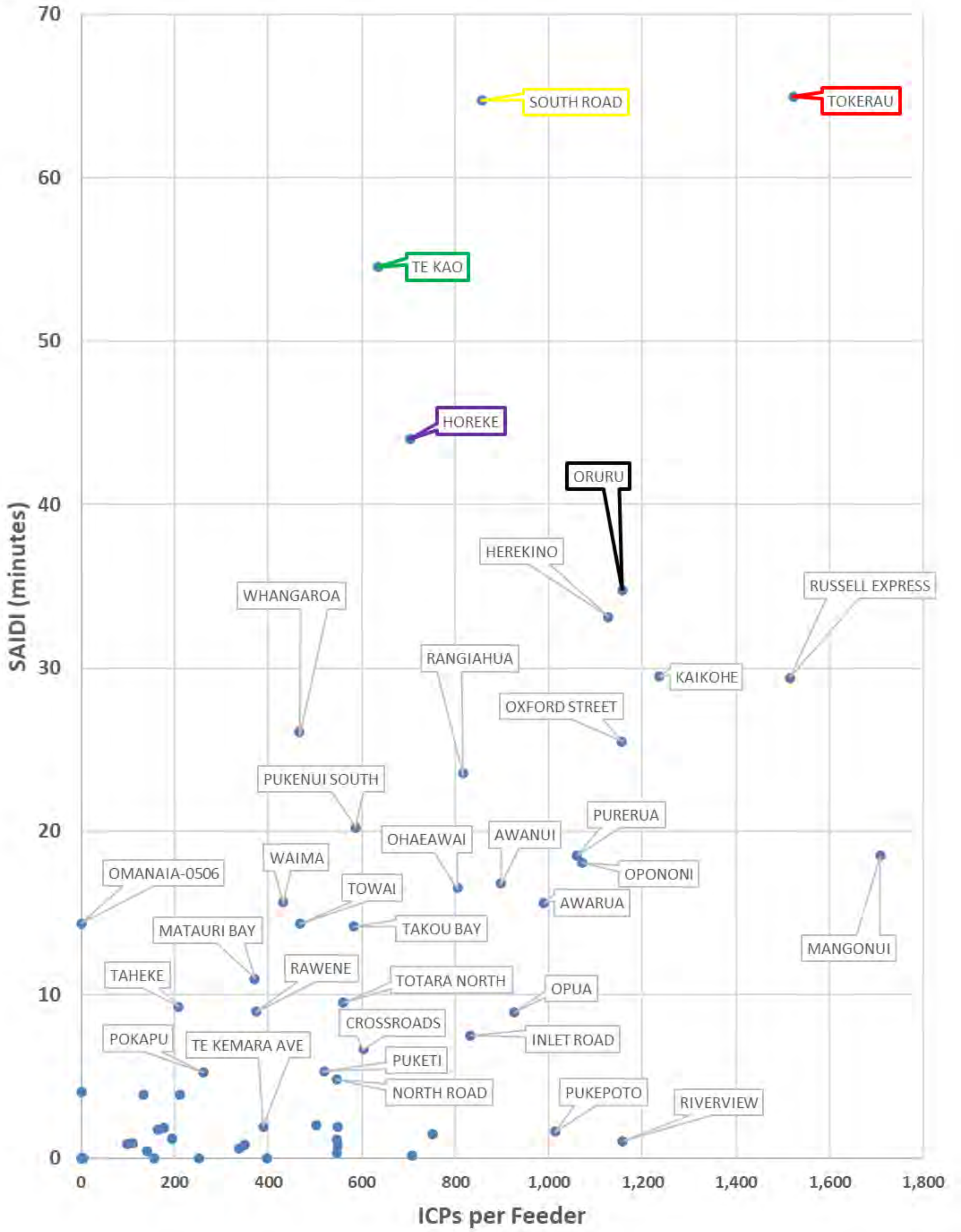


Figure 7 Unplanned SAIDI vs ICPs for distribution feeders over the period YE2021/YE2020/YE2022.

Table 4 Distribution feeders sorted by Unplanned SAIDI for YE2021/YE2020/YE2022 period: Including trend & upward rank

			Unplanned SAIDI (minutes)					UPWARD
No.	Substation - CB	Feeder Name	YE2020	YE2021	YE2022*	ALL	TREND	RANK
1	TAIPA-1205	**TOKERAU**	36.5	11.7	16.8	65.0		
2	OKAHU RD-1105	**SOUTH ROAD**	14.6	23.8	26.3	64.8	UP	**1**
3	PUKENUI-131142	**TE KAO**	17.4	14.0	23.2	54.6	UP	**2**
4	KAIKOHE-0111	**HOREKE**	14.9	23.8	5.3	44.0	DOWN	
5	TAIPA-1206	**ORURU**	10.8	12.9	11.0	34.7	UP	**8**
6	OKAHU RD-1109	HEREKINO	10.5	19.9	2.7	33.1	DOWN	
7	KAIKOHE-0107	KAIKOHE	16.9	12.5	0.0	29.5	DOWN	
8	KAWAKAWA-0209	RUSSELL EXPRESS	0.8	19.0	9.6	29.4	UP	**5**
9	KAEO-191722	WHANGAROA	7.0	1.1	18.0	26.1	UP	**3**
10	OKAHU RD-1108	OXFORD STREET	12.6	10.6	2.3	25.5	DOWN	
11	KAIKOHE-0105	RANGIAHUA	3.9	8.1	11.6	23.6	UP	**4**
12	PUKENUI-131132	PUKENUI SOUTH	4.8	5.3	10.1	20.2	UP	**6**
13	TAIPA-1208	MANGONUI	8.8	5.3	4.4	18.5		
14	WAIPAPA-0408	PURERUA	12.5	0.4	5.6	18.5		
15	OMANAIA-051762	OPONONI	3.7	12.3	2.0	18.1		
16	NPL-1406	AWANUI	3.6	7.6	5.6	16.8	UP	
17	KAIKOHE-0110	OHAEAWAI	5.0	4.7	6.8	16.5	UP	**9**
18	OMANAIA-051772	WAIMA	2.9	4.2	8.6	15.7	UP	**7**
19	KAIKOHE-0108	AWARUA	8.8	6.0	0.8	15.6	DOWN	
20	KAWAKAWA-0206	TOWAI	3.4	5.7	5.2	14.4	UP	
21	OMANAIA-0506	OMANAIA-0506	14.3	0.0	0.0	14.3	DOWN	
22	WAIPAPA-0407	TAKOU BAY	4.8	6.0	3.3	14.2		
23	KAEO-191732	MATAURI BAY	6.3	2.8	1.9	11.0		
24	KAEO-191782	TOTARA NORTH	2.2	4.7	2.6	9.5		
25	KAIKOHE-0109	TAHEKE	6.6	2.5	0.2	9.3	DOWN	
26	OMANAIA-051742	RAWENE	0.0	5.3	3.6	9.0	UP	
27	KAWAKAWA-0208	OPUA	3.0	5.9	0.0	8.9		
28	KERIKERI-181142	INLET ROAD	3.5	2.3	1.7	7.5		
29	MT POKAKA-171122	CROSSROADS	0.5	4.0	2.2	6.7		
30	WAIPAPA-0405	PUKETI	3.4	0.8	1.2	5.3		
31	MOEREWA-031312	POKAPU	0.7	3.5	1.1	5.3		
32	NPL-1408	NORTH ROAD	4.3	0.3	0.2	4.8		
33	OMANAIA-0504	OMANAIA-0504	4.1	0.0	0.0	4.1	DOWN	
34	KAEO-191712	OMAUNU ROAD	1.9	0.6	1.4	3.9		
35	WAIPAPA-0409	AERODROME ROAD	2.8	1.0	0.0	3.9		
36	HARURU-0609	JOYCES ROAD	2.0	0.0	0.0	2.0		
37	MOEREWA-031322	MOEREWA NO 1	0.9	1.0	0.0	1.9		
38	HARURU-0605	TE KEMARA AVE	0.8	1.1	0.0	1.9		
39	KAWAKAWA-0210	KARETU	1.7	0.2	0.0	1.9		
40	KAEO-191772	OROTERE	0.9	0.2	0.7	1.7		
41	OKAHU RD-1110	PUKEPOTO	1.6	0.0	0.0	1.6		
42	HARURU-0606	TI BAY	0.0	1.4	0.1	1.5		
43	MT POKAKA-171112	BULLS GORGE	0.7	0.3	0.2	1.2		
44	KERIKERI-181132	COBHAM ROAD	0.0	0.0	1.1	1.1		
45	WAIPAPA-0406	RIVERVIEW	0.0	1.0	0.0	1.0		
46	HARURU-0608	ONEWHERO	0.2	0.8	0.0	0.9		
47	MOEREWA-031372	TAU BLOCK	0.0	0.9	0.0	0.9		
48	KERIKERI-181112	KERIKERI ROAD	0.6	0.1	0.0	0.8		
49	KERIKERI-181182	HONE HEKE ROAD	0.0	0.8	0.0	0.8		
50	HARURU-0607	PUKETONA	0.5	0.0	0.1	0.6		
51	OKAHU RD-1106	KAITAIA WEST	0.0	0.4	0.0	0.4		
52	MT POKAKA-171132	TIMBER MILL	0.0	0.0	0.4	0.4		
53	KERIKERI-181172	RANUI AVENUE	0.3	0.0	0.0	0.3		
54	OKAHU RD-1107	REDAN ROAD	0.0	0.2	0.0	0.2		

* The YE2022 summary results above are only for the six-month period April through September 2021. Note that the trend has been established by doubling the YE2022 unplanned SAIDI.

7.4 Short-term Equipment Performance

Table 5 summarises the unplanned SAIDI performance (over the period YE2020, YE2021 and the first six months of YE2022) by equipment categories, sorted from highest to lowest. Table 5 also shows the percentage contributed by the individual equipment types and we have also assessed whether the SAIDI contributions appear to be increasing using the following:

- Doubling the YE2022 SAIDI figures (as the data supplied only includes 6 months). This view is based on the fact that the unplanned SAIDI over the months of April-September in YE2020 and YE2021 contributed 38% and 49% respectively to the year-end totals.
- Linearly trending the data over the three periods.
- Indicating an upward trend if the slope of the trend-line is significantly positive.

Examination of the values in Table 5 indicates the following:

- The top five equipment categories contribute 70% of TEN's unplanned SAIDI and are:
  - Conductor Span.
  - Pole.
  - Unknown.
  - X-arm.
  - Tail/Lead/Jumper
- The top ten equipment categories contribute 90% of TEN's unplanned SAIDI.
- Increasing SAIDI contributions from the following equipment categories:
  - Conductor Span.
  - Unknown.
  - X-arms.
  - Insulators (pin and termination).

Given the significant contribution due to top five equipment categories Ergo has continued to review, in more detail, the reasons for the failures of equipment failures categories in the sections that follow.

Table 5: Unplanned SAIDI by equipment for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	**Equipment**	**YE2020**	**YE2021**	**YE2022***	**SUBTOTAL**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Conductor Span	106.1	59.0	70.0	235.2	28%	28%	UP
2	Pole	62.5	47.7	29.2	139.4	17%	44%	
3	Unknown	21.6	36.1	35.2	92.9	11%	55%	UP
4	Xarm	17.3	49.8	21.1	88.2	10%	66%	UP
5	Tail/Lead/Jumper	28.4	8.9	5.8	43.2	5%	71%	
6	Circuit Breaker	0.1	33.9	2.0	35.9	4%	75%	
7	Insulator (Pin)	0.6	18.1	15.5	34.1	4%	79%	UP
8	Insulator (Suspension)	11.8	9.7	10.3	31.8	4%	83%	
9	Binder	8.7	4.8	8.3	21.8	3%	86%	
10	Tx Dist	6.1	8.9	4.9	20.0	2%	88%	
11	Insulator (Termination)	3.0	0.6	9.5	13.2	2%	90%	UP
12	Regulator	9.5	0.0	3.1	12.6	1%	91%	
13	Cable	4.4	2.7	1.1	8.2	1%	92%	
14	Cable Termination	1.2	5.8	0.0	7.0	1%	93%	
15	Conductor Termination	5.0	0.2	1.6	6.7	1%	94%	
16	Switch	5.2	1.2	0.0	6.4	1%	95%	
17	Sectionaliser	1.3	3.1	1.6	6.0	1%	95%	
18	Link	4.4	0.8	0.2	5.4	1%	96%	
19	Conductor Joint	0.6	4.7	0.0	5.2	1%	97%	
20	TX SWER INS	4.1	0.0	0.0	4.1	0%	97%	
21	Switch	1.1	1.4	1.4	4.0	0%	98%	
22	Fuse Base	1.6	1.3	0.8	3.8	0%	98%	
23	Lightning Arrestor	2.4	0.5	0.3	3.2	0%	98%	
24	Fuse Element	0.1	0.3	2.6	3.0	0%	99%	
25	Recloser	1.6	0.5	0.8	2.9	0%	99%	
26	STRUCTURE TX	1.8	0.0	0.0	1.8	0%	99%	
27	Stay Assembly	1.2	0.1	0.0	1.4	0%	99%	
28	Tx SWER Isolating	0.9	0.2	0.0	1.1	0%	100%	
29	CONDUCTOR ROAD XING	0.9	0.0	0.0	0.9	0%	100%	
30	Tx Dist	0.7	0.0	0.1	0.8	0%	100%	
31	Other	0.6	0.1	0.0	0.8	0%	100%	
32	Circuit Breaker	0.6	0.0	0.0	0.6	0%	100%	
33	COMMS EQUIPMENT	0.3	0.0	0.0	0.3	0%	100%	
34	Other	0.0	0.2	0.0	0.2	0%	100%	
35	CONTROL EQUIPMENT	0.1	0.0	0.0	0.1	0%	100%	
36	SUB STN TX	0.0	0.0	0.0	0.0	0%	100%	
37	Fuse Base	0.0	0.0	0.0	0.0	0%	100%	
	TOTALs	**315.9**	**300.8**	**225.7**	**842.4**	**100%**		

* The YE2022 summary results above are only for the six-month period April through September 2021.

7.4.1 Conductor Span Performance

The following Table 6 illustrates the causes of Conductor Span related SAIDI during the period YE2021/YE2020/YE2022, which shows the following:

- The top three causes accounted for 84% of the SAIDI.
- 70% resulted from tree/vegetation related interference.
- 10% resulted from conductor failure.
- Tree related SAIDI appears to be increasing.

Table 6: Summary: Conductor Span related unplanned SAIDI by cause for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	Equipment	YE2020	YE2021	YE2022*	SUBTOTAL	% of TOTAL	Cumulative %	TREND
1	Tree (Fall on Line)	47.1	17.0	30.5	94.6	40%	40%	UP
2	Tree Contact	25.4	26.3	19.5	71.2	30%	70%	UP
3	Conductor Failure	15.3	8.2	7.6	31.1	13%	84%	
4	Bird Strike	6.1	0.4	2.9	9.4	4%	88%	
5	Possum Damage	6.2	0.3	0.6	7.2	3%	91%	
6	External Tree Works	0.2	4.8	1.8	6.8	3%	94%	
7	Binder Failure	3.8	0.0	0.0	3.8	2%	95%	
8	Tree (Fall on Structure)	0.0	0.0	3.8	3.8	2%	97%	UP
9	Fault on Customer Premises	0.8	0.1	1.8	2.7	1%	98%	
10	Storm	0.0	0.3	1.0	1.3	1%	99%	
11	Machine Contact Lines	0.0	0.6	0.3	0.9	0%	99%	
12	Cause Unknown	0.0	0.8	0.1	0.9	0%	99%	
13	Xarm Failure	0.5	0.0	0.0	0.5	0%	100%	
14	Suspension Clamp Failure	0.4	0.0	0.0	0.4	0%	100%	
15	Joint Failure	0.2	0.0	0.0	0.2	0%	100%	
16	Lightning Strike	0.0	0.1	0.0	0.1	0%	100%	
17	Network Security/Safety 3RD Party Interference	0.0	0.1	0.0	0.1	0%	100%	
18	Internal Tree Works (Line Contact)	0.0	0.1	0.0	0.1	0%	100%	
19	Vehicle Vs Lines	0.0	0.0	0.0	0.0	0%	100%	
20	Ground Conditions/Slips	0.0	0.0	0.0	0.0	0%	100%	
21	Other Equipment Failure	0.0	0.0	0.0	0.0	0%	100%	
	TOTAL	106.1	59.0	70.0	235.2	100%		

* The YE2022 summary results above are only for the six-month period April through September 2021.

Ergo has “dug deeper” into the data to examine, in more detail, the top three causes of Conductor Span related SAIDI. Table 7 illustrates the total number of incidents and the mean time to restore/repair (MTTR). Again, we have assessed the trend using the methodology outlined in Section 6 (page 9), which infers the following:

- Tree related incidents are relatively static (i.e. no significant trends).
- The restoration/repair times associated with tree incidents appears to be trending upwards.
- Conductor failures appear to be remaining relatively static.

Table 7: Conductor Span: Top three causes: Mean-time-to-restore/repair (MTTR) and number of incidents

	Tree (Fall on Line)		Tree Contact		Conductor Failure	
Year	MTTR (hours)	Count	MTTR (hours)	Count	MTTR (hours)	Count
YE2020	5.1	51	2.5	35	11.1	26
YE2021	5.9	24	4.4	47	13.2	13
YE2022*	9.3	20	3.6	23	10.9	12
TREND	UP	DOWN	UP	UP	-	-

* The YE2022 summary results above are only for the six-month period April through September 2021.

7.4.2 Pole Performance

The following Table 8 illustrates the causes of Pole related SAIDI during the period YE2021/YE2020/YE2022. Table 8 shows the following:

- The majority of incidents have been vehicle related at 88%.
- The second highest cause at 6% has been tree/vegetation related.
- Pole related SAIDI does not appear to be increasing, and vehicle related incidents appears to be trending downwards.

Table 8: Summary: Pole related unplanned SAIDI by cause for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	**Equipment**	**YE2020**	**YE2021**	**YE2022***	**SUBTOTAL**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Vehicle Vs Pole	52.4	46.8	23.7	123.0	88%	88%	DOWN
2	Tree (Fall on Line)	3.7	0.0	4.0	7.8	6%	94%	
3	External Tree Works	2.8	0.0	0.0	2.8	2%	96%	
4	Storm	2.3	0.4	0.0	2.7	2%	98%	
5	Pole Failure	0.3	0.0	1.5	1.7	1%	99%	
6	Other Equipment Failure	0.7	0.1	0.0	0.7	1%	99%	
7	Tree (Fall on Structure)	0.0	0.5	0.0	0.5	0%	100%	
8	VEHICLE VS OVERHEAD WIRES	0.1	0.0	0.0	0.1	0%	100%	
9	Insulator Missing/Hanging	0.1	0.0	0.0	0.1	0%	100%	
10	Ground Conditions/Slips	0.0	0.0	0.0	0.0	0%	100%	
11	Tree Machine Contact Lines	0.0	0.0	0.0	0.0	0%	100%	
	TOTAL	**62.5**	**47.7**	**29.2**	**139.4**			

* The YE2022 summary results above are only for the six-month period April through September 2021.

Table 9 illustrates the total number of incidents and the mean time to restore/repair (MTTR) for the main cause of Pole related SAIDI. Again, we have assessed the trend using the methodology outlined in Section 6 (page 9). Table 9 infers that the MTTR for Vehicle vs Pole has remained relatively stable, whilst the number of incidents is indicating a slight upward trend.

Table 9: Conductor Span: Top cause: Mean-time-to-restore/repair (MTTR) and number of incidents

	Vehicle Vs Pole	
Year	**MTTR (hours)**	**Count**
YE2020	6.84	18
YE2021	6.27	18
YE2022*	6.32	12
TREND	-	UP

* The YE2022 summary results above are only for the six-month period April through September 2021.

7.4.3 Unknown Performance

The following Table 10 illustrates the third highest contributor to unplanned SAIDI which is categorised as "unknown" during the period YE2021/YE2020/YE2022. This category is clearly indicated to be trending up and we note that TEN recently mentioned this upward trend in company reports (refer to Item 3 in Section 5).

Table 10: Summary: Unknown related unplanned SAIDI by cause for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	**Equipment**	**YE2020**	**YE2021**	**YE2022***	**SUBTOTAL**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Cause Unknown	21.7	35.7	35.0	92.4	99%	99%	UP
2	Lightning Strike	0.3	0.4	0.0	0.8	1%	1%	
3	Storm	0.2	0.0	0.2	0.4	0%	0%	
	TOTAL	**22.3**	**36.1**	**35.2**	**93.6**			

* The YE2022 summary results above are only for the six-month period April through September 2021.

Again, we have examined the core data relating to the unknown category and found that the mean time to restore has remained relatively constant and surprisingly the number of events is indicated to be trending down (refer to Table 11), which appears to contradict the information in Table 10. However, on further investigation Ergo has determined that the average SAIDI associated with the unknown category of events has trended up significantly and this is shown in Table 11.

Table 11: Unknown: Top cause: Mean-time-to-restore/repair (MTTR) and number of incidents

	Cause Unknown		
Year	**MTTR (hours)**	**Count**	**Average SAIDI per event (mins)**
YE2020	2.26	69	0.31
YE2021	2.00	41	0.87
YE2022*	2.21	26	1.35
TREND	-	DOWN	UP

* The YE2022 summary results above are only for the six-month period April through September 2021.

7.4.4 X-Arm

The following Table 12 illustrates the causes of x-arm related SAIDI during the period YE2021/YE2020/YE2022. Table 12 shows the following:

- 95% has been due to *x-arm failure* or *corrosion/rot*.
- There has been a small amount due to *vandalism* / *intentional-damage*.
- X-arm related SAIDI does appear to be trending slightly upwards.

Table 12: Summary: X-arm related unplanned SAIDI by cause for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	**Equipment**	**YE2020**	**YE2021**	**YE2022***	**SUBTOTAL**	**% of TOTAL**	**Cumulative %**	**TREND**
1	Xarm Failure	16.2	41.2	19.5	76.9	87%	87%	UP
2	Corrosion/Rot	0.0	5.4	1.3	6.7	8%	95%	
3	Vandalism/Intentional Damage	0.0	3.1	0.0	3.1	4%	98%	
4	Tree (Fall on Line)	1.2	0.0	0.0	1.2	1%	100%	
5	Insulator Missing/Hanging	0.0	0.0	0.3	0.3	0%	100%	
6	Tree Contact	0.0	0.1	0.0	0.1	0%	100%	
	TOTAL	**17.3**	**49.8**	**21.1**	**88.2**			

* The YE2022 summary results above are only for the six-month period April through September 2021.

We have examined the core data relating to the x-arm SAIDI and found that, for the major contributor of *x-arm failure*, the mean time to restore has consistently reduced but the number of events is indicated to be trending upwards (refer to Table 13). This infers that TEN's performance in relation to restoration/repair has improved but the number of failures is increasing.

Table 13: X-arm: Top cause of *x-arm failure*: Mean-time-to-restore/repair (MTTR) and number of incidents

	Xarm Failure		
Year	**MTTR (hours)**	**Count**	**Average SAIDI per event (mins)**
YE2020	5.42	23	0.70
YE2021	3.09	32	1.29
YE2022*	2.26	23	0.85
TREND	DOWN	UP	-

7.4.5 Tail/Lead/Jumper

The following Table 14 illustrates the causes of Tail/Lead/Jumper related SAIDI during the period YE2021/YE2020/YE2022. Table 14 shows the following:

- 78% was due to the category *Conductor Tail Blown Off*. This category has trended downwards.
- 10% was due to conductor failures.
- 8% was due to joint failure, although all occurring in YE2022.

Table 14: Summary: Tail/Lead/Jumper related unplanned SAIDI by cause for YE2021/YE2020/YE2022

		SAIDI (minutes)						
No	Equipment	YE2020	YE2021	YE2022*	SUBTOTAL	% of TOTAL	Cumulative %	TREND
1	Conductor Tail Blown Off	28.1	4.4	1.3	33.7	78%	78%	DOWN
2	Conductor Failure	0.3	3.9	0.2	4.4	10%	88%	
3	Joint Failure	0.0	0.0	3.7	3.7	8%	97%	UP
4	Corrosion/Rot	0.0	0.0	0.7	0.7	2%	99%	
5	Tree Contact	0.0	0.5	0.0	0.5	1%	100%	
6	Normal Aging/Degradation	0.0	0.2	0.0	0.2	0%	100%	
	TOTAL	28.4	8.9	5.8	43.2			

* The YE2022 summary results above are only for the six-month period April through September 2021.

7.5 Restoration Times & SAIDI vs Event Numbers

In Section 7.4 Ergo noted that restoration/repair times appeared to be trending upwards, particularly in relation to Conductor Span events involving vegetation (refer to Section 7.4.1). We have thus examined the restoration/repair times for unplanned SAIDI and Figure 8 illustrates a graph of the percentage of events versus restoration/repair times for the three period of YE2020, YE2021 and YE2022. Examination of Figure 8 shows the following:

- The percentage of incidents restored/repaired within a given time is relatively consistent with some small variation.
- In YE2020 90% of events were restored/repaired within ≈15 hours, compared with YE2021/YE2022 when 90% of events were repaired with ≈12 hours.
- In YE2020/2022 80% of events were restored/repaired within ≈7.5 hours, compared with YE2021 when 90% of events were repaired with ≈4.5 hours

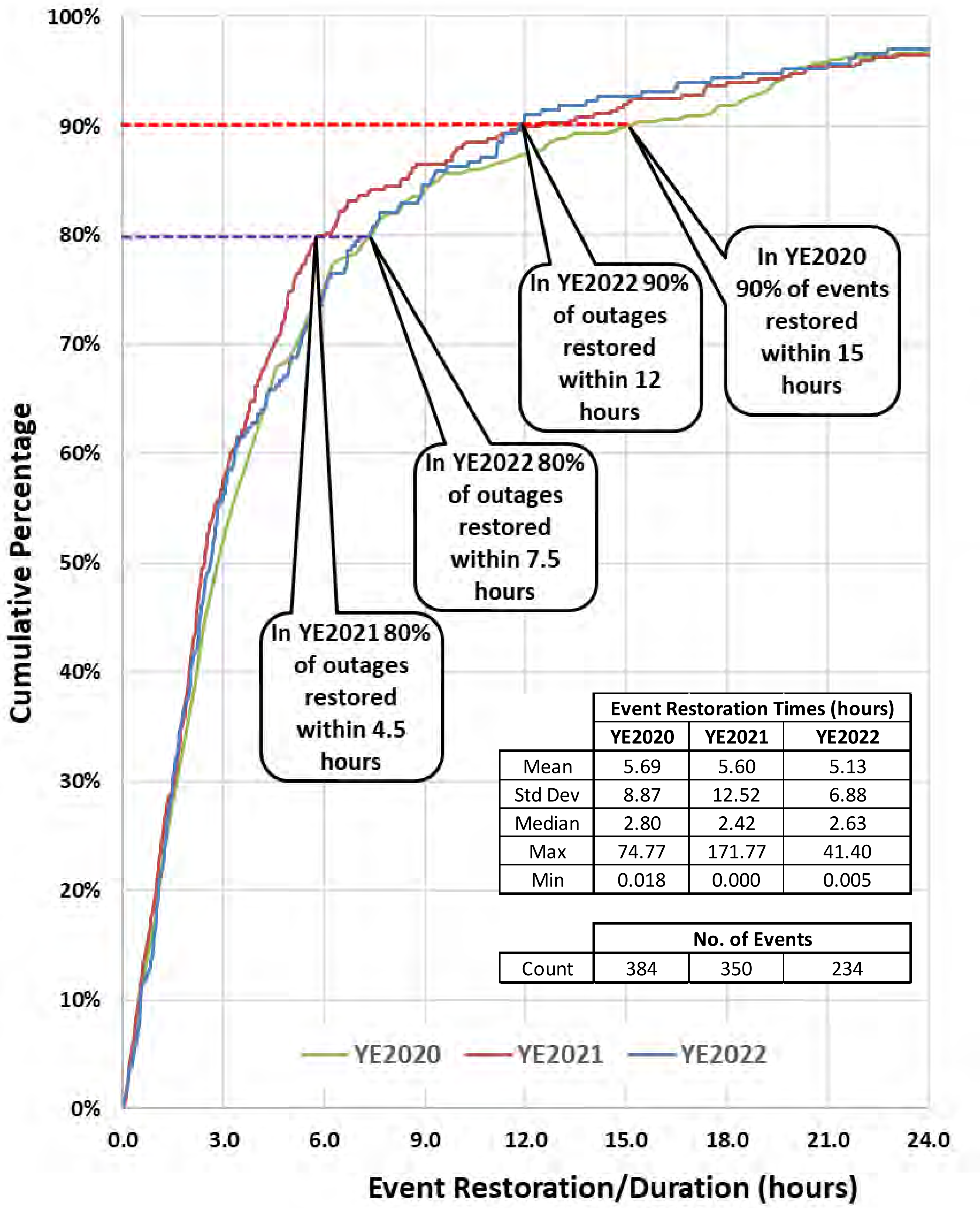
On face value Figure 8 does not provide evidence of any significant trends and we note that there is not a “linear translation” between event restoration/repair times and SAIDI due to each outage involving different amounts of consumers.

A more “definitive picture” is gained by examining the percentage of incidents versus SAIDI contribution which is illustrated in Figure 9. Figure 9 shows that in YE2022 the top 50% of SAIDI contributing events (i.e. greater than the median value) consistently contributed larger SAIDI amounts than that in YE2020 and YE2021. We note that this statement does not apply to ALL of the top 50% of events as, for example, in YE2020 there was a single event that contributed the most SAIDI of 25.36 minutes for the entire YE2020/YE2021/YE2022 period. These large events are typically limited to sub-transmission outages that occur rarely and impact a significant number of consumers (i.e. the Kaikohe-Kaitaia 110kV overhead line). We also note that Figure 9 does not necessarily support an “increasing trend” as the best performance occurred in YE2021 were the top 50% of SAIDI events where consistently lower.

Ergo has summarised the top 50% of SAIDI events by outage type in Table 15 and included a possible outcome involving the doubling of the recent six months of YE2022 SAIDI. Table 15 infers increases in SAIDI associated with the outage types of weather, unknown and vegetation.

There is the possibility that Figure 9 is not a fair comparison due to the fact that the YE2022 data only includes the autumn/winter/spring period. Given this fact, Ergo has repeated the results shown in Figure 9 but this time, in all cases, comparing the YE2020/YE2021/YE202 SAIDI data only for the period April through September. The results are shown in Figure 10 and they further confirm that the top 50% of YE2022 SAIDI contributing events consistently contributed larger SAIDI amounts than that in YE2021 and YE2020.

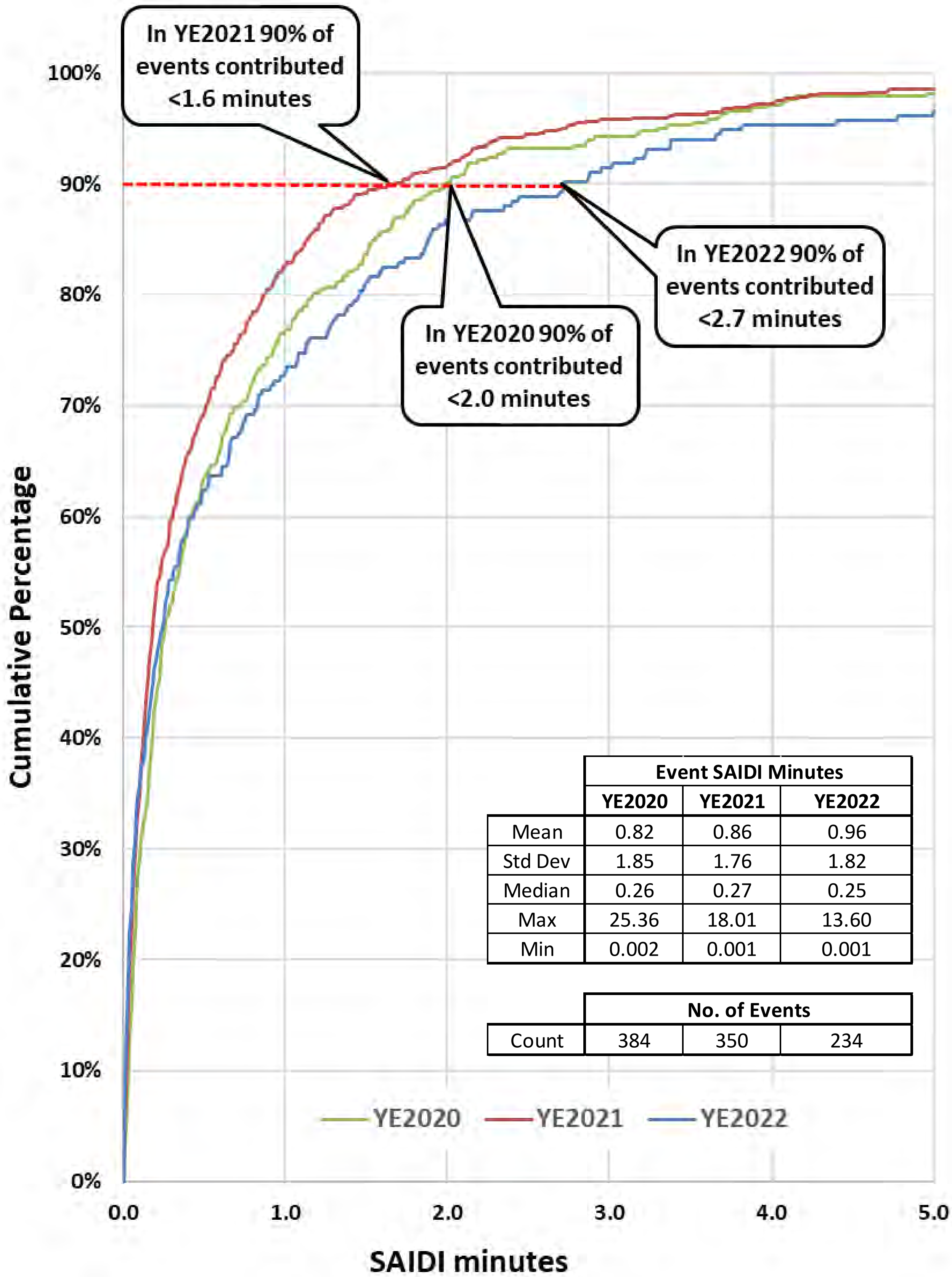
Ergo notes that TEN installed an Advanced Distribution Management System (ADMS) in 2020, which is used to calculate its SAIDI data. We recommend that TEN confirm that modifications to this system have not affected TEN's recorded unplanned SAIDI.



	Event Restoration Times (hours)		
	YE2020	YE2021	YE2022
Mean	5.69	5.60	5.13
Std Dev	8.87	12.52	6.88
Median	2.80	2.42	2.63
Max	74.77	171.77	41.40
Min	0.018	0.000	0.005

	No. of Events		
Count	384	350	234

Figure 8 Unplanned SAIDI events: Cumulative percentage vs outage time for YE2021/YE2020/YE2022.



	Event SAIDI Minutes		
	YE2020	YE2021	YE2022
Mean	0.82	0.86	0.96
Std Dev	1.85	1.76	1.82
Median	0.26	0.27	0.25
Max	25.36	18.01	13.60
Min	0.002	0.001	0.001

	No. of Events		
Count	384	350	234

Figure 9 Unplanned SAIDI events: Cumulative percentage vs SAIDI minutes for YE2021/YE2020/YE2022.

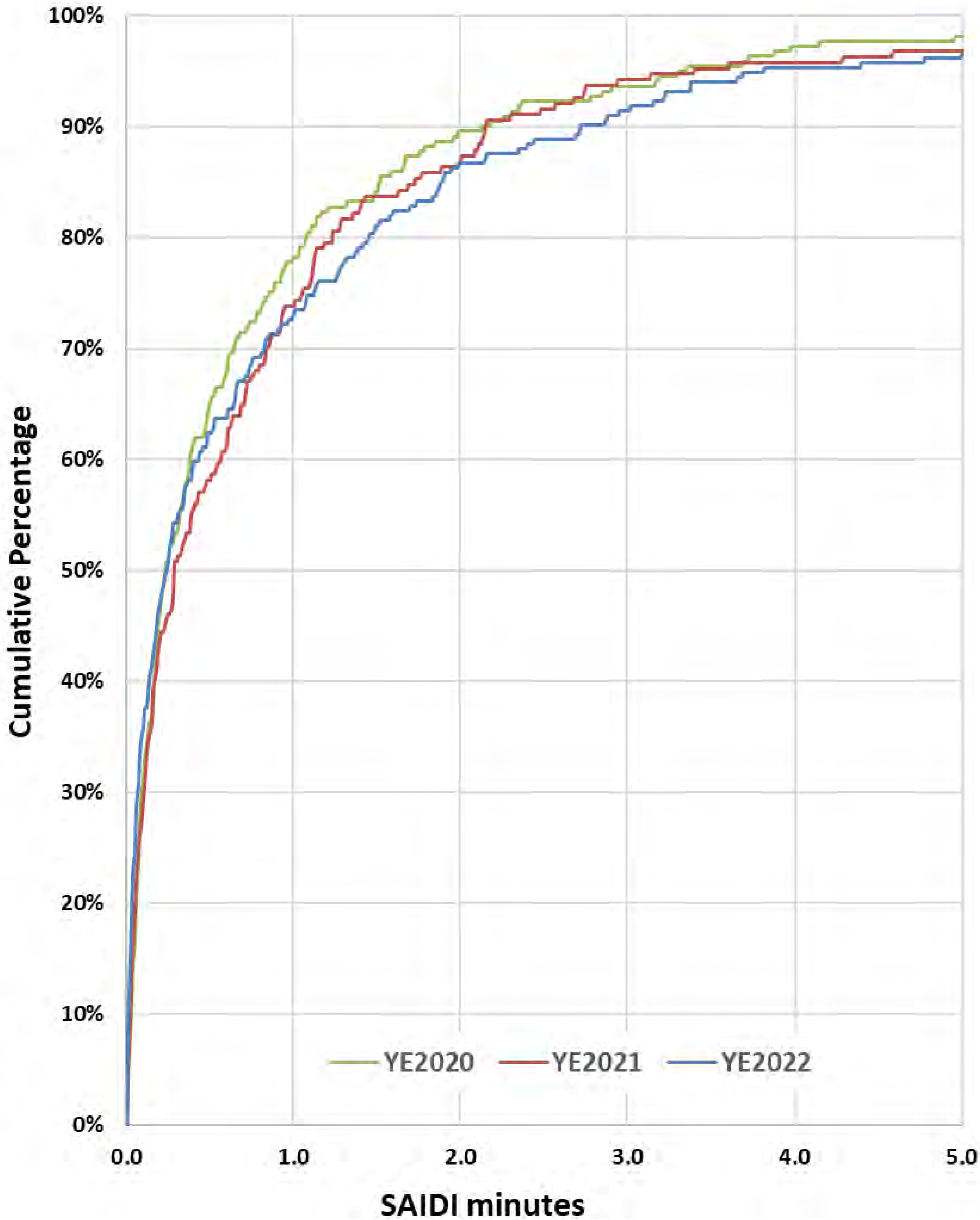


Figure 10 Unplanned SAIDI events: Cumulative percentage vs SAIDI minutes for YE2021/YE2020/YE2022 (All based on the April to September period).

Table 15: Summary: Top 50% unplanned SAIDI events by outage for YE2021/YE2020/YE2022

	YE2020				YE2021				YE2022				YE2022 - Doubled	
	SAIDI		Number		SAIDI		Number		SAIDI		Number		SAIDI	Number
Outage Type	**mins**	**%**	**Count**	**%**	**mins**	**%**	**Count**	**%**	**mins**	**%**	**Count**	**%**	**mins**	**Count**
Weather	2.3	1%	1	1%	0.3	0%	1	1%	24.2	11%	4	3%	48.4	8
Unknown	16.8	6%	24	13%	37.9	13%	31	16%	36.4	17%	20	17%	72.7	40
Vegetation	76.7	26%	56	30%	41.8	14%	43	22%	57.9	27%	26	23%	115.7	52
Defective Equipment	115.1	39%	70	37%	137.2	47%	89	45%	61.0	28%	44	38%	122.0	88
Environment	0.0	0%	0	0%	0.0	0%	0	0%	0.0	0%	0	0%	0.0	0
Third Party	58.1	20%	21	11%	56.0	19%	23	12%	28.7	13%	17	15%	57.5	34
Lightning	6.9	2%	6	3%	3.2	1%	3	2%	5.6	3%	2	2%	11.1	4
Human Error	4.0	1%	2	1%	13.3	5%	2	1%	0.0	0%	0	0%	0.0	0
Wildlife	13.0	4%	8	4%	1.1	0%	4	2%	3.2	1%	2	2%	6.3	4
TOTAL	**293.0**	**100%**	**188**	**100%**	**290.8**	**100%**	**196**	**100%**	**216.9**	**100%**	**115**	**100%**	**433.7**	**230**

7.6 Worst Feeder Performance by Cause

Section 7.3 presented the performance of TEN's distribution feeders. The following sections examine the causes of the unplanned SAIDI on TEN's five worst performing feeders (over the period YE2020/YE2021/YE2020).

7.6.1 Tokerau Feeder (Taipa Substation CB1205)

The following Table 16 illustrates the unplanned SAIDI recorded on the Tokerau feeder, which indicates a significant amount (50%) has been due to defective equipment (mostly x-arm failures). Third party damage has also contributed significantly (38%). There has been a small amount (5%) due to vegetation. The information in Table 16 infers that TEN should be focusing on refurbishing the equipment on the Tokerau feeder, particularly the x-arms.

Table 16 Unplanned SAIDI: Tokerau Feeder

Tokerau Feeder	**Unplanned SAIDI (minutes)**				
Tapia Substation CB1205	**YE2020**	**YE2021**	**YE2022**	**Sub-total**	
Defective Equipment	12.8	9.7	10.0	32.5	50%
Cable Termination	0.0	1.4	0.0	1.4	
Conductor Joint	0.3	0.0	0.0	0.3	
Fuse Base	0.3	0.0	0.0	0.3	
Lightning Arrestor	0.0	0.0	0.3	0.3	
Link	0.1	0.0	0.0	0.1	
Sectionaliser	1.1	0.0	0.0	1.1	
Tail/Lead/Jumper	0.0	2.1	0.0	2.1	
Xarm	10.9	6.2	9.7	26.7	
Third Party	19.3	0.1	5.4	24.8	38%
Pole	19.3	0.0	5.4	24.6	
Stay Assembly	0.0	0.1	0.0	0.1	
Unknown	0.6	1.8	1.3	3.7	6%
Unknown	0.6	1.8	1.3	3.7	
Vegetation	2.9	0.1	0.0	3.0	5%
Conductor Span	2.9	0.1	0.0	3.0	
Wildlife	0.9	0.0	0.2	1.1	2%
Conductor Span	0.0	0.0	0.2	0.2	
Link	0.9	0.0	0.0	0.9	
Grand Total	**36.5**	**11.7**	**16.8**	**65.0**	

7.6.2 South Road Feeder (Okahu Rd Substation CB1105)

Table 17 illustrates the unplanned SAIDI recorded on the South Road feeder, which indicates a significant amount (48%) has been due to *vegetation*. A lower contribution has been due to *defective equipment* (21%), *unknown* (16%) and t*hird party* (13%).

The information in Table 17 infers that TEN should be focusing on managing vegetation adjacent to the South Road feeder.

Table 17 Unplanned SAIDI: South Road Feeder

South Road Feeder	Unplanned SAIDI (minutes)				
Okahu Rd Substation CB1105	**YE2020**	**YE2021**	**YE2022**	**Sub-total**	
Defective Equipment	1.1	9.2	3.0	13.3	21%
Binder	0.2	0.6	0.0	0.9	
Conductor Joint	0.1	0.0	0.0	0.1	
Conductor Span	0.1	0.6	0.2	0.9	
Fuse Base	0.0	0.0	0.0	0.0	
Insulator (Pin)	0.0	0.3	0.0	0.3	
Insulator (Suspension)	0.5	5.6	0.0	6.1	
Link	0.0	0.2	0.0	0.2	
Regulator	0.0	0.0	2.3	2.3	
Tail/Lead/Jumper	0.0	0.9	0.2	1.1	
TX POLE MOUNT	0.0	0.0	0.0	0.0	
TX SWER DIST	0.1	0.0	0.0	0.1	
Xarm	0.1	1.0	0.2	1.2	
Lightning	2.0	0.0	0.0	2.0	3%
TX SWER INS	1.9	0.0	0.0	1.9	
Unknown	0.2	0.0	0.0	0.2	
Third Party	0.6	4.2	3.3	8.1	13%
Conductor Span	0.0	4.2	0.0	4.2	
Pole	0.0	0.0	3.3	3.3	
Stay Assembly	0.6	0.0	0.0	0.6	
Unknown	3.8	3.1	3.6	10.5	16%
Fuse Element	0.0	0.0	0.7	0.7	
Sectionaliser	0.0	0.1	0.0	0.1	
Unknown	3.8	3.0	2.9	9.7	
Vegetation	7.0	7.2	16.5	30.8	48%
Conductor Span	5.9	7.2	13.5	26.6	
Pole	0.0	0.0	3.0	3.0	
Xarm	1.2	0.0	0.0	1.2	
Wildlife	0.0	0.0	0.0	0.0	0%
Conductor Span	0.0	0.0	0.0	0.0	
Grand Total	**14.6**	**23.8**	**26.3**	**64.8**	

7.6.3 Te Kao Feeder (Pukenui Substation CB131142)

Table 18 illustrates the unplanned SAIDI recorded on the Te Kao feeder, which indicates the majority of SAIDI (66%) has been due to *defective equipment*. A moderate contribution has been due to *weather* (25%) and a small amount due to *vegetation*.

The information in Table 18 infers that TEN should be focusing on refurbishing the equipment on the Te Kao feeder, particularly x-arms and insulators.

Table 18 Unplanned SAIDI: Te Kao Feeder

Te Kao Feeder	Unplanned SAIDI (minutes)				
Pukenui Substation CB131142	YE2020	YE2021	YE2022	Sub-total	
Defective Equipment	16.4	10.3	9.5	36.2	66%
Binder	1.7	1.5	0.0	3.2	
Conductor Span	3.4	0.0	0.0	3.4	
Conductor Termination	3.2	0.0	0.0	3.2	
Fuse Base	0.1	0.0	0.0	0.1	
Insulator (Termination)	1.5	0.0	6.1	7.6	
Link	0.0	0.0	0.1	0.1	
MULTIPLE ITEMS	4.1	0.0	0.0	4.1	
Sectionaliser	0.0	0.0	0.0	0.1	
Stay Assembly	0.0	0.0	0.0	0.0	
Tx Dist	0.0	3.5	0.2	3.8	
TX POLE MOUNT	1.2	0.0	0.0	1.2	
TX SWER INS	1.1	0.0	0.0	1.1	
Xarm	0.0	5.2	3.1	8.4	
Lightning	0.0	0.0	0.0	0.0	0%
Fuse Base	0.0	0.0	0.0	0.0	
Unknown	1.0	0.4	0.0	1.5	3%
Link	0.0	0.1	0.0	0.1	
Sectionaliser	0.0	0.0	0.0	0.0	
Unknown	1.0	0.3	0.0	1.3	
Vegetation	0.0	3.2	0.0	3.2	6%
Conductor Span	0.0	3.2	0.0	3.2	
Weather	0.0	0.0	13.6	13.6	25%
Insulator (Pin)	0.0	0.0	13.6	13.6	
Wildlife	0.0	0.1	0.0	0.1	0%
Conductor Span	0.0	0.1	0.0	0.1	
Grand Total	**17.4**	**14.0**	**23.2**	**54.6**	

7.6.4 Horeke Feeder (Kaikohe Substation CB0111)

Table 19 illustrates the unplanned SAIDI recorded on the Te Kao feeder, which indicates a significant amount (53%) has been due to *defective equipment*. A lower contribution has been due to *third party* (19%) and *vegetation* (19%).

The information in Table 19 infers that TEN should be focusing on refurbishing the equipment on the Te Kao feeder and, to a lesser extent, vegetation management.

Table 19 Unplanned SAIDI: Horeke Feeder

Horeke Feeder	Unplanned SAIDI (minutes)				
Kaikohe Substation CB0111	YE2020	YE2021	YE2022	Sub-total	
Defective Equipment	1.7	18.8	2.7	23.2	53%
Conductor Span	0.1	0.0	0.0	0.1	
Fuse Base	0.0	0.9	0.0	0.9	
Insulator (Suspension)	0.0	2.2	2.7	4.9	
Link	0.0	0.0	0.0	0.0	
MULTIPLE ITEMS	1.4	0.0	0.0	1.4	
Recloser	0.0	0.0	0.0	0.0	
Tail/Lead/Jumper	0.1	0.1	0.0	0.2	
Tx Dist	0.0	0.0	0.0	0.0	
Xarm	0.1	15.6	0.0	15.7	
Environment	0.0	0.0	0.0	0.0	0%
Conductor Span	0.0	0.0	0.0	0.0	
Human Error	0.0	0.0	0.0	0.0	0%
Switch	0.0	0.0	0.0	0.0	
Lightning	0.0	0.0	0.0	0.0	0%
Fuse Element	0.0	0.0	0.0	0.0	
Third Party	3.9	4.0	0.3	8.2	19%
Cable Termination	0.0	0.0	0.0	0.0	
Conductor Span	0.0	0.0	0.3	0.3	
Pole	3.9	4.0	0.0	7.9	
Unknown	0.1	0.0	2.2	2.4	5%
Fuse Element	0.0	0.0	0.0	0.0	
Sectionaliser	0.0	0.0	0.9	0.9	
Unknown	0.1	0.0	1.4	1.5	
Vegetation	7.4	0.9	0.0	8.3	19%
Conductor Span	7.4	0.9	0.0	8.3	
Wildlife	1.8	0.0	0.0	1.8	4%
Conductor Span	1.8	0.0	0.0	1.8	
Fuse Element	0.0	0.0	0.0	0.0	
Grand Total	**14.9**	**23.8**	**5.3**	**44.0**	

7.6.5 Oruru Feeder (Tapia Substation CB1206)

Table 20 illustrates the unplanned SAIDI recorded on the Oruru feeder, which indicates a significant contribution (33%) has been due to *vegetation* and *third party* (26%). A lower contribution has been due to *defective equipment* (19%) and *unknown* (14%).

The information in Table 20 infers that TEN should be focusing on managing vegetation adjacent to the Oruru feeder, reviewing pole related third party damage and undertaking targeted refurbishment of the line equipment.

Table 20 Unplanned SAIDI: Oruru Feeder

Oruru Feeder	**Unplanned SAIDI (minutes)**				
Tapia Substation CB1206	**YE2020**	**YE2021**	**YE2022**	**Sub-total**	
Defective Equipment	1.8	2.7	1.3	5.8	17%
Conductor Span	0.0	0.3	0.0	0.3	
Other	0.0	0.2	0.0	0.2	
Switch	0.0	0.2	0.0	0.2	
Tail/Lead/Jumper	0.0	1.4	0.0	1.4	
TX POLE MOUNT	1.7	0.0	0.0	1.7	
Xarm	0.1	0.6	1.3	2.0	
Lightning	1.9	0.1	0.0	2.0	6%
Tx Dist	0.0	0.1	0.0	0.1	
TX POLE MOUNT	1.9	0.0	0.0	1.9	
Third Party	0.4	7.9	0.9	9.2	26%
Cable	0.4	0.0	0.0	0.4	
Pole	0.0	4.7	0.9	5.6	
Xarm	0.0	3.1	0.0	3.1	
Unknown	0.9	0.9	3.1	4.9	14%
Fuse Element	0.0	0.0	0.7	0.7	
Unknown	0.9	0.9	2.4	4.2	
Vegetation	5.8	1.4	4.2	11.4	33%
CONDUCTOR ROAD XING	0.9	0.0	0.0	0.9	
Conductor Span	4.8	1.4	4.2	10.4	
Weather	0.0	0.0	1.5	1.5	4%
Pole	0.0	0.0	1.5	1.5	
Grand Total	**10.8**	**12.9**	**11.0**	**34.7**	

8. Summary/Recommendations

Ergo has reviewed the information supplied and noted the following:

- Over the period 1999 through 2020 TEN's reported SAIDI has varied significantly, with its annual SAIDI (planned and unplanned) varying from 329 minutes (2001) to 1,838 minutes (2015) with an average of 575 minutes.
- Over the last decade TEN has invested a significant amount of capital on its network in an effort to stabilize its SAIDI performance. This expenditure was formulated in its TE2020 Project that has mostly focused on its sub-transmission network. The TE2020 Project has yet to be completed, but the expenditure appears to be delivering the benefits intended.

We have also analysed TEN's recent unplanned SAIDI data (YE2020, YE2021 and YE2022[8]) and have determined the following for the period considered:

- TEN's sub-transmission network has typically contributed ≈15% to its unplanned SAIDI performance. However, we note that the sub-transmission SAIDI can vary significantly due to high-impact-low-probability (HILP) events and its contribution could be higher from time-to-time.
- TEN's distribution network has typically contributed the vast majority of ≈85% to its unplanned SAIDI performance.
- Overall the unplanned SAIDI performance in YE2020 and YE2021 has been very similar.
- The April-September YE2022 data infers that the year-end unplanned SAIDI could be higher than the unplanned SAIDI recorded in YE2020 and YE2021. This view is based on doubling the YE2022 data and the fact that the unplanned SAIDI over the months of April-September in YE2020 and YE2021 contributed 38% and 49% respectively to the year-end totals.
- Over the period YE2020/YE2021/YE2022 the following are the outage types that have contributed to TEN's unplanned SAIDI:
    - *Defective equipment* (39%).
    - *Vegetation* (22%).
    - *Third Party* (18%).
    - *Unknown* (12%).
    - *Weather* (3%).
    - *Human Error* (2%).
    - *Wildlife* (2%)
    - *Lightning* (2%).
    - *Environment* (0%).
- The five worst performing sections of TEN's network have been associated with the following substation supplies (in order of performance):
    - Kaikohe substation.
    - Okahu Rd substation.
    - Taipa substation.
    - Pukenui substation.
    - Omanaia substation.
- The five worst performing feeders on TEN's (in order of performance):
    - **Tokerau feeder** (CB1205) fed from the Taipa zone substation. A high proportion of unplanned SAIDI on this feeder has been due to *defective equipment*.

[8] The data for this year only includes the period April 2021 through September 2021 (i.e. a six-month period).

  - **South Road feeder** (CB1105) fed from the Okahu zone substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *vegetation* and the unplanned SAIDI is trending upwards.
  - **Te Kao feeder** (131142) fed from the Pukenui zone substation. A high proportion of unplanned SAIDI on this feeder has been due to *defective equipment* and the unplanned SAIDI is trending upwards.
  - **Horeke feeder** (CB0111) fed from the Kaikohe zone substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *defective equipment* and the unplanned SAIDI is trending upwards.
  - **Oruru feeder** (CB1206) fed from the Taipa substation. A high proportion of the unplanned SAIDI reported against this feeder has been due to *vegetation* and *third party* and the unplanned SAIDI is trending upwards.

  Collectively the above five feeders contributed 36% of TEN's unplanned SAIDI.

- The top five equipment categories that have contributed to 71% of TEN's unplanned SAIDI are (in order of magnitude):
  - **Conductor span**. The major causes of outages in this category (70%) relate to vegetation *Tree (Fall on Line)* and *Tree Contact*. The SAIDI contributions appears to be trending upwards.
  - **Pole.** The major cause of outages in this category (88%) related to *Vehicle-vs-Pole*. This category appears to be trending downwards.
  - **Unknown.** As the category name indicates the cause of the SAIDI event is unknown. This category is trending upwards.
  - **X-arm.** The major causes of this category are *X-arm Failure* and *Corrosion/Rot* and they appear to be trending upwards.
  - **Tail/Lead/Jumper**. The major causes of outages in this category are *Conductor Tail Blown Off*, *Conductor Failure* and *Joint Failure*. This category appears to be trending downwards.
- There is clear evidence that the SAIDI contributions of the higher value unplanned SAIDI events (i.e. 0.5 minutes to 5 minutes) have been larger in YE2022 than in the previous YE2020 and YE2021 periods. This is demonstrated by the fact that, for example, the 90th percentile YE2022 SAIDI event contributed 2.7 minutes as opposed to 2.0 minutes in YE2020 and 1.6 minutes in YE2021. The increase is not clearly demonstrated in the event restoration/repair times and the data indicates that the majority of outage types contributing to the increase in the higher value unplanned SAIDI events during YE2022 are as follows:
  - *Vegetation*.
  - *Unknown*.
  - *Weather*.

8.1 Recommendations

Ergo recommends that TEN consider the following actions:

- Initiating a project/programme that focuses on the worst SAIDI performing distribution feeders (for example, the five feeders discussed above), which could include the following initiatives:
  - The installation of additional line fault indicators (LFIs) to assist with the identification of fault locations and reduce restoration/repair times.
  - The installation of reclosers and/or sectionalisers to reduce the number of consumers exposed to faults and to improve restoration times. This should involve targeting the number of ICPs to be sectionalised by the devices.
  - Higher levels of and/or more focused vegetation management.
  - Targeted replacement of equipment reaching end-of-life, particularly cross-arms as the number of failures appears to be increasing.
  - Installation of additional feeders in order to reduce the number of ICP's supplied by individual feeders.[9]
  - Upgrading existing lines or installing new lines in order to improve feeder back-feed options and reduce consumer restoration times.
  - Ongoing use/expansion of TEN's ADMS[10] to improve information management and implementation of distribution automation.
- Investigate the underlying reason for the increasing unplanned SAIDI minutes that have been reported against the outage type of *Unknown*. There is not sufficient information in the SAIDI database for Ergo to determine the underlying reasons for the increase, but we note that the number of the *Unknown* events has been decreasing.
- Investigate the underlying reason for the increasing unplanned SAIDI minutes that have been reported against the outage type of *Vegetation*. This category is a major contributor to TEN's unplanned SAIDI reported in the *Device Affected* category of *Conductor Span* and the data infers that restoration/repair times associated with *Conductor Span* related *vegetation* outages are increasing.
- Detailed investigation and reporting of all unplanned SAIDI events that exceed, say, 1 minute, which would typically involve investigating ≈120 events/annum. A less onerous regime could involve SAIDI events that exceed 2 minutes and ≈50 events/annum. The output from these investigations should inform TEN's future SAIDI initiatives.

Given the size of the distribution network Ergo is of the view that TEN needs to initially focus its efforts on the worst performing sections/feeders. Furthermore, based on our previous experiences, we recommend that TEN ensure that any initiatives (and expenditure) are closely tracked and reported against to ensure that they are delivering benefit (i.e. SAIDI reductions). We expect that the benefits will not be immediate and only become evident over the long term, in the same manner as the benefits associated with TEN's YE2020 Project.

---

9 For example, the Tokerau feeder supplies the highest number of ICPs (≈1500) and was the worst performing feeder over the 2020/2021/2022 period.

10 Advanced Distribution Management System.

9. Appendices

Appendix 1 Glossary

ADMS	Advanced Distribution Management System
kV	Kilovolts
MW	Megawatts
MVArs	Mega Volt Amps Reactive
MVA	Mega Volt Amps
p.u.	per-unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index

Appendix 5

SAIDI Investigation

Summary Report

Prepared for Top Energy

18 February 2022

Table of Contents

Executive summary

The System Average Interruption Duration Index (SAIDI) metric is defined as the sum of all customer interruption durations divided by the total number of customers served. Towards the start of the regulatory year ending in 2022 (YE2022), Top Energy detected a possibility that the total SAIDI might exceed the regulatory cap of 380 minutes, prompting an investigation into factors that might explain high SAIDI numbers. Within this project, Harmonic aimed to explore the usefulness of Top Energy's internal datasets to help identify these factors, as well as to gain a better understanding of SAIDI minutes overall.

A selection of data extracts were determined and provided to Harmonic. These included extracts from the ADMS, SAP, Smartrak and FieldGo systems. The extracts provided information relating to incidents dating back to YE2020, and corresponding details on the relevant equipment affected and employee responses.

Exploration of the data uncovered several key findings that helped shed light on SAIDI, with a particular emphasis on explaining the impact of incident duration and factors that are associated with it.

- Short duration incidents are responsible for the majority of SAIDI, however single, very long incidents within the 1000-1200 minute range can generate a significant amount (>10 minutes) of SAIDI, despite being very rare.
- Winter months and bad weather are particularly impactful on both the frequency and duration of incidents. The four months of June to September are responsible for nearly half of the total SAIDI.
- Vehicle response times and travelling times do not account for long duration incidents.
- The top four substations contribute more than half of all SAIDI, these being Kaikohe / Kaikohe 33kV, Okahu Rd and Taipa. In general, this is due to a higher frequency of events affecting a large number of ICPs, rather than longer incident durations.
- Incidents affecting poles are strongly associated with longer durations.

In addition, some areas for data improvement were discovered during the project and detailed within this report.

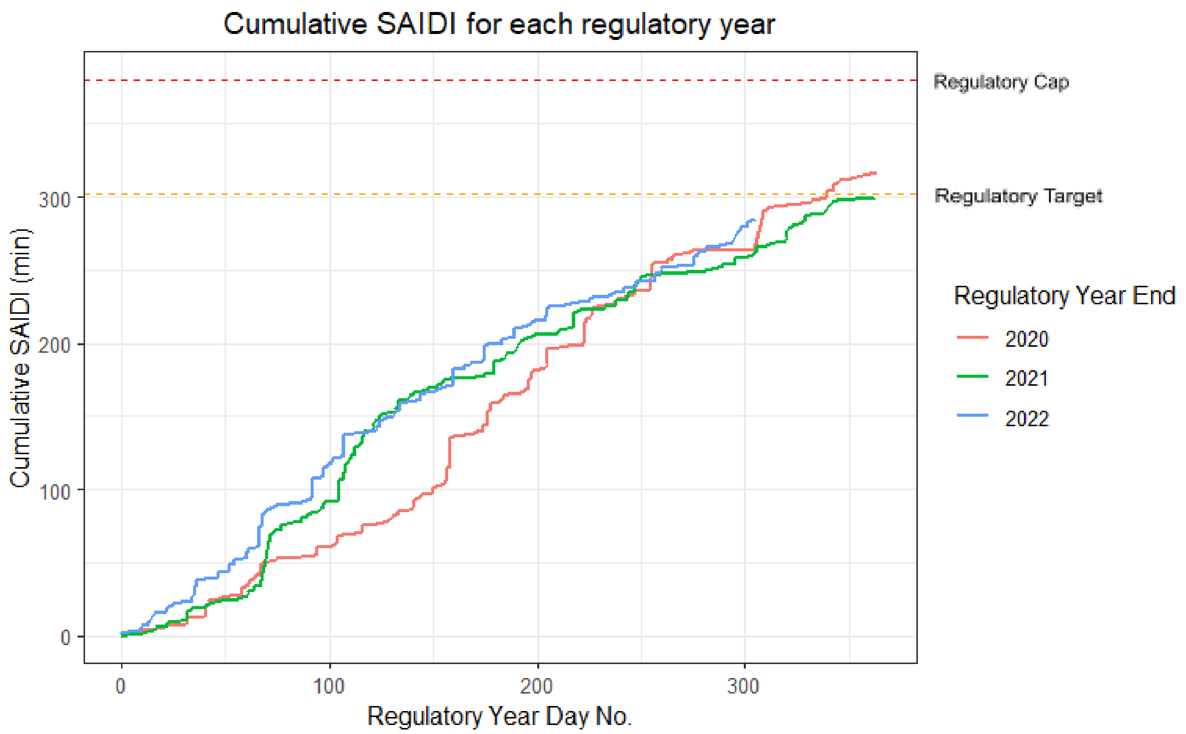
Glossary of terms

Term	Definition
Incident	An electricity outage incident. In this report, we are primarily focused on unplanned outages.
SAIDI	System Average Interruption Duration Index $$S = \frac{\sum U_i N_i}{N_T}$$ Where S is the SAIDI, U and N are the incident time and number of affected customers for location i respectively, and N_T is the total number of customers served. This is typically measured in minutes.
ADMS	Advanced Distribution Management System
SAP	Systems Applications and Products
Regulatory Year	SAIDI regulatory years run from April to March.
SA2	Statistical Area 2 as defined by Stats NZ in 2022. The SA2 geography aims to reflect communities that interact together socially and economically. In populated areas, SA2s generally contain similar sized populations.

Introduction

The System Average Interruption Duration Index (SAIDI) metric is commonly used by electric power utilities as a measure of network reliability. SAIDI is defined as the sum of all customer interruption durations divided by the total number of customers served. It is desirable to reduce SAIDI minutes as they represent an increase in maintenance costs to the organisation and are a regulated metric.

Towards the start of the regulatory year ending in 2022 (YE2022), Top Energy detected a possibility that the total SAIDI might exceed the regulatory cap of 380 minutes. This was due to a higher than usual rate of increase towards the start of the year. As of February 2022, with 285 cumulative SAIDI minutes, it is unlikely that the cap of 380 minutes will be reached. However, there is still a possibility of exceeding the regulatory target of 302 minutes.



Currently, there is a lack of insight into the factors behind high SAIDI numbers. This project aimed to explore the usefulness of Top Energy's internal datasets to help identify and explain these factors, as well as to gain a better understanding of SAIDI minutes overall.

The goals of this first phase of the project were to:

- Gain access to and an understanding of Top Energy's datasets.
- Determine whether the Top Energy datasets can provide an insight into the increase in SAIDI minutes observed in 2021.
- Identify which factors, if any, are correlated with the increase.

Methodology

The R programming language was used to load, transform, explore and analyse the data.

Data Sources

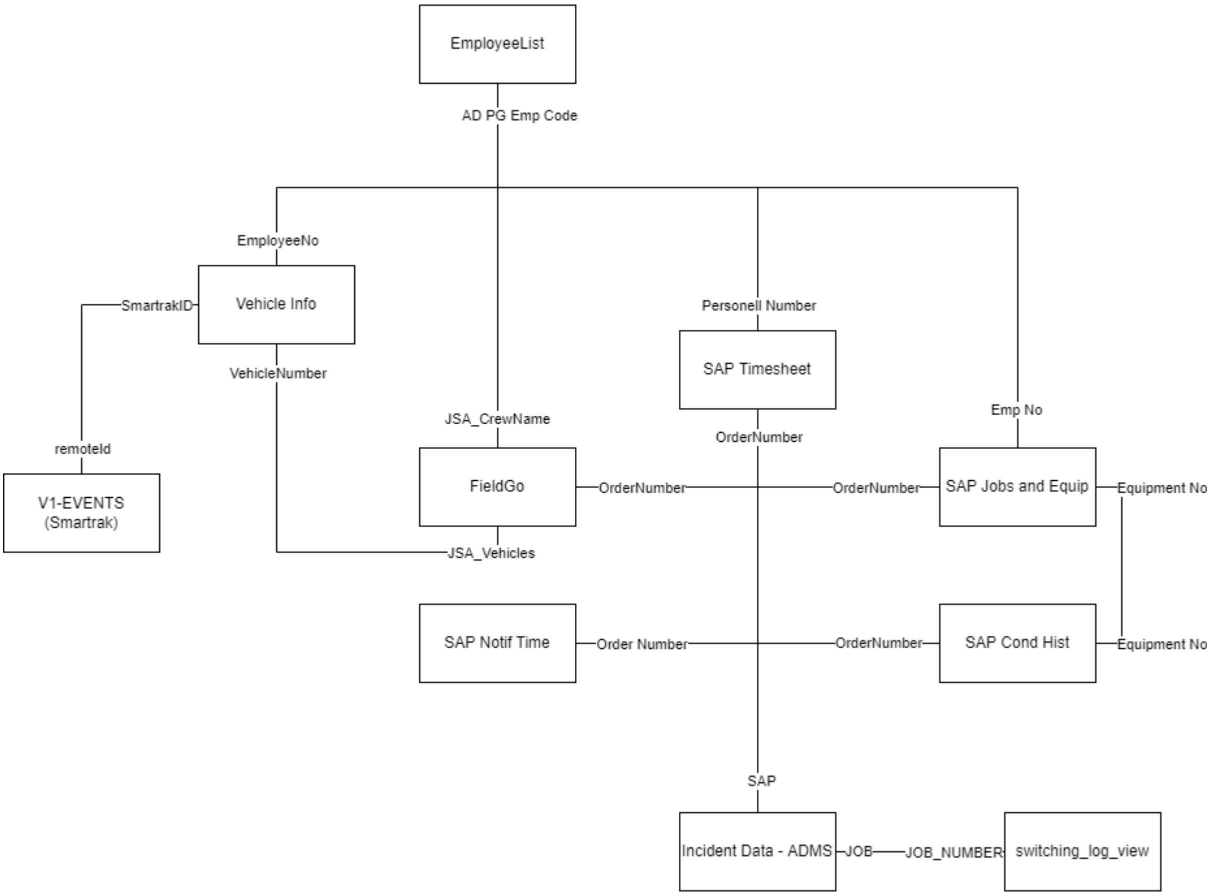
Top Energy provided Harmonic with extracts from the following data sources:

Data Source Name	Extracts Provided
Advanced Distribution Management System (ADMS)	• *Incident Data sheet:* A master list of incidents and their associated properties. • *switching_log_view.xlsx (26-01-2022):* Timestamped worker events associated with particular jobs.
Systems Applications and Products (SAP)	• *Jobs and Equip sheet:* Equipment properties associated with a particular incident. • *Notif Time sheet:* Actual notification time to the worker of the incident. • *Condition History sheet*: Timestamped equipment condition measurements. • *Timesheet Info sheet*: Timesheet entries for each worker. • *Vehicle Hours sheet*: Logged vehicle hours.
FieldGO	• *JSA SignOn sheet*: Sign in / sign off times for workers.
Smartrak	• *V1-EVENTS-xxxx.xlsx (03-02-2022)*: Timestamped vehicle event data provided in four Excel files labelled 2019 to 2022.
Misc.	• *EmployeeList sheet*: A list of employees and employee attributes. • *Vehicle Info sheet*: A list of vehicles and vehicle attributes.

All the extracts provided as a sheet were included within the "incident_data.xlsx" Excel workbook provided by Top Energy which was last updated on 11-02-2022.

The data extracts were linked together using the following unique IDs:

- SAP order number
- ADMS job ID
- Vehicle number
- AD PG Emp Code



Data schema for the various provided extracts.

Cleaning and Subsetting

The following steps were performed:

ADMS

- Incidents were filtered to only unplanned incidents, leaving 1098 incidents spanning 2019 to 2022 (regulatory years ending 2020 to 2022).
- A duplicated incident ID (INCD-6304-F) was removed.
- Combined the 6.6 and 6.35kV voltages into one (replaced all instances of 6.6 with 6.35). Top Energy had indicated that these two voltages although recorded differently actually represented the same real life value.

SAP

- Duplicated order numbers in the notification times data were removed, keeping the earliest recorded notification time for each order number.

Smartrak

- The cleaned data was joined onto FieldGo by vehicle identifier (the "work centre" field), and this was subsequently joined with the cleaned ADMS dataset.
- Orders that could not be matched to a vehicle were filtered out.
- It was also observed that vehicle trips associated with an order could span multiple days, not just the timeframe in which the incident occured. To address this, only vehicle events with "rt_date" timestamps within the incident start and end datetime, were kept.

General

- Variables with information stored as characters were converted to lower-case, fixing inconsistencies in the data such as kilovolts being written as "kV" in one instance, and "KV" in another.

Feature Generation

The following features were generated on a per incident basis:

Data source	Feature	Description	Assumptions
ADMS / SAP	Incident start time	The earliest known incident start date. Calculated from the earliest date between ● The SAIDI clock start time ● The earliest SAP notification	● The SAIDI clock start / SAP notifications are a good proxy for the actual start of the incident.
SAP	Number of employees sent	The unique number of employee IDs recorded in the SAP timesheet data, for a given order number	● The timesheet log is the source of truth on whether a worker worked on a particular incident, not the FieldGo data which often contradicts the timesheet data.
SAP	Max, min, mean and median employee tenure of employees sent	Calculated by linking the employee IDs recorded in the SAP timesheet data to the EmployeeList metadata.	● The timesheet log is the source of truth on whether a worker worked on a particular incident, not the FieldGo data which often contradicts the timesheet data.
SAP	Extreme weather	A flag based on whether someone recorded “Extreme Weather - PSA” as their Paycode Description within the timesheet data.	● Extreme weather events are accurately and consistently recorded in workers’ Paycode Description.
SAP	Equipment condition	The measured equipment condition at the time of the incident. Generated by taking the latest asset condition measurement within the SAP condition history data that occurred before the incident end date.	● The latest asset condition measurements are reflective of the asset condition at the time of incident. I.e. either assets degrade slowly over time, or asset measurements are frequent and accurate.

SAP	Equipment age	The age of the equipment calculated from the start of the incident, based on its startup date.	NA
SAP	Device	For the purpose of specifically investigating cross-arms, poles, transformers, and conductors. All device affected entries containing: "tx" were renamed "transformers" all entries containing 'conductor' were renamed to conductor.	NA
SAP	Truck sent	Whether or not a truck was recorded as being sent in the vehicle hours data.	• String matching the word "truck" in the long text field of SAP vehicle hours is equivalent to determining whether a truck was sent with that order number.
ADMS	Employee response time	Calculated from the time difference between the start of the incident, and the earliest "confirmed", "executed" or "completed" ADMS event with action verb containing "close", "open", "remove", "replace", or "check".	• Assumptions listed in "Incident start time". • Action verbs containing "close", "open", "remove", "replace", or "check" can only be performed when the worker is on site. • The time difference between the worker arriving on site, and recording a key action verb is minimal. • Action verb timestamps are accurate.
ADMS	Employee time on site	Calculated from the time difference between the latest and earliest "confirmed", "executed" or "completed" ADMS event with action verb containing "close", "open", "remove", "replace", or "check".	• Action verbs containing "close", "open", "remove", "replace", or "check" can only be performed when the worker is on site. • The time difference between the worker entering or leaving the

		If the latest key action verb is recorded after the recorded end of the incident (i.e. the worker continued after incident resolution), then the latest action time is set to the end of the incident. This is because we are interested in the time spent resolving the incident - so any time spent working after resolution is irrelevant.	site, and recording a key action verb is minimal. • Action verb timestamps are accurate.
Smartrak	Vehicle response time	Calculating by taking the time between when the earliest vehicle starts driving and the incident start time.	• Only vehicle trips that "key on" after the incident start time, are considered relevant work. This excludes trips starting just prior to the incident start date.
Smartrak	Average vehicle driving distance	Calculated by filtering out all but the text entries marked "key off" , then taking the average of trip distances travelled by each vehicle, per incident.	• Only vehicle trips with an rt_date that takes place between the incident start and end time are considered travel during the incident.
Smartrak	Number of vehicles sent	Calculated by counting the number of unique vehicle IDs associated with each "incident"	NA
Smartrak	Number of trips	Calculated by counting the total number of "key off" events that occur within the incident period.	• Each "key off" event is associated with a vehicle trip. This may be occasionally untrue if a driver restarts their vehicle for any reason.
Smartrak	Average vehicle time travelling	Calculated by using the "extra info" field to determine the travel time per trip vehicle makes during the incident, then taking the average of all trip times for each individual	• Vehicle trips which conclude after the incident duration are not relevant to the calculation. •

		vehicle.	
Smartrak	Average percentage of indent time spent driving	Calculated by dividing the average number of hours travelled by a vehicle, divided by the incident duration time.	NA

Approach to Analysis

The goal of this project was originally to explain the high SAIDI numbers observed in YE2022 compared to previous years. Considering that the total SAIDI in YE2022 (as of January) was not observed to be significantly higher than YE2021 or YE2020 when compared at a similar point in time, this project instead focused on finding factors that could explain higher SAIDI numbers in general, rather than causes for high SAIDI in YE2022 specifically.

- This was achieved by breaking SAIDI down into two aspects:
- The number (frequency) of incidents
- The duration of incidents

Exploration was performed to determine whether any factors (if at all) correlated with either of these aspects. In general, due to a lack of external time series data independent of incidents occurring, there was a focus on explaining incident duration, rather than frequency. This issue is elaborated upon within the absent datasets section.

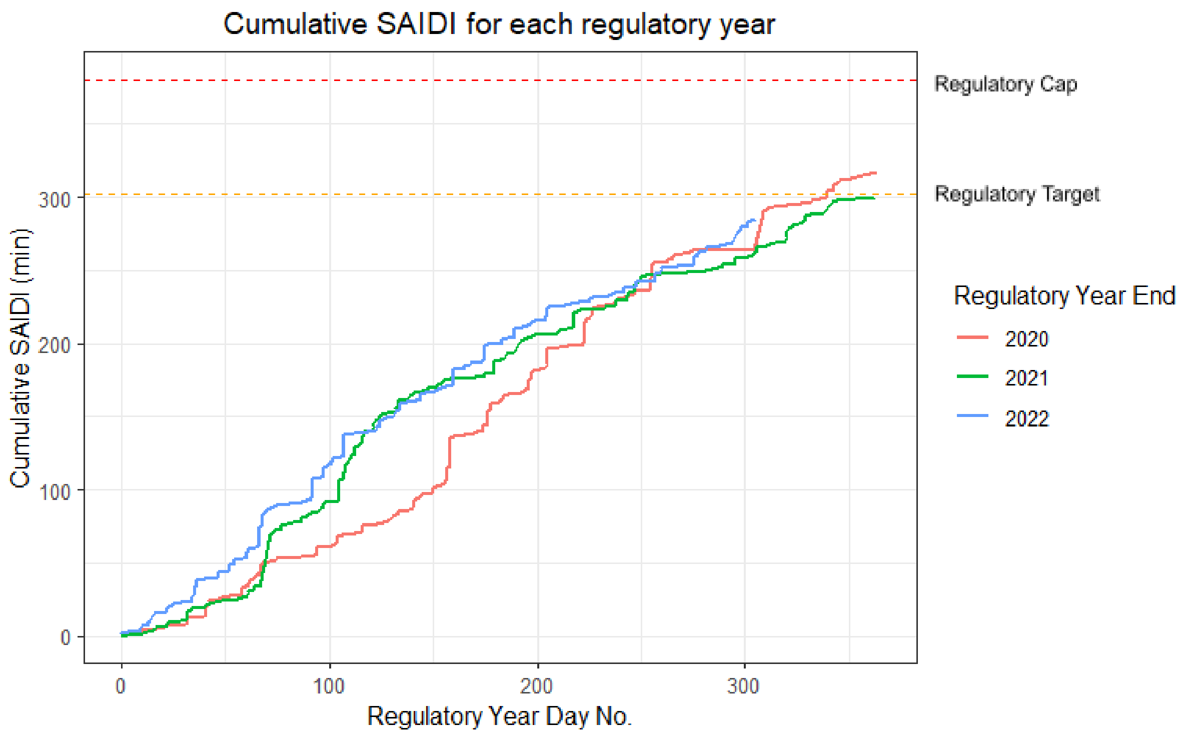
Results

SAIDI Breakdowns

The following figures show SAIDI breakdowns by various attributes such as time, geography and other factors.

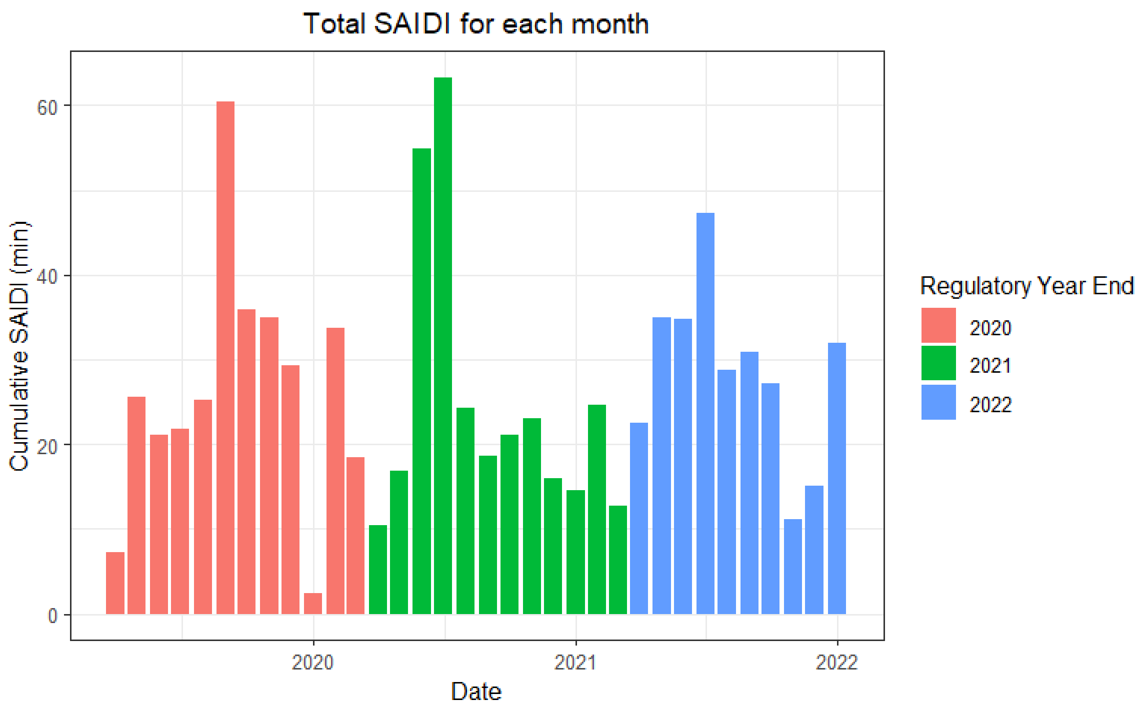
By regulatory year

Regulatory Year Ending	Total SAIDI
2020	315.9
2021	300.6
2022 (Incomplete)	284.6



As of January, SAIDI in YE2022 has slightly outpaced both YE2021 and YE2020. Assuming that there are no unexpected spikes, we would expect YE2022 to end with approximately the same amount of SAIDI as in YE2020, therefore breaching the regulatory target of 302 minutes. This is due to a consistently higher than average SAIDI in the opening months of the regulatory year, and an unexpectedly high January compared to previous years.

By month

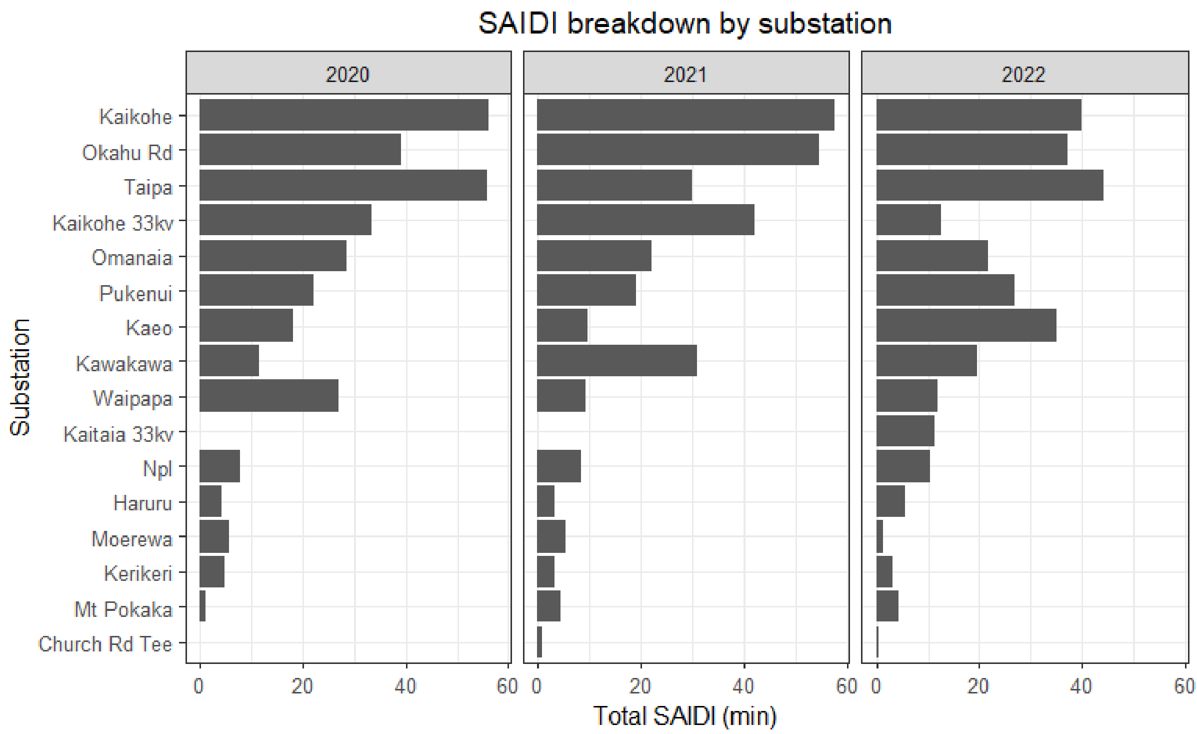


Plotting SAIDI by month shows annual seasonality, with the winter / spring months (June to October) typically having much higher SAIDI than in summer / autumn. This is intuitive, as many SAIDI incidents are likely caused by bad weather such as strong winds.

By substation

The following analysis concerns breakdowns of SAIDI by the substation affected, as provided within the ADMS data.

Note that Kaikohe 33kV is considered a separate substation to Kaikohe.



Substations	Sum of SAIDI (over all years)	Num of Incidents	Mean Incident Duration (min)	Mean ICPs affected
Kaikohe	153.56	200	366.6	274
Okahu Rd	131.0	184	356.2	272
Taipa	130.3	90	394.8	608
Kaikohe 33kv	88.9	12	110.9	4645
Omanaia	72.0	88	378.5	264

Top five Substations by total SAIDI across 2020, 21 and 22.

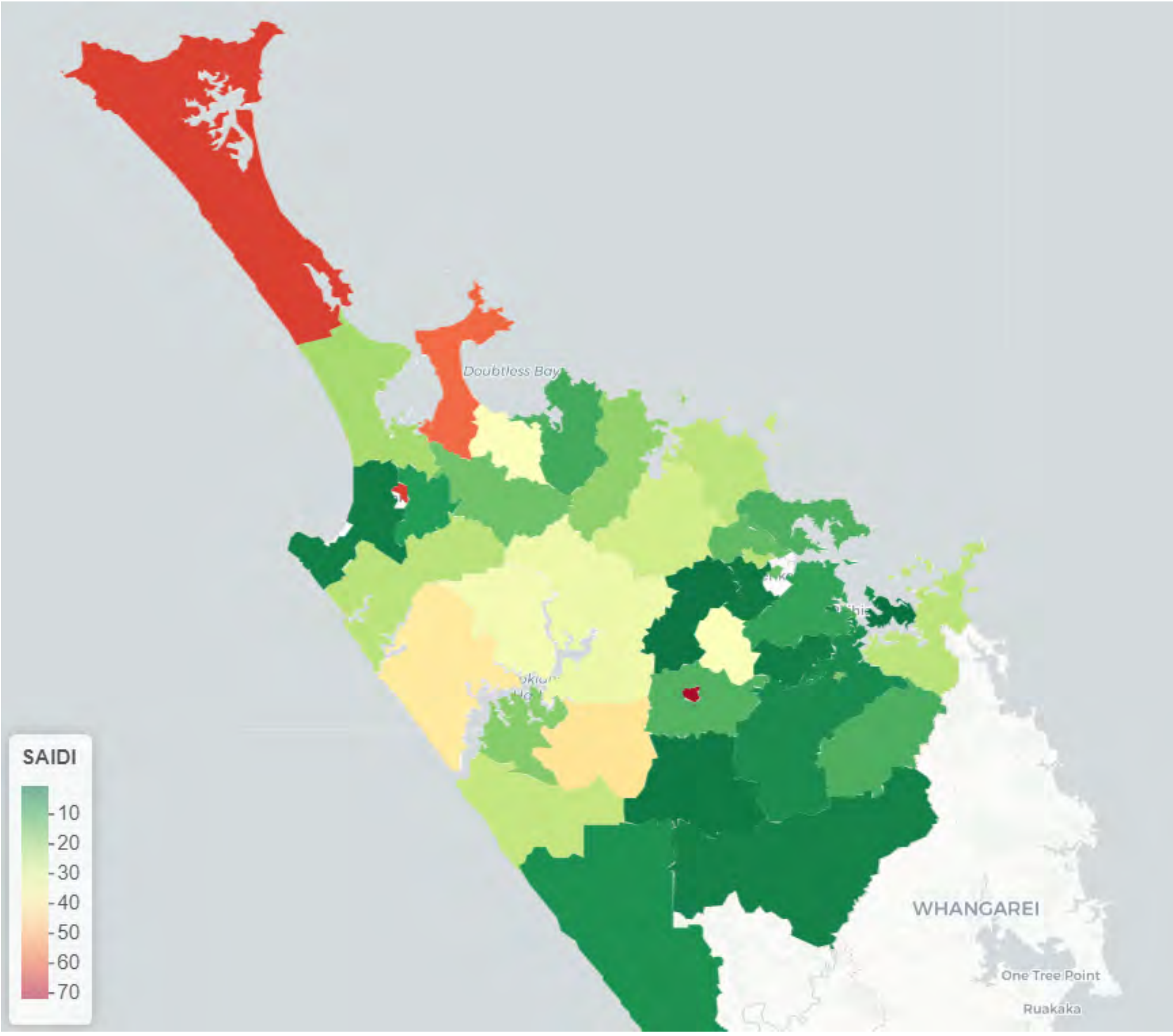
The top four substations (Kaikohe / Kaikohe 33 kV, Okahu Rd and Taipa) are responsible for 55.8% of all SAIDI. From the table above, we can see that although the mean incident duration and number of ICPs affected fluctuates between the substations, the number of incidents is correlated with high SAIDI numbers. This indicates that it is the frequency of incidents, not the speed at which they resolve, which differentiates high SAIDI substations versus the rest.

The key outlier is the Kaikohe 33kV substation, which although having a relatively lower incident frequency and mean incident duration, affects on average an extremely high number of ICPs. Of note was an incident in YE2021 that affected 21,723 ICPs for 26.5 minutes generating 12.94 SAIDI minutes in total.

It is worth noting that the Kaeo substation has had a relatively large percentage increase in SAIDI in 2022 compared to previous years. This was due to both a higher frequency of incidents, as well as longer incidents on average.

By SA2

The following analysis concerns breakdowns of SAIDI by their geographical location, grouped by Statistical Area 2 (SA2) definitions by Stats NZ. Incidents were placed in a SA2 by matching the provided incident address and area to coordinates. Note that this process relied on reverse geocoding, which although properly limited to the correct area of New Zealand, may be occasionally inaccurate in terms of coordinates.



Total SAIDI minutes by SA2 (summed over all 3 years)

SA2	Sum of SAIDI (over all years)	Num of Incidents	Mean Incident Duration (min)	Mean ICPs affected
Kaikohe	71.4	53	167.4	748
Kaitaia East	63.8	53	319.4	679
North Cape	63.5	59	278.9	285
Karikari Peninsula	58.1	39	279.2	585
Waimā Forest	41.9	48	389.0	352

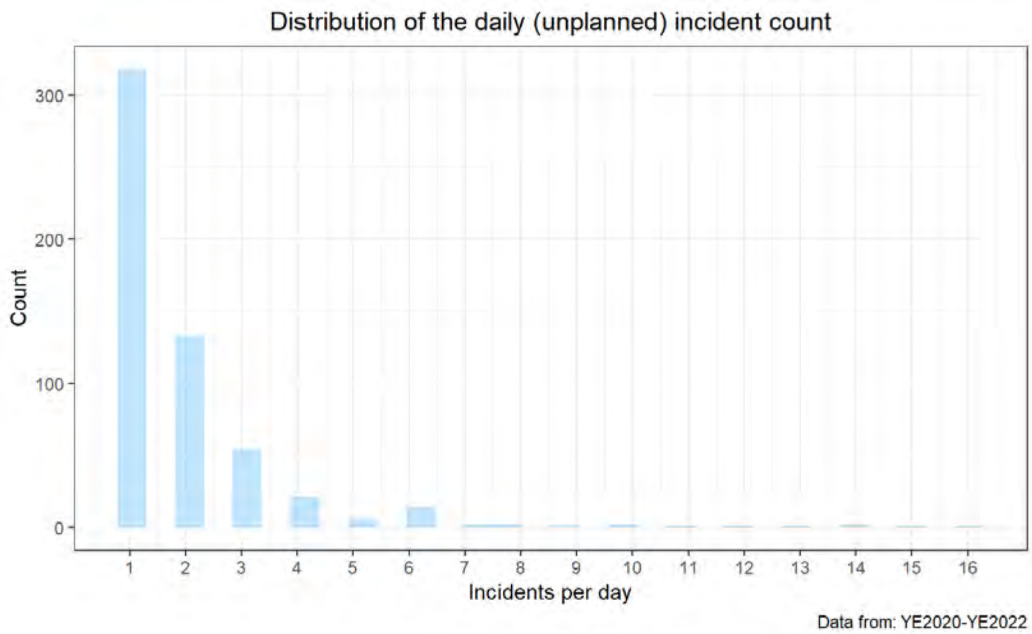
Top five SA2s by total SAIDI across 2020, 21 and 22.

Although Kaikohe has relatively shorter incident durations on average, the number of ICPs affected is on average higher - and therefore it has the highest sum of SAIDI of all substations. Once again we can see that the incident durations are not the differentiating factor between the various geographic areas.

Waimā Forest has an extremely long average incident duration - but due to the relatively lower number of ICPs affected and lower frequency of incidents, it generates less SAIDI than the others in the top five.

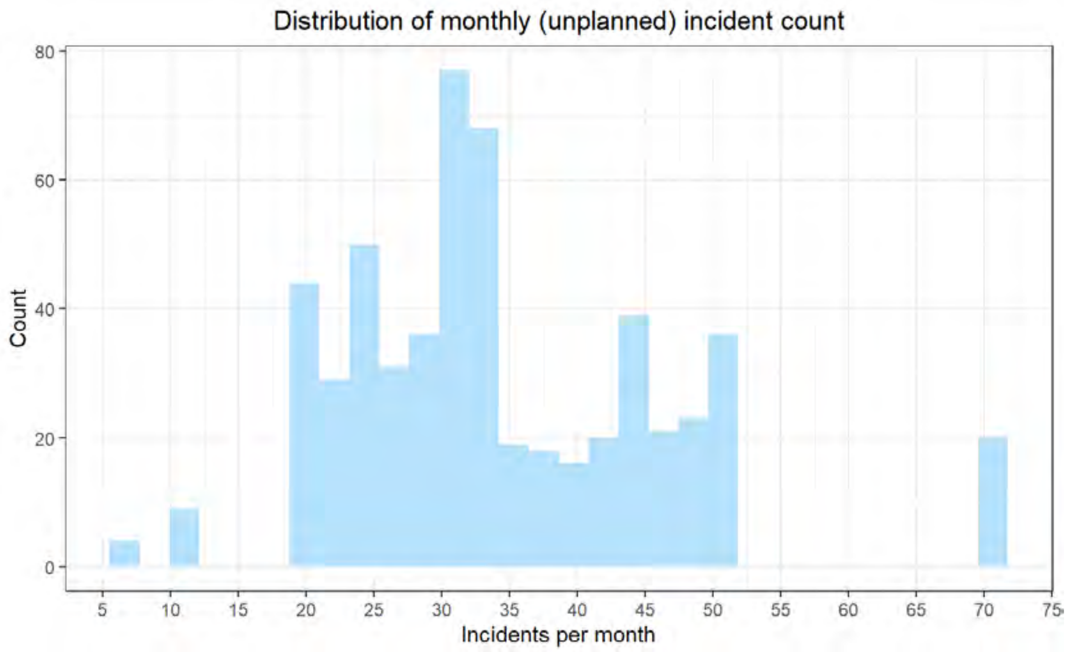
Frequency Analysis

It was observed that incidents do not always happen in isolation, and it was of interest to understand the determining factors behind why some days observe more than others.



This is the breakdown of how many incidents are observed on the days with outages.

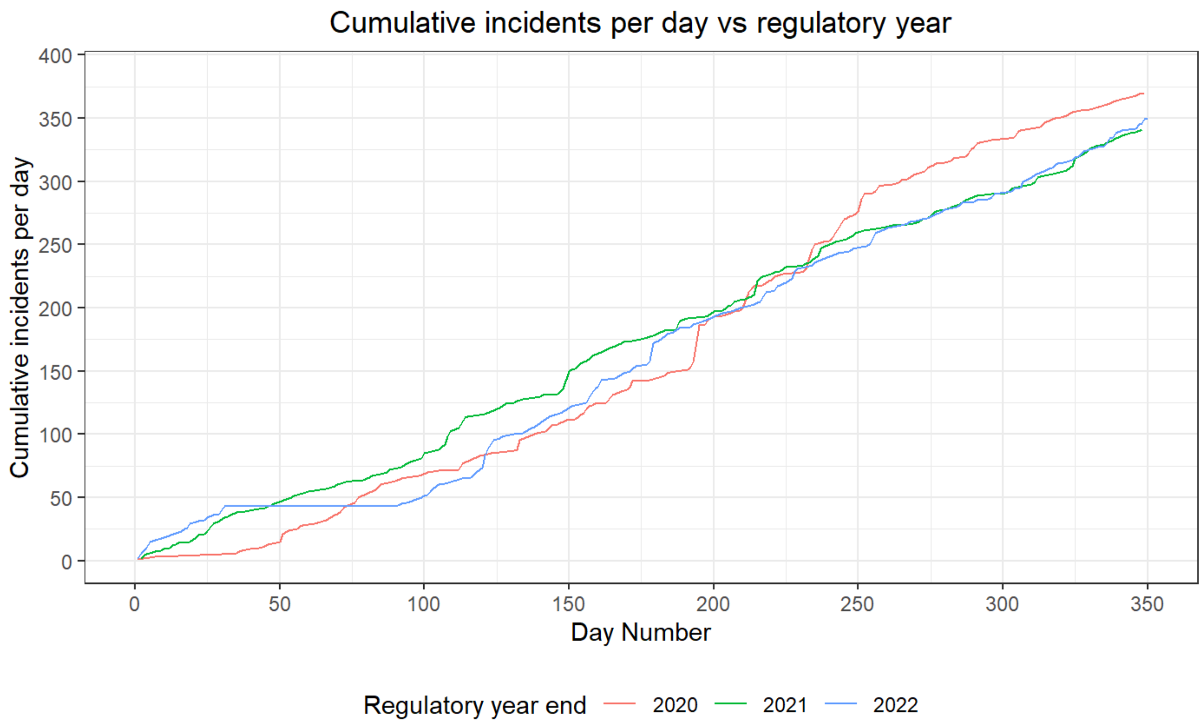
Clearly, it is rare for multiple incidents to occur on a day as the mean number of incidents occurring is 1.96 per day, while the median number of incidents is just 1 per day. However when an incident occurs, 25% of the time it is not in isolation, and several others will also occur.



This is the breakdown of how many incidents are observed in the months with outages.

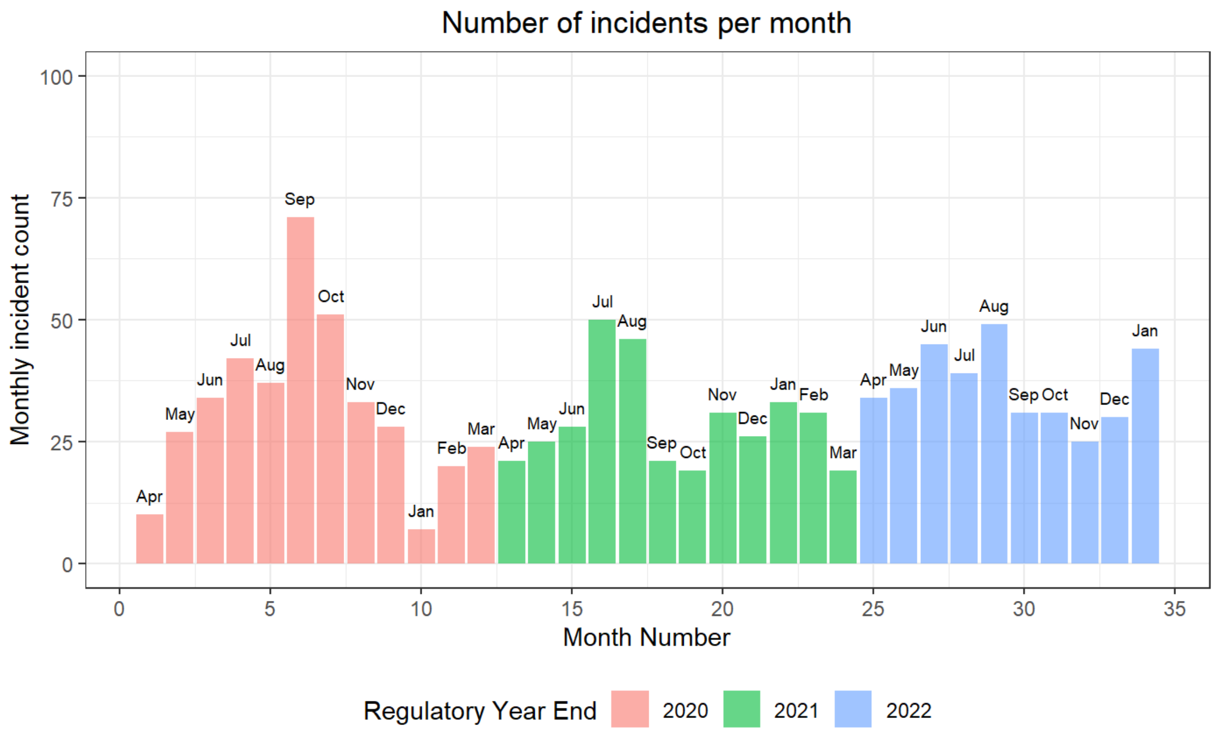
When examined at the monthly level, the mean number of incidents per month is 34.2 with a median of 32 incidents per month. The majority of data falls between 26 and 42 incidents per month. Additionally, this figure illustrates how few months observed are relatively incident free -(<20 observations).

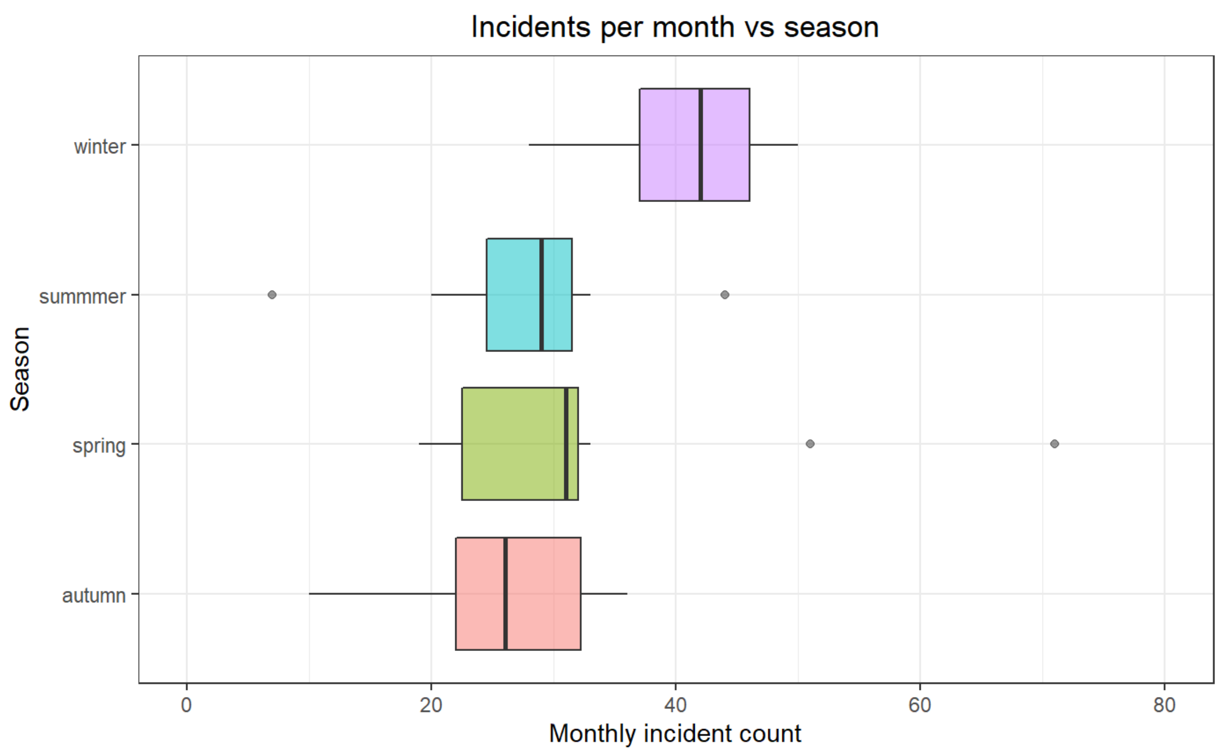
By regulatory year



As the above demonstrates, across each of the regulatory years, the distribution of daily saidi count is mostly similar across the year, from YE2021-YE2022. However, YE2020 is markedly distinct with both a higher number of total incidents. There is also a shift in when the incidents occur, with a greater proportion of them occurring in the latter part of the regulatory year.

By month

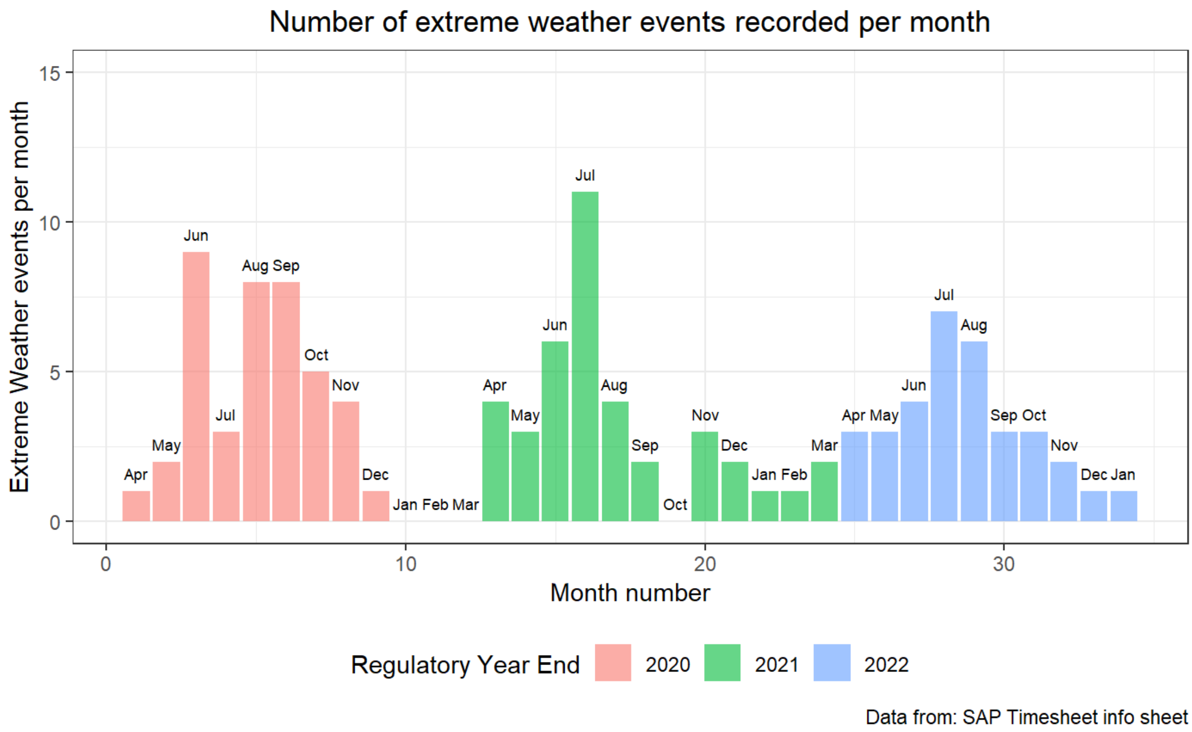

Number of incidents per month
Monthly incident count
Month Number
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Regulatory Year End
2020
2021
2022


Incidents per month vs season
Season
winter
summmer
spring
autumn
Monthly incident count

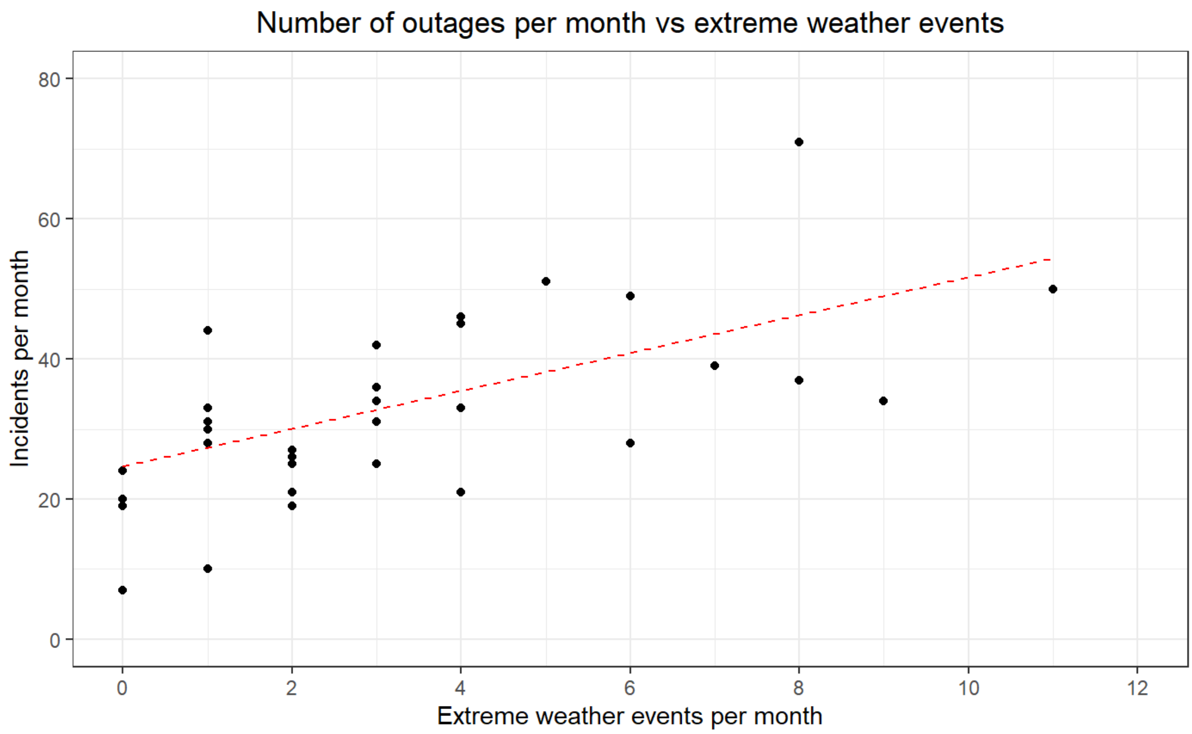
Month of the year is important with regard to the incident frequency. There is also a subtle seasonal pattern. For YE2021-YE2022 there is a spike in the incident frequency during Winter (June-August) before declining across Spring (September-November). However, YE2020's monthly incident count peaked during September instead. However, with only 3 regulatory years worth of data, caution must be taken when attempting to infer a seasonal pattern.

As expected, there is typically a heightened incidence of extreme weather events (as recorded by employees) over the winter period. This led to an investigation into weather effects.

Weather effects



As expected, spikes in the monthly incident count often coincide with a spike in the number of monthly extreme weather events. Further analysis determined there was a statistically significant relationship between the monthly incident count and the extreme weather events per month. This can be seen in the following figure.

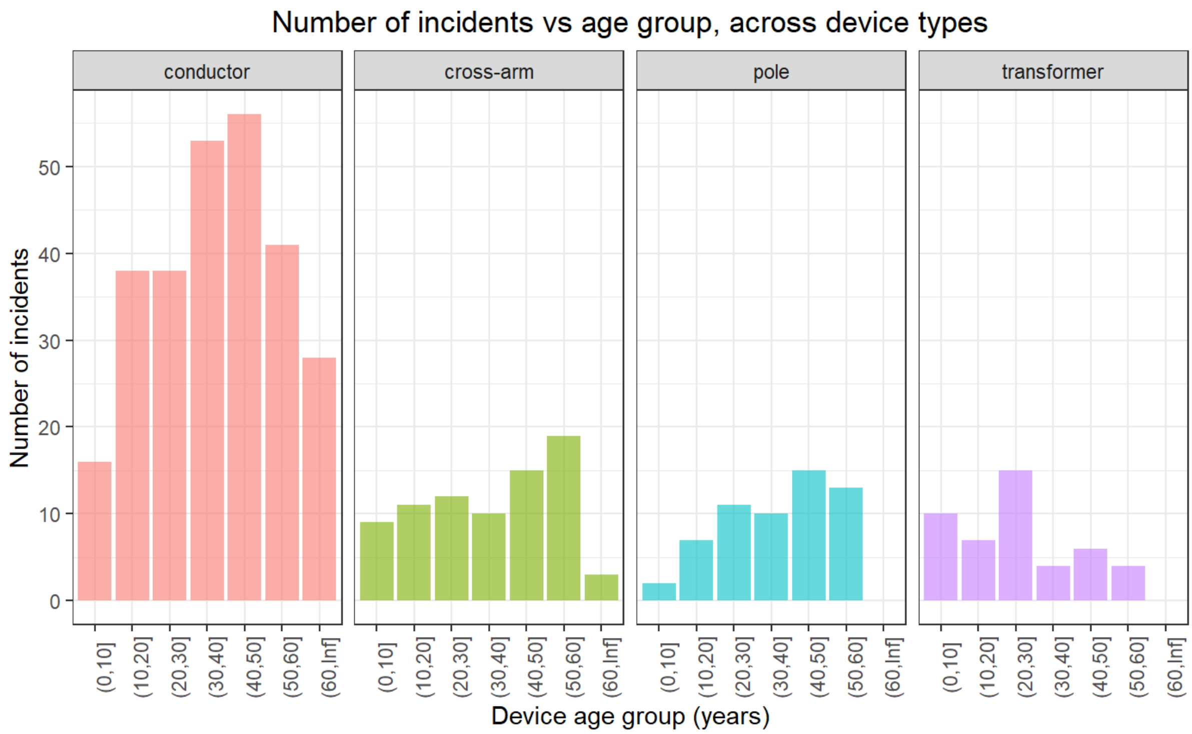


The red line represents the line of best fit.

This would suggest that while weather has a statistically significant effect on the number of incidents occurring, the correlation between the two is limited, and other factors should also be taken into account

A caveat associated with investigating the weather, is of course that it has been assumed that all extreme weather events are accurately recorded, despite there being no specific information about environmental variables.

Device age analysis



This figure utilised data from the SAP Condition History sheet.

Conductor failures were significantly more common (44% of incidents) than either cross-arm, pole or transformer failures. It is worth noting that pole and transformer related incidents comprise less than 1% of the data, and with so few observations, inferences are difficult to make.

- **Conductors**: There is no strong correlation between device age and the number of incidents, with 30-40 & 40-50 year age groups representing the highest proportion of conductor incidents. Furthermore, the oldest conductors are responsible for the second fewest number of conductor failures.
- **Cross arm**: Ignoring the oldest conductors (of which there are only a few observations) generally it appears that increasing cross-arm age is correlated with the number of cross-arm incidents. This potentially highlights that cross-arms should be replaced more regularly.

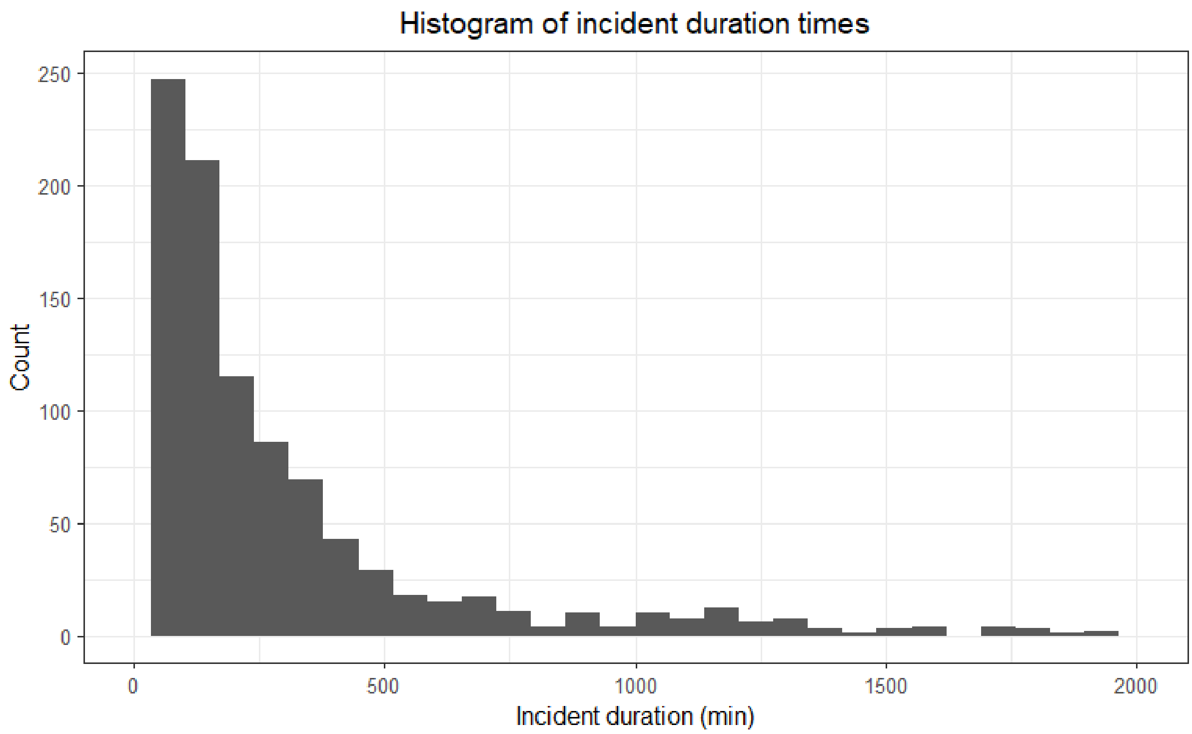
- **Pole**: Similar to cross arms, there is a correlation between number of pole incidents and age group.
- **Transformers**: Unexpectedly, it appears that older transformers are responsible for the fewest transformer related incidents. This suggests that non-age related factors related to transformer affected incidents may be more impactful.

Duration Analysis

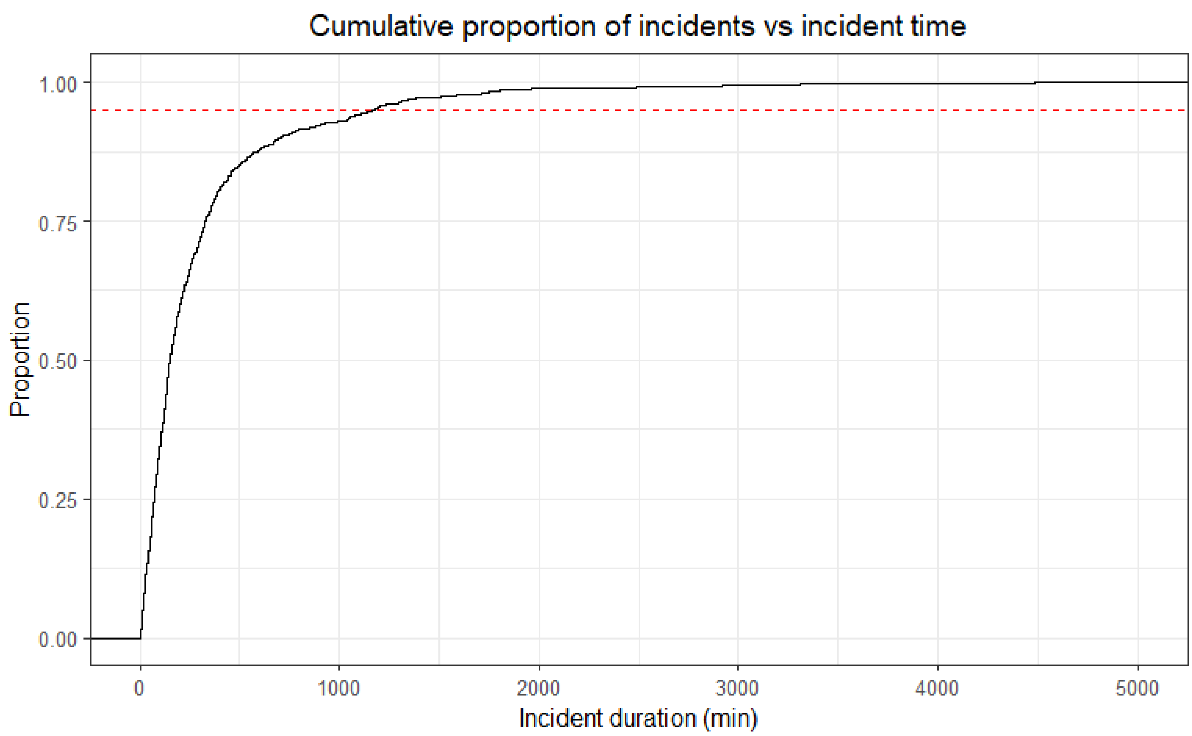
The following figures show breakdowns of the duration of incidents - defined by the start and end times within the ADMS data. These durations should be considered the SAIDI clock durations - not necessarily when the outage / problem may have actually occurred. For unplanned outages, the start time used depends on the process by which the incident was detected.

- If it was a Customer Fault Call received by the Call Centre, the start time is the Call record entry time;
- If it was an Automated Protection Device Activation Alarm, the start time is the Device operation time.

The above only applies if it is an HV fault and a no power call. Otherwise, the start time is recorded only when the power is completely off - e.g. when a worker isolates the section.



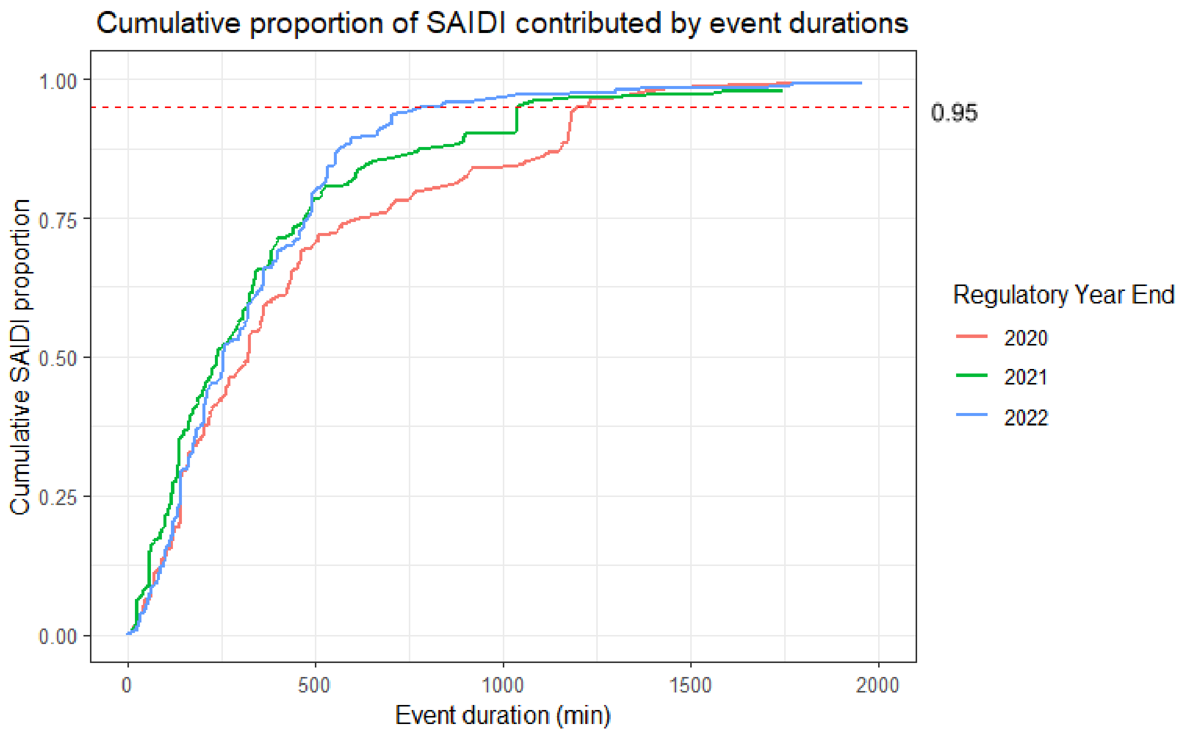
The above is filtered to incidents shorter than 2000 min. There are 16 incidents out of 1098 that are longer at 2000 min.

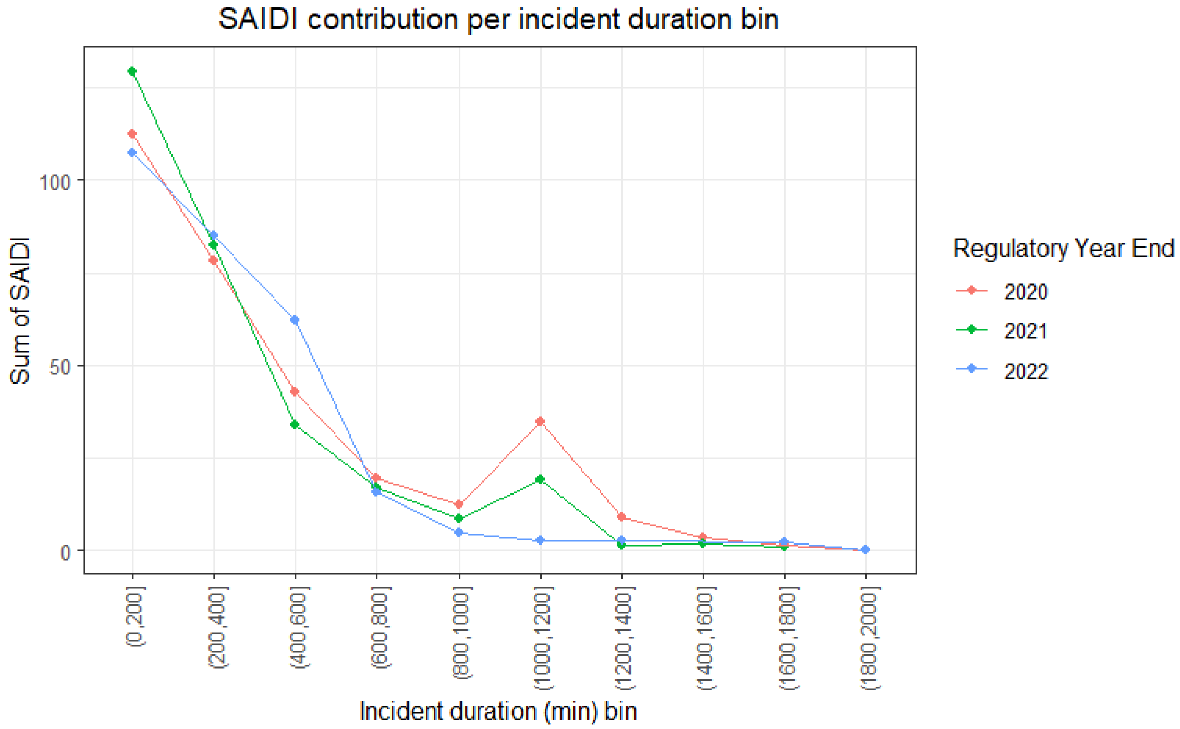


From the above plots, we can see that incident durations are clearly skewed towards shorter durations. Around 95% of all incidents are under ~1250 min = 20.8 hours (i.e. just under a day). 99% of incidents are under ~2000min. Overall, the mean duration length is 320 min, and the median is 152 min. This indicates that there are a few very large outliers that skew the mean higher than the median.

SAIDI contribution breakdown

The following charts show how the various durations of incidents contribute to the SAIDI across the different years.



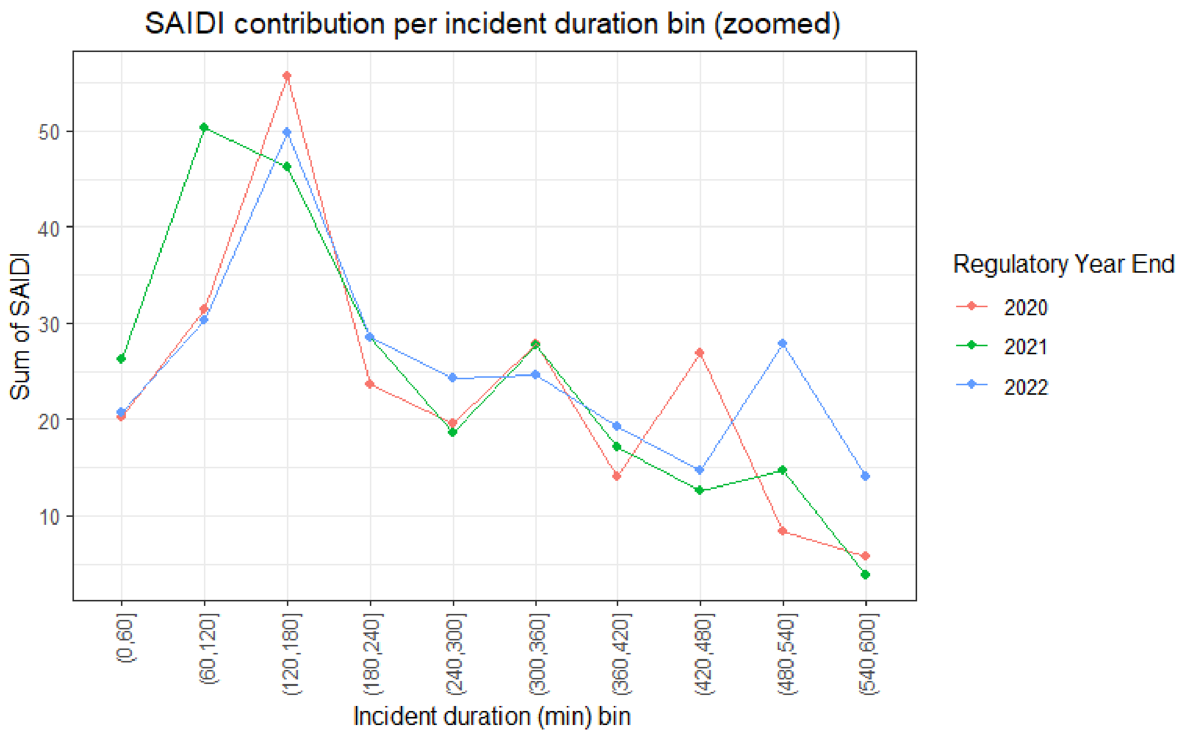


It can be concluded that the majority of SAIDI is generated by shorter incidents. We can see that 95% of all SAIDI in the year is generated by events shorter than ~750 minutes in YE2022, ~1000 minutes in YE2021 and ~1250 minutes in YE2020. There is a trend of shorter duration incidents contributing more to the overall SAIDI.

It is interesting to note that within YE2020 and YE2021, a significant proportion of SAIDI was due to incidents within the 1000-1200 minute range, which is completely absent in the YE2022 data.

- In 2020, it seems that a large part of this was a vehicle vs. pole incident INC200841 at Tapia substation. It resulted in 17.3 SAIDI minutes, lasted 1186 minutes and affected 1070 ICPs.
- In 2021 there was a defective equipment incident INCD-3469-F at Kaikohe. It resulted in 13.993 SAIDI minutes, lasted 1040.317 minutes and affected 488 ICPs.

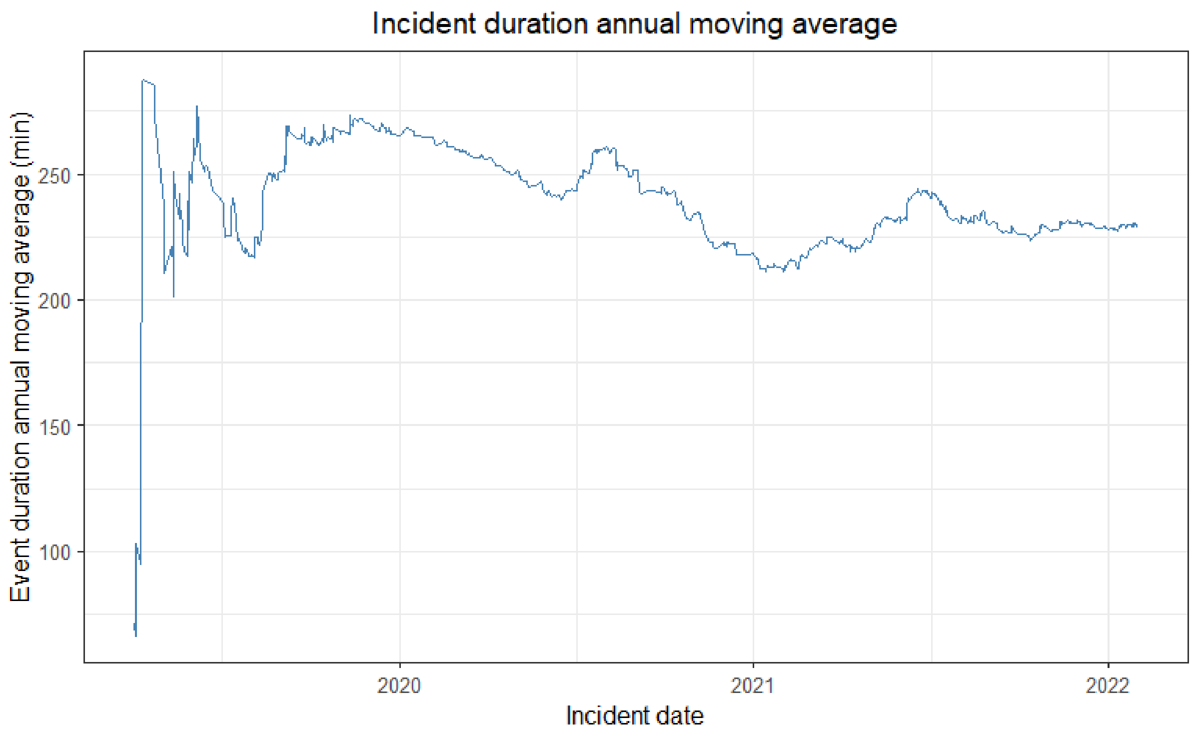
These large singular incidents seem to be the reason for the spike in contribution at higher durations.



Zooming into the duration bins between 0 and 600 minutes, we can see that there is a peak in SAIDI contribution for incidents in the 120-180 minute bin. This is despite the fact that incidents in the 0-120 minute range are in fact more common.

Incident durations over time

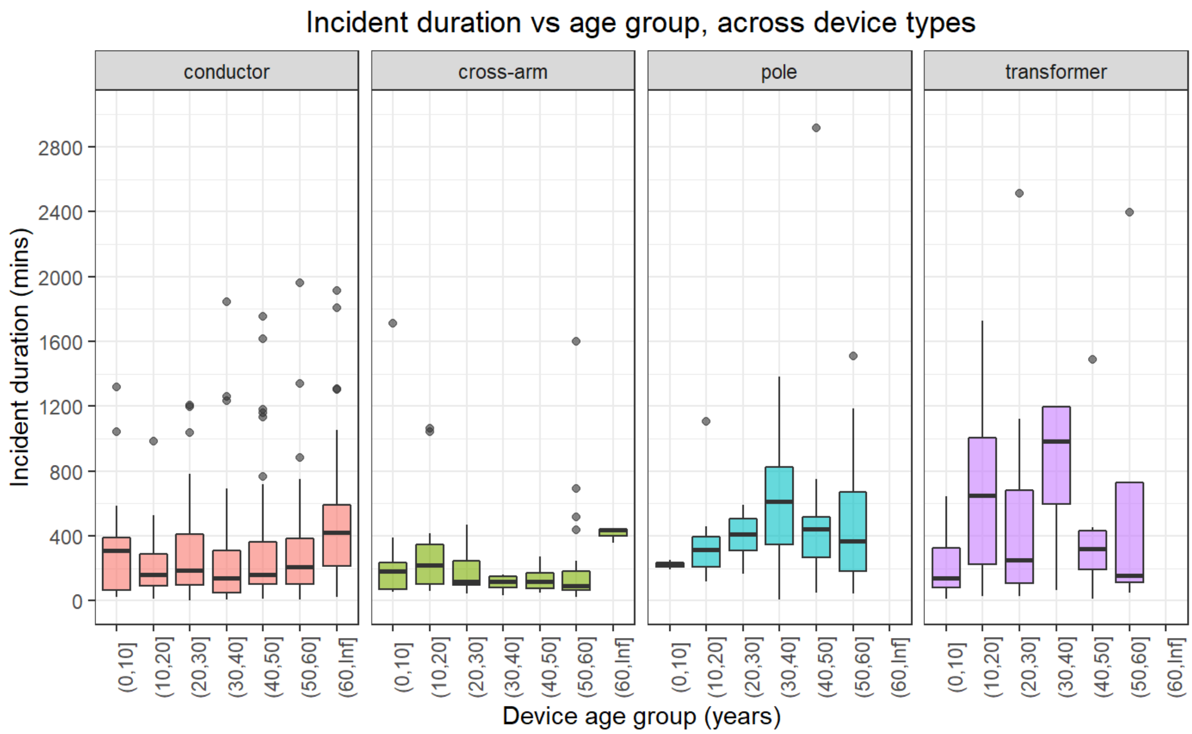
Regulatory Year End	Mean Incident Duration (min)	Median Incident Duration (min)
2020	341	167
2021	316	141
2022	274	146



Rolling yearly average of incident durations

The average incident duration has slightly decreased from YE2020. This can be explained by YE2022 lacking many extremely long (>1000 min) duration incidents. Despite this decrease, YE2022 is still outpacing both YE2021 and YE2020 in SAIDI. This supports the conclusion that in general, long duration incidents are not responsible for any significant portion of the total SAIDI.

Device age analysis



This figure utilised data from the SAP Condition History sheet. For visual purposes 3 incidents longer than 3000 minutes were not displayed.

- **Conductors**: The oldest conductors had the highest median event duration (439 mins) of all age groups. Interestingly, the most recent conductors had the second highest incident duration mins (310 mins).
- **Cross arms**: The oldest components had the highest median duration (437 mins) followed by the 10-20 year age group (221 mins median duration).
- **Poles**: Poles in the 30-40 years category had the highest median incident duration time, and there was little correlation between pole age and median incident duration.
- **Transformers**: The 30-40 year age group has a median duration of 984 mins, significantly higher than the 10-20 year group (median 649 mins). Evidently, the correlation between transformer device age and median incident duration was not significant.

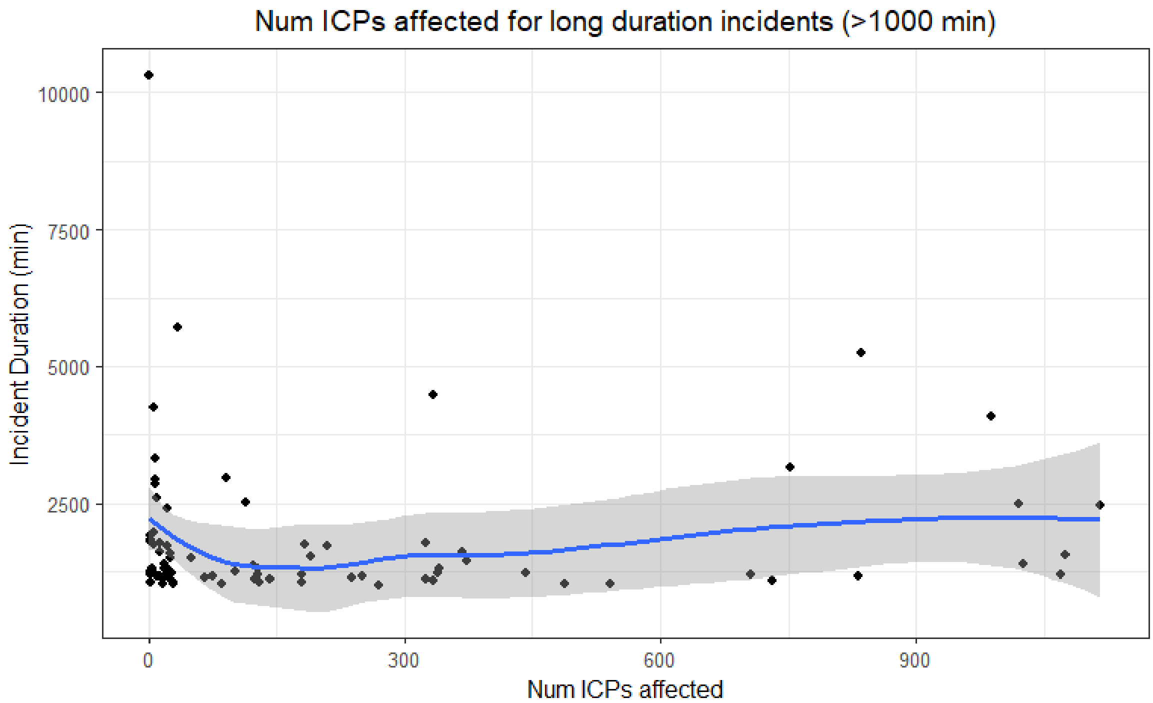
Variables associated with incident duration

Within the appendix are contained a selection of variables plotted against incident duration. These variables were chosen as they contained values that had an obvious effect on the distribution of incident duration times.

Categorical variables are plotted as boxplots with the outliers (below the 25% and 7above the 75% quantile) removed. Values that appeared less than 10 times were lumped into an Other category. Continuous variables are plotted as a scatter plot with a smoothed fit applied.

- The top three **substations** with the longest incident durations are **Kawakawa**, **Omanaia** and **Kaeo**. There is a gradual decrease in incident duration moving down each substation - there is no one substation that has significantly longer incident durations than the rest.
- Incidents involving the **weather** are also associated with longer incident durations. This can be seen from the long durations observed in incidents with the following attributes:
    - **Lightning and weather outage types**
    - **Lightning strike causes**
    - The **extreme weather** flag from the timesheet data
- The **months** around winter (**June to September**) have the highest incident durations, explaining the higher SAIDI contribution by these months observed before. This is unsurprising, given that these winter months would typically be associated with worse weather.
- There is no significant difference in incident duration between **days of the week**.
- Incidents involving **poles** are clearly associated with longer durations. This can be seen from the long durations observed in incidents with the following attributes:
    - **Third party outage types**
    - **Vehicle vs. pole incident causes**
    - **Pole device affected (object type** and **equipment type)**

- The **voltage** with the longest incident durations is **6.35kV**. There are only 64 incidents in total that involve this voltage, however, the median incident duration is much higher than the overall, at 313 minutes.
- The **cable device group** is clearly associated with longer incident durations. There are only ten cable incidents in total, with four of them being longer than 1000 minutes. The longest cable device incident was also the longest incident in the entire dataset at 10,306 minutes. However, the cable incidents tend to affect relatively fewer ICPs and are very rare, hence cable incidents do not contribute greatly to the overall SAIDI minutes. The other device groups are all much closer together in terms of incident duration, with **ground mounted devices** having the shortest incident duration on average.
- Many of the very long durations (> 1000 min) are incidents that affected a relatively small **number of ICPs**. Since the number of ICPs affected is small, the SAIDI generated is also relatively small - hence it is likely that these incidents are deprioritised.



- Older / more fatigued assets seem to be associated with longer incident durations. The top two **asset condition labels** associated with the longest incident durations are

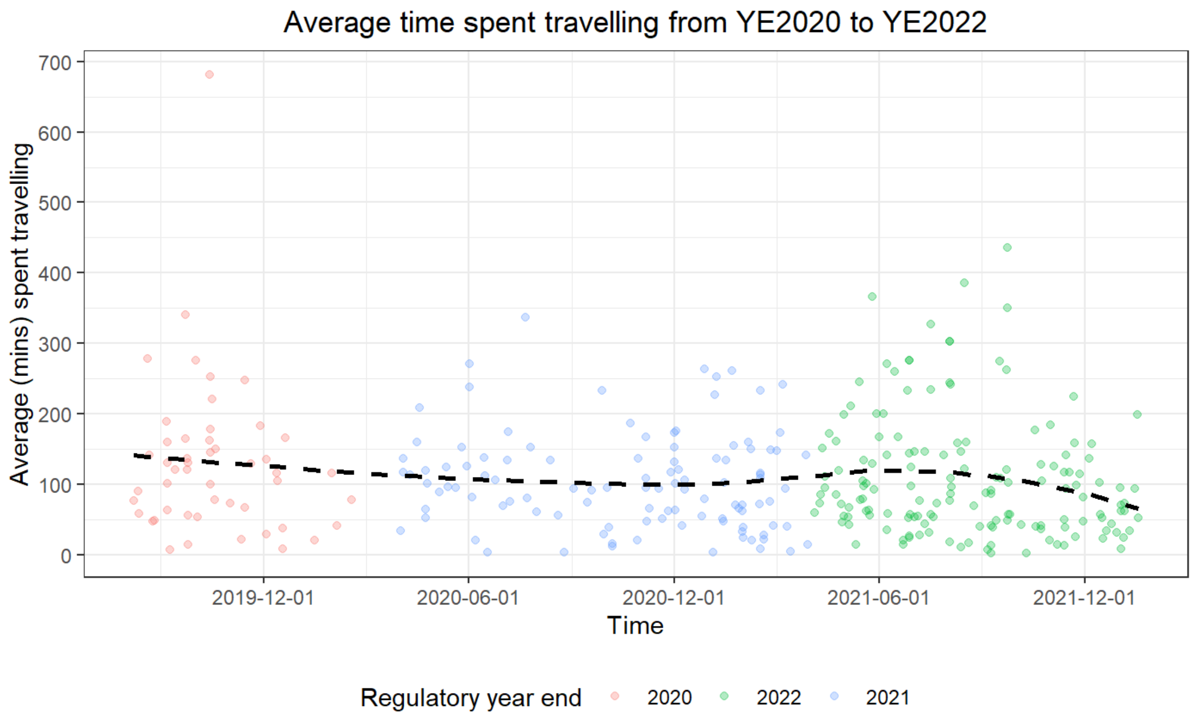
0 **Unknown** and **3 Fatigued.** These labels themselves are correlated with older equipment age, as expected. For equipment labelled as "unknown", this indicates that there has been no recorded inspection. Note that the majority (74%) of incidents failed to match to an asset condition (due to missing data). Only 10 incidents were associated with an asset labelled as "0 Unknown". Interestingly, "4 Unreliable" and "5 End of Life" (lumped as Other) did not seem to be correlated with longer incident durations - however this is inconclusive due to having only a small sample of incidents for both of these condition levels.

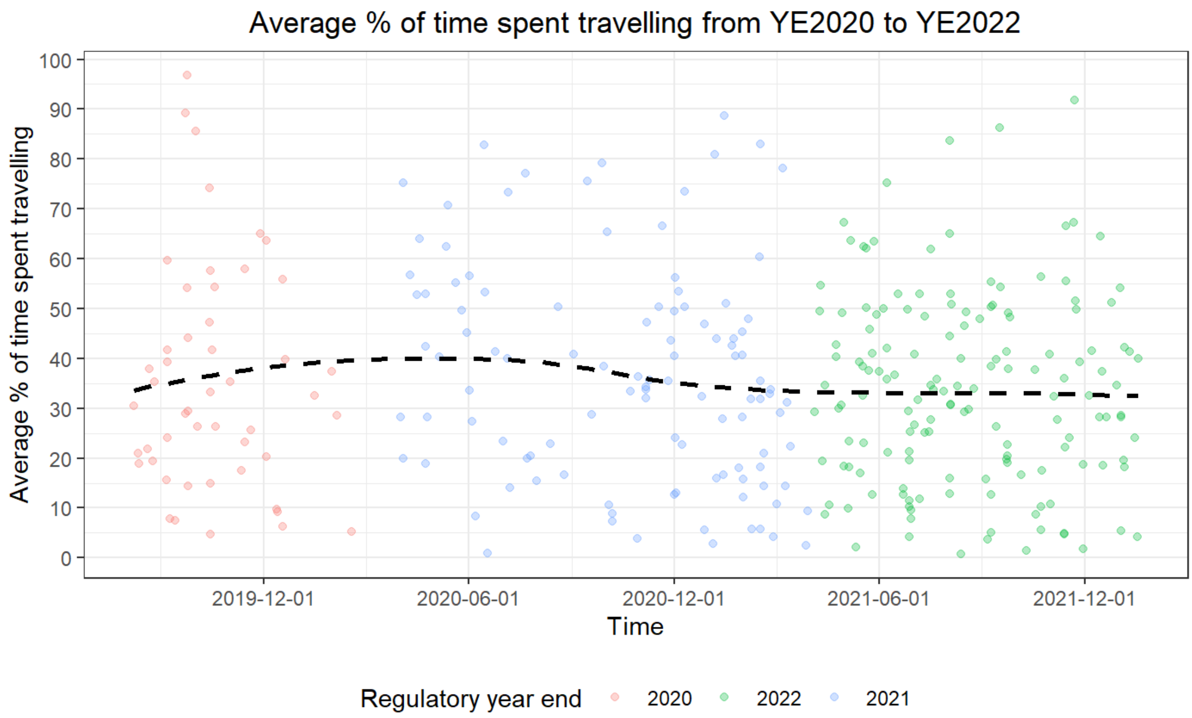
Incident Response Analysis

Vehicle response

To analyse the vehicle response, the unplanned ADMS incidents which could be associated with Smartrak data were selected for analysis. The features as described within the feature generation section were used.

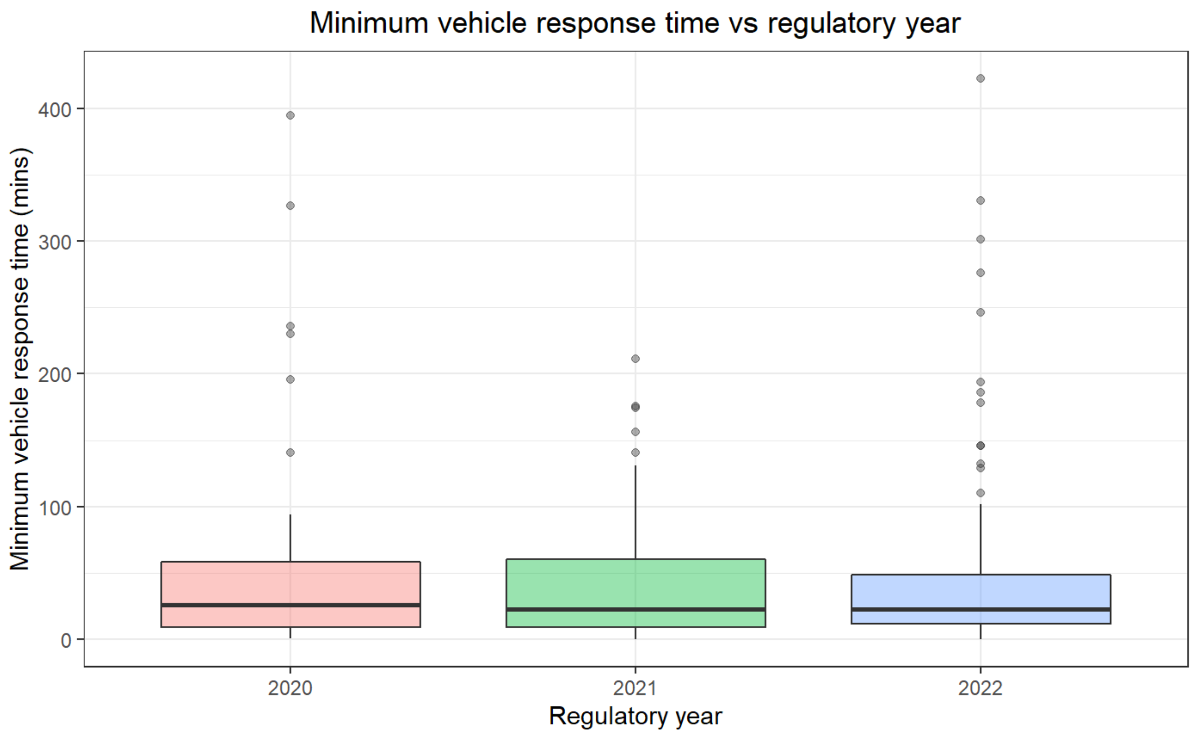
Response over time





Interestingly, while the average travel time per vehicle appears to exhibit a subtle downward trend over the course of the past 3 regulatory years, the percentage of Incident time spent travelling has not significantly changed within the same period.

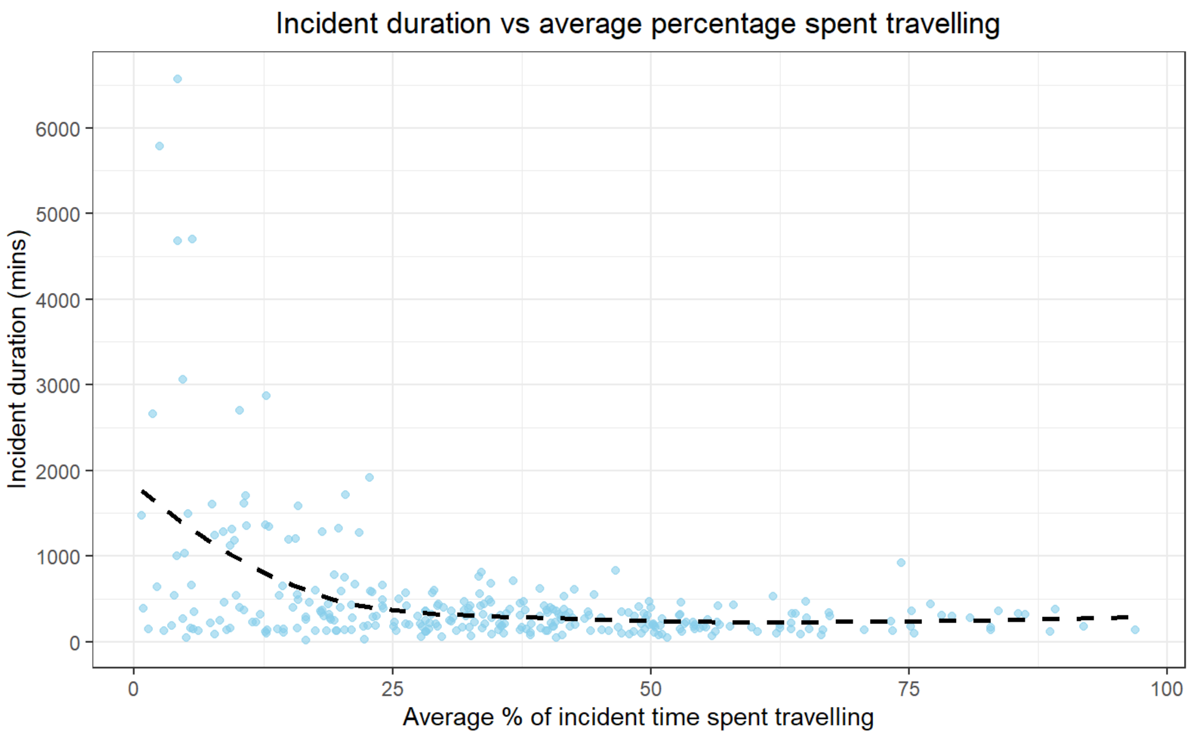
Although caution must be exercised with the interpretation of these events as a significant number of incidents are not accounted for in the vehicle response analysis. This is covered in more depth in [quality issues].



It appears that the delay between an incident starting and the first vehicle trip has not changed noticeably from YE2020-YE2022, and this potentially identifies an area for improvement in the way that vehicles respond to incidents..

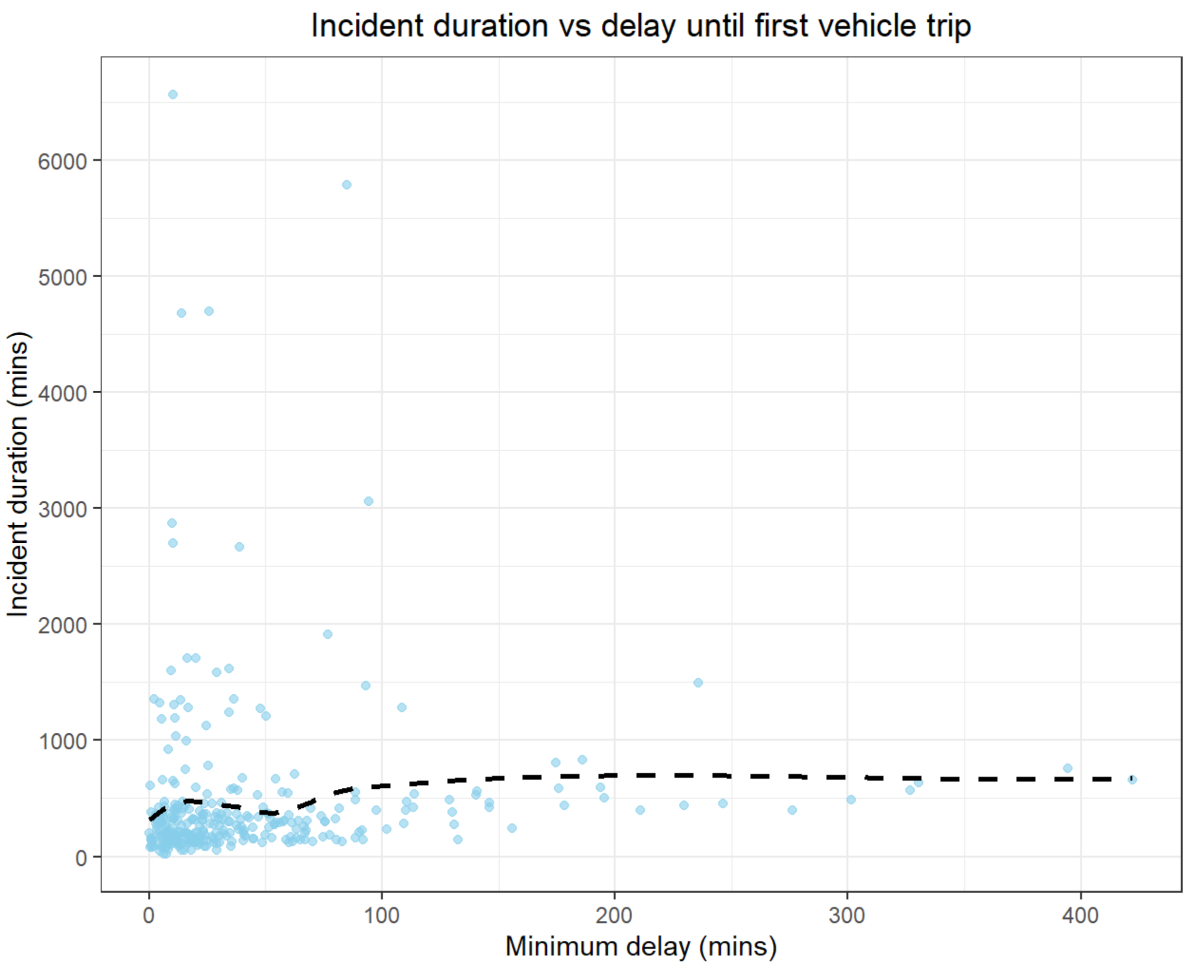
Relationship between Incident Duration and Vehicle Response

Each of these vehicle response features was compared against the corresponding incident duration data.



As conveyed by the above figure, with longer incident times (>1000 minutes), less than a quarter of the actual incident duration involves workers driving. Moreover, when neglecting these longer times it appears that the relationship between percentage of incident time and duration does not change noticeably. From this it might be concluded that travel related issues do not appear to significantly affect long events.

This observation is supported by an investigation into the vehicle response times.



Shown here is the minimum delay (response time) of the first vehicle after an incident begins. The overall trend (black) appears flat.

The large scatter about the trendline above figure also demonstrates a weak relationship between the vehicle response time (mean 44 minutes) and incident duration - suggesting that particularly long delays do not significantly affect the total incident time. By extension, the longest incidents tend to have below average delays.Despite this, for incidents under 1000 minutes there does seem to be a positive correlation between incident duration and minimum delay.

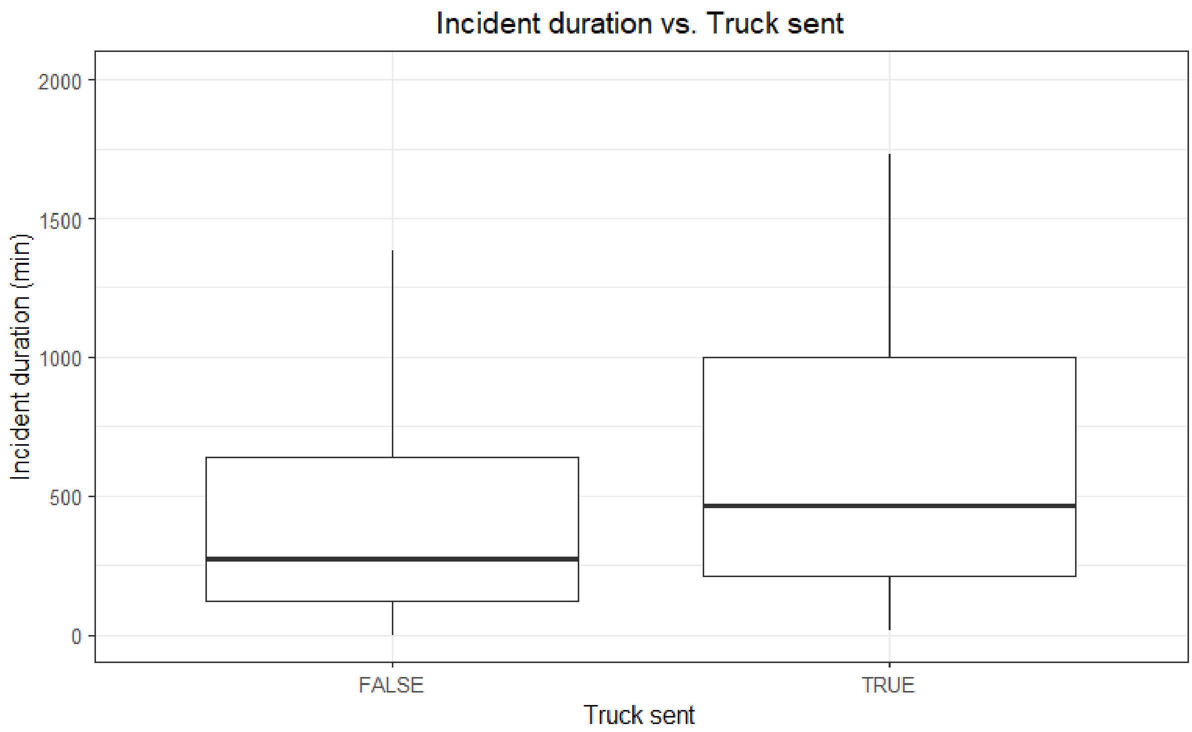
Evidently, while vehicle related issues such as delay and travel time do not seem to majorly contribute to longer(>1000 min) SAIDI incident duration, improving the vehicle response time would have a positive impact on event duration.

Trucks sent

Another area of interest is the types of vehicles sent to an incident, based on the SAP vehicle hours data. There are a variety of truck types recorded, including

- Small truck (6-8m)
- Medium truck (8-10m)
- 3 tonne truck
- 5-8 tonne truck

For the purposes of this analysis, any incident involving any of the above vehicle types is considered an incident where a truck was sent.

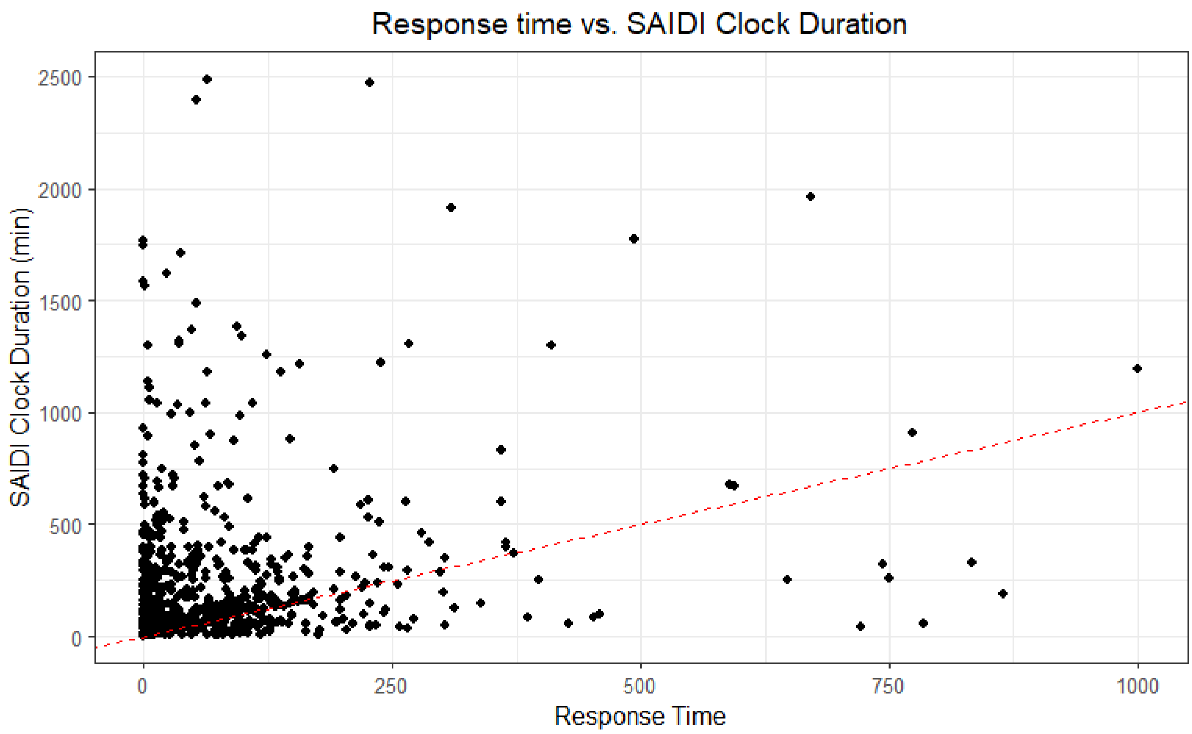


From the graph above, we can see that incidents involving trucks have a median duration 72% higher than incidents that do not involve trucks.

An examination of the vehicle hours data show that whereas incidents without trucks on average send around 2-3 unique vehicles in total, incidents with trucks send on average 4. This supports the conclusion that trucks are often only sent after the initial few vehicles, resulting in delays when an incident requires a truck to ship parts (e.g. a pole) that are required for resolution.

Employee Response Time

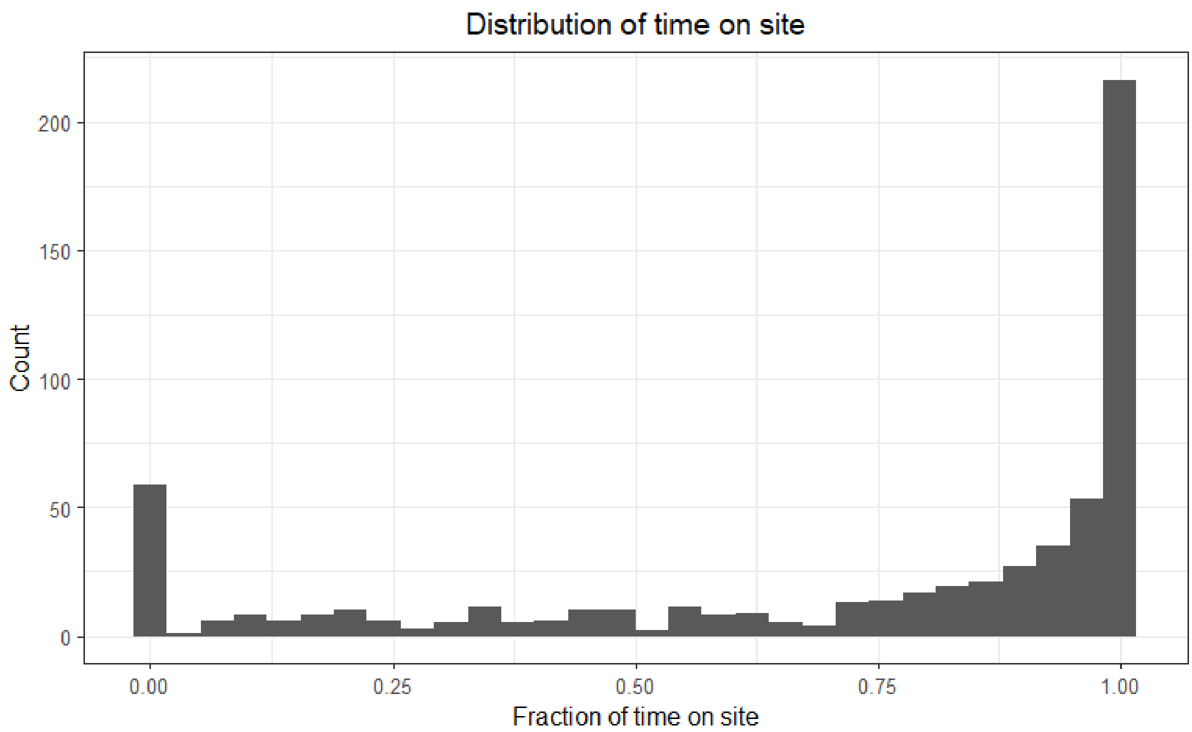
Utilising the ADMS employee event data, the first onsite action was approximated as described in the feature generation section. This allowed for the calculation of an employee "response time" (time since incident start to arrive on site) and "time on site" (total time spent on site during incident). These features were analysed against the total event duration.



The dotted red line represents when the response time is equal to the SAIDI clock duration.

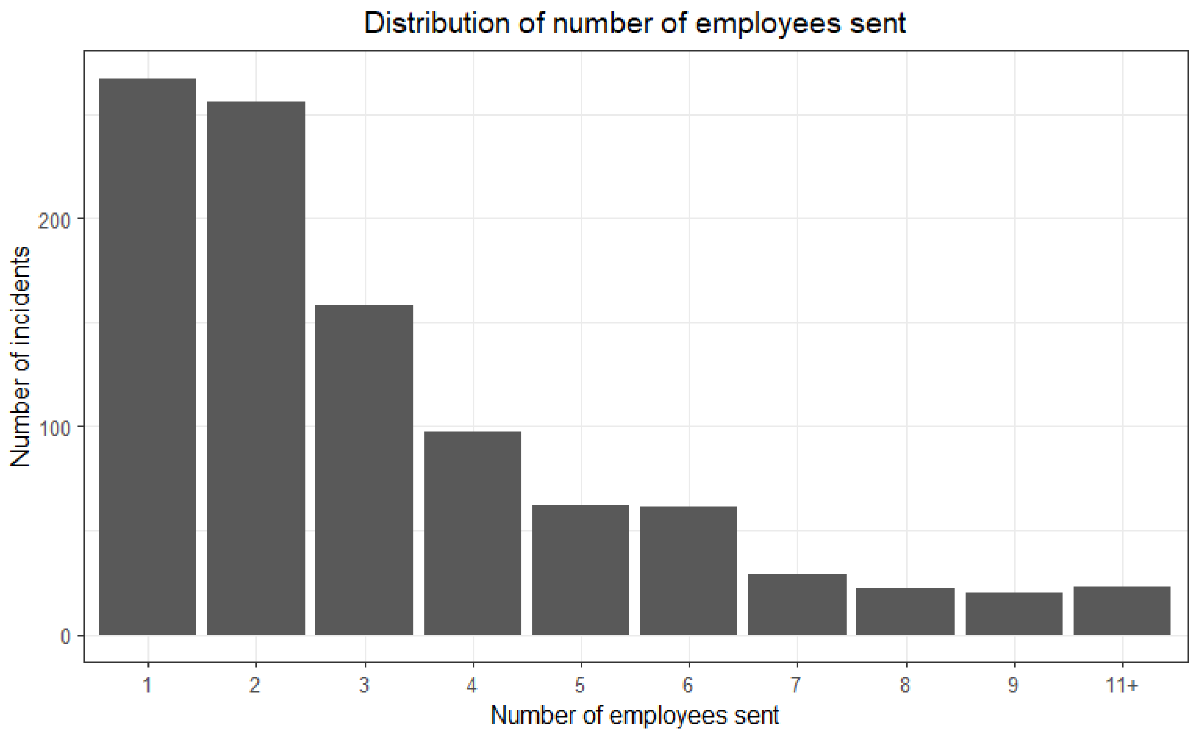
The above graph displays some issues with the reliability of the method to calculate response time. There are several points lying below the dotted red line, indicating that the response time was longer than the SAIDI clock duration. In these cases, this is due to the SAP notification time being much earlier than the actual SAIDI clock start time. As described earlier, in some instances, the SAIDI clock start time is adjusted to when the worker isolates a section - therefore only starting when the worker is already on site and working. This also explains why there are many points with essentially zero response time - since the first logged ADMS event would correspond with the start of the SAIDI clock.

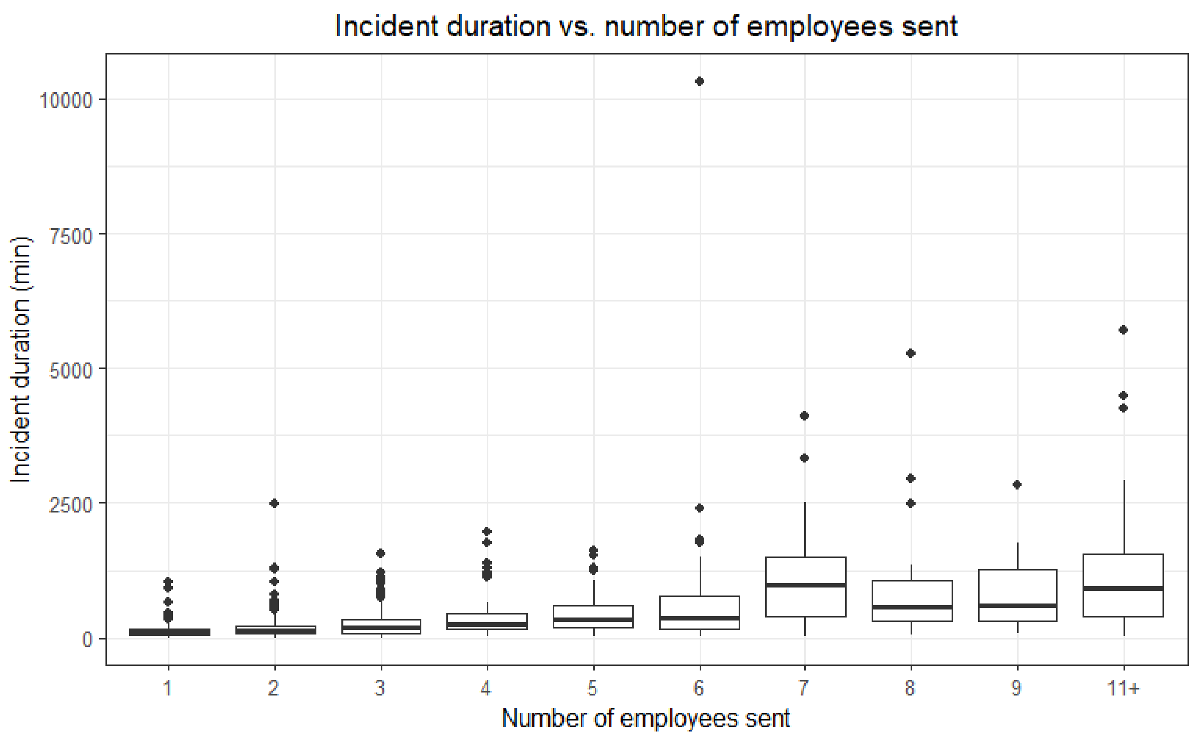
In general, it is difficult to make any conclusions due to the caveats associated with the method of calculating response time.



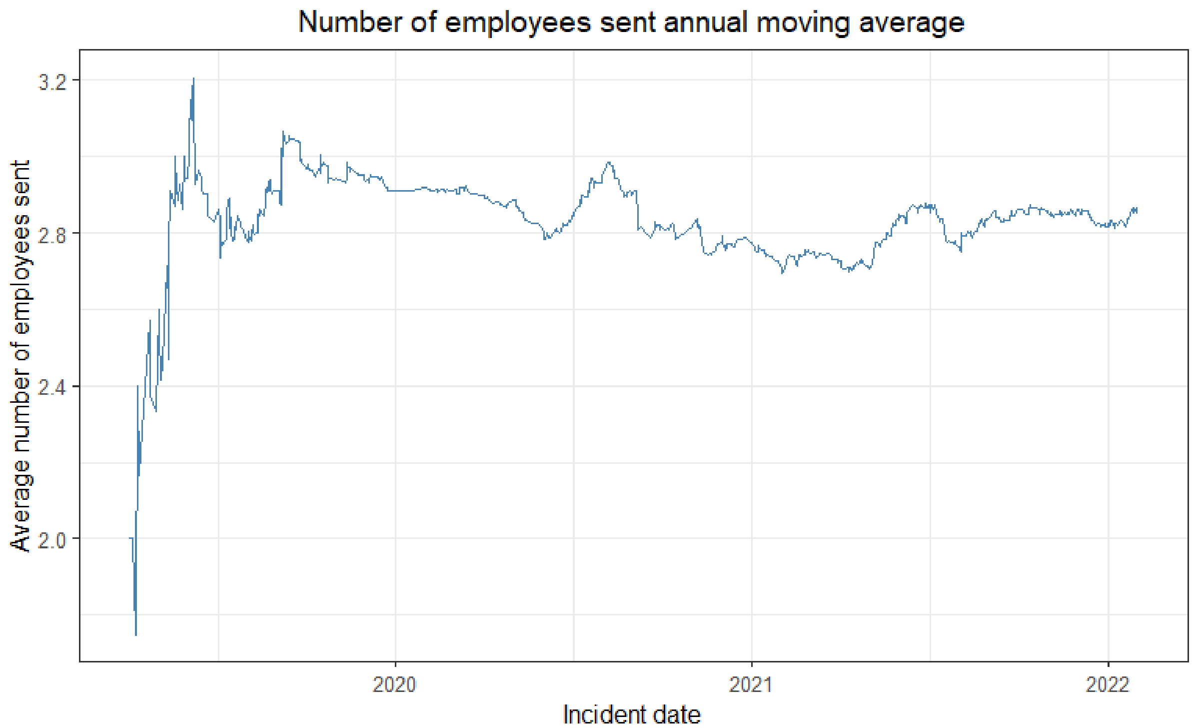
Similarly, calculations of the time on site based on employee actions show two spikes at 0 and 1. Incidents with a time on site of 0 are due to successive ADMS events being recorded at the exact same time. Incidents with a time on site of 1 are due to ADMS events being inherently linked to the SAIDI clock start and end times (i.e. the SAIDI clock starts when the first key action verb is logged, and ends when the last key action verb is logged). In either case, this highlights the difficulty in using the ADMS event data to approximate the time on site.

Employees Sent





The average number of employees sent is around 2-3. There is a clear and expected relationship between longer duration incidents, and an increase in the total number of employees sent. In this case, it is intuitive that longer durations result in more workers being sent to the site.



There is no evidence that the number of employees being sent to a site is decreasing over time, nor are there any significant differences year on year. Therefore, it is difficult to attribute any variation in SAIDI to this factor.

Conclusions and Recommendations

Key Findings

Short duration incidents are responsible for the majority of SAIDI

- The amount of SAIDI contributed by short incidents is trending upwards, with 95% of all SAIDI in YE2022 being contributed by incidents shorter than around 750 minutes.
- Based on YE2021 and YE2020, there is a risk of a single, very long incident to contribute a significant amount of SAIDI (>10 SAIDI minutes), especially if it affects a large number of ICPs. This rare "high impact" incident has yet to have happened in YE2022.

Recommendations: Since frequent, shorter incidents are contributing the majority of SAIDI, improving the response time to these incidents would have a significant effect. On the other hand, reducing the chance of a very long, high impact incident from occurring could also reduce SAIDI. We should note that if such a high impact incident were to occur in YE2022, we could expect YE2022's final SAIDI total to be far over the regulatory target.

Winter months and bad weather are impactful

- There is a clear and observable increase in both frequency and duration of incidents during the winter months of the year.
- Winter months are responsible for 35.7% of all SAIDI. Including September, this jumps to 47.9%.
- Extreme weather events and lightning strikes result in longer duration incidents.

Recommendations: Prepare in advance for an increase in incidents during the winter months / forecasted bad weather. Account for winter months in any budgeting of SAIDI for the year.

Vehicle response does not explain long duration incidents

- When an incident is long, the majority of time spent by an employee is on site.
- Neither percentage of time spent travelling, nor vehicle response time are associated with longer duration incidents.

- The longer an incident, the lower the percentage of time actually spent travelling.
- The longest incidents also tend to correspond with below average vehicle delays.

Recommendations: Improving vehicle response is unlikely to make any significant difference to incidents that are very long (>1000 min). However, for short incident durations, reducing overall vehicle times may be effective.

The top 4 substations contribute more than half of all SAIDI

- The top four substations (Kaikohe / Kaikohe 33kV, Okahu Rd and Taipa) are responsible for 55.8% of all SAIDI. These four substations have generally been the top contributors to SAIDI from YE2020 to YE2022.
- These substations are not associated with long duration events, but have some combination of either a high incident frequency, or average number of ICPs affected. Kaikohe and Okahu Rd both seem to have an unusually high number of incidents (>100), whereas Kaikohe 33kV and Taipa affect a large number of ICPs.
- Kaikohe 33kV in particular affects an unusually large number of ICPs, resulting in high SAIDI numbers despite incidents being of shorter length.

Recommendations: Since these substations affect a large number of ICPs when they fail, improving employee response to these substations specifically would greatly help reduce SAIDI. Further investigation is recommended to determine why Kaikohe and Okahu Rd seem to have high incident frequencies.

Pole incidents are strongly associated with long incident durations

- Vehicle vs. Pole is the cause with the third highest median incident duration.
- The median incident duration for incidents involving “pole” object types is 289 minutes - 90% longer than the overall median of 152 minutes. Poles represent 17% of all SAIDI - only behind “conductor span” as the highest contributing device affected.
- Incidents where a “truck” vehicle was sent to site have a 72% higher median duration than incidents where no truck was sent. Often these trucks carry poles to the site and are only sent after the initial vehicle.

Recommendations: Improve the response to incidents involving poles. This may involve a further investigation to determine the underlying reason behind the longer than average resolution time. One explanation could be the fact that the pole trucks are often sent as a successive vehicle - however investigations into vehicle times seem to indicate that vehicle travel time do not necessarily explain longer incident durations.

Data Improvement Opportunities

The following is a list of opportunities to improve the data provided by Top Energy, based on challenges that arose during the project.

Quality issues

Logged “cause” for the incident is inconsistent

The “cause” field within the ADMS incident data is logged by the workers. This results in some inconsistent causes being specified. For example, the various causes listed in the weather effects section that all shared the underlying cause of a storm.

For example:

- On 05/09/2019 there were 16 events - the highest number of daily incidents observed in this analysis.
- The “cause” noted in the ADMS varies across each incident and was noted as “tree (fall on line)”, ”storm” , ”conductor tail blown off”.
- While the cause is mostly different for each event, it can be inferred they are mostly consequences of extreme weather.

Solution: To provide a limited set of causes for the employees, and allow multiple causes to be associated with a single incident. For example, an incident that could have all the following causes: “tree (fall on line)”, “strong winds” and “tree contact”.

Cannot join in vehicle features due to missing matches

To join in vehicle events from the Smartrak data to a particular incident, a join utilising the unique vehicle IDs and dates was performed which involved joining smartrak to FieldGo, then

ADMS. This resulted in a number of incidents unsuccessfully joining with any vehicle events (72%).

Solution: Have the associated SAP order number recorded in the Smartrak data whenever a vehicle event is logged.

Missing equipment age:

The SAP Jobs and Equipment data is missing “start up date” entries. After joining this to the SAP Condition History sheet by order number and calculating the equipment age, 26% of observations must be dropped because the age cannot be calculated or is incorrect (0 or negative years).”

Solution: Flag relevant rows for later correction. Identify what might cause these issues and potentially try to resolve them.

Inability to accurately determine the true incident start time

Since the SAIDI clock can be adjusted based on its regulatory definition, it does not accurately represent the true start of the incident (when a customer is affected by the incident). Although the SAP notification times are a close proxy, they also present some issues:

- Occasionally, the SAP notification time will be logged as coming after tasks performed by the worker as according to the ADMS events data. This implies that the worker was on site before being notified.
- The SAP notification times are missing for 10% of the incidents.

Solution: Determine the reason behind the inconsistencies above, and record a feature for each incident that provides the sole source of truth to calculate metrics such as response time.

Duplicated / Missing SAP numbers within the ADMS incident data

- There are 48 incidents that lack a recorded SAP order number.
- 19 incidents have an invalid character recorded, such as “a”, “none” or “tba”.

- There are 12 SAP order numbers that are duplicated accounting for 28 unique incidents.

The above issues mean that there are a number of incidents that:

- Lack information that needs to be joined in from the SAP datasets.
- Will contain duplicate information joined in from SAP that is shared with other incidents (this is because the order number is used as the key to join in data).

Duplicate SAP order numbers are thought to be due to workers resolving multiple related incidents in one order.

Solution: Associate data with specific incident IDs, rather than just order numbers. This means that data such as vehicle and employee response data can be joined to the specific incident, rather than an “order” which might involve multiple incidents.

Discrepancies between the ADMS, FieldGo and SAP Timesheet data

The FieldGo data’s “JSA sign on” and “JSA sign off” times do not correspond to the hours logged by each employee in the SAP timesheet data. The JSA time signed in tends to be much shorter than the hours registered by each employee in their timesheet.

A few entries in the FieldGo data indicate that some employees are incorrectly signed out before they have signed in, although these situations are rare (<1%). Multiple “JSA time on” entries take place long after an incident has been completed, for example, a day after the recorded incident end time.

The number of personnel assigned according to the SAP timesheet does not match with the FieldGo data. To remedy this, we used the SAP timesheet data as the single source of truth.

In addition there are a number of incidents (366) within the ADMS incidents data that do not have a corresponding FieldGo entry.

Count of order numbers only in ADMS	Count of order numbers in both	Count of order numbers only in FieldGo
366	654	3516

Many of the issues with the FieldGo data can be explained due to discipline issues - workers are generally not forced to sign in and out in an accurate manner.

Solution: Improve discipline in workers to increase the reliability of the FieldGo sign on / off entries.

Absent datasets

Data prior to YE2020

The three regulatory years of data provided have all been examples of years where the annual SAIDI reaches above 300 minutes. Additional years of information would allow for comparison with a year that had relatively lower SAIDI (e.g. YE2019). This would allow for a determination of any differences between years with low SAIDI versus years with high SAIDI - for example whether severe weather events were more common.

In addition, this would provide more data for a successful forecast model to be built, as discussed in the later forecasting section.

Weather data

The features we have explored in this report are all recorded upon an incident occurring. This inherently makes it difficult to discover reasons for increases in incident frequency, since data on days where no incidents occurred is missing.

Future work could more closely examine daily weather variables (such as wind direction, speed, rainfall levels) to determine a more precise relationship between weather effects and incident frequency.

Asset condition over time

Similar to weather data a regular time series of asset condition measurements could be used as an additional predictor for the frequency of incidents. Currently, measurements are associated with order numbers.

Future Work

The following is a list of potential future projects that could be undertaken by Harmonic around Top Energy's SAIDI data.

Forecasting

A forecast of SAIDI could allow for more accurate planning for the future, as well as provide an indication of when Top Energy is over / underperforming in terms of SAIDI during the regulatory year.

This forecast could be done in a hierarchical manner - generating outputs both at the smaller substation level, as well as larger SA2 aggregations and overall.

The following datasets would likely improve forecasting performance:

- Further historical SAIDI data
- Weather forecasts, including historical forecasts
- Historical asset conditions
- Other time series data that is collected independently of incidents occurring

Interactive Dashboard

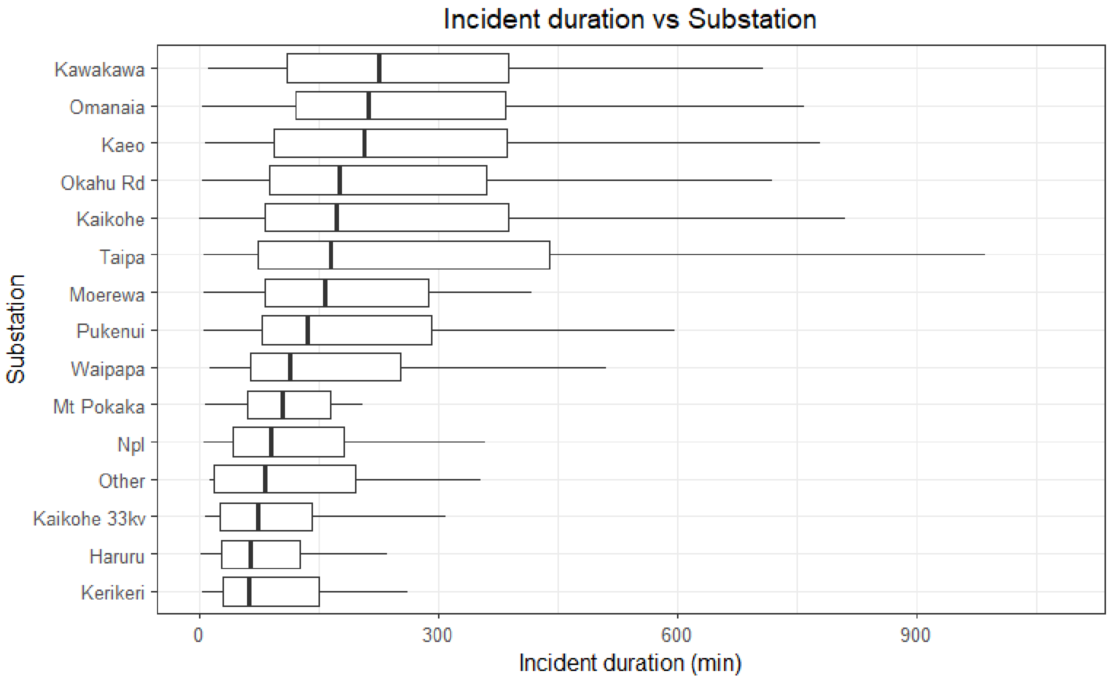
An interactive dashboard could be created using a tool similar to PowerBI or RShiny. This would allow for some of the graphical outputs within this report to be generated on the fly by Top Energy users. Some examples of functionality might include:

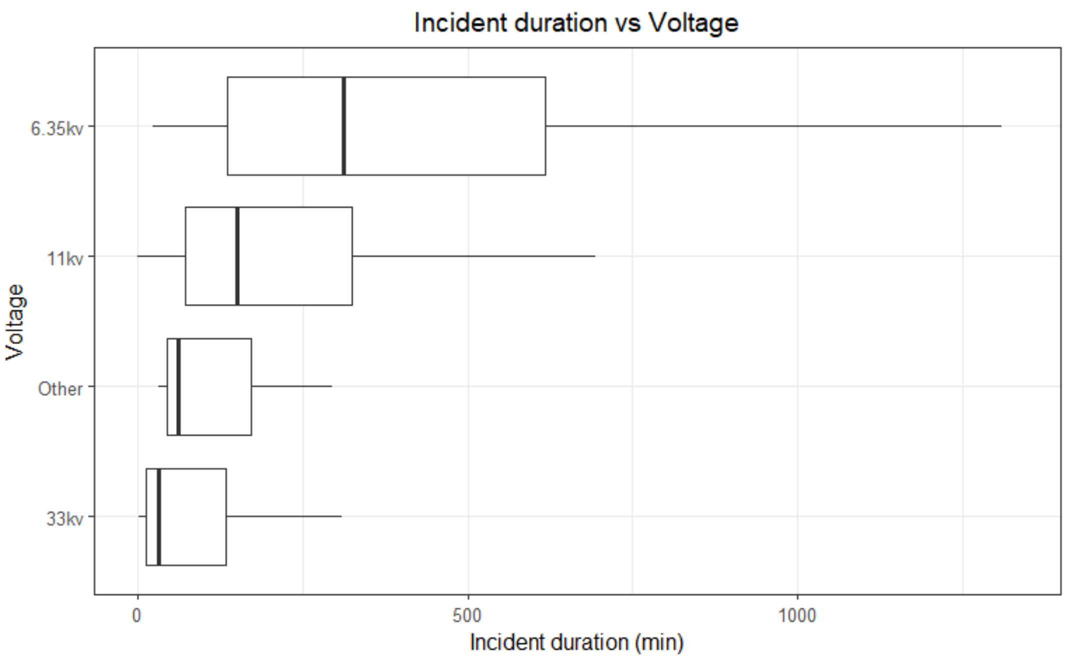
- Heatmaps will drill down functionality, breakdowns of SAIDI, incident frequency and duration and other metrics
- Metrics relating to employee response plotted over time, for example vehicle travel times or time spent on site
- Various breakdowns of incident frequency and duration by a selection of features as done so in this report

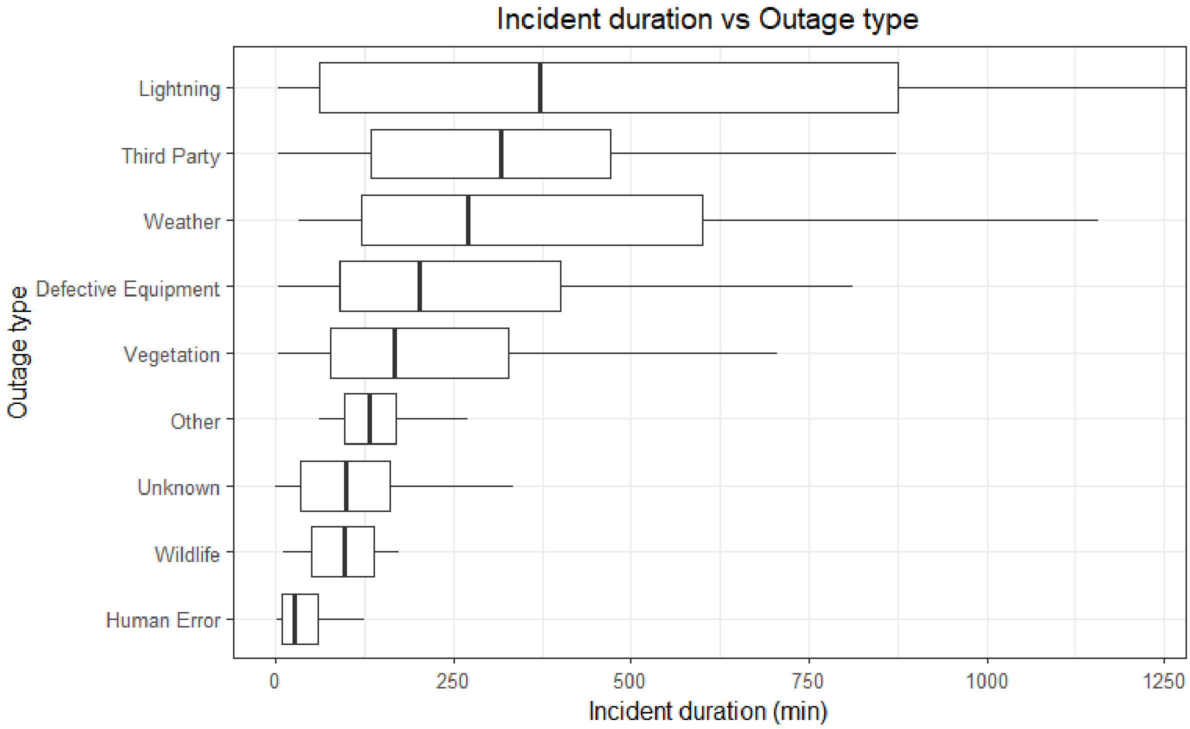
The dashboard might be automatically updated on a semi-regular basis - for example once a week / month, depending on the kind of data being reported.

Appendices

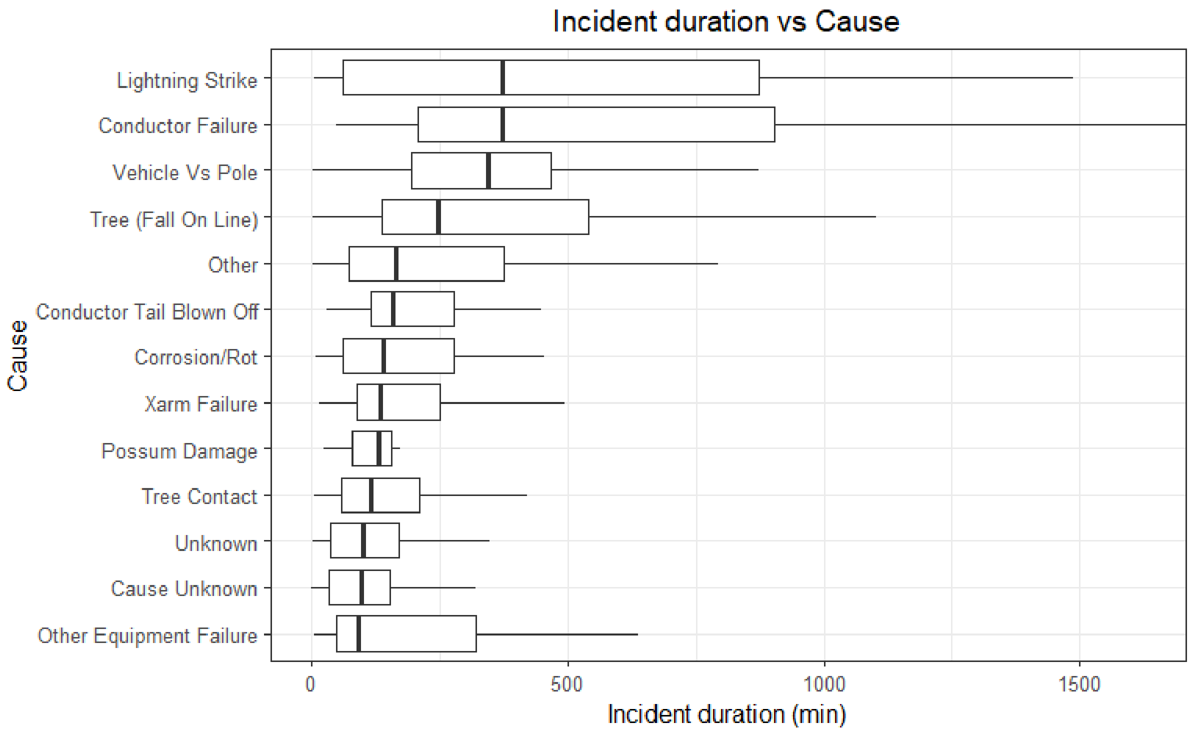
Incident Duration Plots



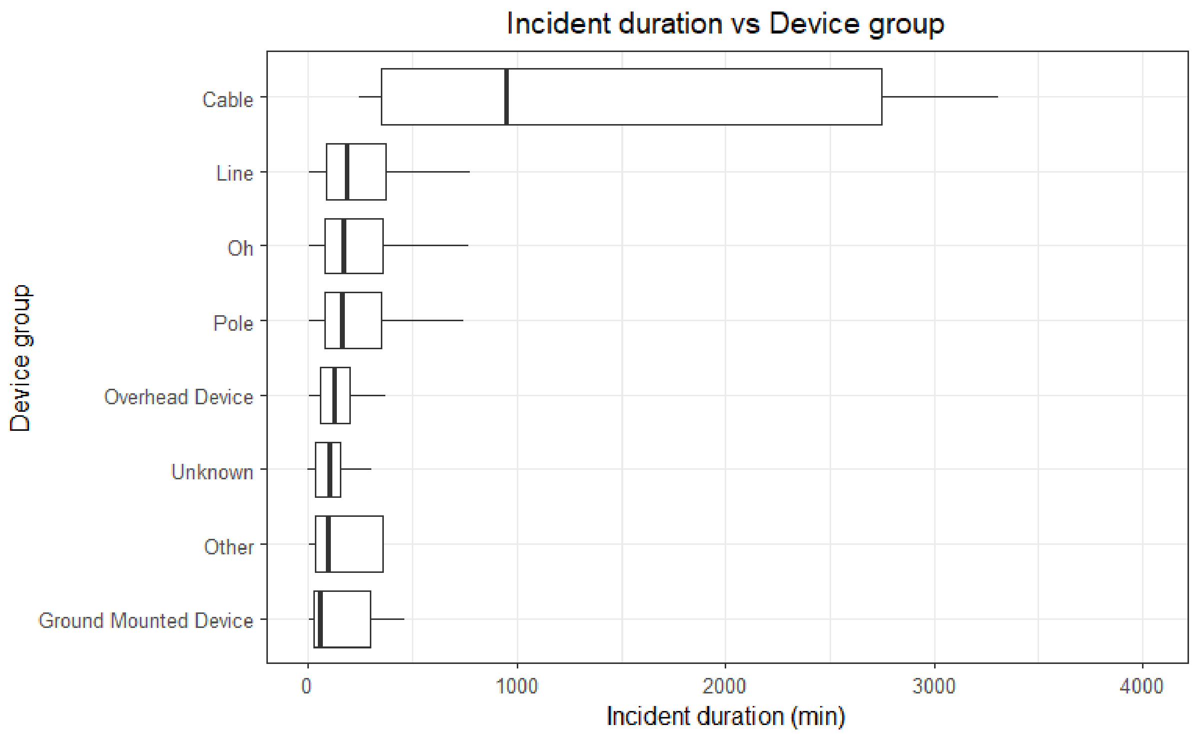


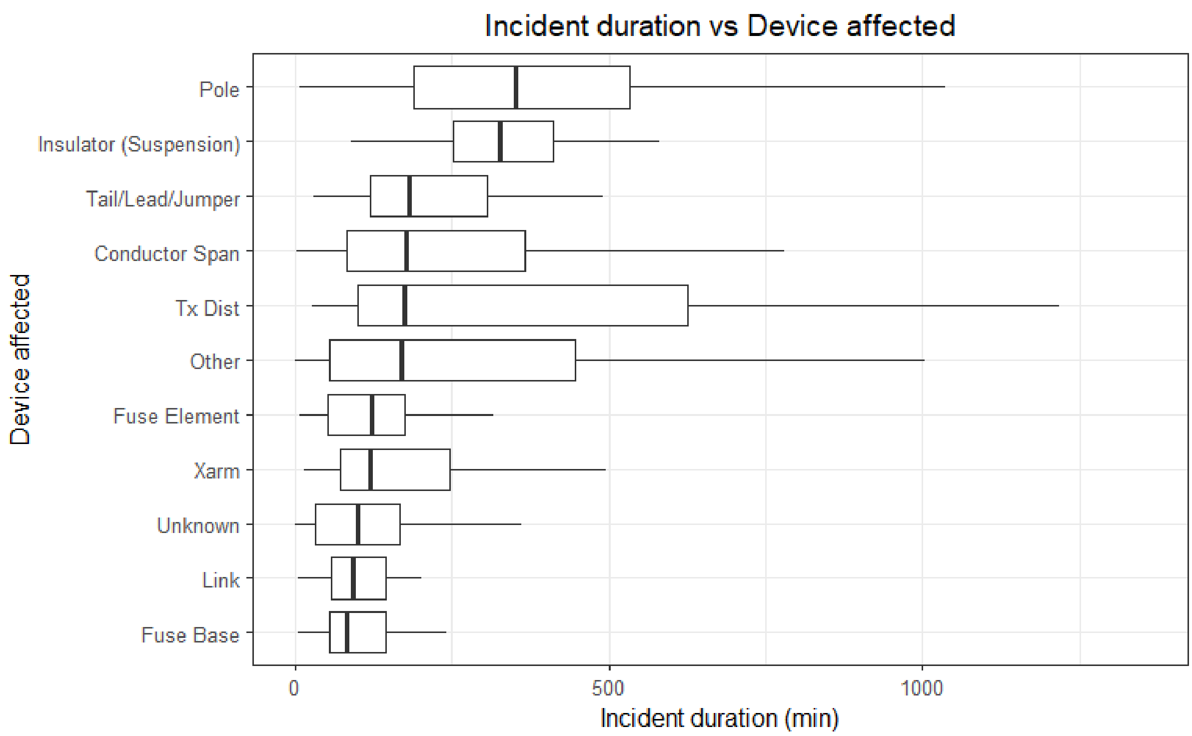


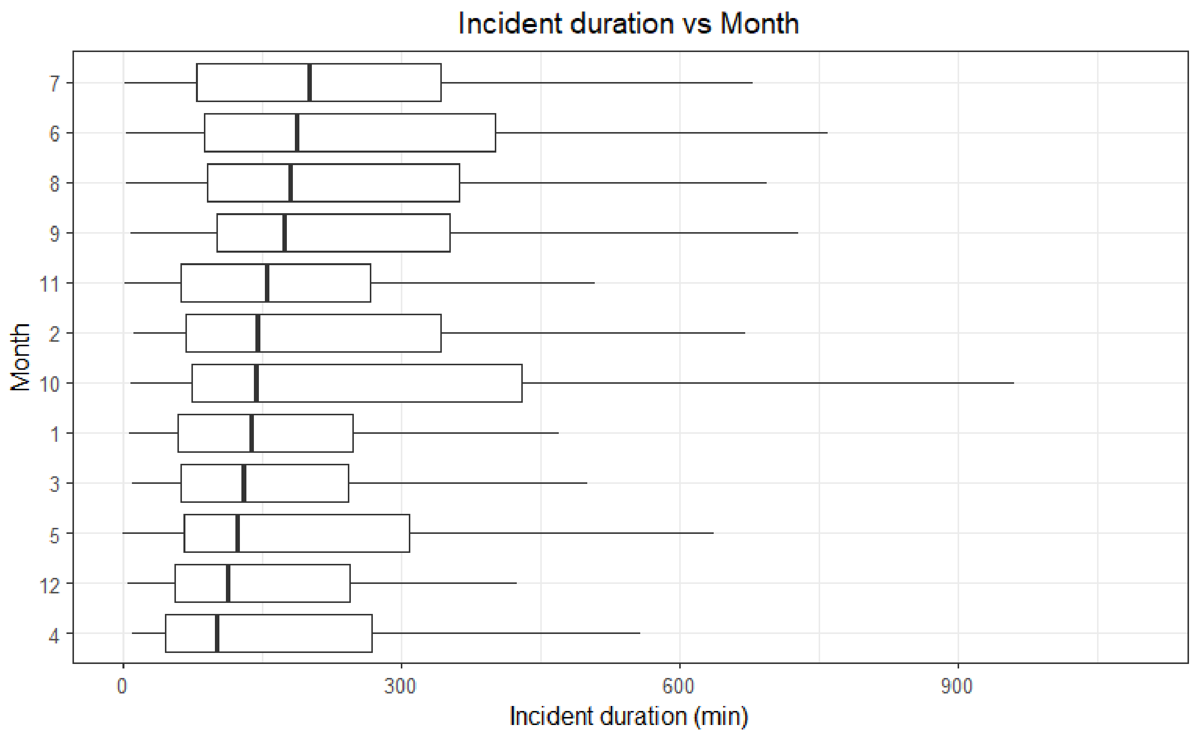
Incident duration vs Outage type
Outage type
Lightning
Third Party
Weather
Defective Equipment
Vegetation
Other
Unknown
Wildlife
Human Error
0
250
500
750
1000
1250
Incident duration (min)

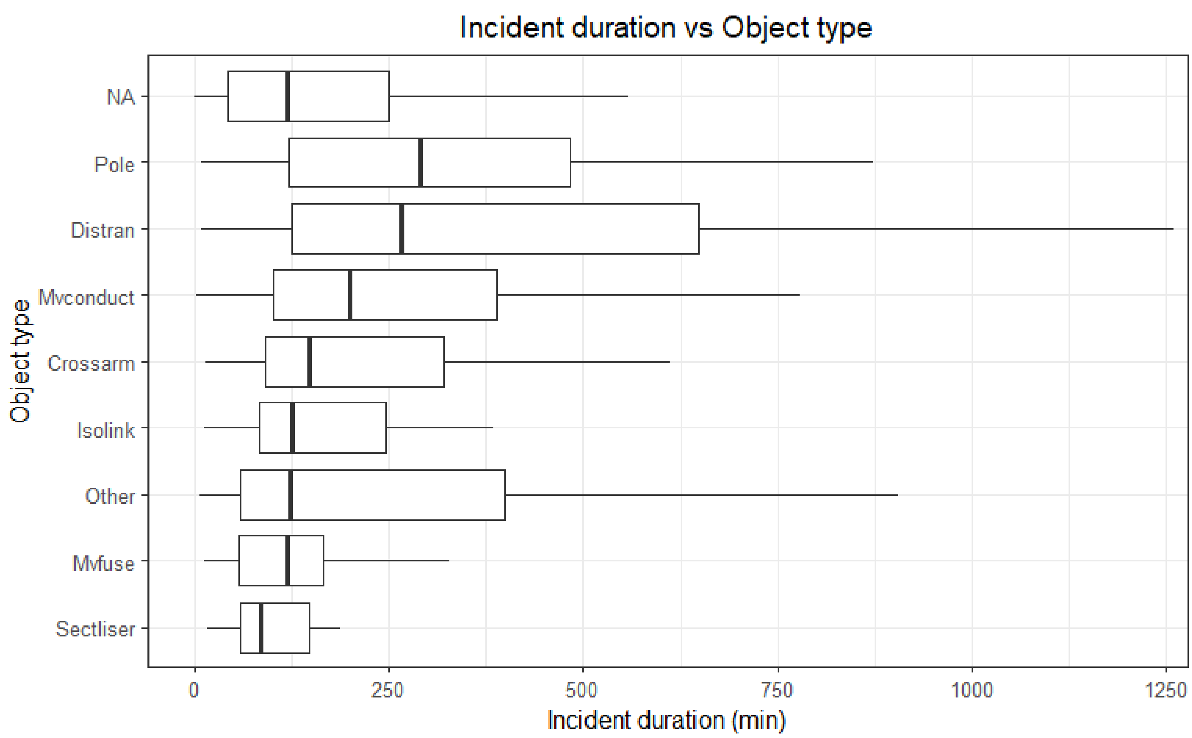


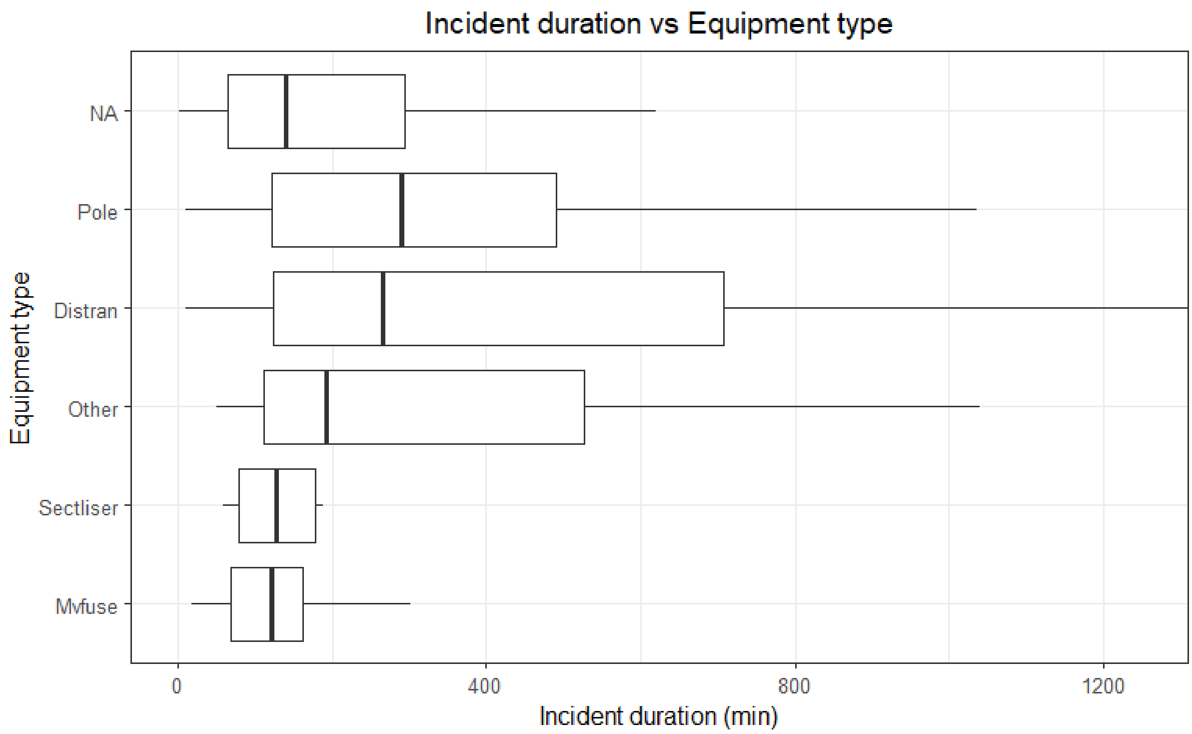
Incident duration vs Cause
Cause
Lightning Strike
Conductor Failure
Vehicle Vs Pole
Tree (Fall On Line)
Other
Conductor Tail Blown Off
Corrosion/Rot
Xarm Failure
Possum Damage
Tree Contact
Unknown
Cause Unknown
Other Equipment Failure
0
500
1000
1500
Incident duration (min)


Incident duration vs Device group
Device group
Cable
Line
Oh
Pole
Overhead Device
Unknown
Other
Ground Mounted Device
0
1000
2000
3000
4000
Incident duration (min)

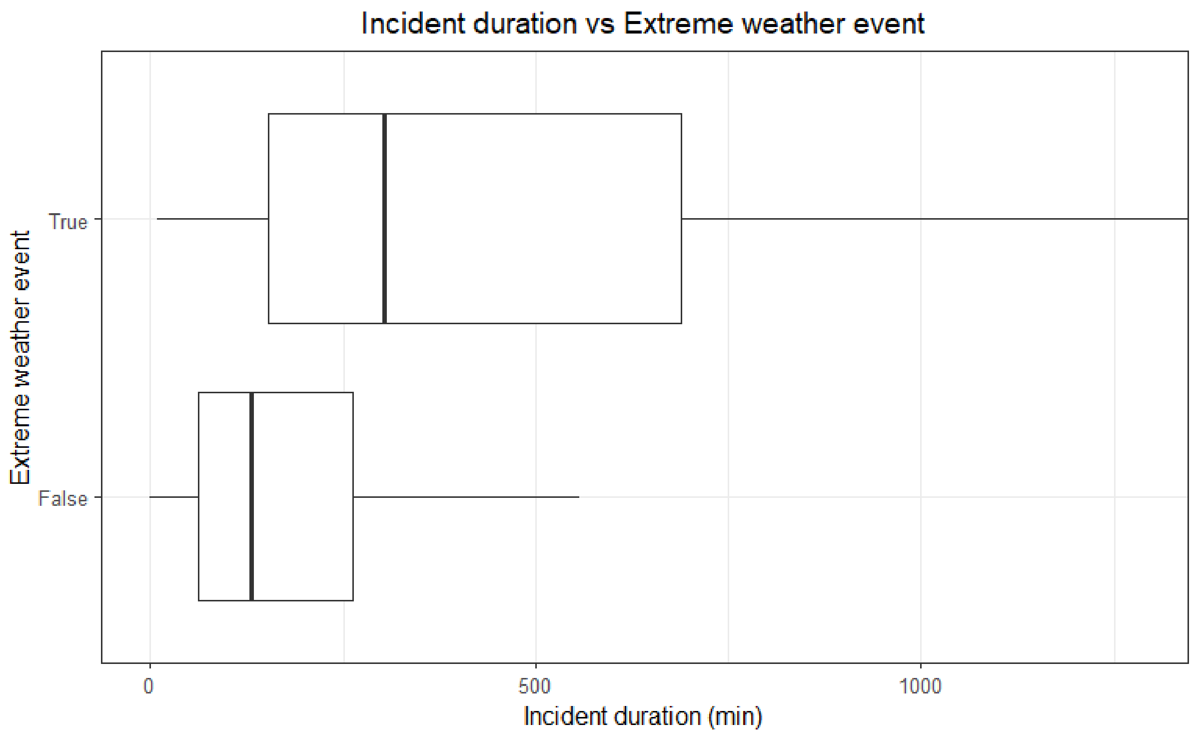

Incident duration vs Device affected
Device affected
Pole
Insulator (Suspension)
Tail/Lead/Jumper
Conductor Span
Tx Dist
Other
Fuse Element
Xarm
Unknown
Link
Fuse Base
0
500
1000
Incident duration (min)

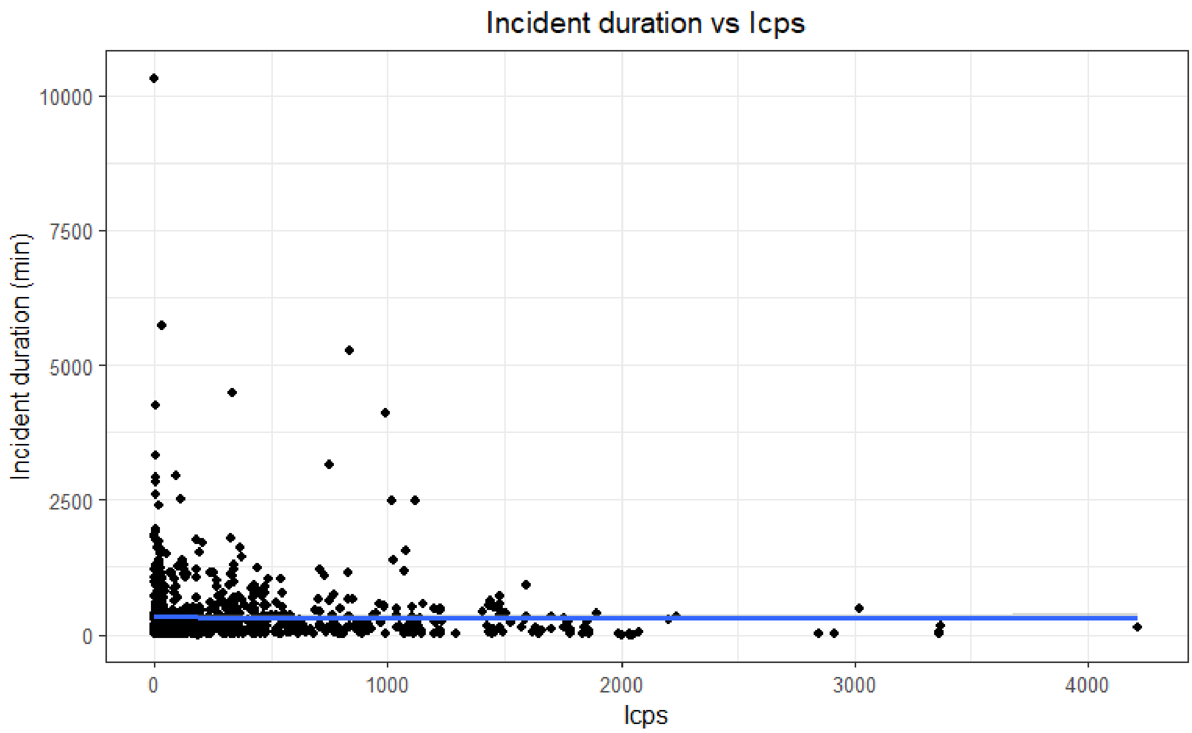

Incident duration vs Month
Month
7
6
8
9
11
2
10
1
3
5
12
4
0
300
600
900
Incident duration (min)

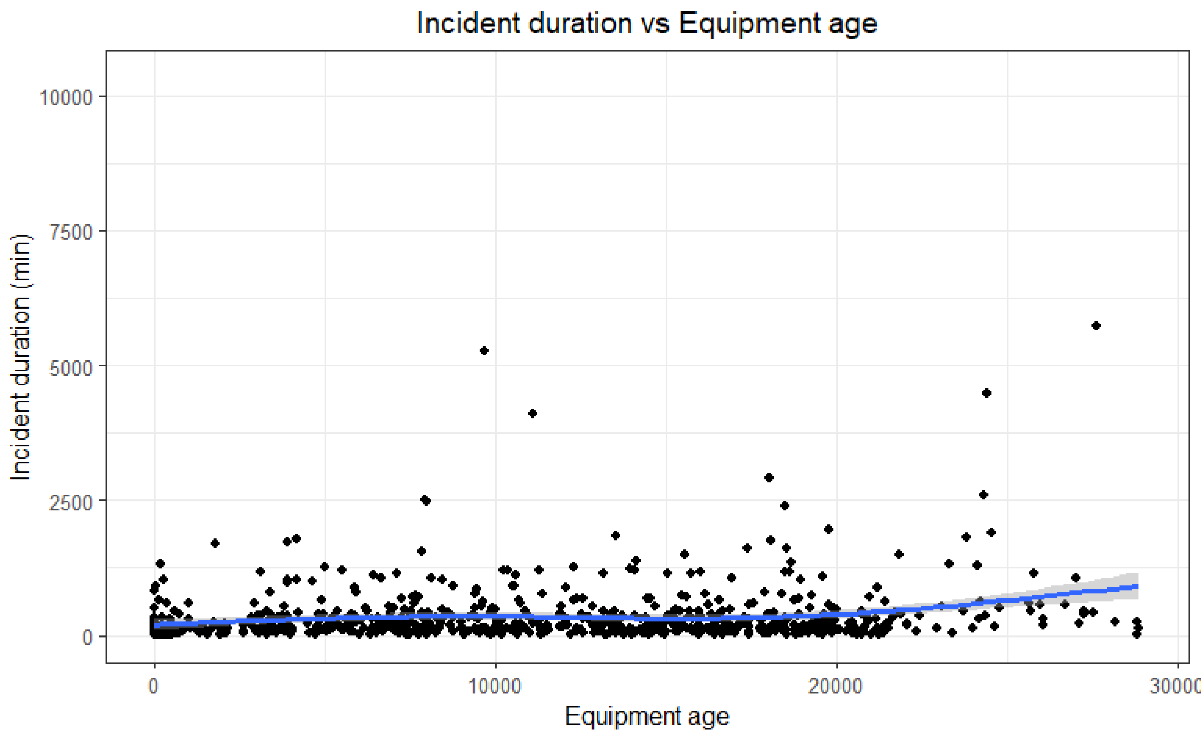

Incident duration vs Object type
Object type
NA
Pole
Distran
Mvconduct
Crossarm
Isolink
Other
Mvfuse
Sectliser
0
250
500
750
1000
1250
Incident duration (min)


Incident duration vs Equipment type
NA
Pole
Distran
Other
Sectliser
Mvfuse
Equipment type
0
400
800
1200
Incident duration (min)


Incident duration vs Asset condition label
NA
0 Unknown
3 Fatigued
4 Unreliable
2 Serviceable
1 New
Other
Asset condition label
0
500
1000
1500
Incident duration (min)

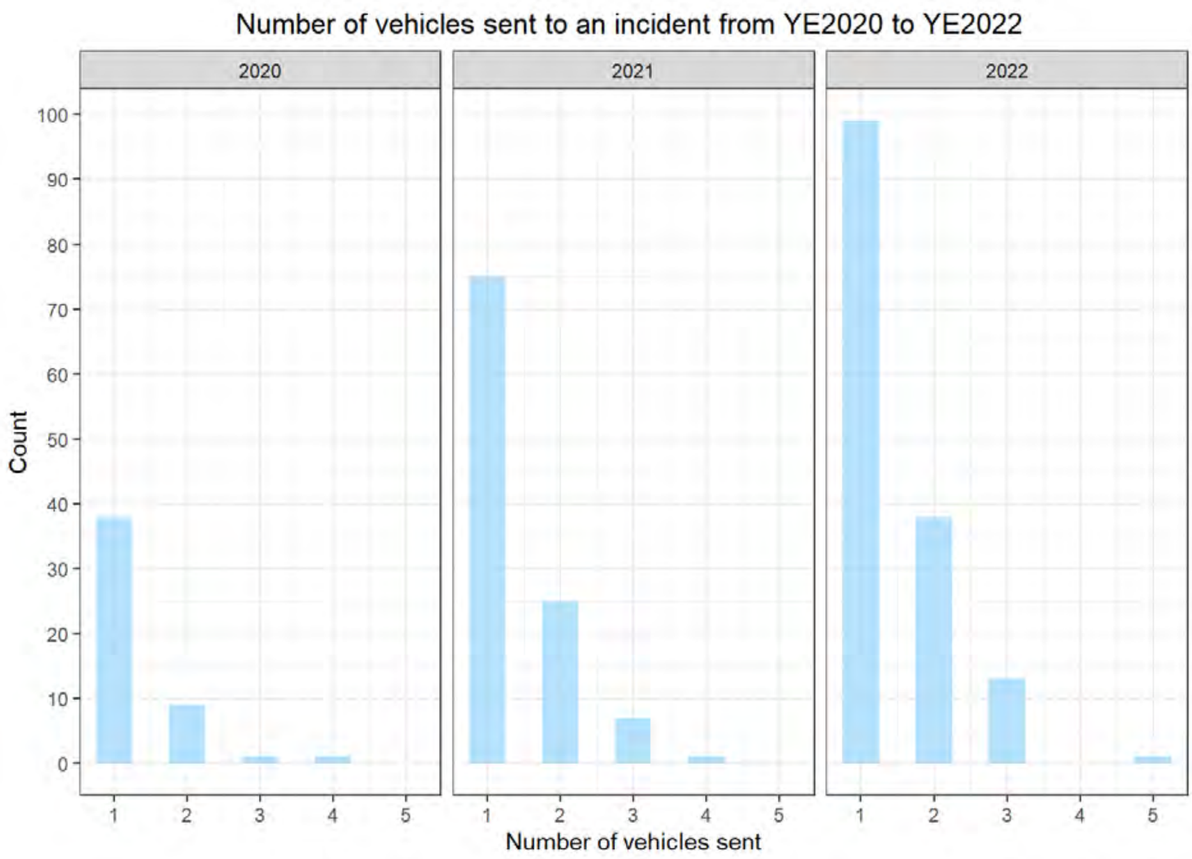

Incident duration vs Extreme weather event
Extreme weather event
True
False
0
500
1000
Incident duration (min)

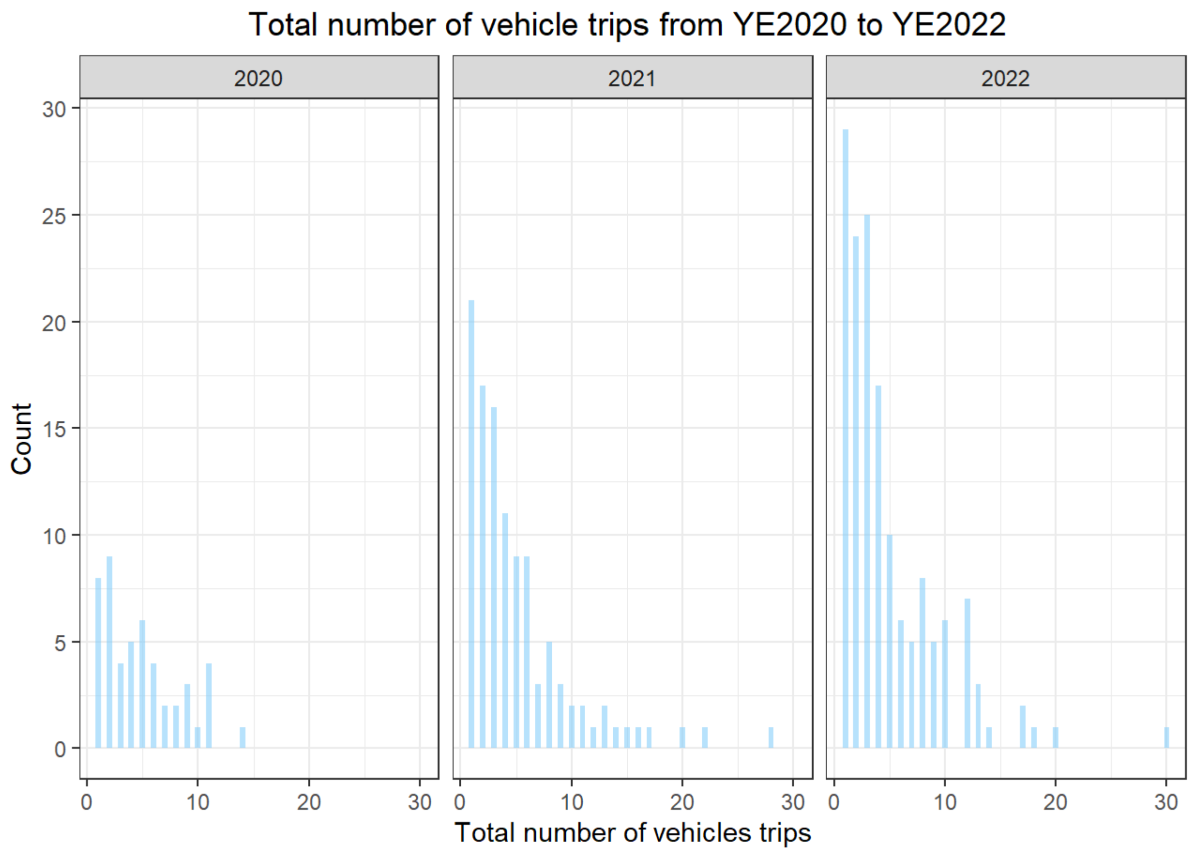

Incident duration vs Icps
Incident duration (min)
10000
7500
5000
2500
0
0
1000
2000
3000
4000
Icps

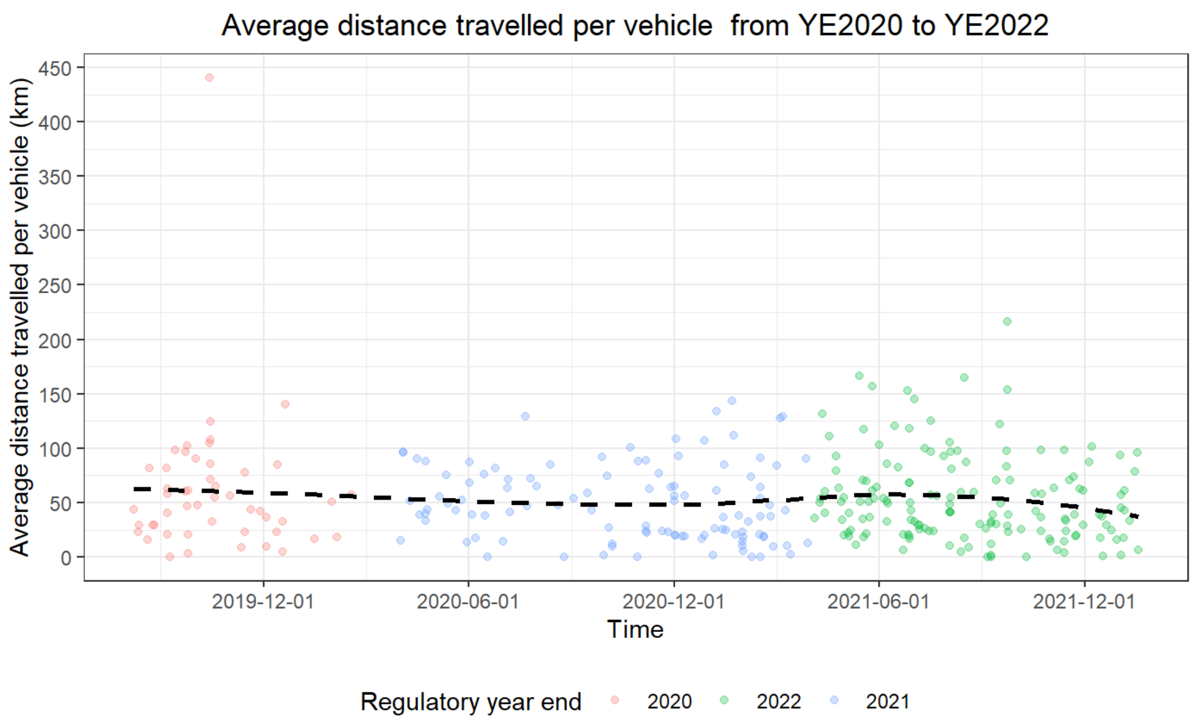

Incident duration vs Equipment age
Incident duration (min)
10000
7500
5000
2500
0
0
10000
20000
30000
Equipment age

Vehicle Response Plots

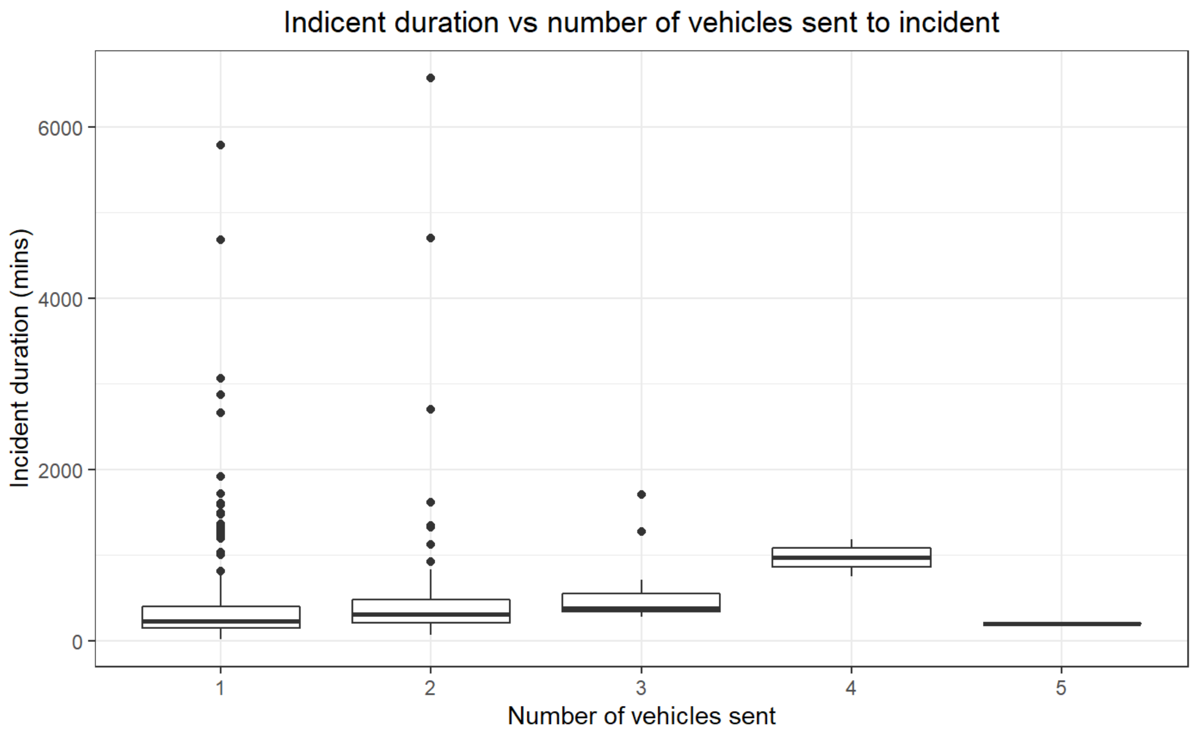
Vehicle metrics against time

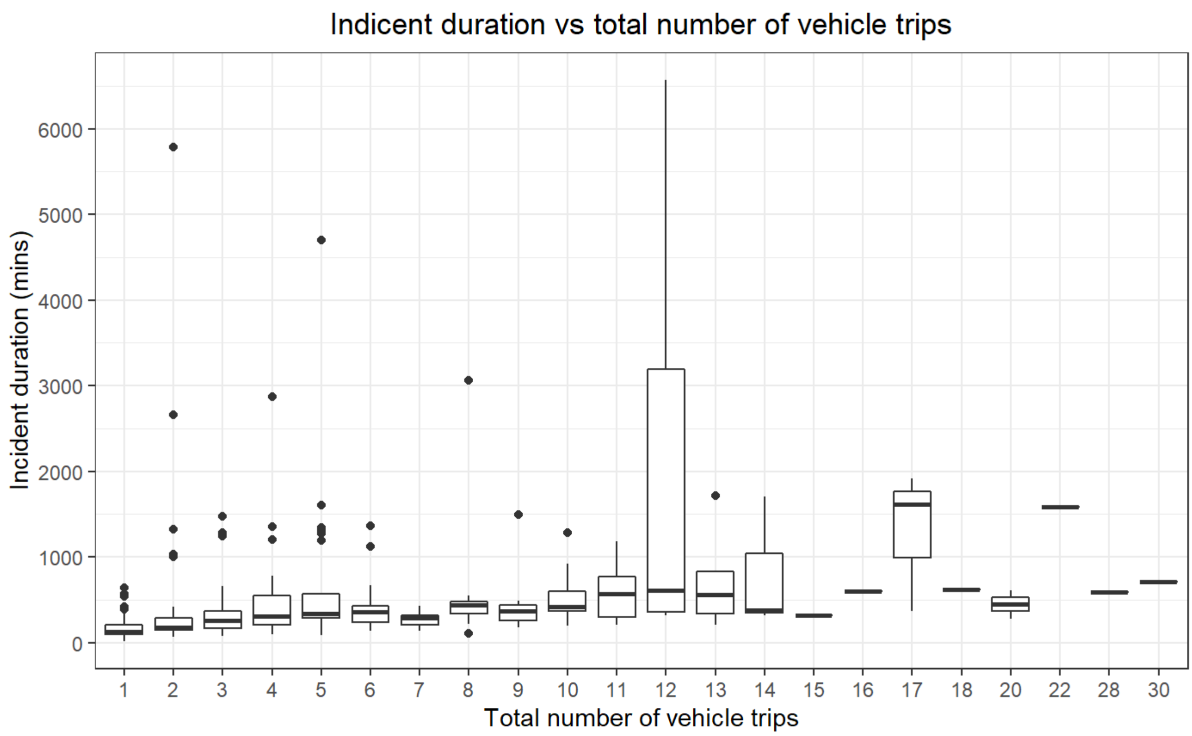


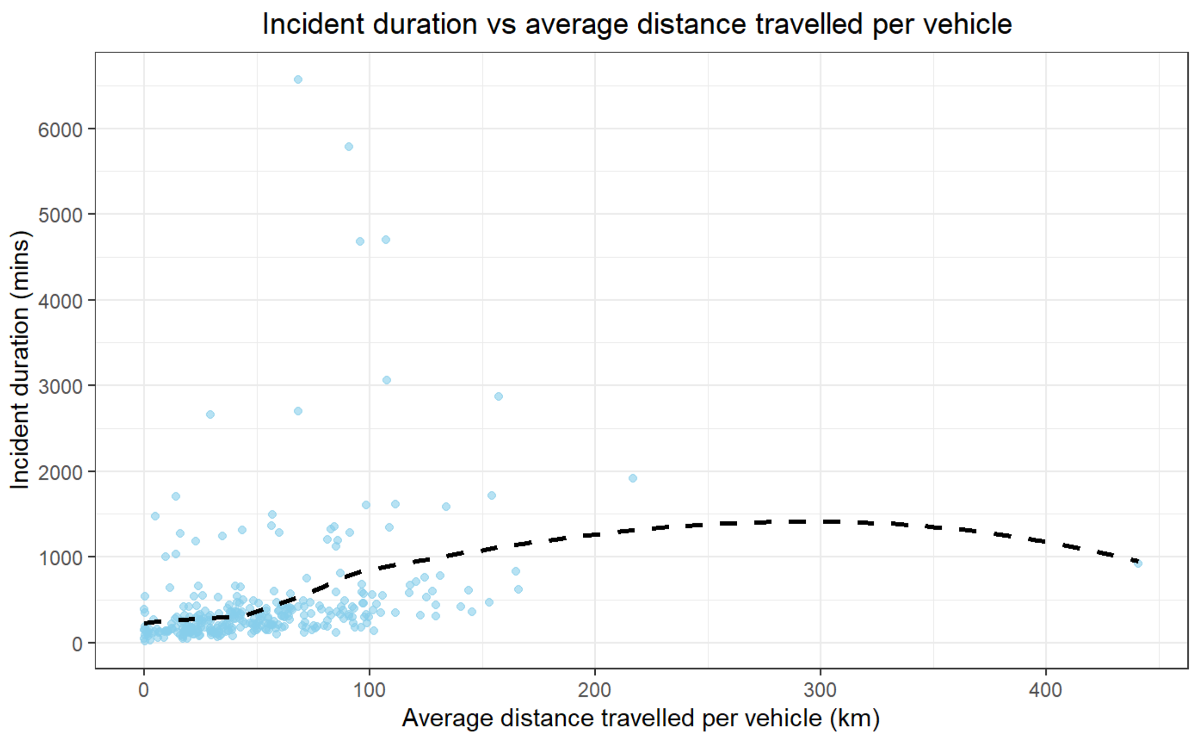

Total number of vehicle trips from YE2020 to YE2022
2020
2021
2022
Count
30
25
20
15
10
5
0
0
10
20
30
Total number of vehicles trips


Average distance travelled per vehicle from YE2020 to YE2022
Average distance travelled per vehicle (km)
450
400
350
300
250
200
150
100
50
0
2019-12-01
2020-06-01
2020-12-01
2021-06-01
2021-12-01
Time
Regulatory year end
2020
2022
2021

Vehicle metrics against duration






Incident duration vs average distance travelled per vehicle
Incident duration (mins)
0
1000
2000
3000
4000
5000
6000
0
100
200
300
400
Average distance travelled per vehicle (km)

Appendix 6

harmonic analytics

SAIDI Investigation

Summary Report

Prepared for Top Energy

5 December 2022

Table of Contents

Executive summary

The System Average Interruption Duration Index (SAIDI) metric is defined as the sum of all customer interruption durations divided by the total number of customers served. Previously, Harmonic was commissioned to explore the usefulness of Top Energy's internal datasets to help identify these factors that might explain high SAIDI numbers, as well as to gain a better understanding of SAIDI minutes overall. This regulatory year, Top has observed a continuing increase in SAIDI that is on pace to breach both the regulatory cap and target. This report seeks to reexamine the causes of SAIDI with updated data and compare them with previous findings.

A selection of data extracts were determined and provided to Harmonic. These included extracts from the ADMS, SAP, Smartrak and FieldGo systems. The extracts provided information relating to incidents dating back to YE2020, and corresponding details on the relevant equipment affected and employee responses.

Exploration of the data uncovered several key findings that helped shed light on SAIDI, with a particular emphasis on explaining the impact of incident duration and factors that are associated with it.

- Incident durations have increased on average in YE2023 and a larger proportion of the total SAIDI can be attributed to long incidents. Despite this, short duration incidents are responsible for the majority of SAIDI. Interestingly, very short events (0 to 200 mins) contribute less to the total SAIDI than in previous regulatory years. Additionally, compared with YE2020-YE2022, the SAIDI contribution due to very long incidents within the 1000-1200 minute range is much less apparent for YE2023.
- The rate at which incidents occur has increased for YE2023 compared with the previous regulatory years.
- Winter months and bad weather are particularly impactful on both the frequency and duration of incidents.
- Vehicle response and travel times do not sufficiently account for long duration incidents. The majority of incident duration times still consists of onsite activity.

- The top 5 substations contribute more than 60% of all SAIDI, these being: Kaikohe / Kaikohe 33kV, Okahu Rd, Taipa, Kawakawa and Omanaia. In general, this is due to a higher frequency of events affecting a large number of ICPs, rather than longer incident durations.
- One interesting observation is the fact that Kawakawa's contribution to total SAIDI has increased in YE2023, due to an increase in the frequency of high SAIDI events. By contrast the total value of SAIDI contributed by Kaikohe and Taipa has been less relative to other substations in YE2023. There has been an increase in outages associated with adverse weather.

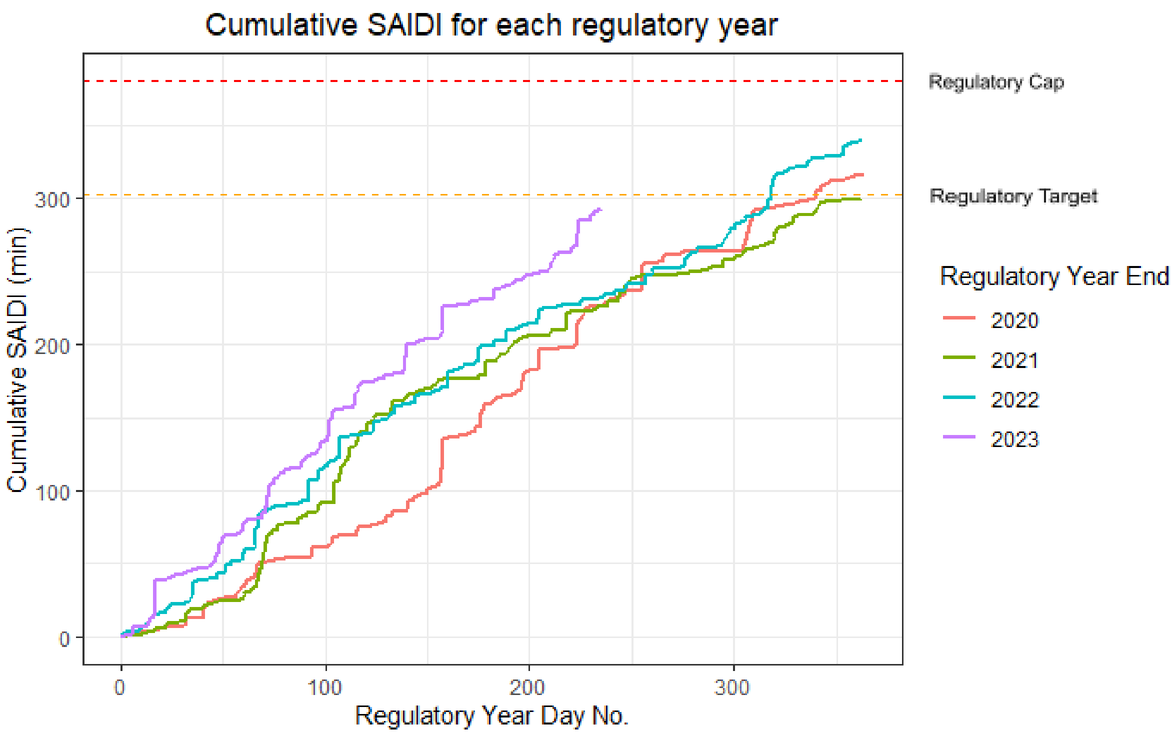
Glossary of terms

Term	Definition
Incident	An electricity outage incident. In this report, we are primarily focused on unplanned outages.
SAIDI	System Average Interruption Duration Index $S = \frac{\sum U_i N_i}{N_T}$ Where S is the SAIDI, U and N are the incident time and number of affected customers for location i respectively, and N_T is the total number of customers served. This is typically measured in minutes.
ADMS	Advanced Distribution Management System
SAP	Systems Applications and Products
Regulatory Year	SAIDI regulatory years run from April to March.
SA2	Statistical Area 2 as defined by Stats NZ in 2022. The SA2 geography aims to reflect communities that interact together socially and economically. In populated areas, SA2s generally contain similar sized populations.

Introduction

The System Average Interruption Duration Index (SAIDI) metric is commonly used by electric power utilities as a measure of network reliability. SAIDI is defined as the sum of all customer interruption durations divided by the total number of customers served. It is desirable to reduce SAIDI minutes as they represent an increase in maintenance costs to the organisation and are a regulated metric.

Top Energy has observed that cumulative SAIDI minutes over the first 3 quarters of YE2023 is already close (293 mins) to exceeding the Regulatory target for 302 mins SAIDI. More concerningly, the 2023 total SAIDI has risen considerably faster than the previous few regulatory years on record, and there is a risk that it may exceed the regulatory cap of 380 minutes.



Methodology

The R programming language was used to load, transform, explore and analyse the data.

Data Sources

Top Energy provided Harmonic with extracts from the following data sources:

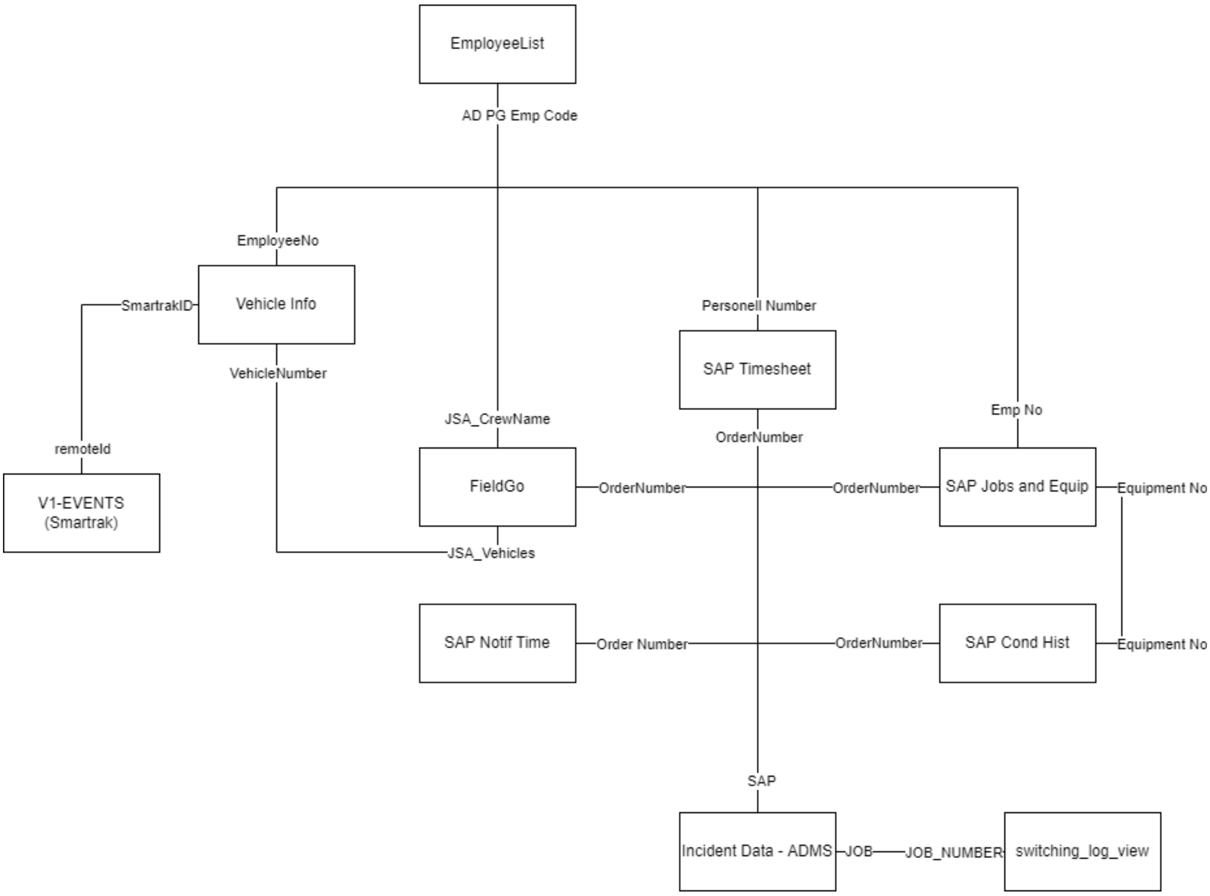
Data Source Name	Extracts Provided
Advanced Distribution Management System (ADMS)	• *Incident Data sheet:* A master list of incidents and their associated properties. • *switching_log_view.xlsx :* Timestamped worker events associated with particular jobs.
Systems Applications and Products (SAP)	• *Jobs and Equip sheet:* Equipment properties associated with a particular incident. • *Notif Time sheet:* Actual notification time to the worker of the incident. • *Condition History sheet*: Timestamped equipment condition measurements. • *Timesheet Info sheet*: Timesheet entries for each worker. • *Vehicle Hours sheet*: Logged vehicle hours.
FieldGO	• *JSA SignOn sheet*: Sign in / sign off times for workers.
Smartrak	• *V1-EVENTS-xxxx.xlsx* : Timestamped vehicle event data provided in four Excel files labelled 2019 to 2022.
Misc.	• *EmployeeList sheet*: A list of employees and employee attributes. • *Vehicle Info sheet*: A list of vehicles and vehicle attributes. • *CliFlo:* NIWA's national climate database for weather data on

	rainfall and gust speed.

All the extracts provided as a sheet were included within the "incident_data.xlsx" Excel workbook provided by Top Energy which was last updated on 11-02-2022.

The data extracts were linked together using the following unique IDs:

- SAP order number
- ADMS job ID
- Vehicle number
- AD PG Emp Code



Data schema for the various provided extracts.

Cleaning and Subsetting

The following steps were performed:

ADMS

- Due to issues with date formatting affecting incidents recorded prior to February 2022, the original incident data from the original report had to be spliced with the latest incident data (up to November 2022). Specifically
  - All incidents prior to April 2020 will be sourced from the phase 1 data (Incidents_by_Date.xlsx, uploaded Feb 17 2022), as there were no date issues there.
  - All incidents post April 2020 will be sourced from the updated incidents data Incidents_by_Date_v2.xlsx sheet (uploaded Nov 22 2022), since that version had the date issue fixed.
- Incidents were filtered to only unplanned incidents, leaving 1543 incidents spanning 2019 to 2022 (regulatory years ending 2020 to 2023).
- A duplicated incident ID (INCD-6304-F) was removed.
- Combined the 6.6 and 6.35kV voltages into one (replaced all instances of 6.6 with 6.35). Top Energy had indicated that these two voltages although recorded differently actually represented the same real life value.
- Additionally, several locations had different names and had to coalesced:
  - Kaitaia, Kaitaia Transmission and Kaitaia 33kv were renamed to **Kaitaia**
  - Kaikohe 33kv was renamed to **Kaikohe Transmission**
  - Okahu was renamed to **Okahu Rd**

SAP

- Duplicated order numbers in the notification times data were removed, keeping the earliest recorded notification time for each order number.

Smartrak

- The cleaned data was joined onto FieldGo by vehicle identifier (the "work centre" field), and this was subsequently joined with the cleaned ADMS dataset.

- Orders that could not be matched to a vehicle were filtered out.
- It was also observed that vehicle trips associated with an order could span multiple days, not just the timeframe in which the incident occurred. To address this, only vehicle events with “rt_date” timestamps within the incident start and end datetime, were kept.

General

- Variables with information stored as characters were converted to lower-case, fixing inconsistencies in the data such as kilovolts being written as “kV” in one instance, and “KV” in another.

Feature Generation

The following features were generated on a per incident basis:

Data source	Feature	Description	Assumptions
ADMS / SAP	Incident start time	The earliest known incident start date. Calculated from the earliest date between ● The SAIDI clock start time ● The earliest SAP notification	● The SAIDI clock start / SAP notifications are a good proxy for the actual start of the incident.
SAP	Number of employees sent	The unique number of employee IDs recorded in the SAP timesheet data, for a given order number	● The timesheet log is the source of truth on whether a worker worked on a particular incident, not the FieldGo data which often contradicts the timesheet data.
SAP	Max, min, mean and median employee tenure of employees sent	Calculated by linking the employee IDs recorded in the SAP timesheet data to the EmployeeList metadata.	● The timesheet log is the source of truth on whether a worker worked on a particular incident, not the FieldGo data which often contradicts the timesheet data.
SAP	Extreme weather	A flag based on whether someone recorded “Extreme Weather - PSA” as their Paycode Description within the timesheet data.	● Extreme weather events are accurately and consistently recorded in workers’ Paycode Description.
SAP	Equipment condition	The measured equipment condition at the time of the incident. Generated by taking the latest asset condition measurement within the SAP condition history data that occurred before the incident end date.	● The latest asset condition measurements are reflective of the asset condition at the time of incident. I.e. either assets degrade slowly over time, or asset measurements are frequent and accurate.

SAP	Equipment age	The age of the equipment calculated from the start of the incident, based on its startup date.	NA
SAP	Device	For the purpose of specifically investigating cross-arms, poles, transformers, and conductors. All device affected entries containing: "tx" were renamed "transformers" all entries containing 'conductor' were renamed to conductor.	NA
SAP	Truck sent	Whether or not a truck was recorded as being sent in the vehicle hours data.	• String matching the word "truck" in the long text field of SAP vehicle hours is equivalent to determining whether a truck was sent with that order number.
ADMS	Employee response time	Calculated from the time difference between the start of the incident, and the earliest "confirmed", "executed" or "completed" ADMS event with action verb containing "close", "open", "remove", "replace", or "check".	• Assumptions listed in "Incident start time". • Action verbs containing "close", "open", "remove", "replace", or "check" can only be performed when the worker is on site. • The time difference between the worker arriving on site, and recording a key action verb is minimal. • Action verb timestamps are accurate.
ADMS	Employee time on site	Calculated from the time difference between the latest and earliest "confirmed", "executed" or "completed" ADMS event with action verb containing "close", "open", "remove", "replace", or "check".	• Action verbs containing "close", "open", "remove", "replace", or "check" can only be performed when the worker is on site. • The time difference between the worker entering or leaving the

		If the latest key action verb is recorded after the recorded end of the incident (i.e. the worker continued after incident resolution), then the latest action time is set to the end of the incident. This is because we are interested in the time spent resolving the incident - so any time spent working after resolution is irrelevant.	site, and recording a key action verb is minimal. ● Action verb timestamps are accurate.
Smartrak	Vehicle response time	Calculating by taking the time between when the earliest vehicle starts driving and the incident start time.	● Only vehicle trips that "key on" after the incident start time, are considered relevant work. This excludes trips starting just prior to the incident start date.
Smartrak	Average vehicle driving distance	Calculated by filtering out all but the text entries marked "key off" , then taking the average of trip distances travelled by each vehicle, per incident.	● Only vehicle trips with an rt_date that takes place between the incident start and end time are considered travel during the incident.
Smartrak	Number of vehicles sent	Calculated by counting the number of unique vehicle IDs associated with each "incident"	NA
Smartrak	Number of trips	Calculated by counting the total number of "key off" events that occur within the incident period.	● Each "key off" event is associated with a vehicle trip. This may be occasionally untrue if a driver restarts their vehicle for any reason.
Smartrak	Average vehicle time travelling	Calculated by using the "extra info" field to determine the travel time per trip vehicle makes during the incident, then taking the average of all trip times for each individual	● Vehicle trips which conclude after the incident duration are not relevant to the calculation.

		vehicle.	
Smartrak	Average percentage of indent time spent driving	Calculated by dividing the average number of hours travelled by a vehicle, divided by the incident duration time.	NA

Approach to Analysis

The goal of this project was to explain the high SAIDI numbers observed in YE2022 and YE2023 compared to previous years. Based on the first 3 quarters of YE2023, Top Energy is set to breach their regulatory cap. This report aims to address the various causes for the high SAIDI observed.This was achieved by breaking SAIDI down into two aspects:

- The number (frequency) of incidents
- The duration of incidents

Exploration was performed to determine whether any factors (if at all) correlated with either of these aspects. In general, due to a lack of external time series data independent of incidents occurring, there was a focus on explaining incident duration, rather than frequency. This issue is elaborated upon within the absent datasets section.

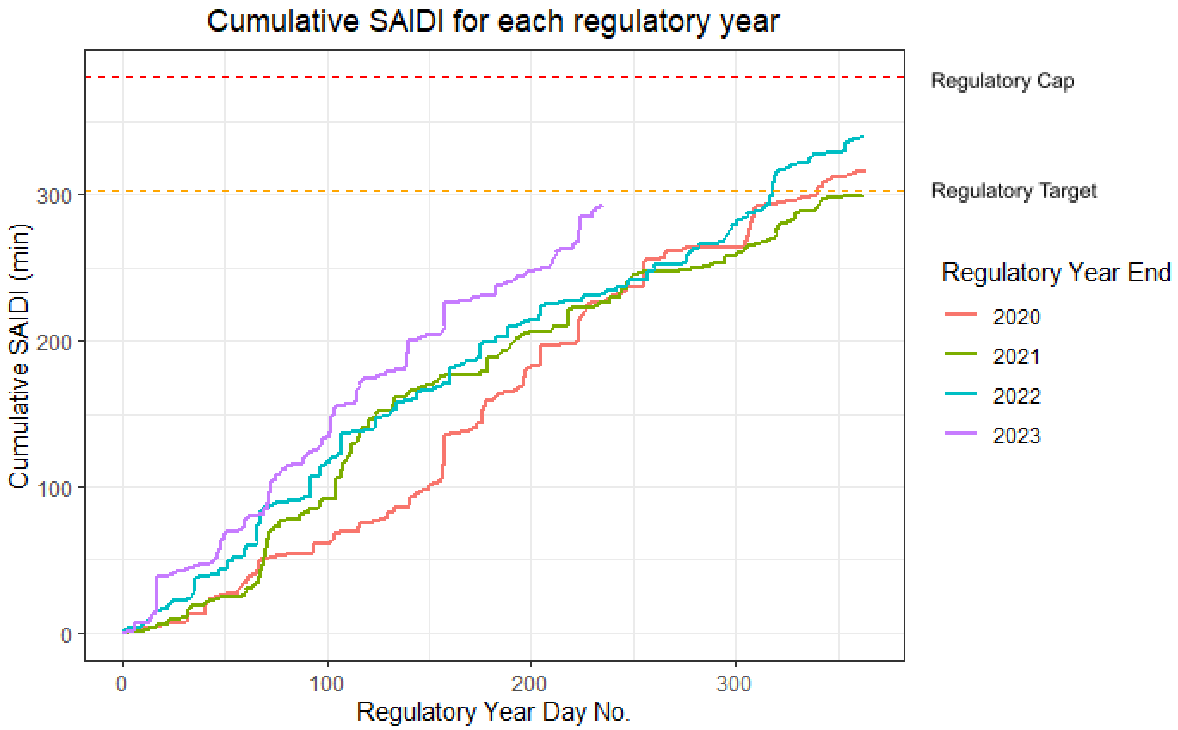
Results

SAIDI Breakdowns

The following figures show SAIDI breakdowns by various attributes such as time, geography and other factors.

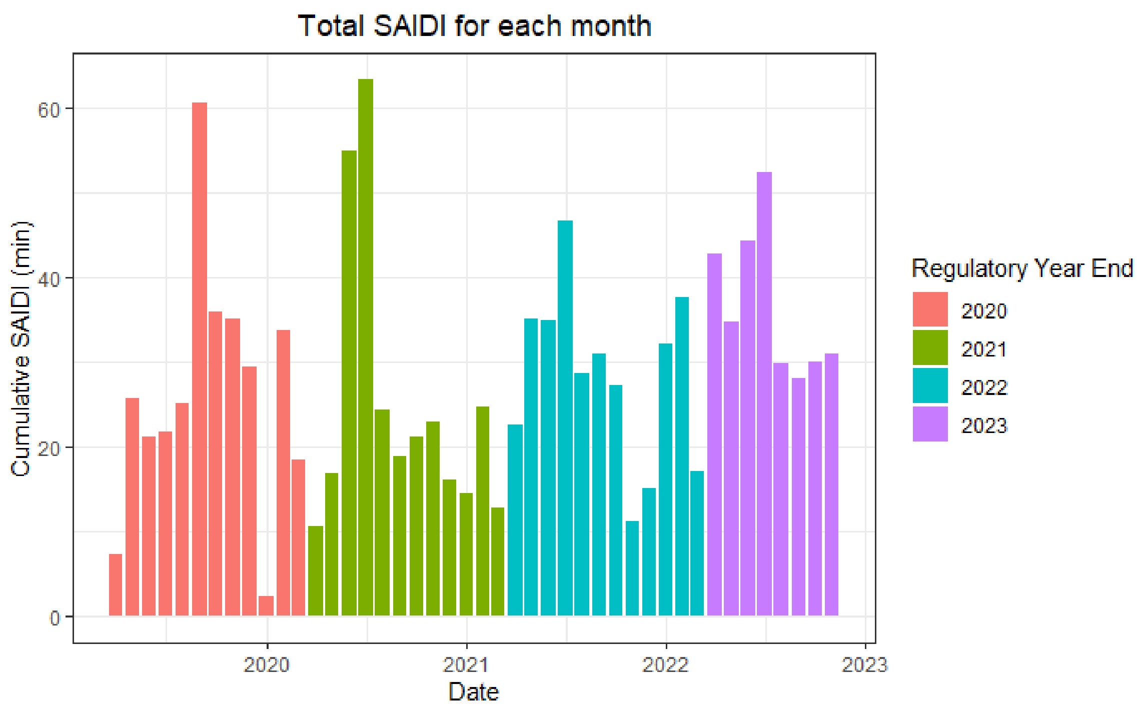
By regulatory year

Regulatory Year Ending	Total SAIDI
2020	315.9
2021	300.6
2022	338.9
2023 (Incomplete)	292.6



As of November 2022, SAIDI in YE2023 has largely outpaced previous years. These spikes in SAIDI minutes can mostly be attributed to days where there are a significant number of low SAIDI incidents (at least 10 in a day) which add up to larger sums of SAIDI, though there are some days where individual incidents produce relatively high SAIDI. These high-scoring SAIDI incidents are usually associated with long event duration and ICP mins. Should the same pattern continue through to the end of YE2023, we would expect the regulatory cap of 380 minutes to be breached.

By month



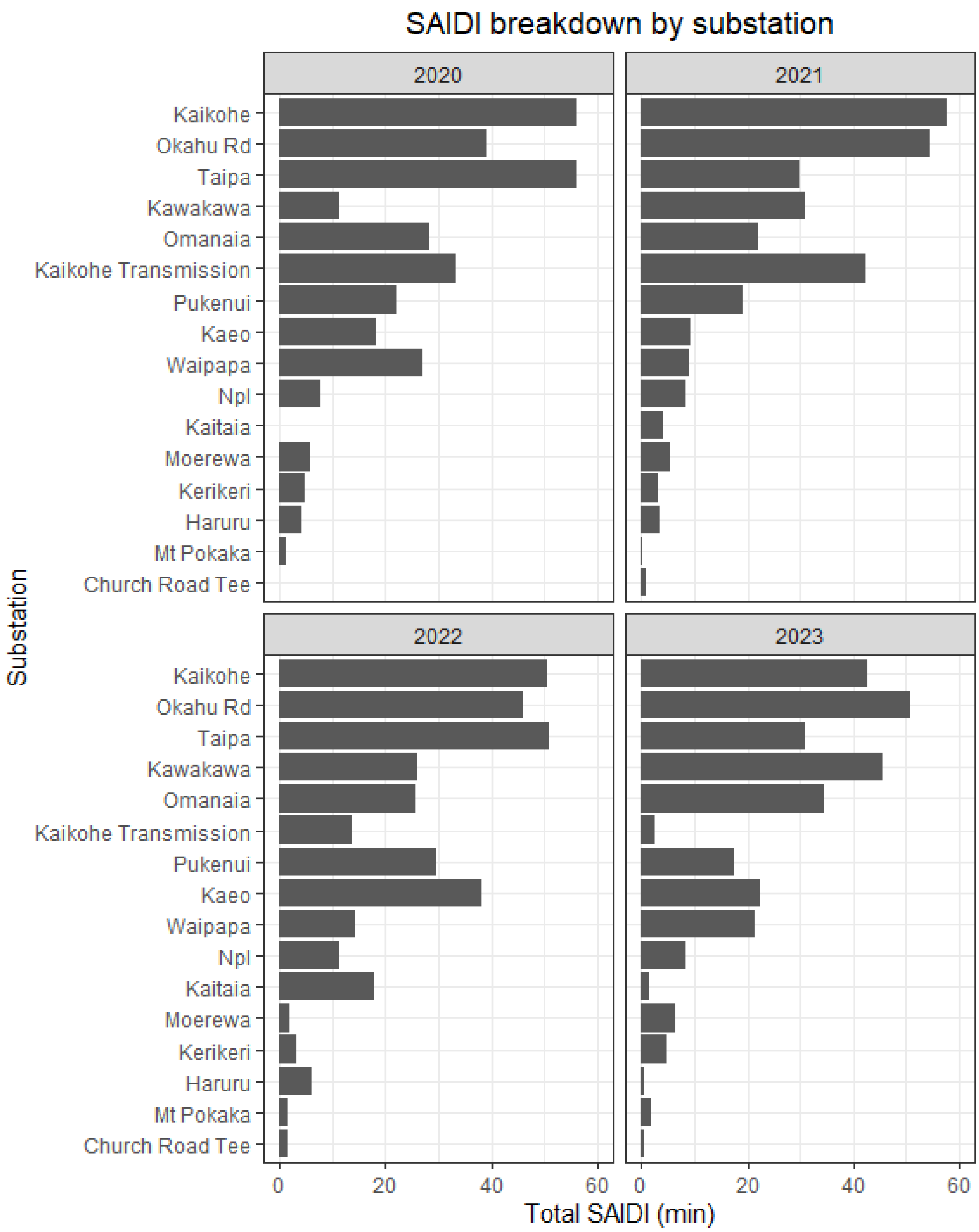
Overall, YE2023 shows consistently higher SAIDI throughout each month. Annual seasonality continues to show, with higher SAIDI in Winter and Spring months (June to October). However, SAIDI has also increased significantly in Summer / Autumn months (December to May) compared to previous years.

A significant portion of SAIDI during July and August YE2023 can be attributed to adverse weather conditions, which make up 47.7 minutes.

By substation

The following analysis concerns breakdowns of SAIDI by the substation affected, as provided within the ADMS data.

Note that Kaikohe Transmission is considered a separate substation to Kaikohe. Kaitaia and Kaitaia Transmission are considered one substation (Kaitaia).



Substations	Sum of SAIDI (over all years)	Num of Incidents	Mean Incident Duration (min)	Mean ICPs affected
Kaikohe	207.0	270	389.4	272.2
Okahu Rd	190.7	252	500.7	305.8
Taipa	167.8	133	512.8	538.1
Kawakawa	113.8	133	407.8	380.4
Omanaia	110.6	131	671.1	267.5

Top five Substations by total SAIDI across 2020, 21, 22 and 23.

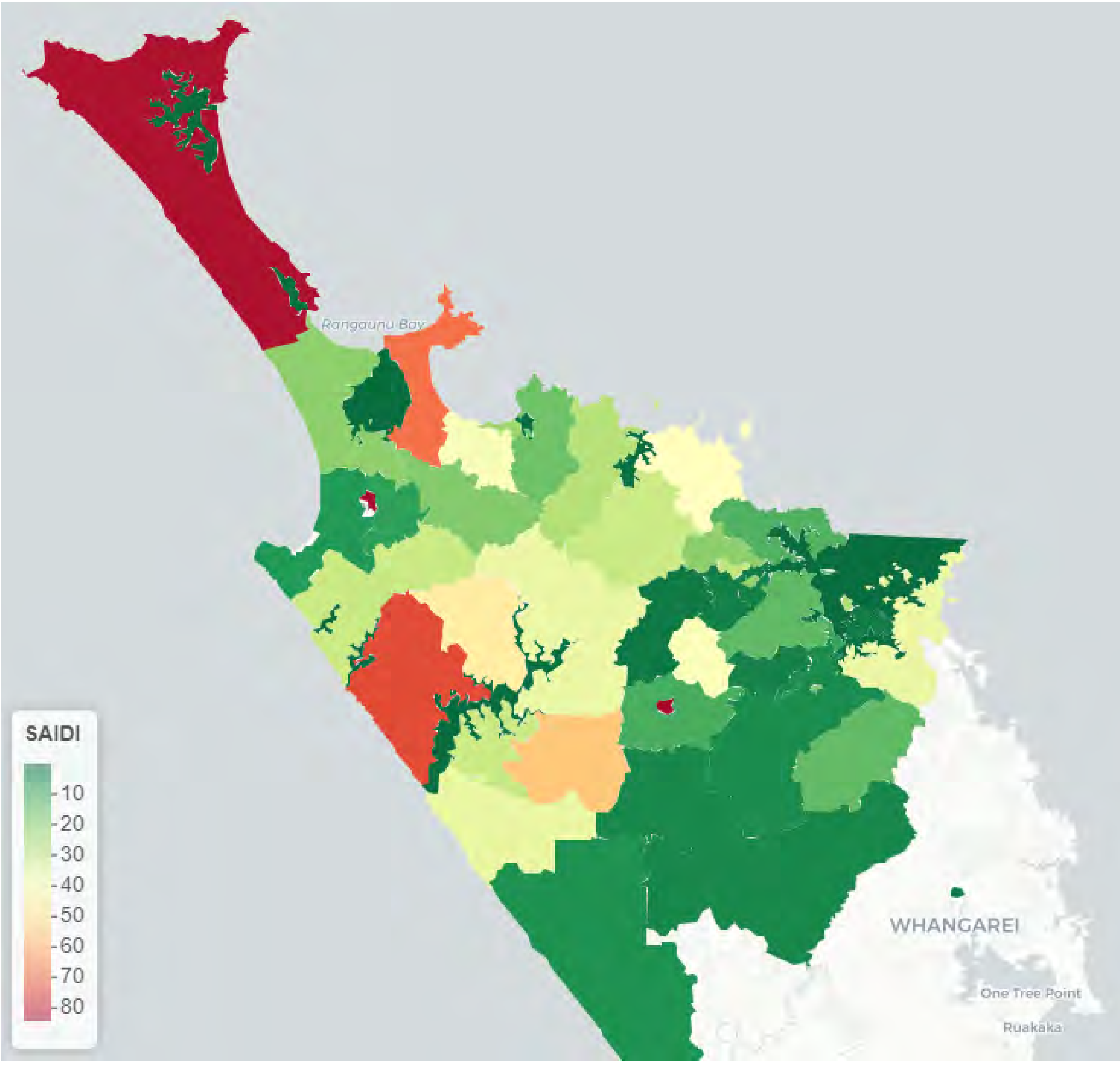
The top five substations (Kaikohe, Okahu Rd, Taipa, Kawakawa and Omanaia) are responsible for 62.9% of all SAIDI minutes since YE2020. High SAIDI numbers still seem to correlate with the number of incidents, as seen in the table above. This reinforces previous conclusions, in that the frequency of incidents continues to differentiate high SAIDI substations from the other substations.

It is interesting to note that Kaikohe and Taipa, which typically generate the highest SAIDI minutes per year in previous regulatory years, have generated less SAIDI compared to other substations in YE2023 as of November 2022. Prior to YE2023, major causes of outages in the past were attributed to defective equipment, vegetation and third parties. These have dropped in YE2023, although there has been an increase in outages attributed to adverse weather.

In YE2023, Kawakawa generated a significantly higher SAIDI score compared to previous years which could be of concern. This is due to an increased frequency of higher SAIDI scoring incidents occurring in YE2023, whereas most of the incidents in previous years generated lower SAIDI minutes. For example, there were 8 incidents of vegetation causing outages which resulted in 14.5 SAIDI minutes generated. This averages out to about 1.8 minutes being generated per incident. 13 incidents relating to defective equipment averaged out to about 0.9 minutes per incident, and 10 adverse weather incidents averaged out to about 0.7 minutes per incident.

By SA2

The following analysis concerns breakdowns of SAIDI by their geographical location, grouped by Statistical Area 2 (SA2) definitions by Stats NZ. Incidents were placed in a SA2 by matching the provided incident address and area to coordinates. Note that this process relied on reverse geocoding, which although properly limited to the correct area of New Zealand, may be occasionally inaccurate in terms of coordinates.



Total SAIDI minutes by SA2 (summed over all 4 years)

SA2	Sum of SAIDI (over all years)	Num of Incidents	Mean Incident Duration (min)	Mean ICPs affected
Kaikohe	84.1	66	192.6	717.9
Kaitaia East	84.0	73	389.0	697.6
North Cape	83.3	86	451.54	283.9
Hokianga North	73.3	103	386.2	175.4
Karikari Peninsula	67.7	55	305.4	510.0

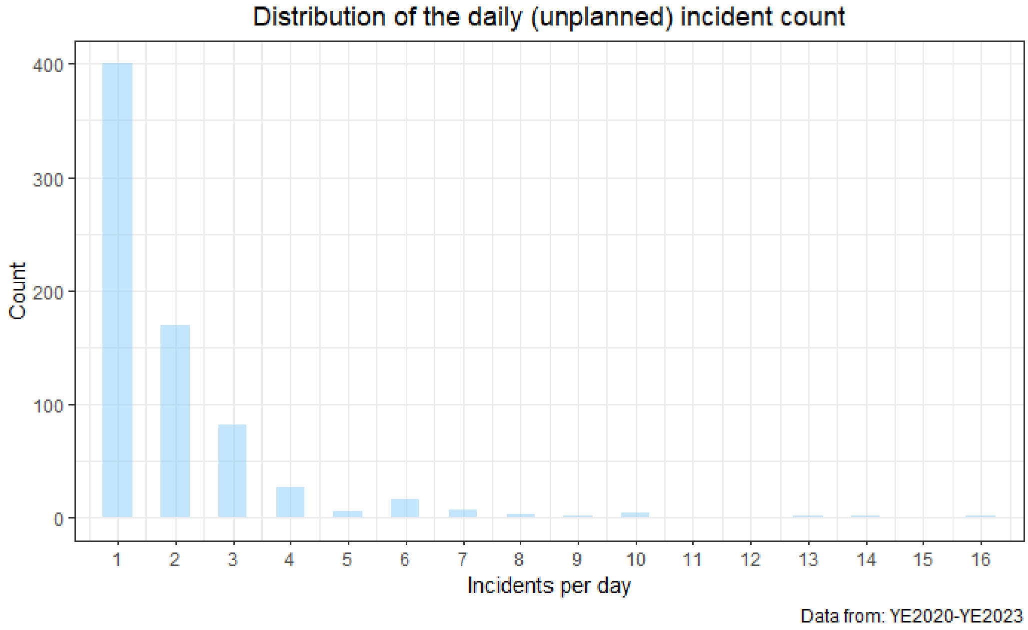
Top five SA2s by total SAIDI across 2020, 21, 22 and 23.

Kaikohe still has relatively shorter incident durations on average, but these incidents affect more ICPs on average resulting in the highest sum of SAIDI. Interestingly, Kaitaia East on the other hand has a similar sum of SAIDI but has more incidents with higher incident duration on average.

This reinforces that incident durations are not the differentiating factor between the various geographic areas, and that it is a combination of factors such as the number of ICPs affected and the frequency of events which influences how much SAIDI is generated.

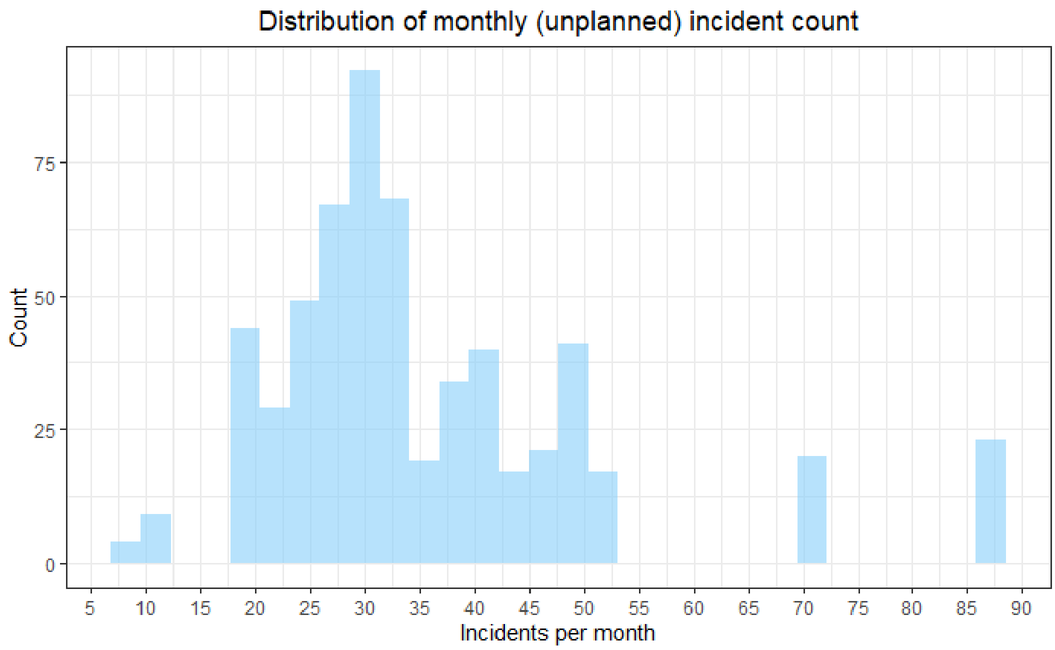
Frequency Analysis

It was observed that incidents do not always happen in isolation, and it was of interest to understand the determining factors behind why some days observe more than others.



This is the breakdown of how many incidents are observed on the days with outages.

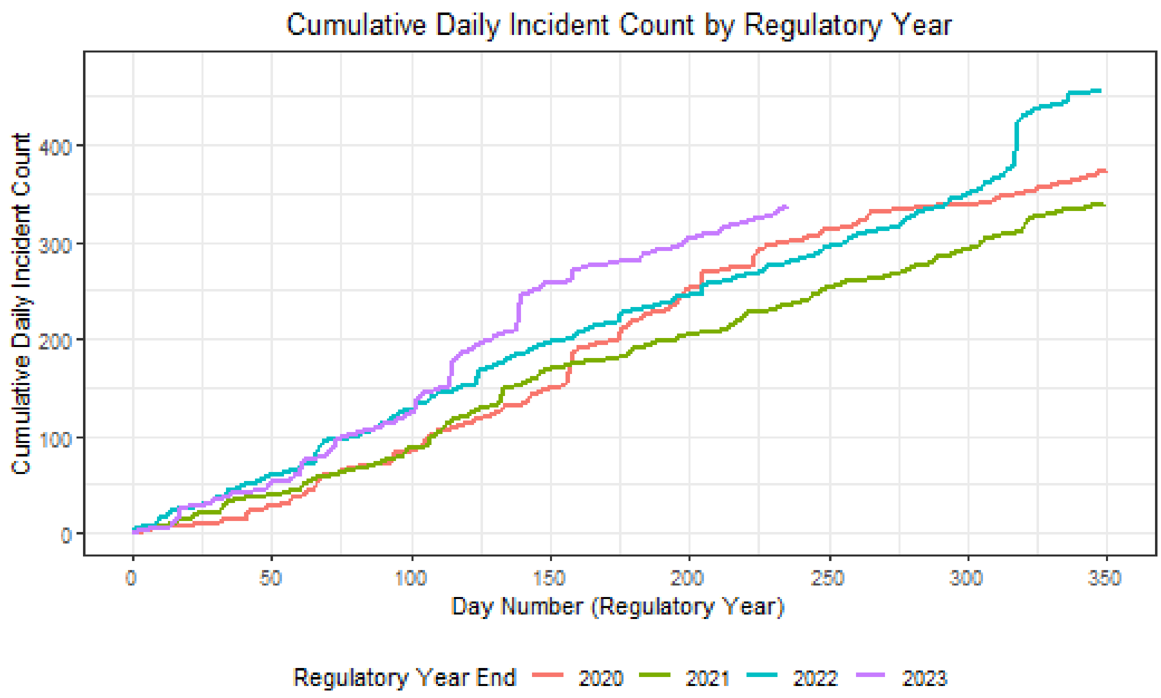
Similarly to the previous report, it is still rare for multiple incidents to occur on days where outages are observed, although the mean number of incidents occurring has risen to 2.12 per day from 1.96 per day. The median number of incidents occurring on days where outages are observed is still 1 per day. When an incident occurs, 21% of the time it is not in isolation, and several other incidents will also occur.



This is the breakdown of how many incidents are observed in the months with outages.

At the monthly level, the mean number of incidents per month has risen from 34.2 to 37.7 incidents per month with a median of 33 incidents per month, previously 32 incidents per month. The majority of months experience between 27 and 46 incidents per month, when previously it was between 26 and 42 incidents per month. Very few months are relatively incident free (<20 incidents observed in a month).

By regulatory year

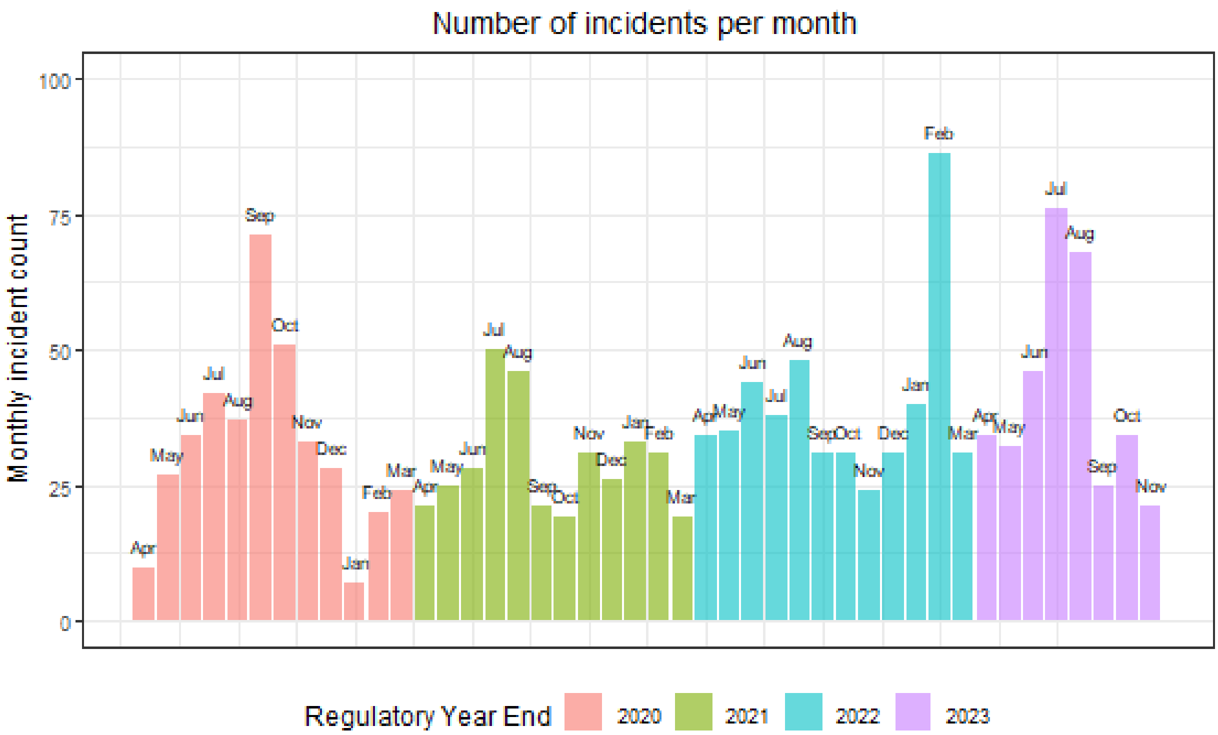


The slope of the lines indicates the rate at which incidents are occuring.

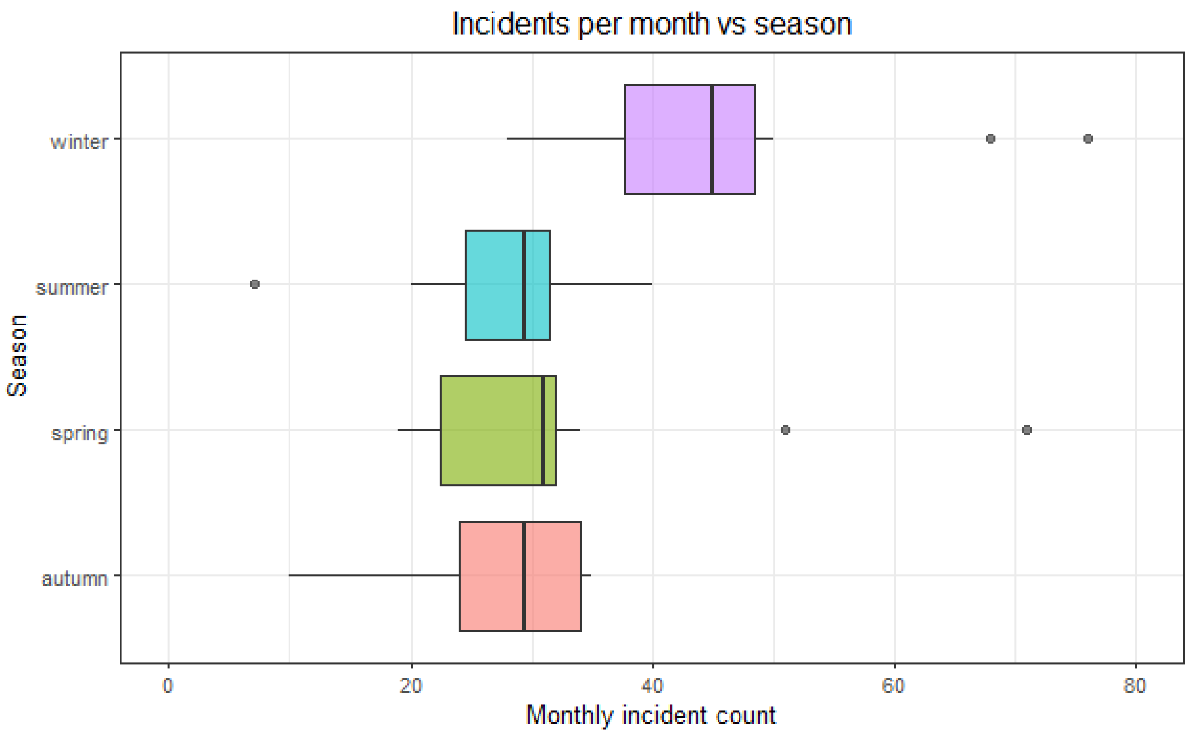
The above figure demonstrates that the total number of incidents has shown to increase in the past two years - with 2022 reaching the highest incident count so far (473 events). The incident counts for each regulatory year generally increase at a steady rate, with the occasional spike. These can occur due to extreme weather events. For example on the 12th-13th of February 2022 (toward the end of YE2022) there were a combined 45 events, most of which were attributed to adverse weather.

The YE2023 incident count was observed to have increased at a much higher rate than the previous years, whereas for each of the previous regulatory years (YE2020 - YE2022), the overall rate of incidents occurring has been quite similar. Although not certain, it is entirely possible that YE2023 may observe more incidents than YE2022 considering that YE2023 has already recorded more incidents in the same time period than any of the previous regulatory years.

By month



Number of incidents per month
Monthly incident count
100
75
50
25
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Regulatory Year End
2020
2021
2022
2023



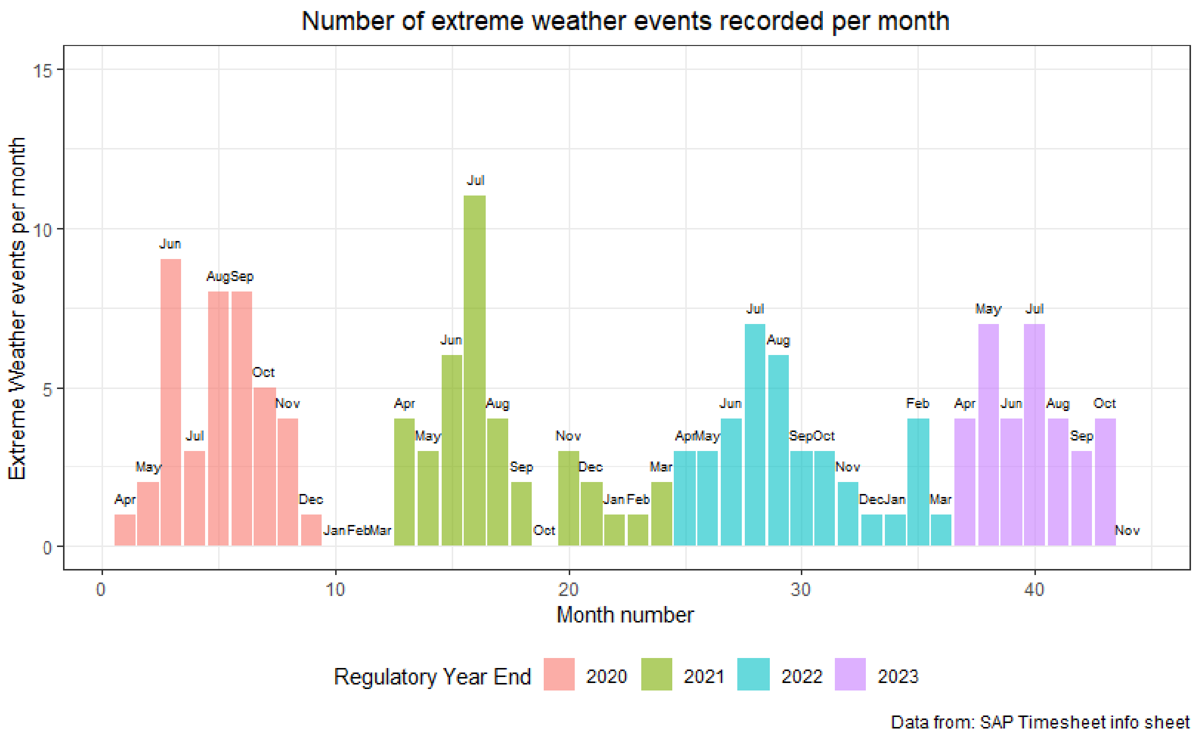
Incidents per month vs season
Season
winter
summer
spring
autumn
0
20
40
60
80
Monthly incident count

In previous years, a subtle seasonal pattern was cautiously noted, with spikes in incident frequency seen during winter / early spring months (June - September). A notable spike in incidents was also observed in February YE2022.

As of November 2022, in YE2023 there have been significantly more incidents observed in the winter months (June - August) compared to previous years, which falls under our expectation of more incidents occurring in the winter months. However, caution must still be taken when attempting to infer a seasonal pattern from 3.67 regulatory years worth of data.

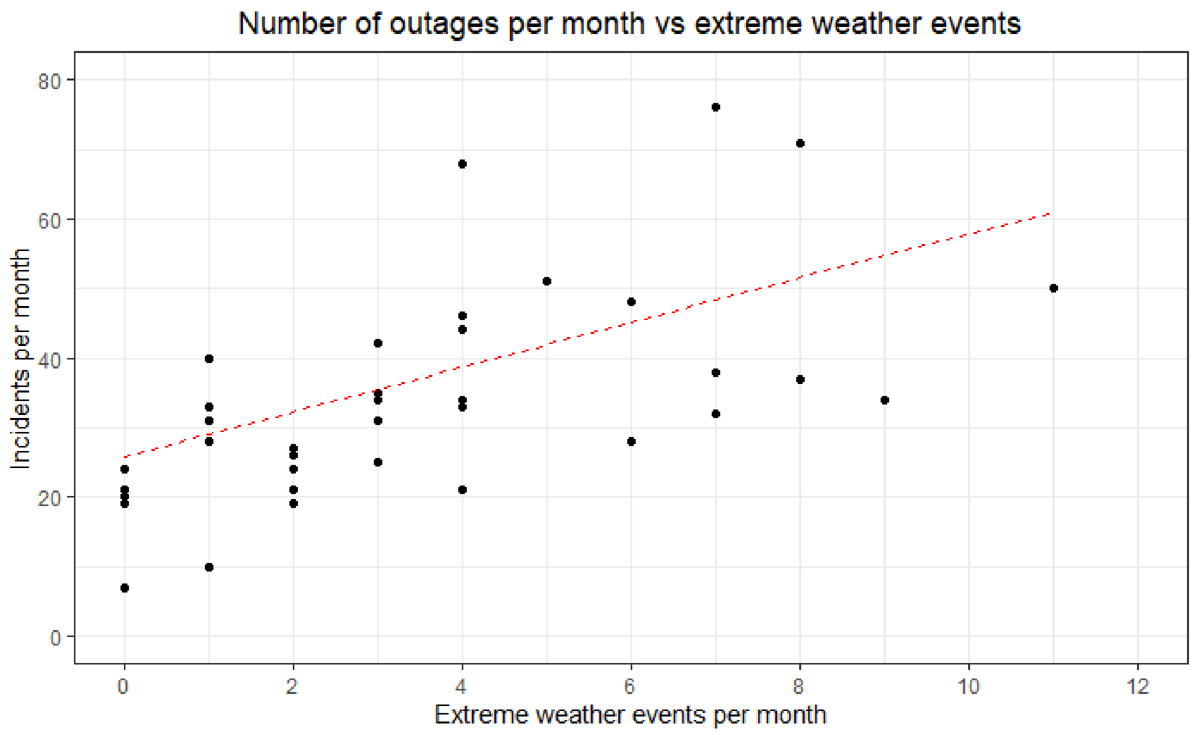
When examining incidents per month by season, there remains a significant increase in incidents per month during winter.

Weather effects



As of November 2022, YE2020 has the most recorded extreme weather events. However, YE2023 follows closely behind and we could expect YE2023 to end with slightly more weather events than in previous years. Interestingly, while we could observe a weak seasonal pattern in previous years, the distribution of extreme weather events for YE2023 follows this pattern weakly but more extreme weather events were recorded per month on average, and a spike in extreme weather events was recorded in May which previously has not been observed.

Spikes in monthly incident count still mostly coincide with spikes in the number of monthly extreme weather events. A statistically significant relationship between the monthly incident count and extreme weather events per month is still observed, as shown in the following figure:

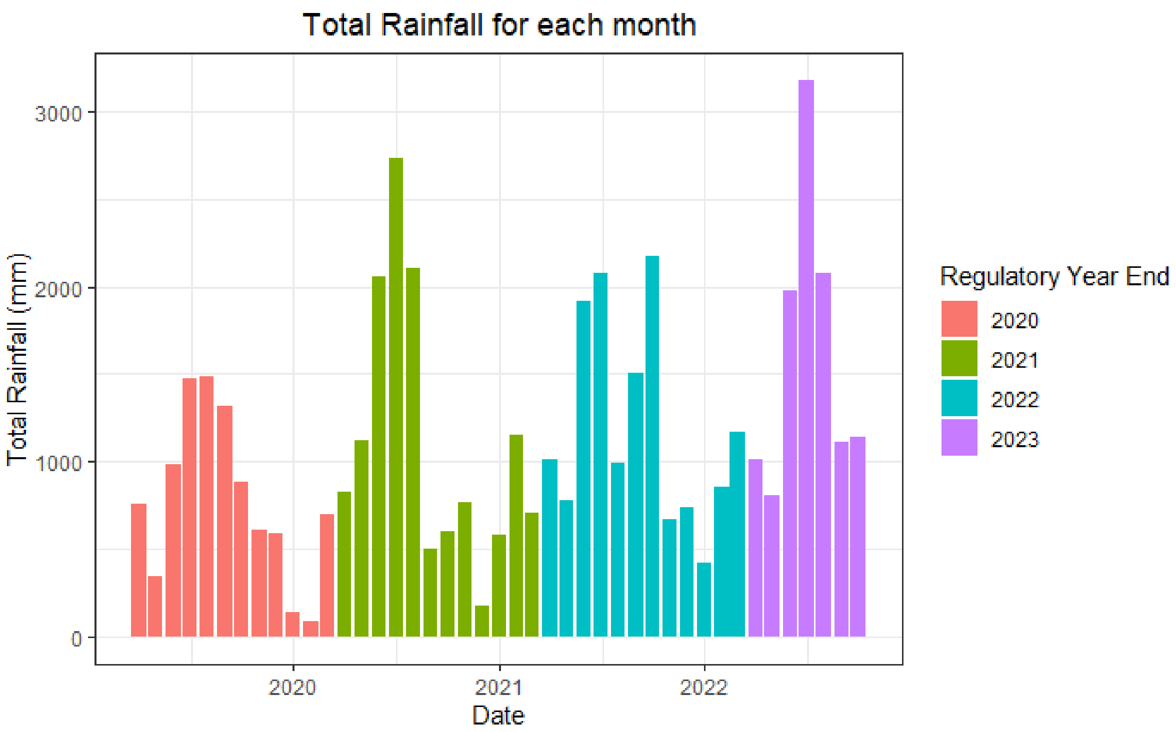


The red line represents the line of best fit.

While weather still has a statistically significant effect on the number of incidents occurring, the correlation between the two is still limited and other factors should also be taken into account.

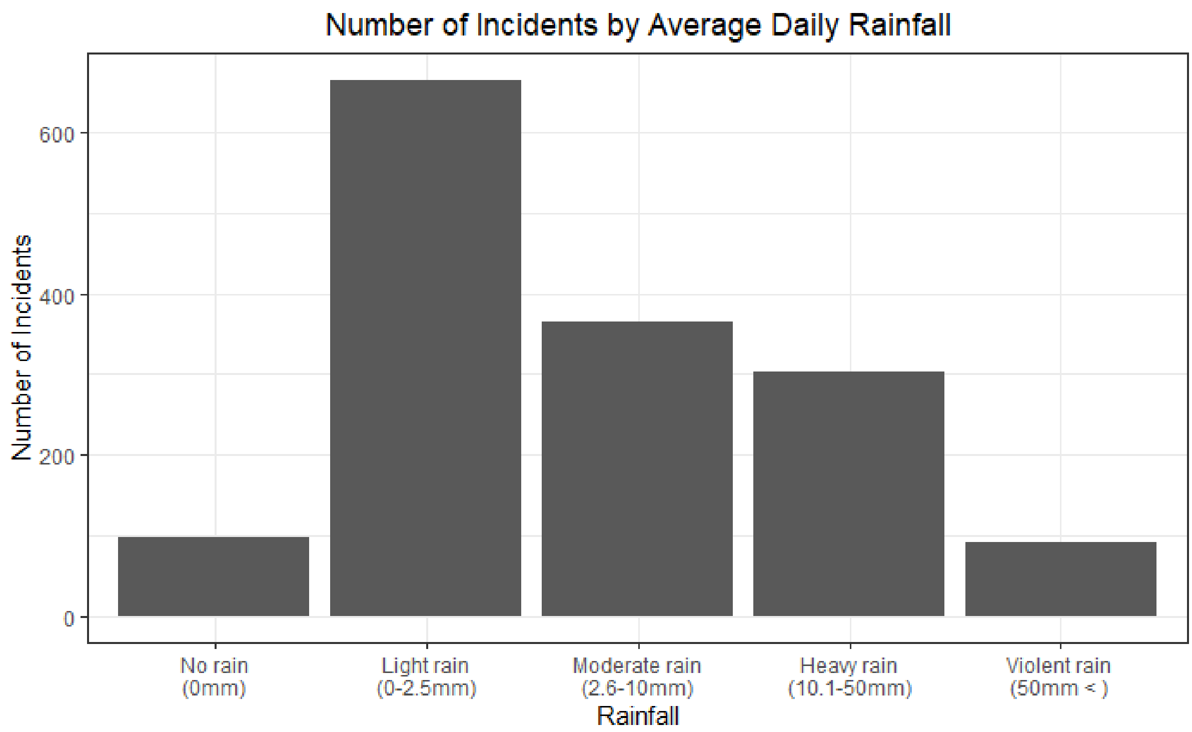
It is assumed that all extreme weather events are accurately recorded, despite there being no specific information about environmental variables.

Rainfall

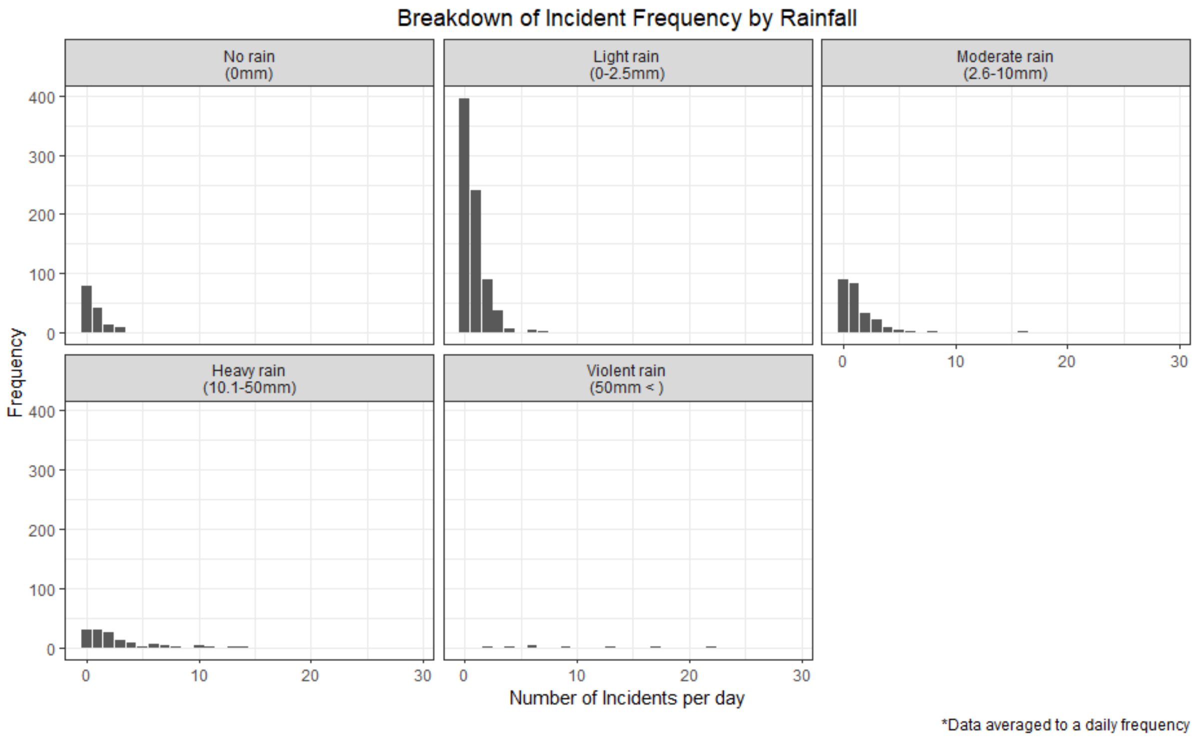


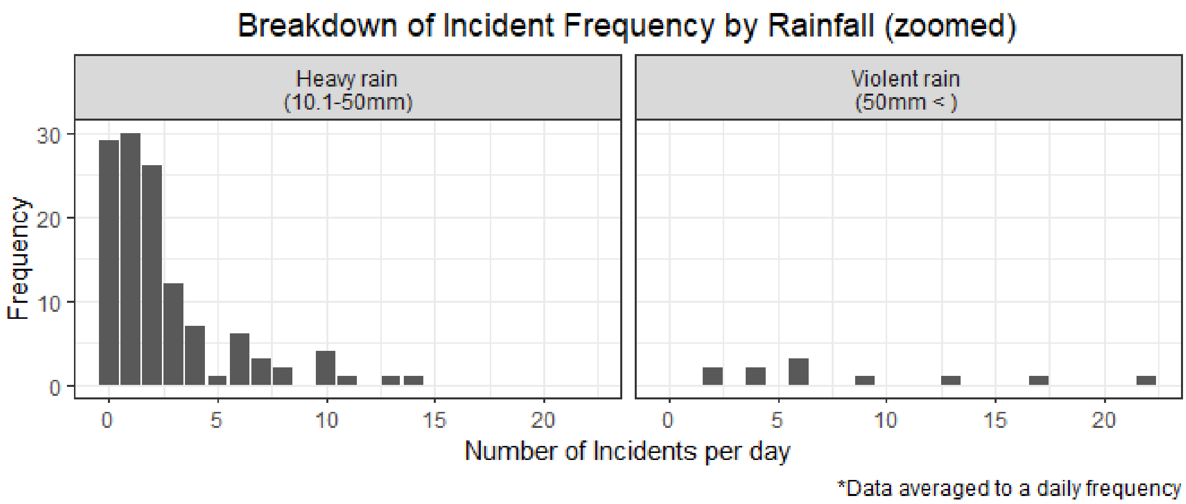
As the above figure shows, YE2023 observed a record high level of monthly rainfall. Despite this high value, the total rainfall is still similar to YE2020 and YE2023. Regulatory years 2020, 2021 and 2023 (incomplete) display the expected pattern of increased rainfall during the winter months, whereas YE2022 exhibits two spikes in total rainfall.

We note that the spike in rainfall in YE2023 corresponds with an observed increase in reported extreme weather events in July, and with an increase in observed incidents in July and August.



The above plot shows that a significant amount of incidents occur under rainy conditions, although it is important to note that this analysis does not take into consideration isolated weather events in different regions. 43.8% of incidents occur when rainfall is light (between 0-2.5mm).

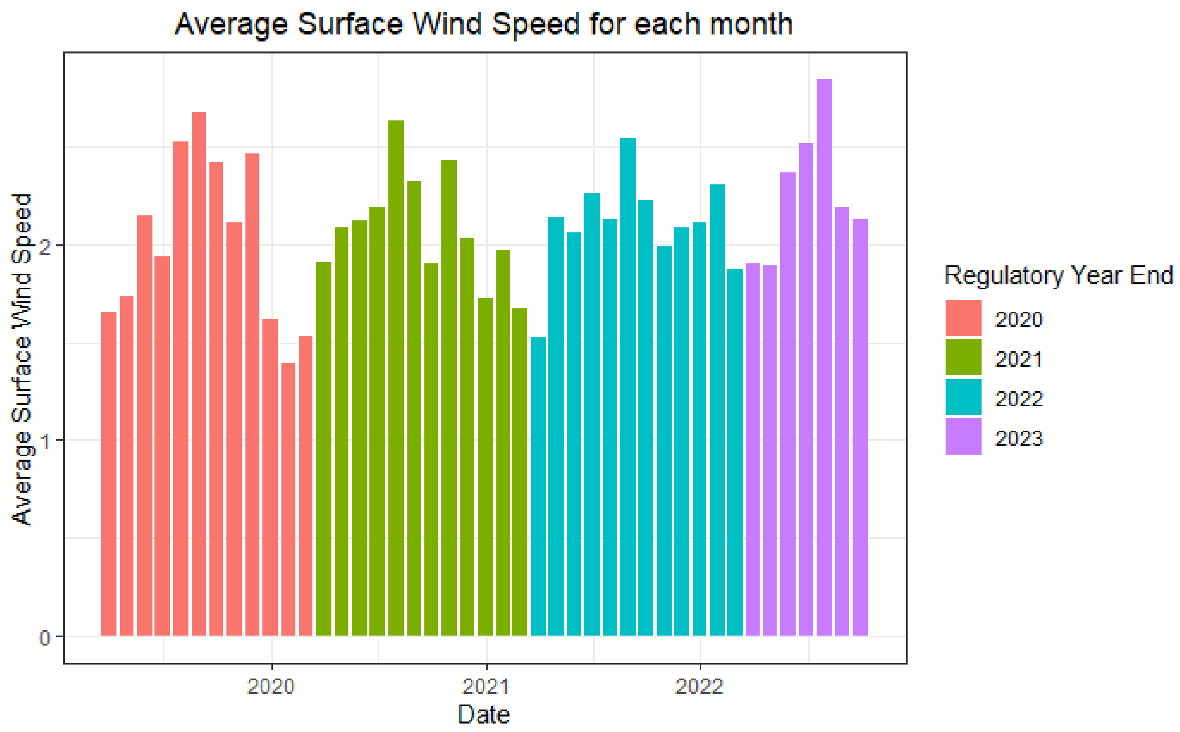




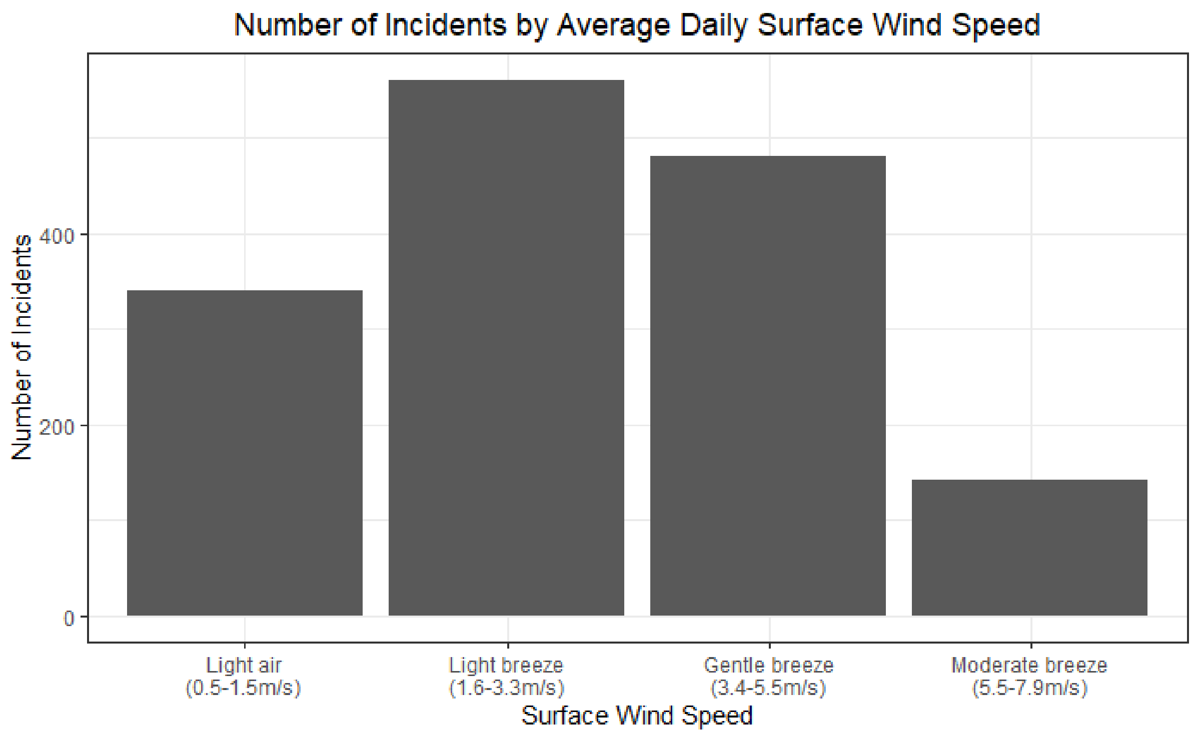
In the plots above, we observe that days where at least 10 incidents have been reported tend to occur during heavy (between 10.1-50mm) and violent (more than 50mm) rainfall conditions. About half of the days where light rain is recorded have no incidents. As rainfall levels increase, we see that there tends to be more incidents reported in a day, and we have not observed any days with no incidents when rainfall levels are recorded as violent (more than 50mm).

It is important to note that rainfall data has not been analysed as a more granular regional level. Therefore, caution should be taken when drawing conclusions about the relationship between rainfall and the frequency of incidents per day. However, we can surmise that there is some relationship between heavy/violent rainfall and the number of incidents reported in a day.

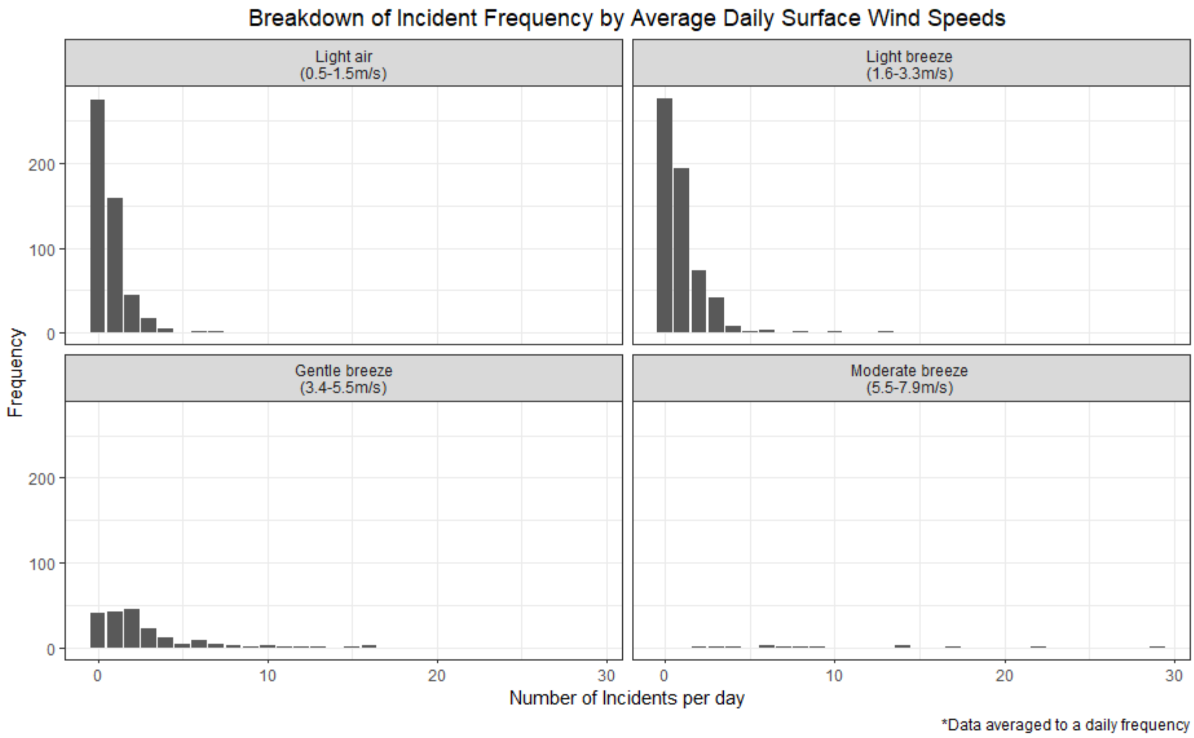
Surface Wind

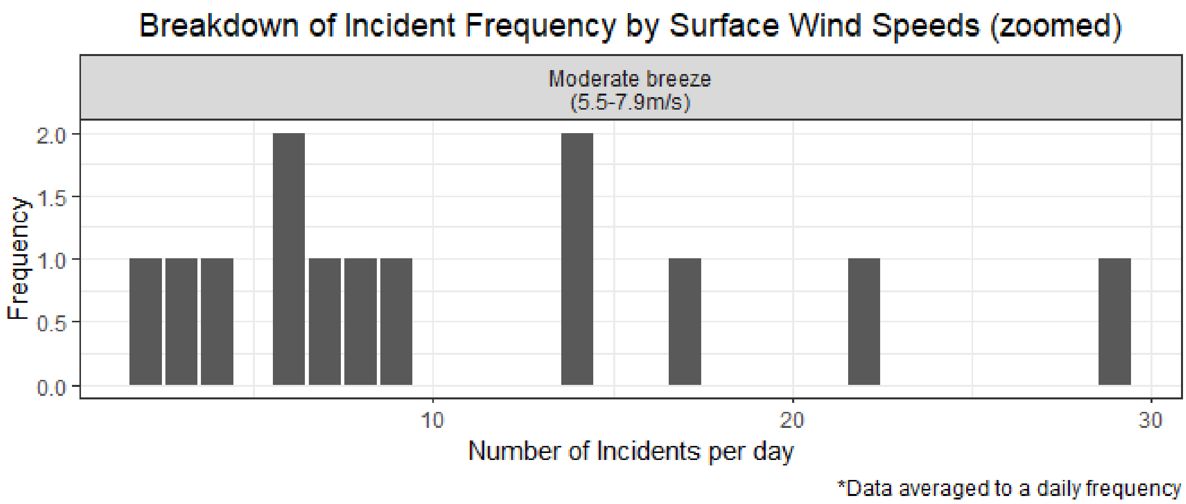


The above figure regarding wind speed shows that average wind speeds typically follow a seasonal pattern, which peaks towards the middle of each regulatory year. This also seems to correspond with an increase in incident counts.



Number of incidents based on binned average daily surface wind speed. Note that surface wind speed recorded in the CLiFlo dataset is not significantly higher than a moderate breeze of 7.9m/s or 30km/hr significantly recorded.



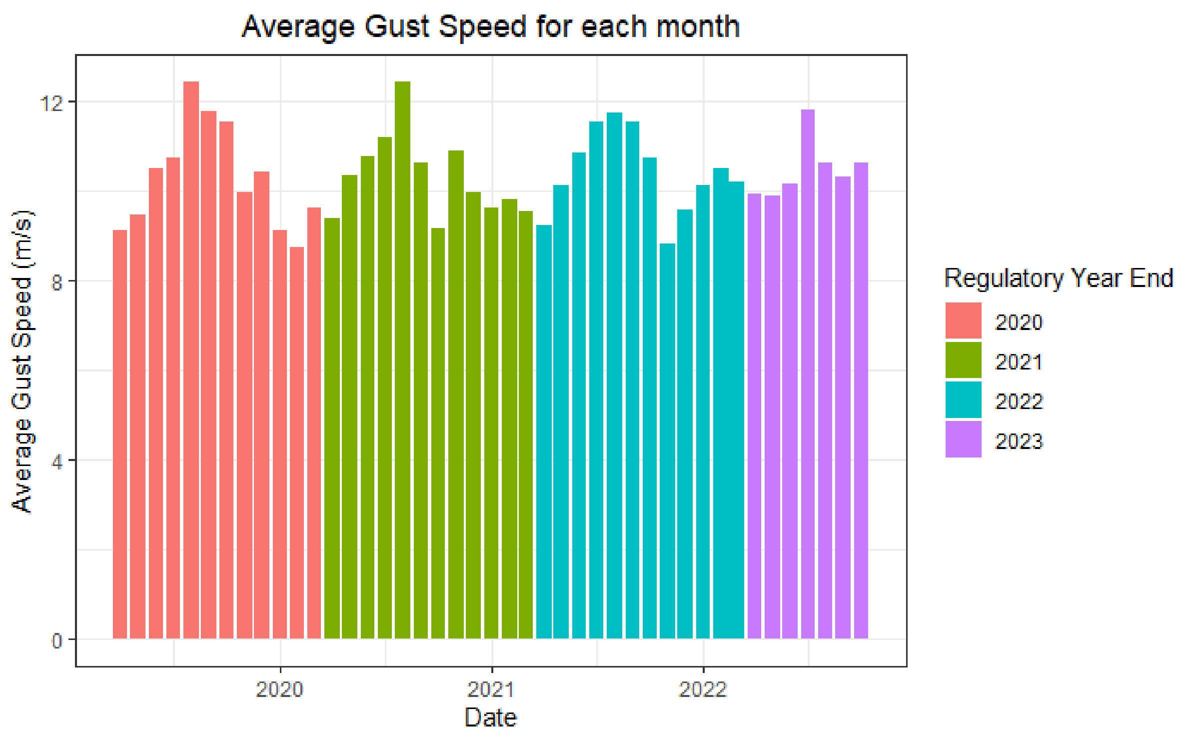


The incident counts for days where average surface speeds were a "moderate breeze". The distribution is markedly more uniform than for other surface wind speed groupings.

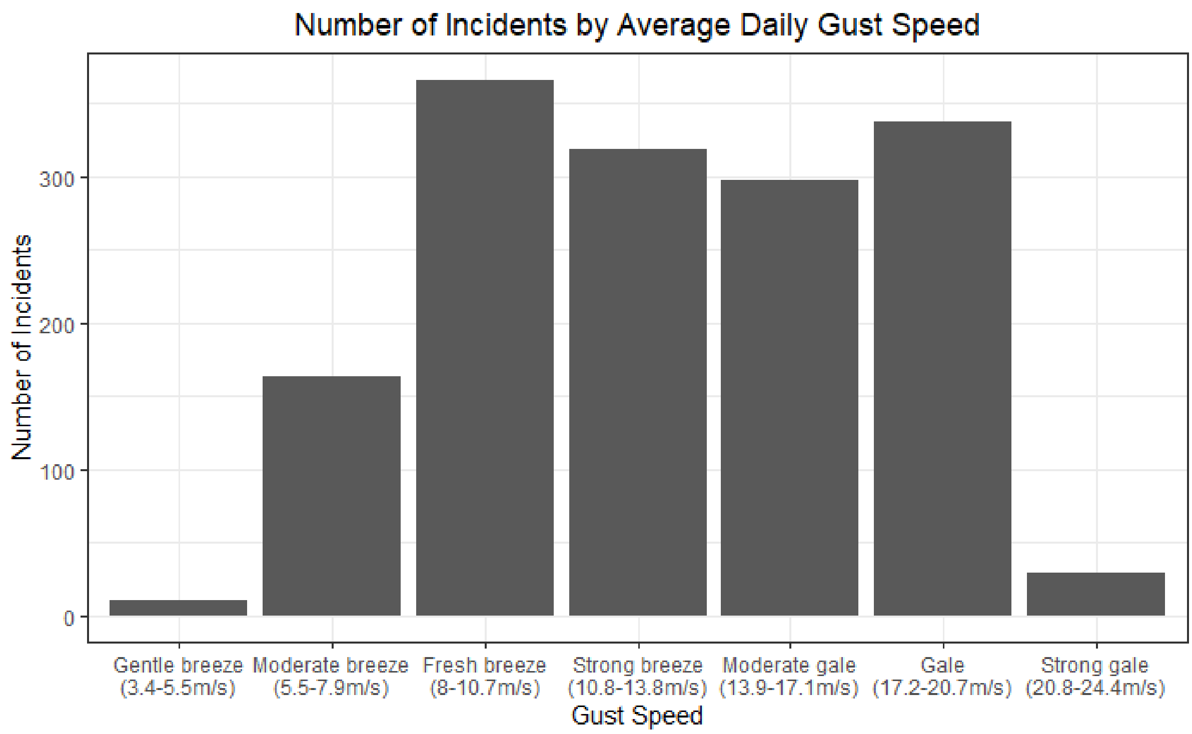
There is a noticeable distinction in the number of incidents when comparing wind speed categories. It appears that as the wind speed increases, the distribution of the incident counts changes. Light air, and light breeze and gentle breeze all become more right-skewed, whilst days with moderate breeze (the highest surface wind speed) demonstrate an even distribution. This suggests that the likelihood of seeing multi-incident days increases with wind speed. In addition to this, the maximum daily incident count for moderate breeze wind (29) is expectedly higher than any of the other (lower) surface wind speed categories.

However, most incidents occurred on days with lower wind speeds (light air and light breeze) - which makes it harder to conclusively determine a strong link between wind speed and incident frequency.

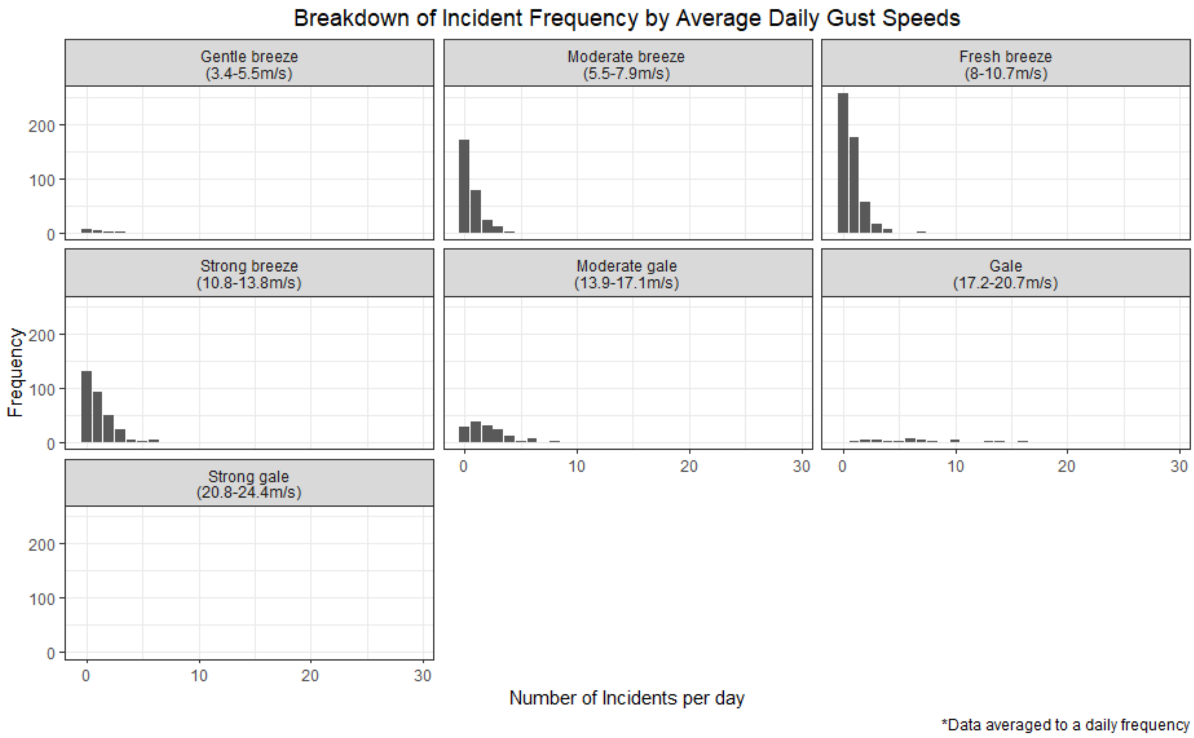
Gust



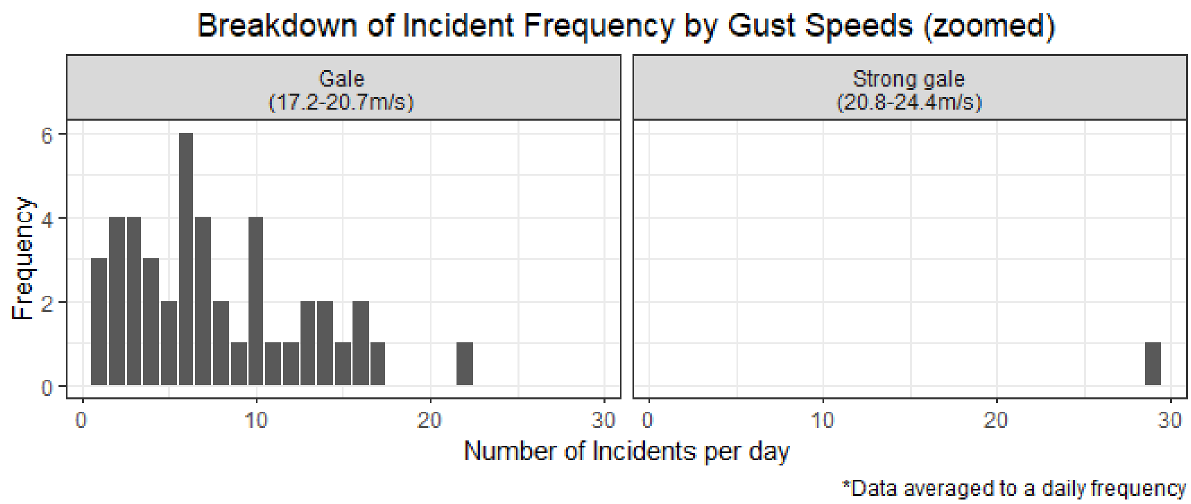
The above figure regarding gust speed indicates a slight deviation from gust speed patterns in YE2023, compared to previous years. A seasonal pattern can be observed throughout the years, but it is interesting to observe that across each month in YE2023 to date, average gust speeds are somewhat consistent throughout the year at around 10 m/s. This excludes July, which jumps up to an average gust speed of 11.8m/s, which also corresponds with a spike in SAIDI and in the number of incidents that were observed during July YE2023.



43.6% of all reported incidents occurred when gust speeds were classified as at least a moderate gale (13.9m/s). Conversely, around 56.3% of all reported incidents occurred under some level of breeze. This suggests that more incidents occur under moderately windy conditions, although further analysis by region would need to be performed to draw more concrete conclusions.



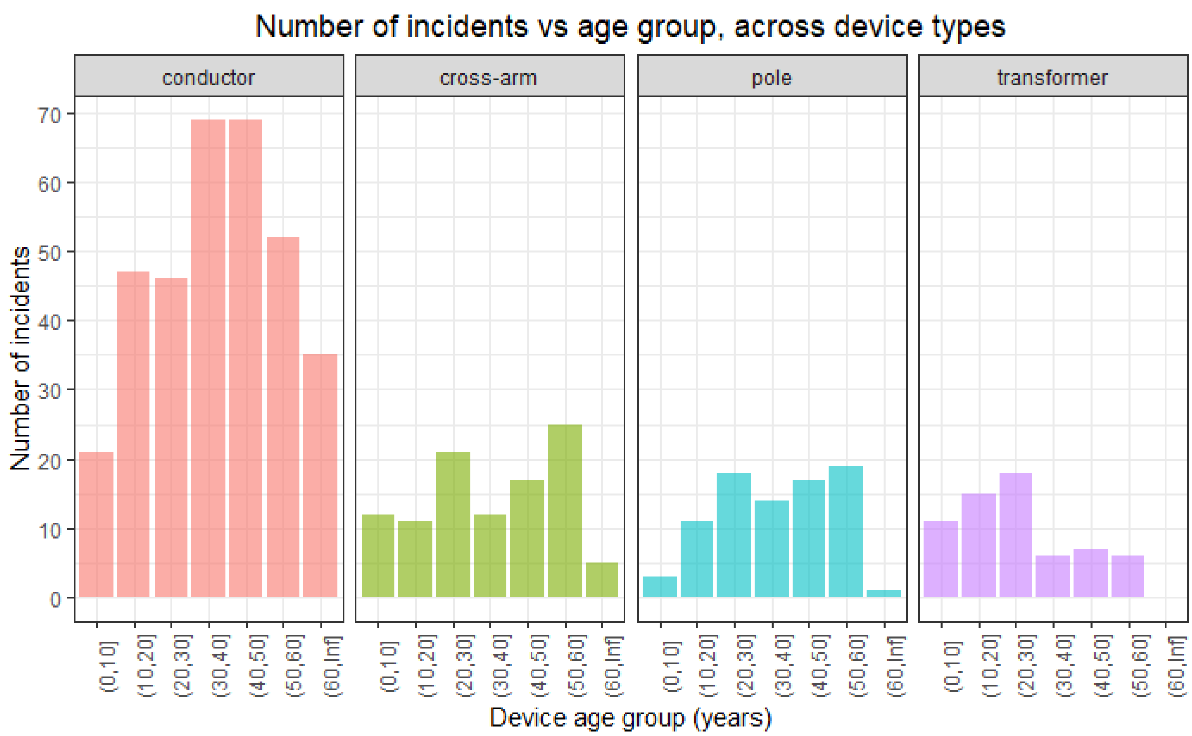
Due to the small number of incidents observed during “gale” or “strong gale” gust speed days, a zoomed in plot is included below.



Gust speeds tended to be on the stronger side (around gale level) on days where at least 10 incidents were reported. Breezy days tend to have a significant amount of days where no incidents are reported, as we could expect. Conversely, on days where gales occurred, at least one incident was always reported. On the day where 29 incidents were reported, gust speeds were reported to be at a strong gale level. It is also interesting to note that we see increasingly more incidents being reported in a day as gust speed increases.

Further analysis would need to be performed to draw conclusions between gust speed and incident frequency, however it is safe to conclude that there appears to be some correlation between gust strength and the number of incidents that are reported in a day.

Device age analysis



This figure utilised data from the SAP Condition History sheet.

Conductor failures remain significantly more common (43% of incidents) than either cross-arm, pole or transformer failures. Overall, there has not been major changes in proportions of incidents by age group across device types from the previous report.

- **Conductors:** There remains no strong correlation between device age and the number of incidents. Conductors in the 30-40 and 40-50 age groups continue to represent the highest proportion of conductor incidents, while the oldest conductors are still responsible for the second fewest number of conductor failures.

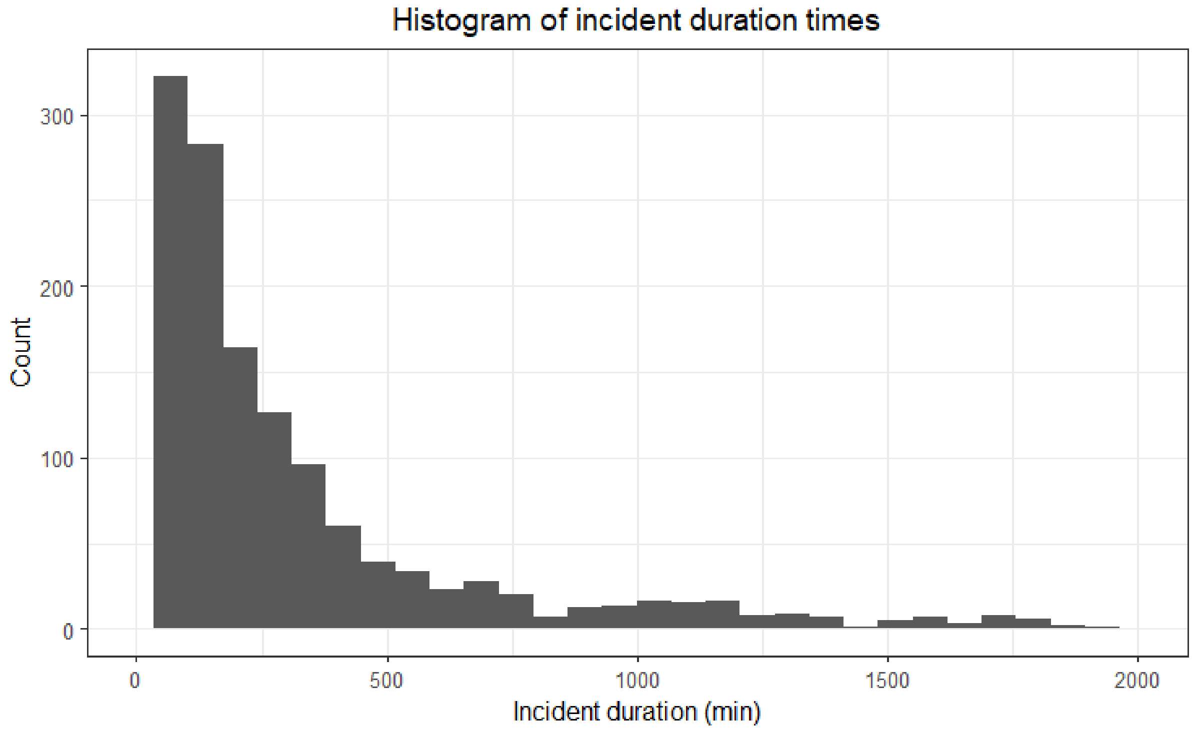
- **Cross arm:** Ignoring the oldest conductors (of which there are only a few observations), increasing cross-arm age continues to seem correlated with the number of cross-arm related incidents. However, since the previous report, there have been more incidents regarding cross-arm devices in the 20-30 year age group.
- **Pole:** There has not been much change in the distribution of pole-related incidents since the previous report, in that there is a correlation between the number of pole incidents and age group. Previously, there were no incidents for poles over 60 years old. However, there have now been some incidents reported since the February 2022 report.
- **Transformers:** Since the last report, there has been an increase in incidents for transformers in the 10-20 years age group. However, older transformers remain responsible for the fewest transformer-related incidents.

Duration Analysis

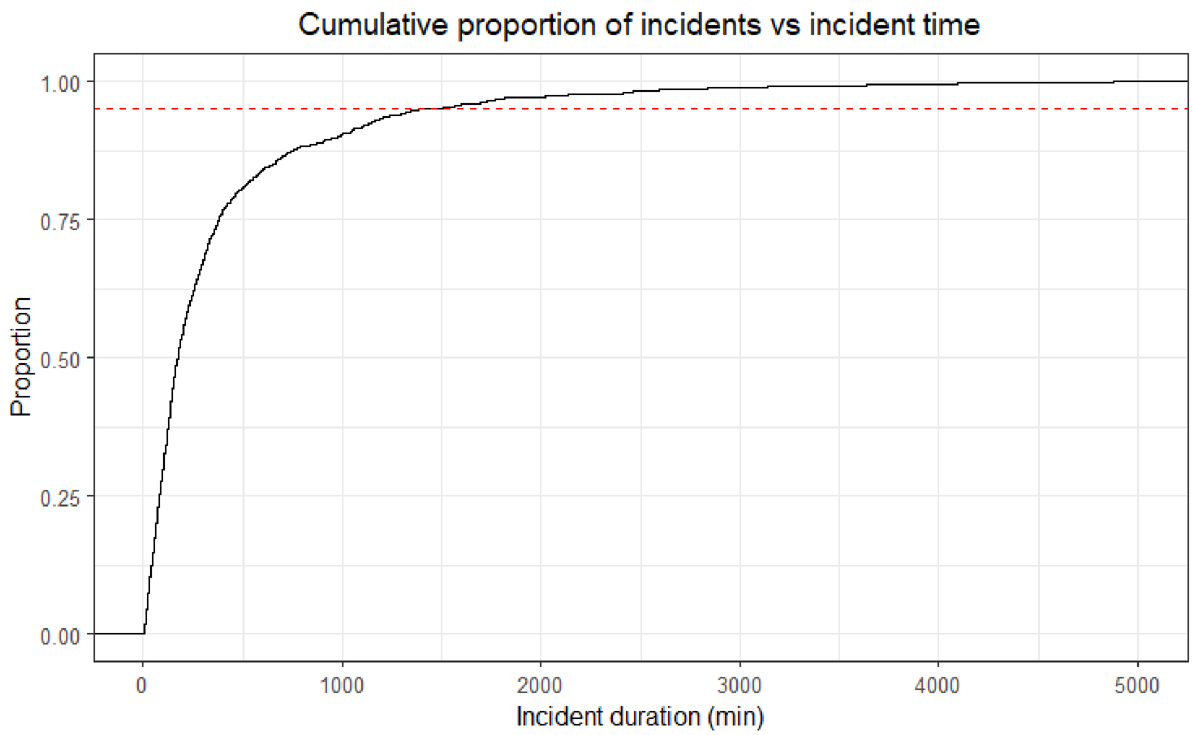
The following figures show breakdowns of the duration of incidents - defined by the start and end times within the ADMS data. These durations should be considered the SAIDI clock durations - not necessarily when the outage / problem may have actually occurred. For unplanned outages, the start time used depends on the process by which the incident was detected.

- If it was a Customer Fault Call received by the Call Centre, the start time is the Call record entry time;
- If it was an Automated Protection Device Activation Alarm, the start time is the Device operation time.

The above only applies if it is an HV fault and a no power call. Otherwise, the start time is recorded only when the power is completely off - e.g. when a worker isolates the section.



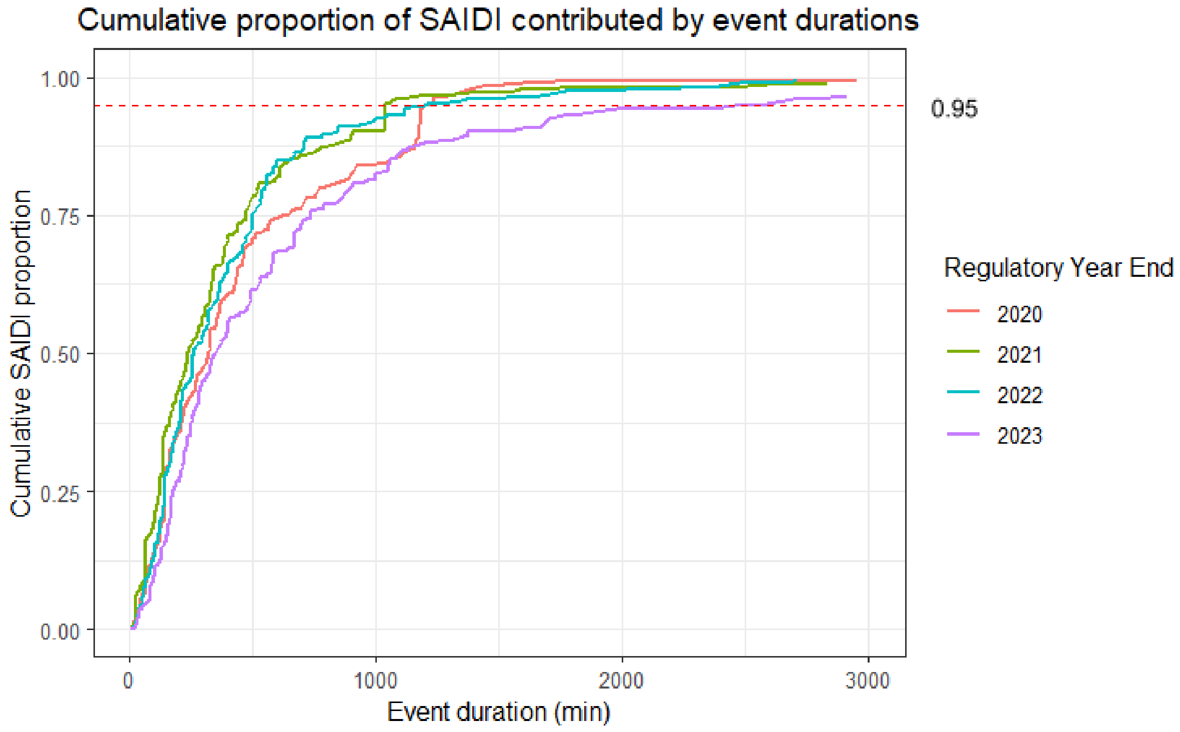
The above is filtered to incidents shorter than 2000 min. There are 50 incidents out of 1543 that are longer at 2000 min.

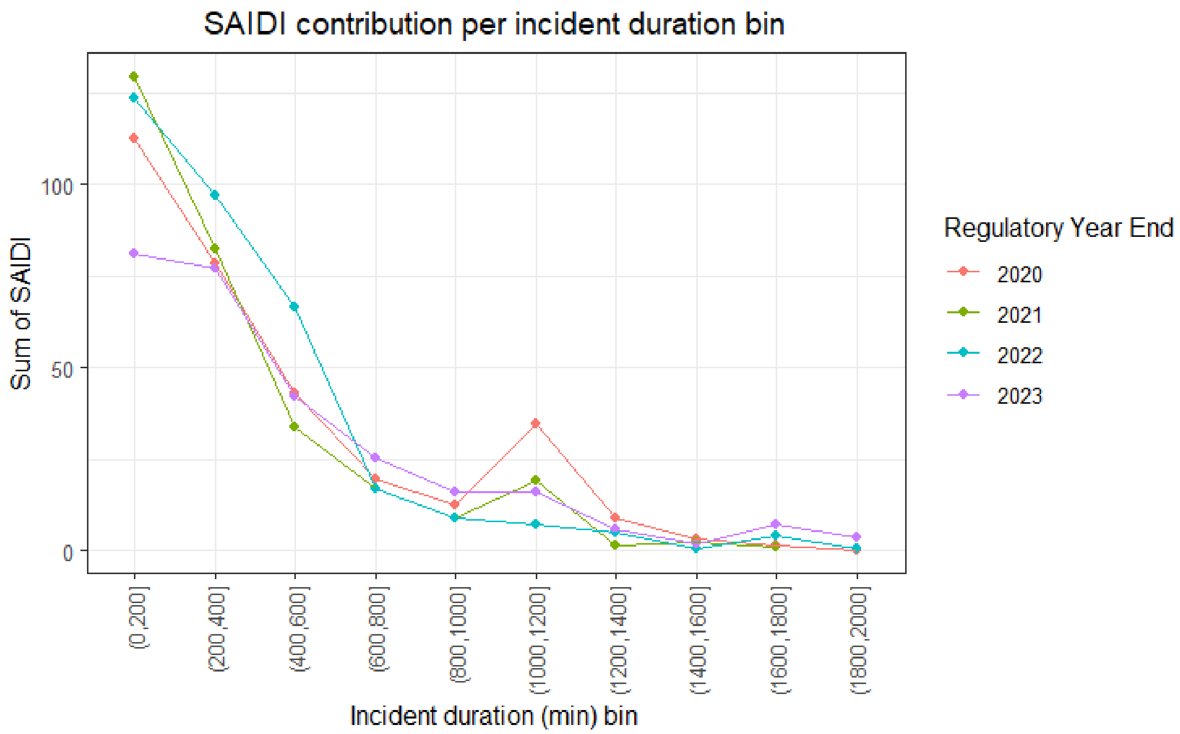


From the above plots, we can see that incident durations are clearly skewed towards shorter durations. Around 95% of all incidents are under ~1560 min = 26 hours (i.e. just over a day). 99% of incidents are under ~4000 min. Overall, the mean duration length is 437 min, and the median is 175 min. This indicates that there are a few very large outliers that skew the mean higher than the median.

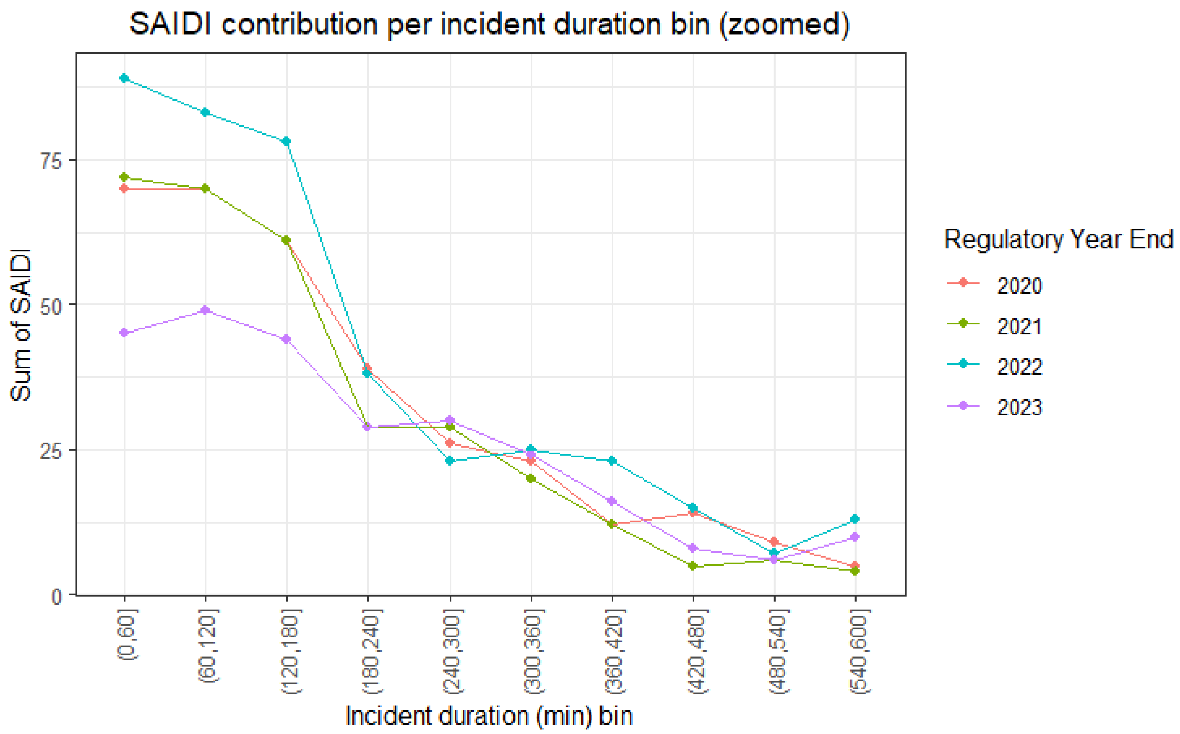
SAIDI contribution breakdown

The following charts show how the various durations of incidents contribute to the SAIDI across the different years.


Cumulative proportion of SAIDI contributed by event durations
Cumulative SAIDI proportion
1.00
0.75
0.50
0.25
0.00
0.95
0
1000
2000
3000
Event duration (min)
Regulatory Year End
2020
2021
2022
2023


SAIDI contribution per incident duration bin
Sum of SAIDI
100
50
0
(0,200]
(200,400]
(400,600]
(600,800]
(800,1000]
(1000,1200]
(1200,1400]
(1400,1600]
(1600,1800]
(1800,2000]
Incident duration (min) bin
Regulatory Year End
2020
2021
2022
2023

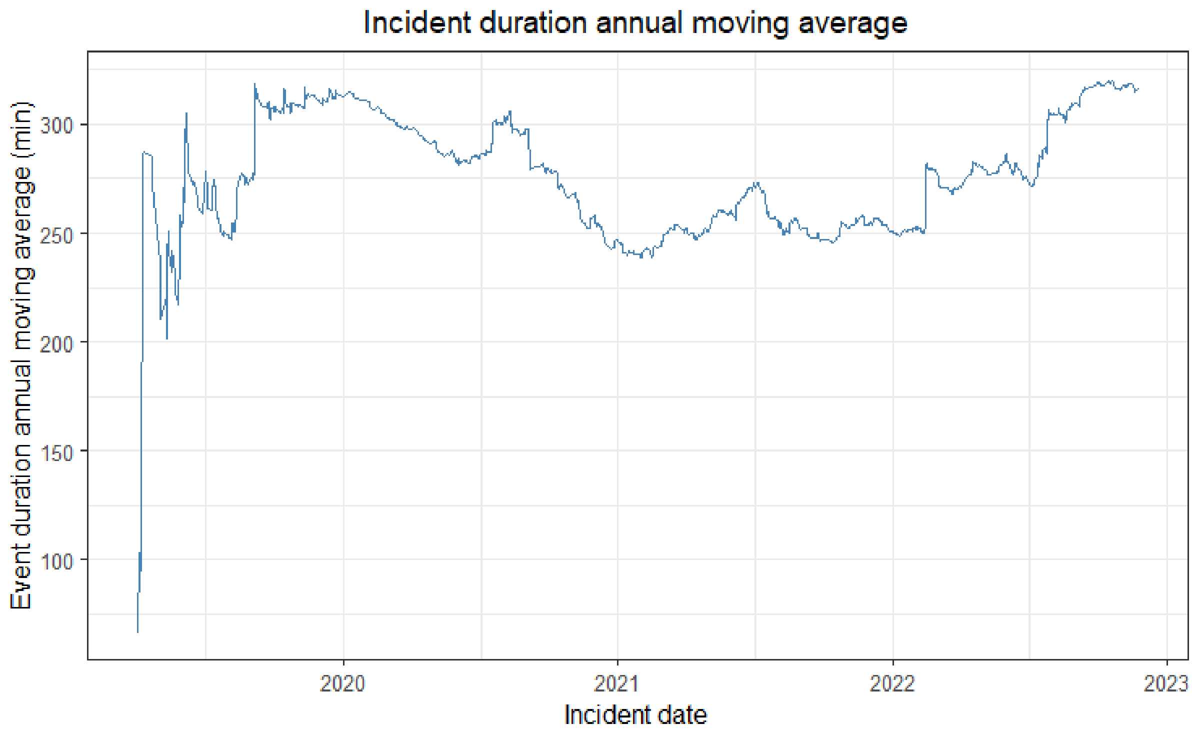
It can be concluded that the majority of SAIDI is generated by shorter incidents. Compared to previous years, a far larger proportion of SAIDI is caused by long incidents in YE2023. The spike in contribution at the 1000 -1200 minute range seems to have disappeared in YE2022 and 23. Instead we see a far smoother distribution between the incident durations. Notably, incidents with a duration of 0-200 minutes contributed far less in YE2023.



Zooming into the duration bins between 0 and 600 minutes, we can clearly see the relative reduction in SAIDI contribution with shorter events.

Incident durations over time

Regulatory Year End	Mean Incident Duration (min)	Median Incident Duration (min)
2020	341	167
2021	344	141
2022	412	168
2023	675	246



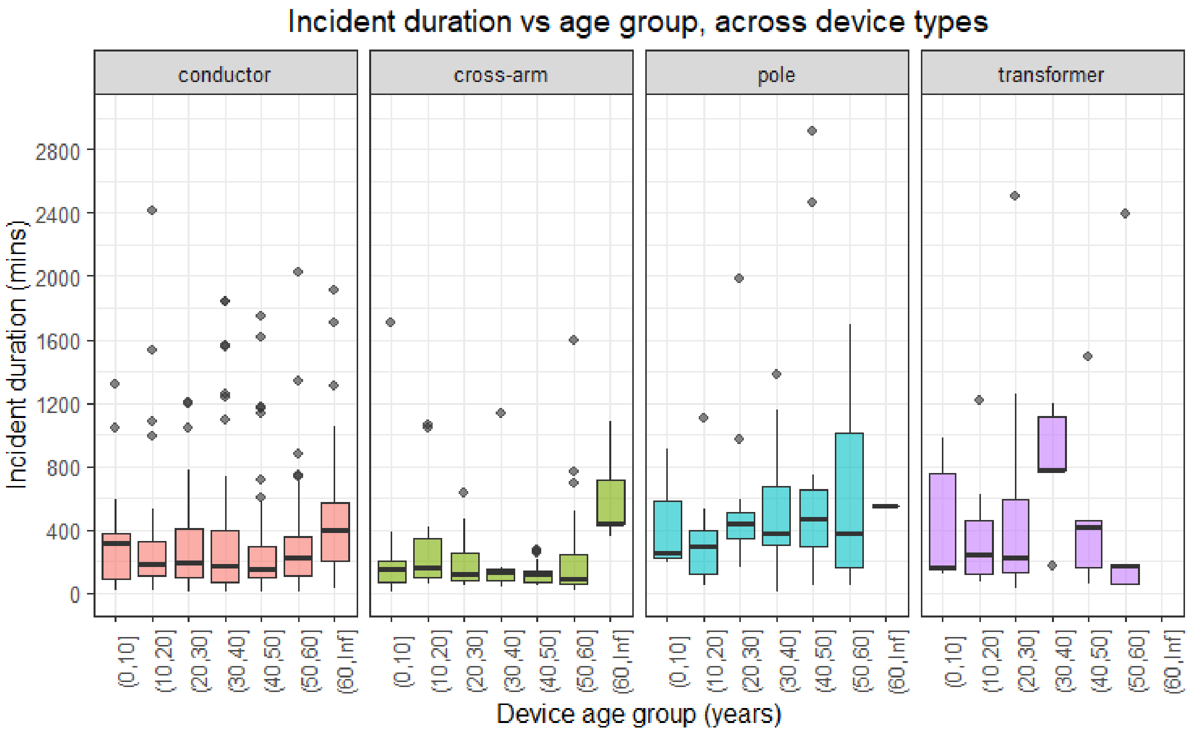
Rolling yearly average of incident durations

We can see the spike in average incident duration starting in late 2022. Notably there were the following incidents:

- A 32,587 min incident in May at the Omanaia substation
- A 20,553 min incident in August at the Kaeo substation
- A 13,472 min incident in July at the Moerewa substation

Before this, there had only been one incident longer than 10,000 min, which was in August 2020 at the Moerewa substation.

Device age analysis



This figure utilised data from the SAP Condition History sheet. For visual purposes 3 incidents longer than 3000 minutes were not displayed.

- **Conductors**: The oldest conductors had the highest median event duration (439 mins) of all age groups. Interestingly, the most recent conductors had the second highest incident duration mins (310 mins).
- **Cross arms**: The oldest components had the highest median duration (437 mins) followed by the 10-20 year age group (221 mins median duration).
- **Poles**: Poles in the 30-40 years category had the highest median incident duration time, and there was little correlation between pole age and median incident duration.
- **Transformers**: The 30-40 year age group has a median duration of 984 mins, significantly higher than the 10-20 year group (median 649 mins). Evidently, the

correlation between transformer device age and median incident duration was not significant.

Variables associated with incident duration

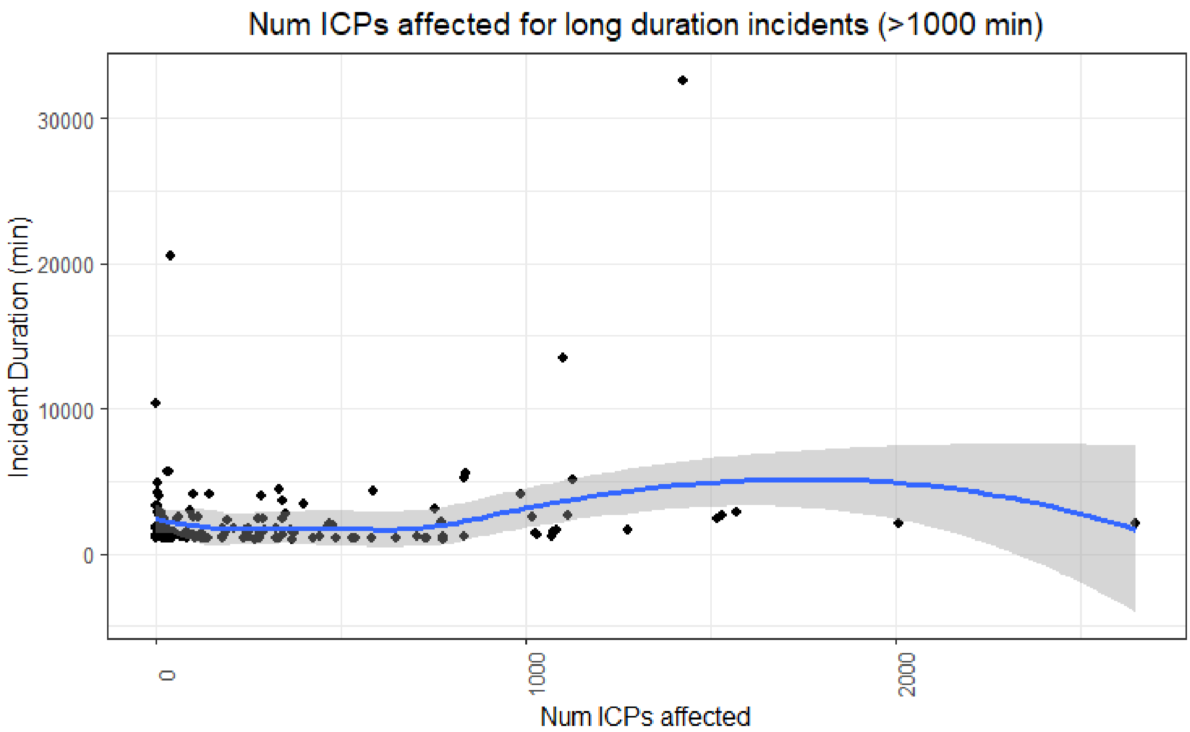
Within the appendix are contained a selection of variables plotted against incident duration. These variables were chosen as they contained values that had an obvious effect on the distribution of incident duration times.

Categorical variables are plotted as boxplots with the outliers (below the 25% and above the 75% quantile) removed. Values that appeared less than 10 times were lumped into an Other category. Continuous variables are plotted as a scatter plot with a smoothed fit applied.

- The top three **substations** with the longest incident durations are **Omanaia**, **Kawakawa** and **Taipa**. There is a gradual decrease in incident duration moving down each substation - there is no one substation that has significantly longer incident durations than the rest.
- Incidents involving the **weather** are also associated with longer incident durations. This can be seen from the long durations observed in incidents with the following attributes:
    - **Storm**
    - **Lightning strike causes**
    - The **extreme weather** flag from the timesheet data
- February has the highest median incident duration - this is almost entirely due to an abnormally high frequency of long duration incidents in early 2022 (17 events longer than 2000 min, compared to none in the previous 2 years). The **months** around winter (**June to September**) generally have the highest incident durations, explaining the higher SAIDI contribution by these months observed before. This is unsurprising, given that these winter months would typically be associated with worse weather.
- There is no significant difference in incident duration between **days of the week**.
- Incidents involving **poles** are clearly associated with longer durations. This can be seen from the long durations observed in incidents with the following attributes:
    - **Third party outage types**

- **Vehicle vs. pole incident causes**
- **Pole device affected (object type** and **equipment type)**

- The **voltage** with the longest incident durations is **6.35kV**. There are only 84 incidents in total that involve this voltage, however, the median incident duration is much higher than the overall, at 339 minutes.
- The **cable device group** is clearly associated with longer incident durations. There are only fourteen cable incidents in total, with eight of them being longer than 1000 minutes. However, the cable incidents tend to affect relatively fewer ICPs and are very rare, hence cable incidents do not contribute greatly to the overall SAIDI minutes. The other device groups are all much closer together in terms of incident duration, with **ground mounted devices** having the shortest incident duration on average.
- Many of the very long durations (> 1000 min) are incidents that affected a relatively small **number of ICPs**. Since the number of ICPs affected is small, the SAIDI generated is also relatively small - hence it is likely that these incidents are deprioritised. An outlier occurred in YE2023, where an extremely long incident (32,587 min incident in May at the Omanaia substation) affected a significant number of ICPs (1426) generating a large amount of SAIDI.



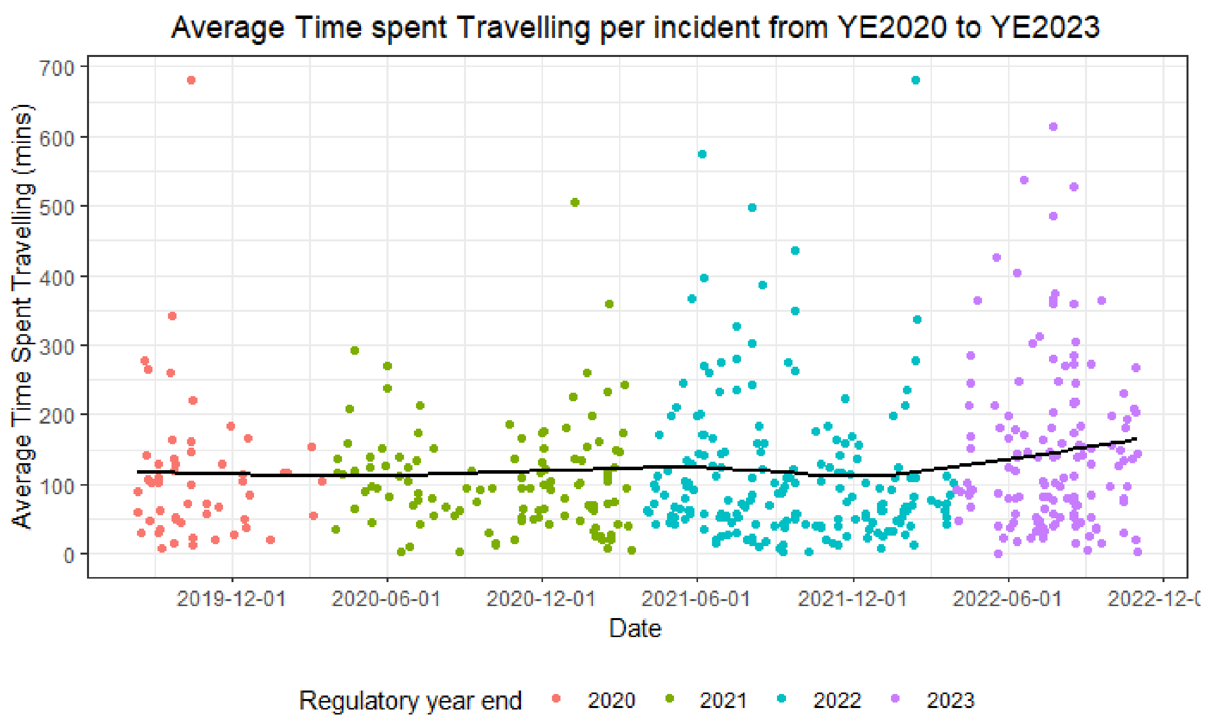
- Older / more fatigued assets seem to be associated with longer incident durations. The top two **asset condition labels** associated with the longest incident durations are **0 Unknown** and **3 Fatigued.** These labels themselves are correlated with older equipment age, as expected. For equipment labelled as “unknown”, this indicates that there has been no recorded inspection. Note that the majority (74%) of incidents failed to match to an asset condition (due to missing data). Only 11 incidents were able to be associated with an asset with condition “0 Unknown”. Interestingly, “4 Unreliable” and “5 End of Life” (lumped as Other) did not seem to be correlated with longer incident durations - however this is inconclusive due to having only a small sample of incidents for both of these condition levels.

Incident Response Analysis

Vehicle response

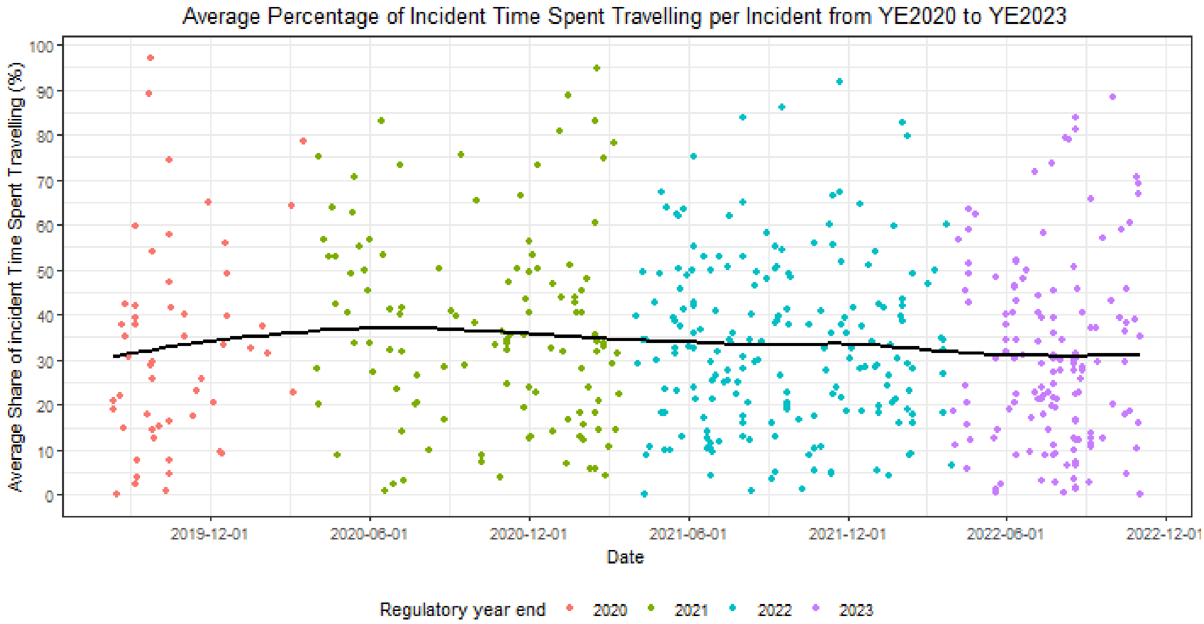
To analyse the vehicle response, the unplanned ADMS incidents which could be associated with Smartrak data were selected for analysis. The features as described within the [feature generation](#) section were used.

Response over time



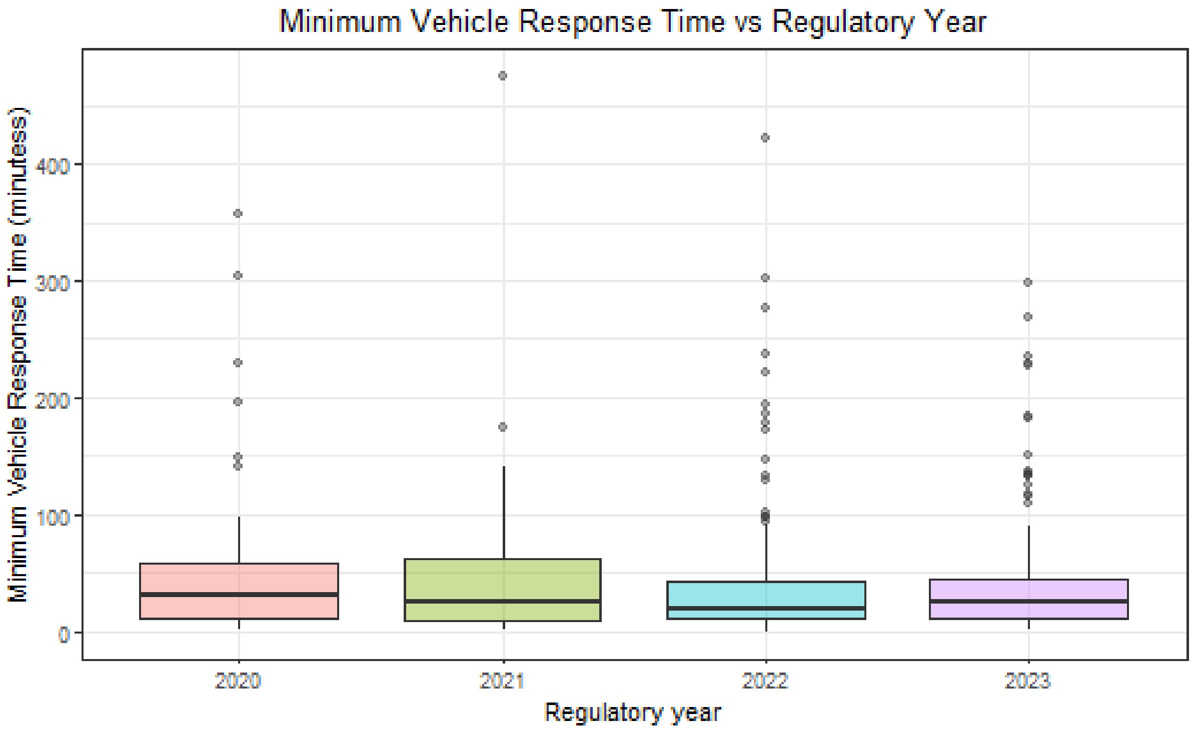
Each data point represents the average of all employees' travel times for each incident.The black trendline represents the average of these values over time.

In YE2023 there appears to have been a slight uptick in the average time spent travelling by each vehicle per incident, which also coincides with the increase in incident duration in the same period This figure also indicates that the variance in average travel time has increased over the years- with YE2022 and YE2023 observing more 'extreme' (300+ minutes) travel times than YE2020-YE2021. However, caution must be exercised when examining the response patterns because the vehicle travel data could not always be reliably matched to the relevant incidents (see Feature Generation).



Each data point represents the average % of incident time spent travelling times per incident.The black trendline represents the average of these values over time.

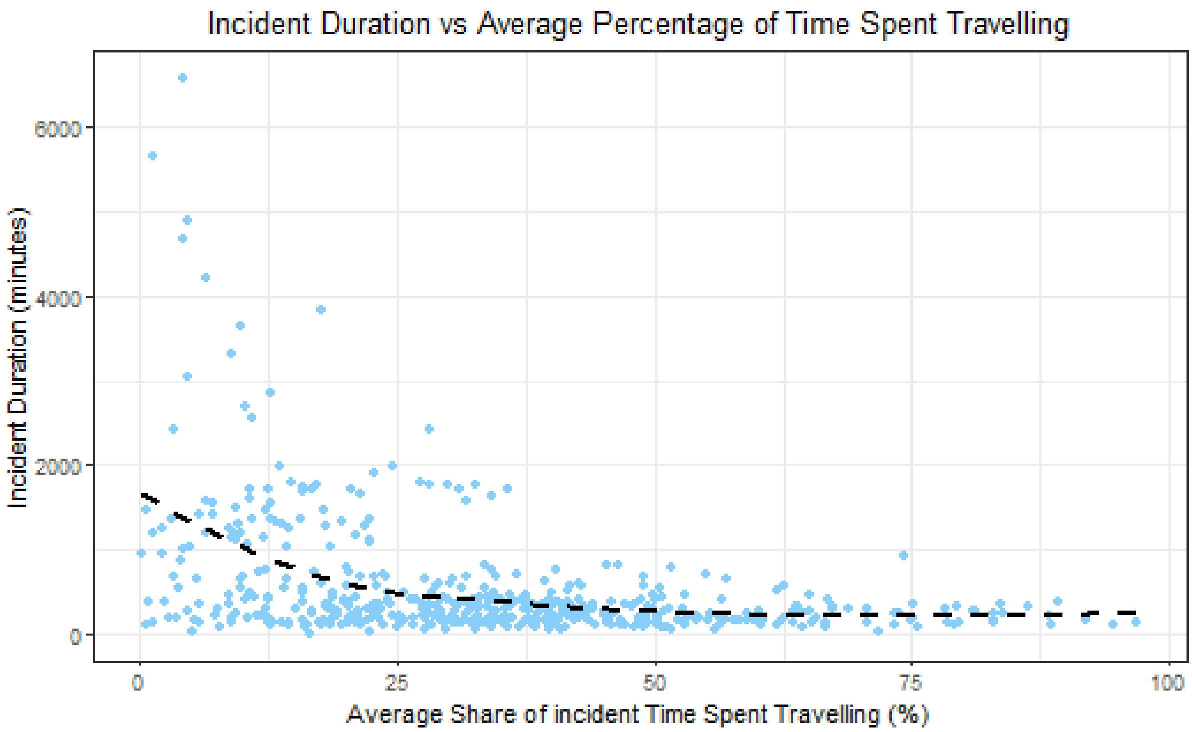
The data appears to show that the proportion of total incident time spent travelling has not significantly changed across the years - despite the travel time slight increase. Instead, it seems to have mostly remained the same - according to the trendline. Assuming that the incident time is equal to the sum of response time, travel time and onsite activity these findings suggest that despite any changes in the average travel time, incident time still consists of onsite activity.



There also appears to be no significant change in the delay between an incident start and the first vehicle sent between between the last two regulatory years. The average vehicle response for YE2022 and YE2023 was 39 minutes and 43 minutes respectively. We also observe that the variation in delay for YE2022 and YE2023 are smaller than the previous two regulatory years. This could possibly indicate that response times are becoming more consistent.

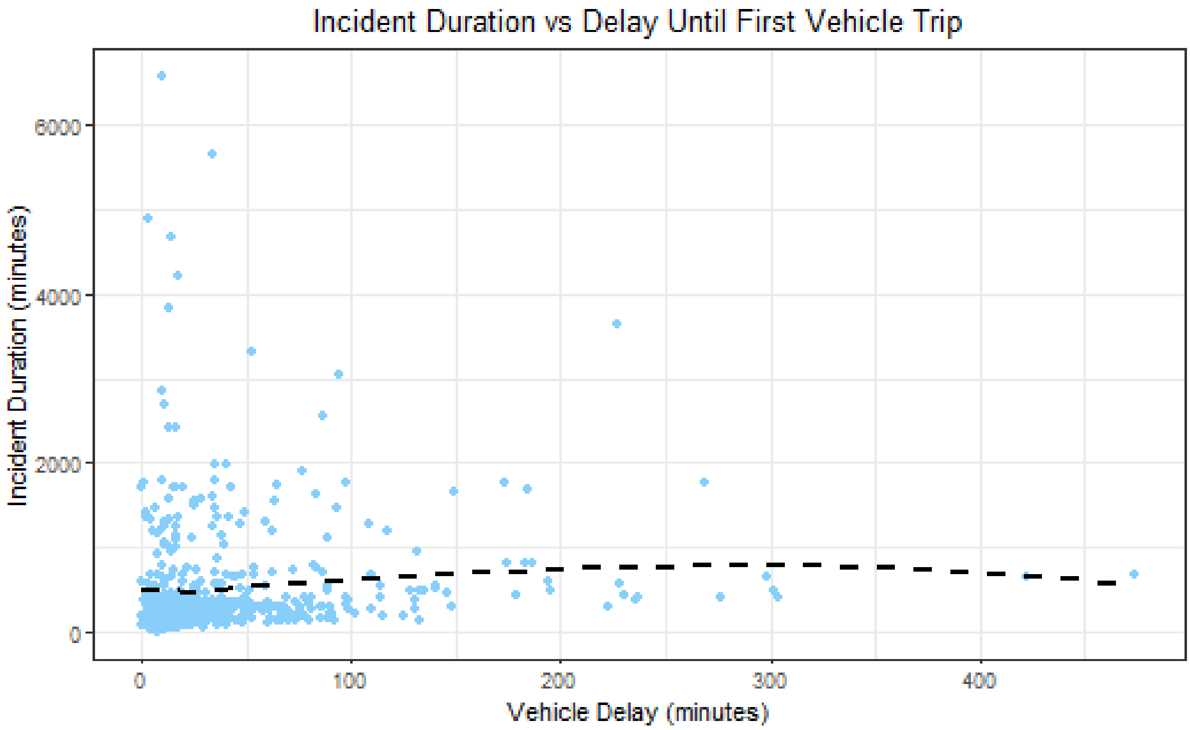
Relationship between Incident Duration and Vehicle Response

Each of these vehicle response features was compared against the corresponding incident duration data.



Similar to the findings of the original report, there does not appear to be a strong association between incident duration and the percentage of time spent travelling. Many observed incidents with observed durations longer than 1000 minutes are less than 20% travel time.

For incidents where employees spent on average between roughly 25% to 100% of the incident time travelling the trend is relatively flat. Despite employees occasionally spending more of their time travelling, there does not seem to be a corresponding change in the incident length - making it hard to attribute employee response to the incident.



Shown here is the minimum delay (response time) of the first vehicle after an incident begins. The overall trend (black) appears flat.

The data does not seem to suggest a strong association between the first vehicle deployed and the incident length. Similar to the previous findings, longer employee delays mostly do not correspond to longer incident durations. Evidently, while vehicle related issues such as delay and travel time do not seem to majorly contribute to longer (>1000 min) incident duration, improving the vehicle response time would have a positive impact on event duration.

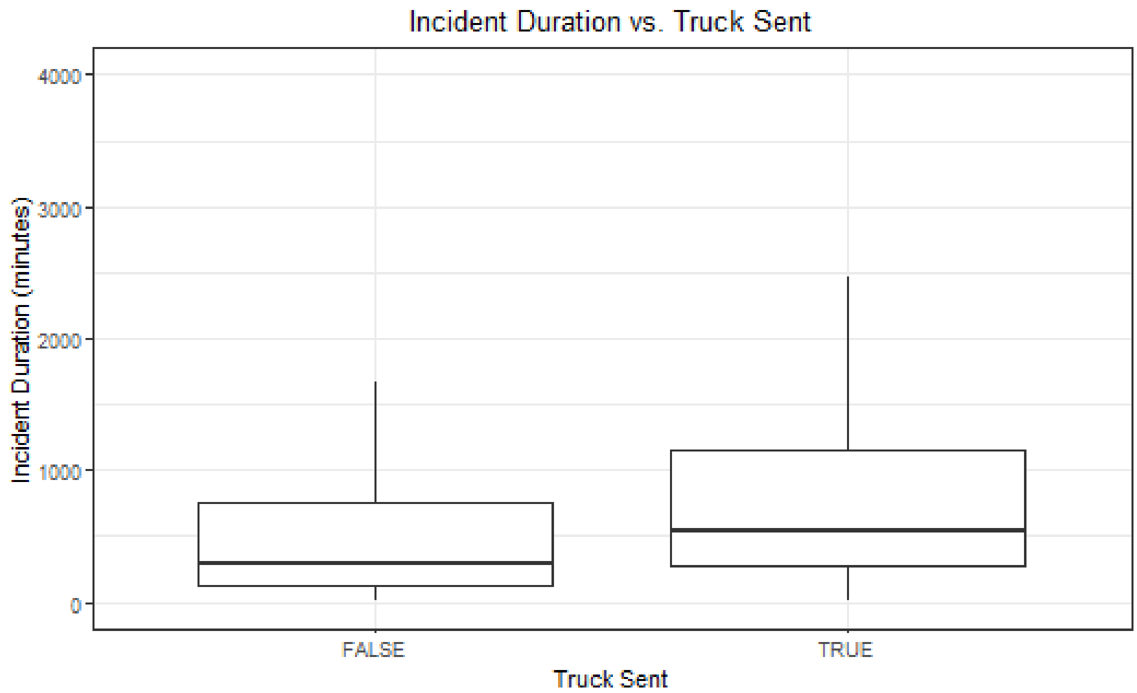
Trucks sent

Another area of interest is the types of vehicles sent to an incident, based on the SAP vehicle hours data. There are a variety of truck types recorded, including

- Small truck (6-8m)
- Medium truck (8-10m)
- 3 tonne truck

- 5-8 tonne truck

For the purposes of this analysis, any incident involving any of the above vehicle types is considered an incident where a truck was sent.

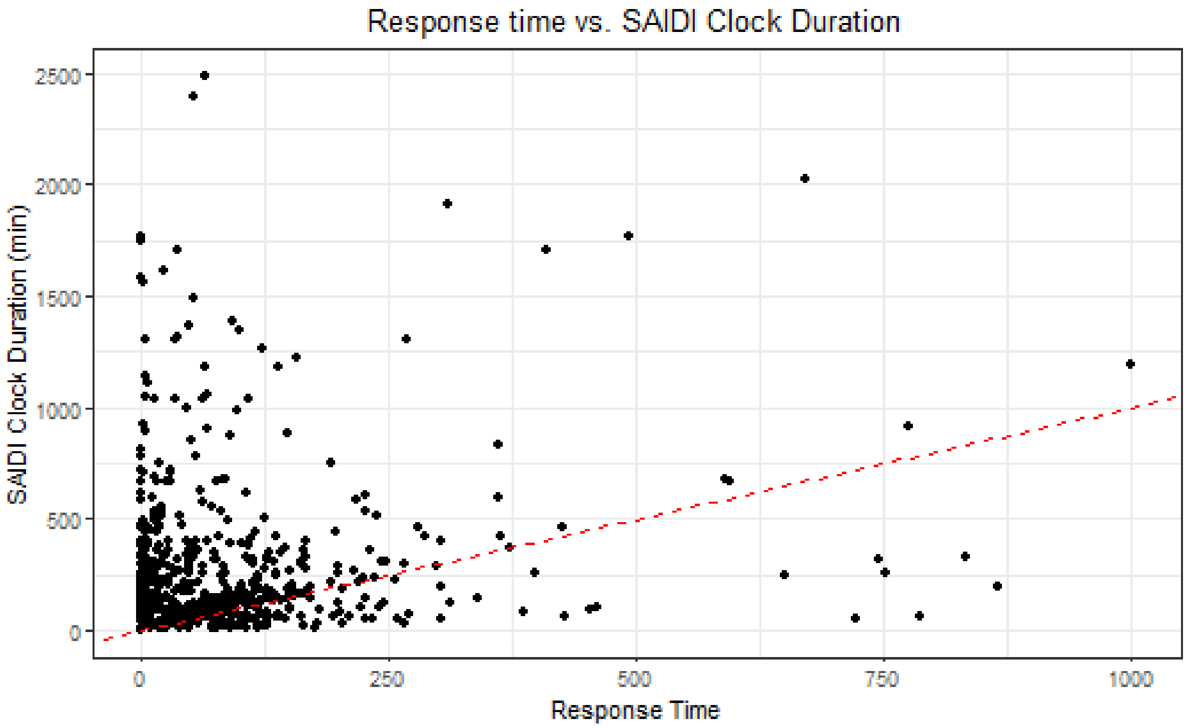


From the graph above, we can see that incidents involving trucks have a higher median duration (532 minutes) than incidents that do not involve trucks (298) minutes.

An examination of the vehicle hours data show that whereas incidents without trucks on average send around 2-3 unique vehicles in total, incidents with trucks send on average 4. This supports the conclusion that trucks are often only sent after the initial few vehicles, resulting in delays when an incident requires a truck to ship parts (e.g. a pole) that are required for resolution.

Employee Response Time

Utilising the ADMS employee event data, the first onsite action was approximated as described in the feature generation section. This allowed for the calculation of an employee "response time" (time since incident start until arrival on site) and "time on site" (total time spent on site during incident). These features were analysed against the total event duration.



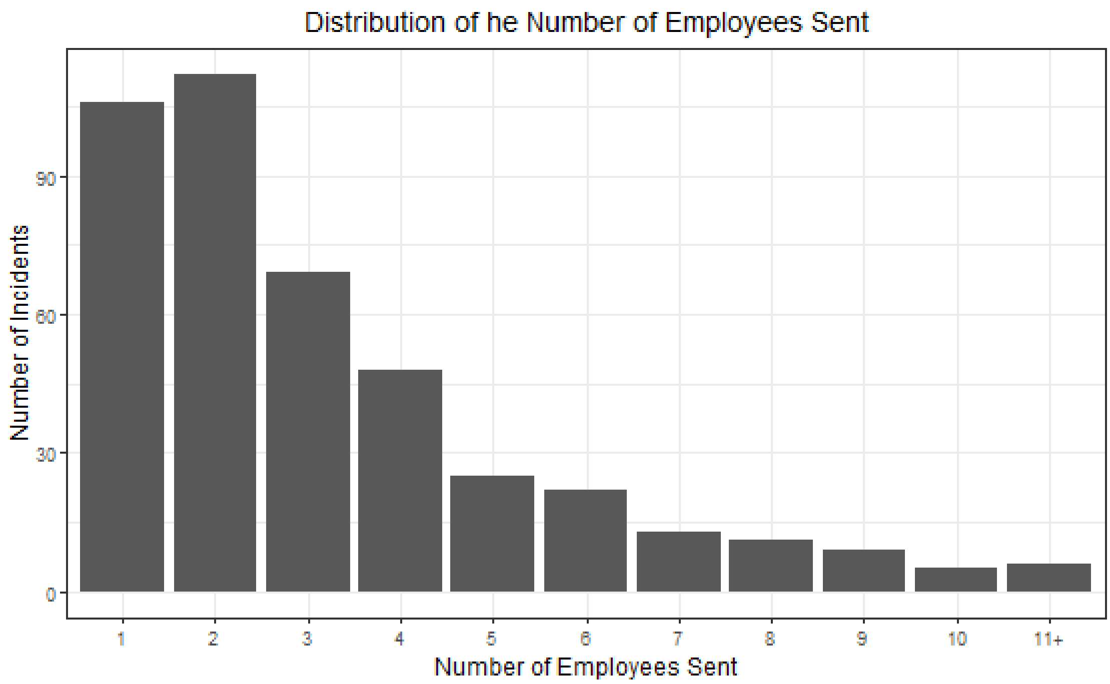
The dotted red line represents when the response time is equal to the SAIDI clock duration.

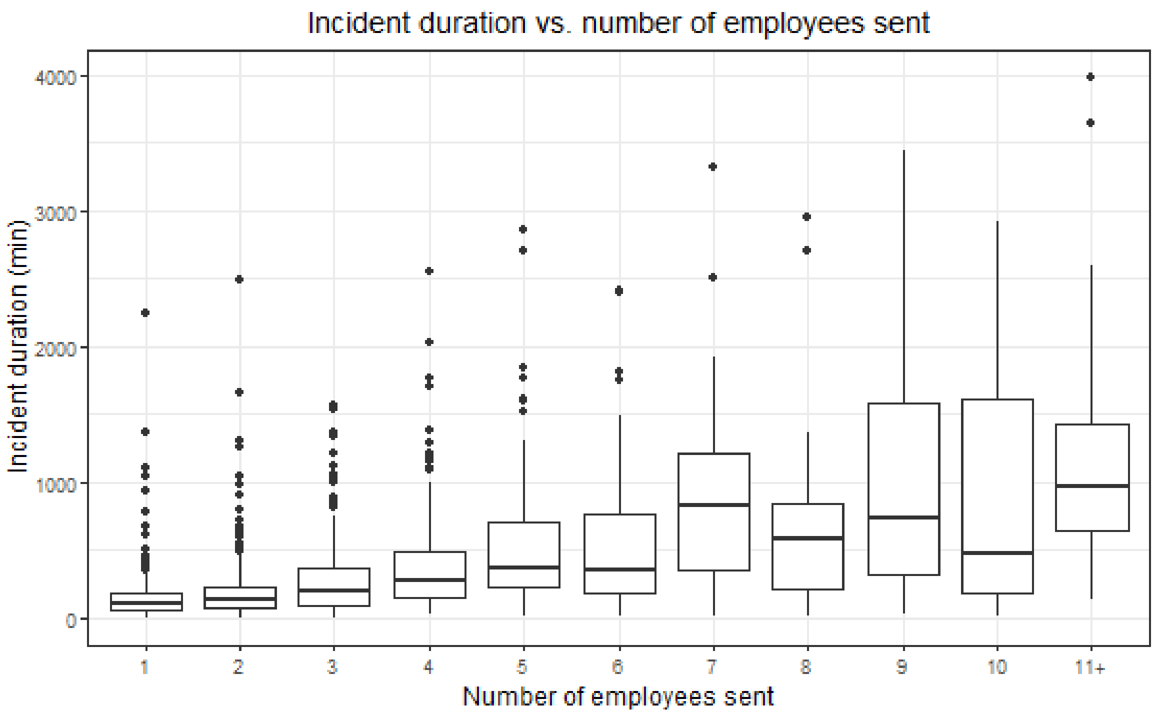
The above graph displays some issues with the reliability of the method to calculate response time. There are several points lying below the dotted red line, indicating that the response time was longer than the SAIDI clock duration. In these cases, this is due to the SAP notification time being much earlier than the actual SAIDI clock start time. As described earlier, in some instances, the SAIDI clock start time is adjusted to when the worker isolates a section - therefore only starting when the worker is already on site and working. This also explains why there are many points with essentially zero response time - since the first logged ADMS event would correspond with the start of the SAIDI clock.

In general, it is difficult to make any conclusions due to the caveats associated with the method of calculating response time.

We attempted to examine the fraction of time employees spent on site by calculating the interval between first and last action verbs recorded in the ADMS. However, there were no available records post January 2022 in this dataset so analysis could only be carried out for the regulatory years 2020 and 2022 (see above figure). This highlights the issues with approximating the employee time on site.

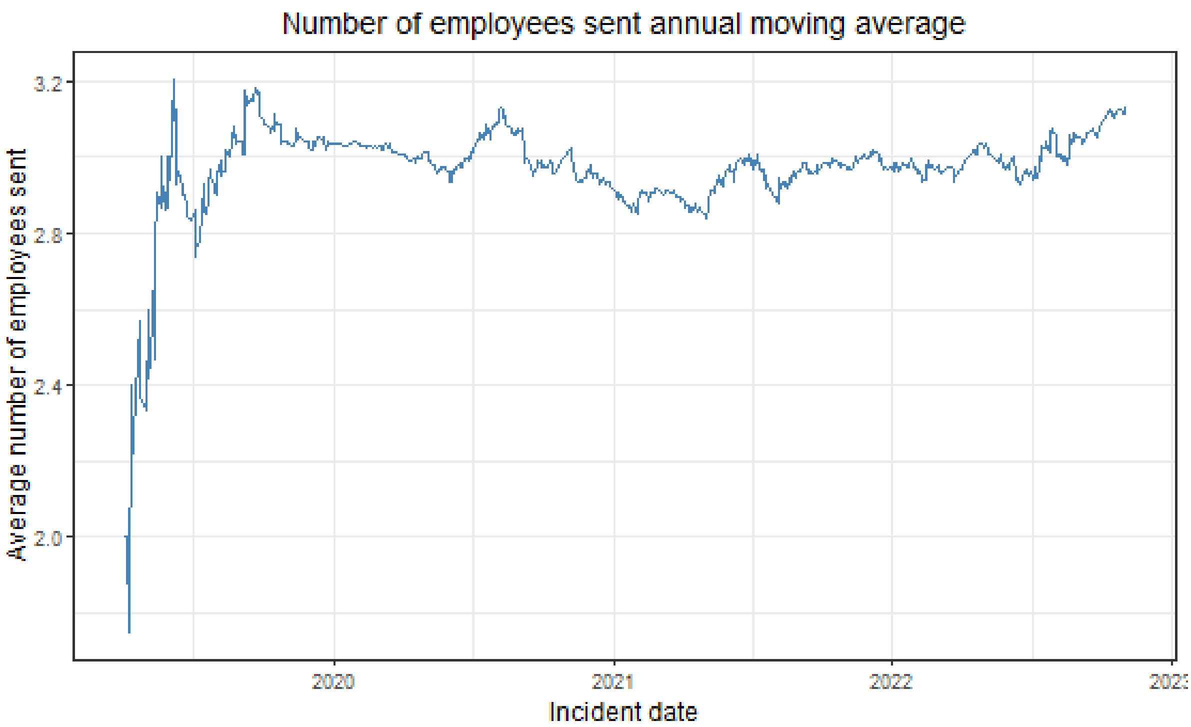
Employees Sent





Incident *Duration by number of employees sent to the incident. Note that major outliers* (>7000 mins) *have been excluded.*

The average number of employees sent is around 2-3. There is a clear and expected relationship between longer duration incidents, and an increase in the total number of employees sent. In this case, it is intuitive that longer durations result in more workers being sent to the site.



The number of employees sent per incident was consistently around 2-3 for the majority of calendar years 2020 to 2022, with a slight uptick towards the end of 2022. This coincided with a similar spike in incident duration towards the end of 2023. Despite this recent increase, the average number of employees sent per incident has still not significantly changed in recent times.

Conclusions and Recommendations

Key Findings

Incident durations have increased on average in YE2023

- There was a higher mean and median incident duration in YE2023 compared to all previous years. This was due to a large number of long duration incidents observed in 2022. Notably, there were 3 incidents longer than 10,000 minutes that all happened within a span of 3 months, all exceeding the previous record of longest duration.
- A far higher proportion of SAIDI is generated by longer incident durations compared to previously. However, most SAIDI is still generated by short incident durations.
- YE2023 had no observable spike at 1000-1200 min in terms of SAIDI contribution unlike prior years. Overall, the contribution to SAIDI across incident duration bins is far smoother than previously. This might be attributable to the amount of normalised events that occurred in YE2023.

Recommendation: Without normalisation, it is likely the long duration incidents that occurred would have resulted in a far more dramatic increase in SAIDI from previous years. As these events are likely influenced by abnormally poor weather during 2022, it is recommended to investigate further what proportion of these long events could be mitigated by improving worker response, and what was unavoidable due to weather.

Incidents have been occurring at a faster rate in YE2023 than in previous years

- The first 3 quarters of YE2023 have seen more incidents than the previous 3 regulatory years.
- There are many frequent spikes in incident count - such as during adverse weather events where the daily incident count can exceed 10.
- Given that the increased rate continues, the total incident count will exceed that of the previous years.

Recommendation: One possible suggestion is that due to the frequent spikes in incidents due to adverse weather, there should be an investigation into how to increase the resilience of infrastructure against these events.

Winter months and bad weather are impactful

- There is a clear and observable increase in frequency of incidents during the winter months of the year.
- Winter months are responsible for 126.3 SAIDI minutes, which is 43% of all SAIDI in YE2023 up to November.
- Adverse weather conditions contribute towards a significant portion of SAIDI during Winter YE2023.
- To date, YE2023 has the second most recorded weather events since YE2020, with more extreme weather events being recorded per month on average compared to previous years. This corresponds slightly with observed incident frequency.
- More SAIDI has been generated in Summer and Autumn months in YE2023, compared to Summer and Autumn in previous years. This is consistent with the increased record count of extreme weather events observed in YE2023.
- Higher surface wind speeds and levels of rain appear to be associated with a greater chance of observing high daily incident counts (10+).
- Gust strengths seem to have some relationship with high daily incident counts as historically, gales and strong gales always result in at least one incident being reported.
- However, the association between measured surface wind speed and rainfall does not appear as strong as expected. The vast majority of incidents still occur during days with little rain, and relatively low wind speeds.

Recommendations: Prepare in advance for an increase in incidents during the winter months / forecasted bad weather. Account for winter months in any budgeting of SAIDI for the year.

Vehicle response does not sufficiently explain long duration incidents

- When an incident is long, the majority of time spent by an employee is on site, and recently a drop in the share of incident time attributed to travelling has decreased

- Neither percentage of time spent travelling, nor vehicle response time are associated with longer duration incidents.
- Vehicle response times (time until the first vehicle begins travelling) have not changed significantly, and the variance in response times has in fact decreased - indicating that responses have improved in terms of consistency.
- However, it is worth noting that the average employee travel time has increased during YE2023, and the frequency of more extreme travel times (>300mins) has been higher in YE2022-YE2022.
- The longer an incident, the lower the percentage of time actually spent travelling.
- The longest incidents also tend to correspond with below average vehicle delays.

Recommendations: Improving vehicle response is unlikely to make any significant difference to incidents that are very long (>1000 min). Instead, focus should be concentrated on improving the efficiency of onsite activity. However, for short incident durations, reducing overall vehicle times may be effective.

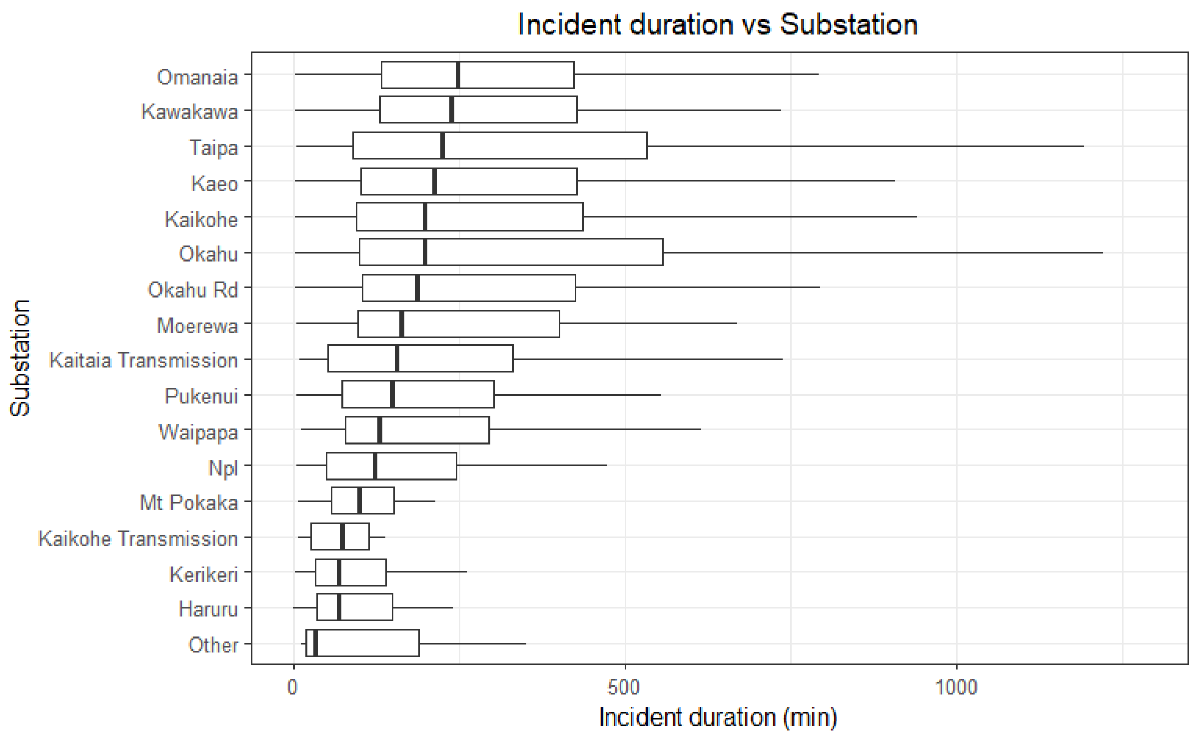
The top 5 substations contribute more than half of all SAIDI

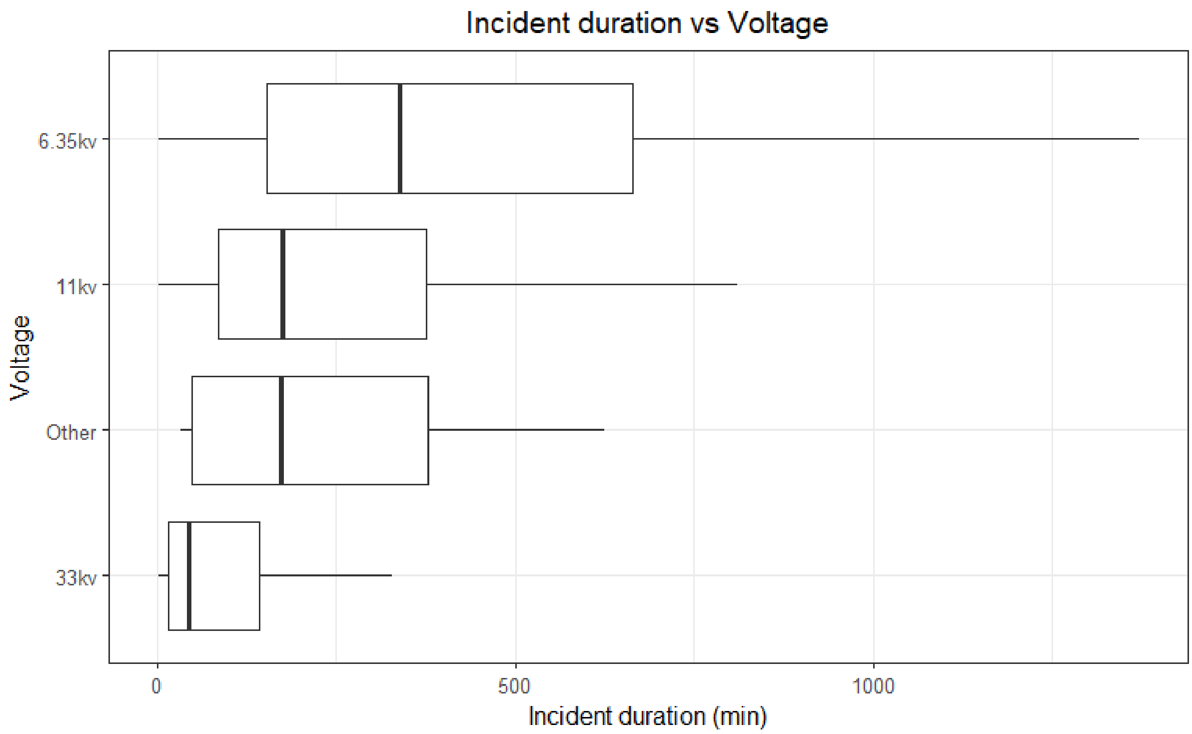
- The top five substations Kaikohe / Okahu Rd / Taipa / Kawakawa / Omanaia) are responsible for 62.9% of all SAIDI. These five substations have generally been the top contributors to SAIDI from YE2020 to YE2022, except for Kawakawa which has been gradually increasing its SAIDI output each year.
- Interestingly, Kaikohe and Taipa, which typically generate the highest SAIDI minutes per year, decreased its SAIDI output in YE2023
- These substations are not associated with long duration events, but have some combination of either a high incident frequency, or average number of ICPs affected. Kaikohe and Okahu Rd both seem to have an unusually high number of incidents (>200), whereas Taipa and Kawakawa affect a large number of ICPs.
- Kawakawa's increase in overall SAIDI can be attributed to an increase in frequency of higher SAIDI scoring incidents in YE2023.

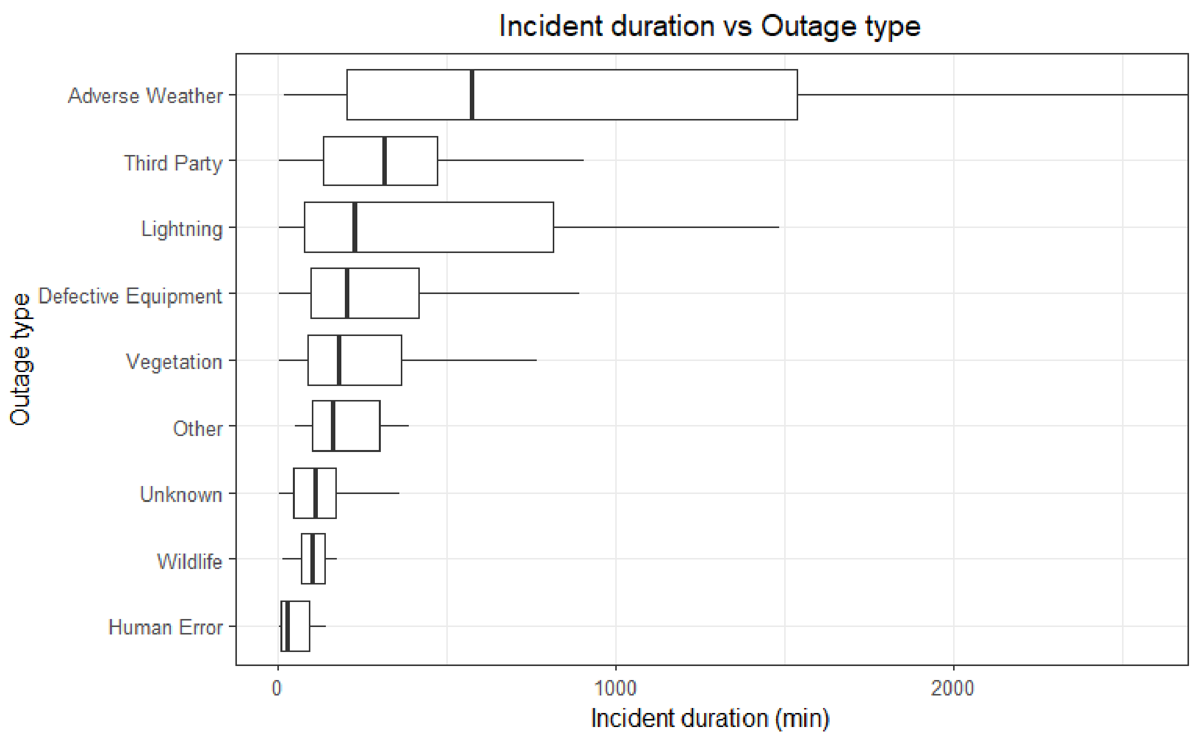
Recommendations: Further investigation is recommended to determine why Kawakawa's SAIDI output in YE2023 has increased.

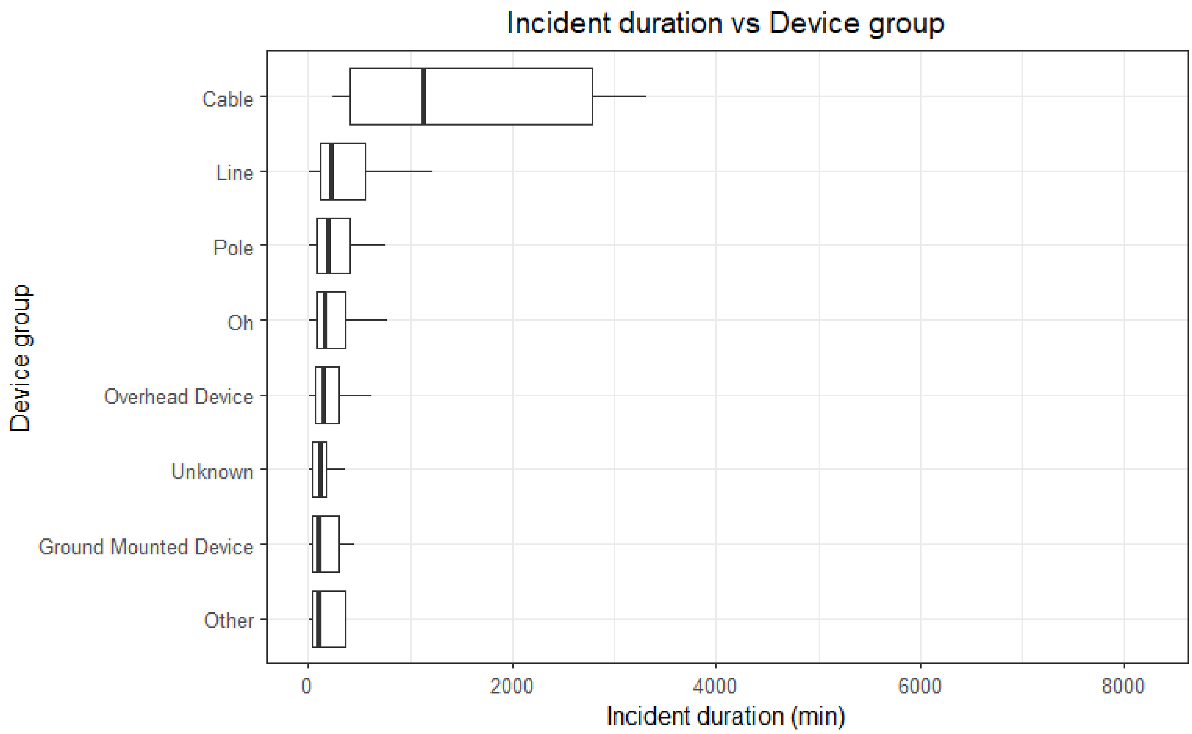
Appendices

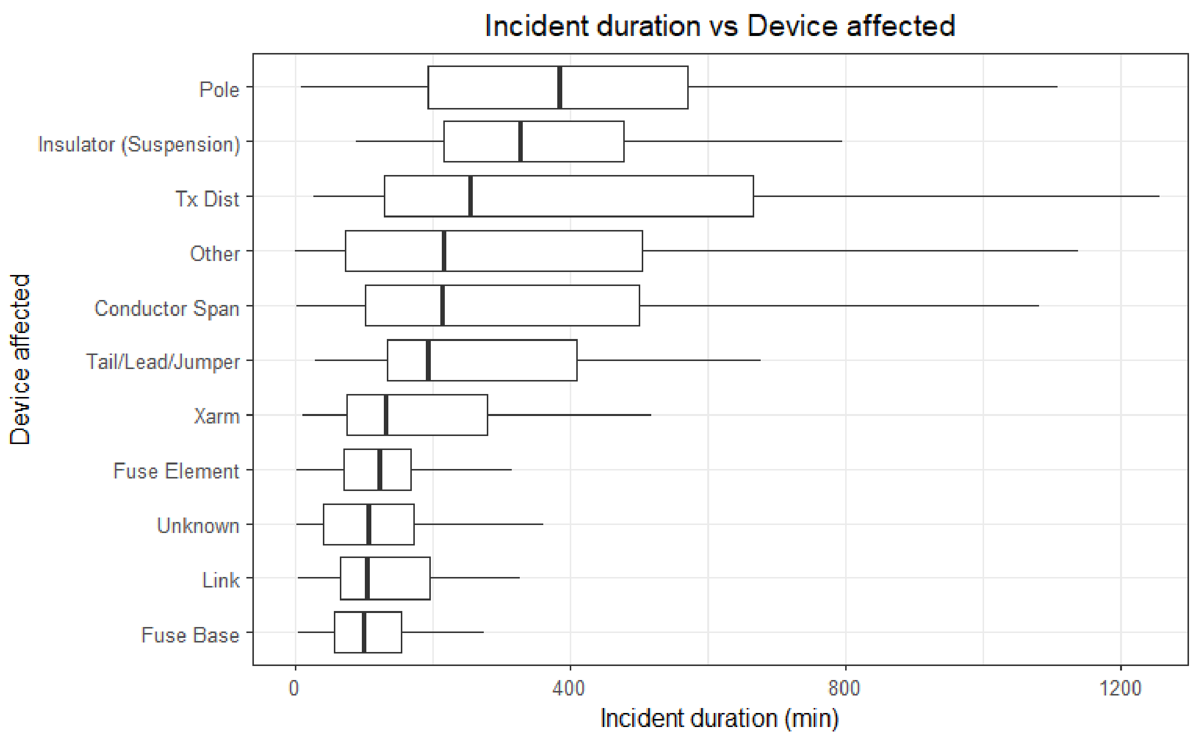
Incident Duration Plots

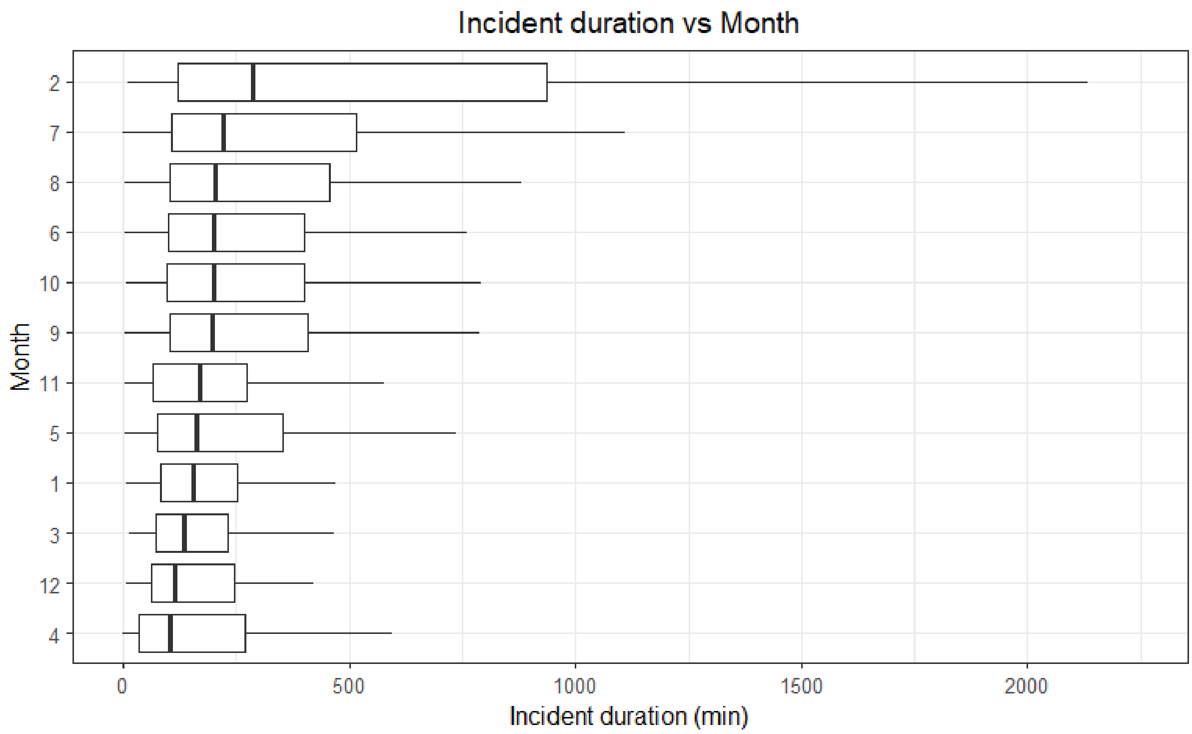


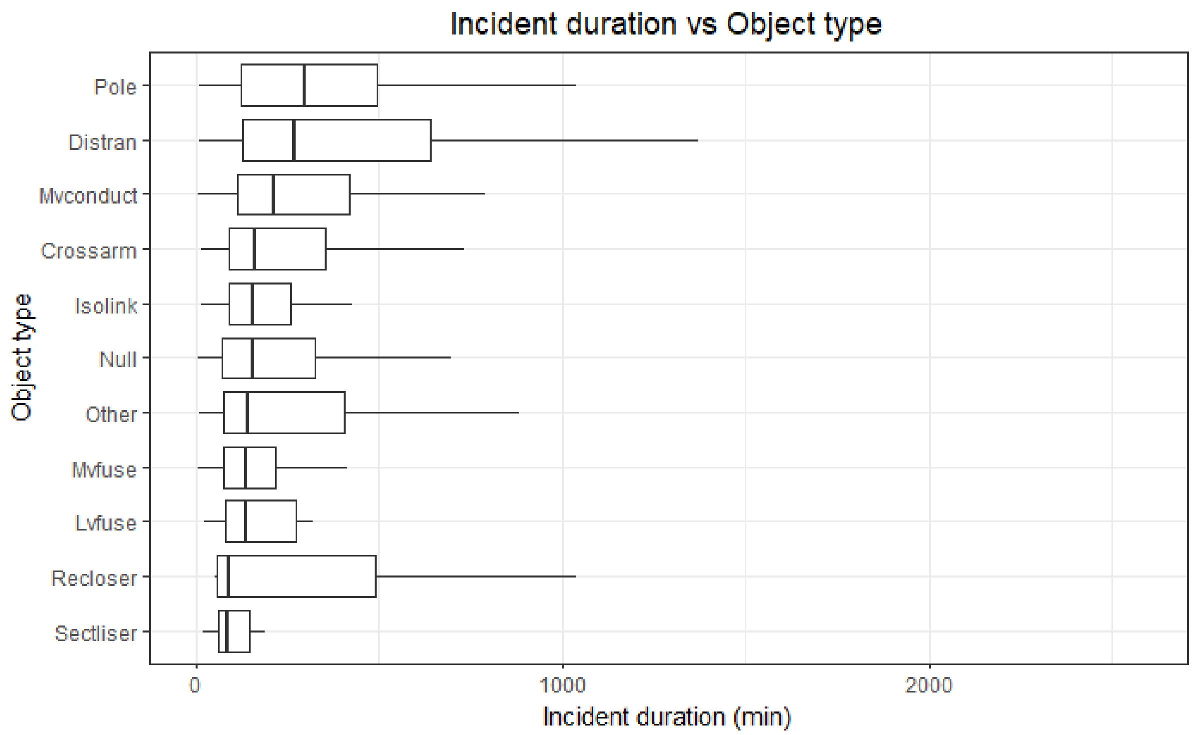

Incident duration vs Voltage
6.35kv
11kv
Other
33kv
Voltage
0
500
1000
Incident duration (min)

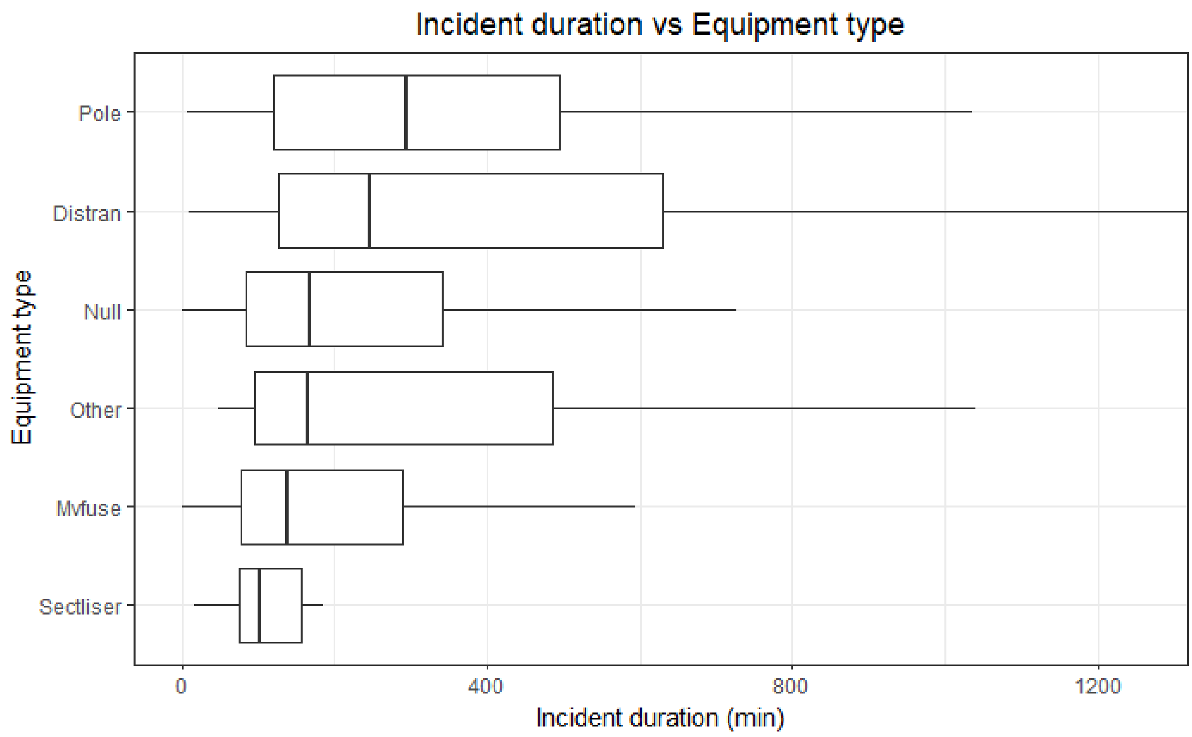

Incident duration vs Outage type
Adverse Weather
Third Party
Lightning
Defective Equipment
Vegetation
Other
Unknown
Wildlife
Human Error
Outage type
0
1000
2000
Incident duration (min)

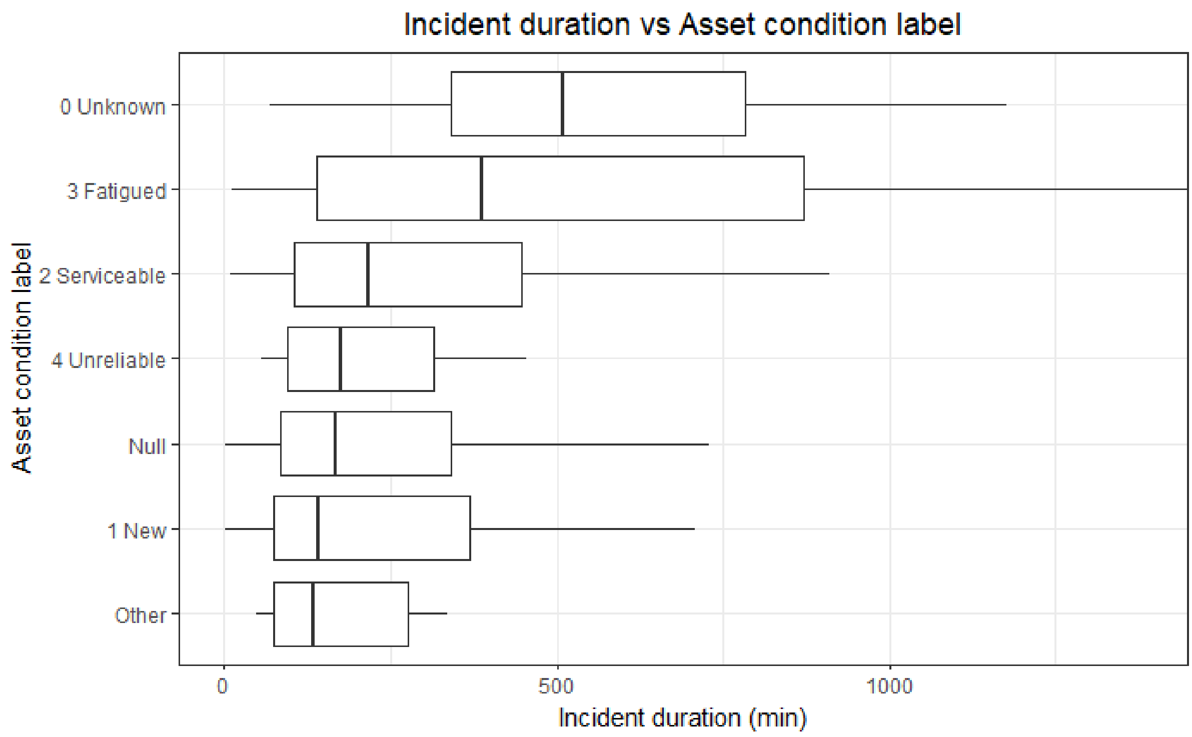

Incident duration vs Device group
Device group
Cable
Line
Pole
Oh
Overhead Device
Unknown
Ground Mounted Device
Other
0
2000
4000
6000
8000
Incident duration (min)

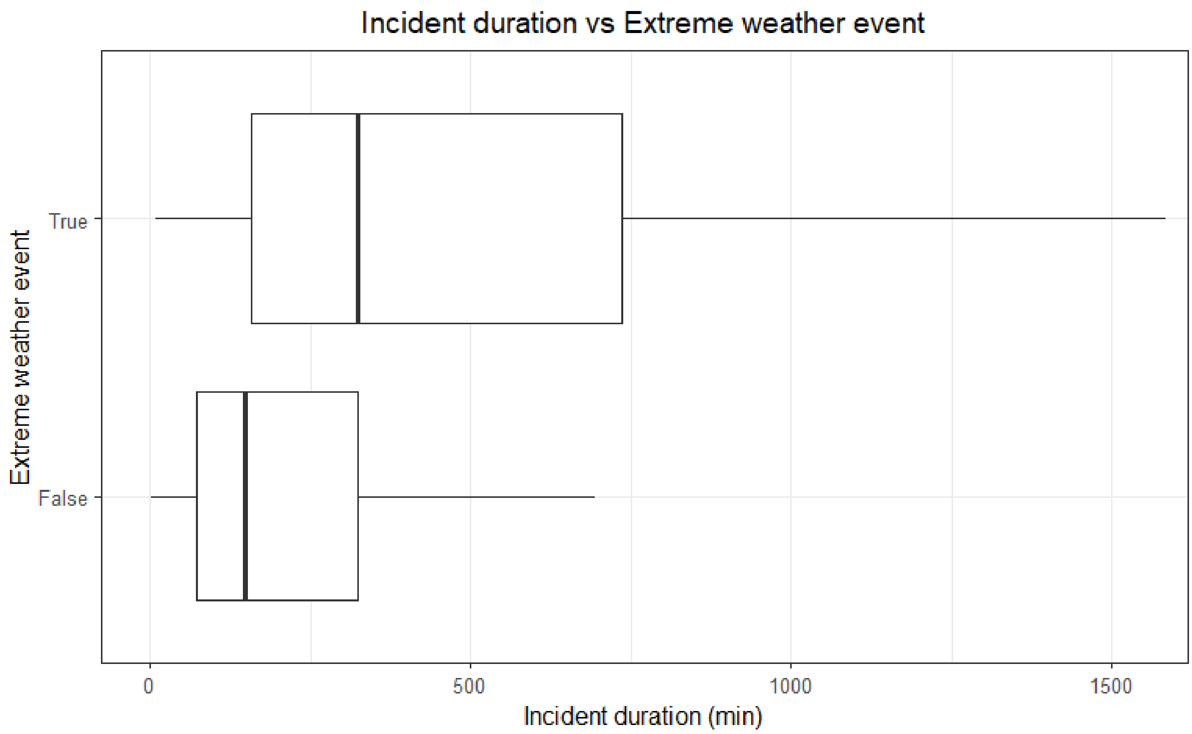

Incident duration vs Device affected
Device affected
Pole
Insulator (Suspension)
Tx Dist
Other
Conductor Span
Tail/Lead/Jumper
Xarm
Fuse Element
Unknown
Link
Fuse Base
0
400
800
1200
Incident duration (min)

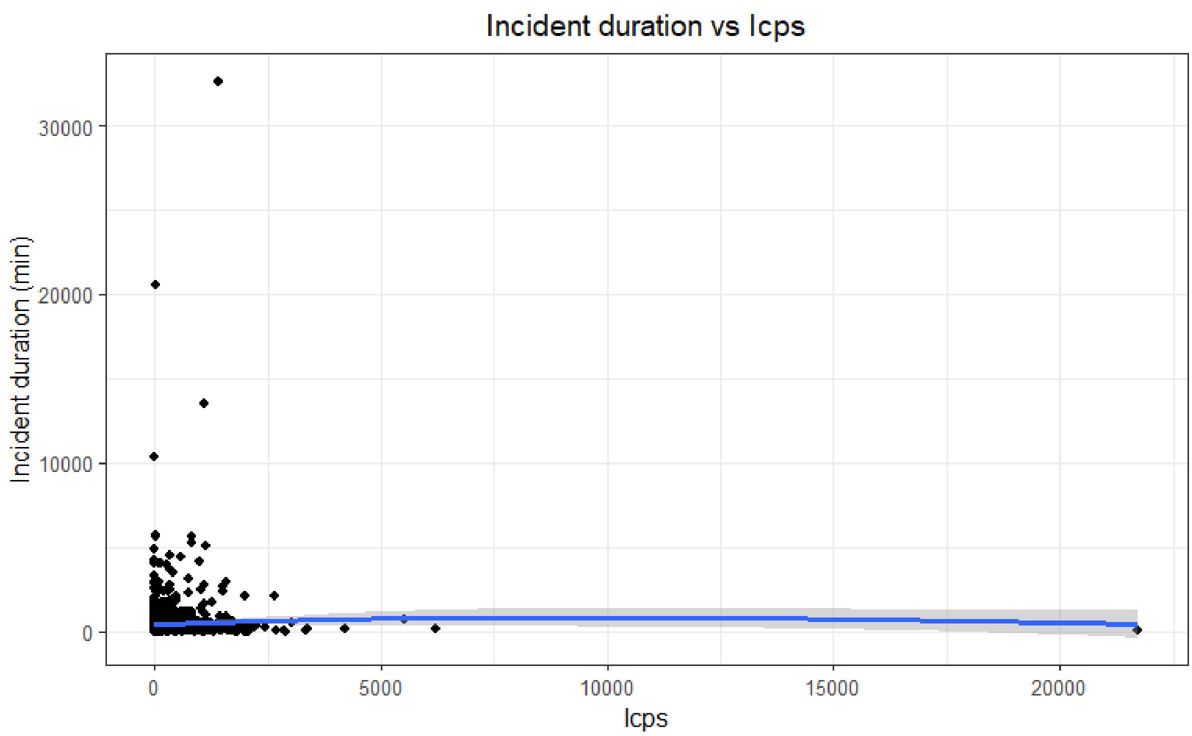

Incident duration vs Month
Month
2
7
8
6
10
9
11
5
1
3
12
4
0
500
1000
1500
2000
Incident duration (min)

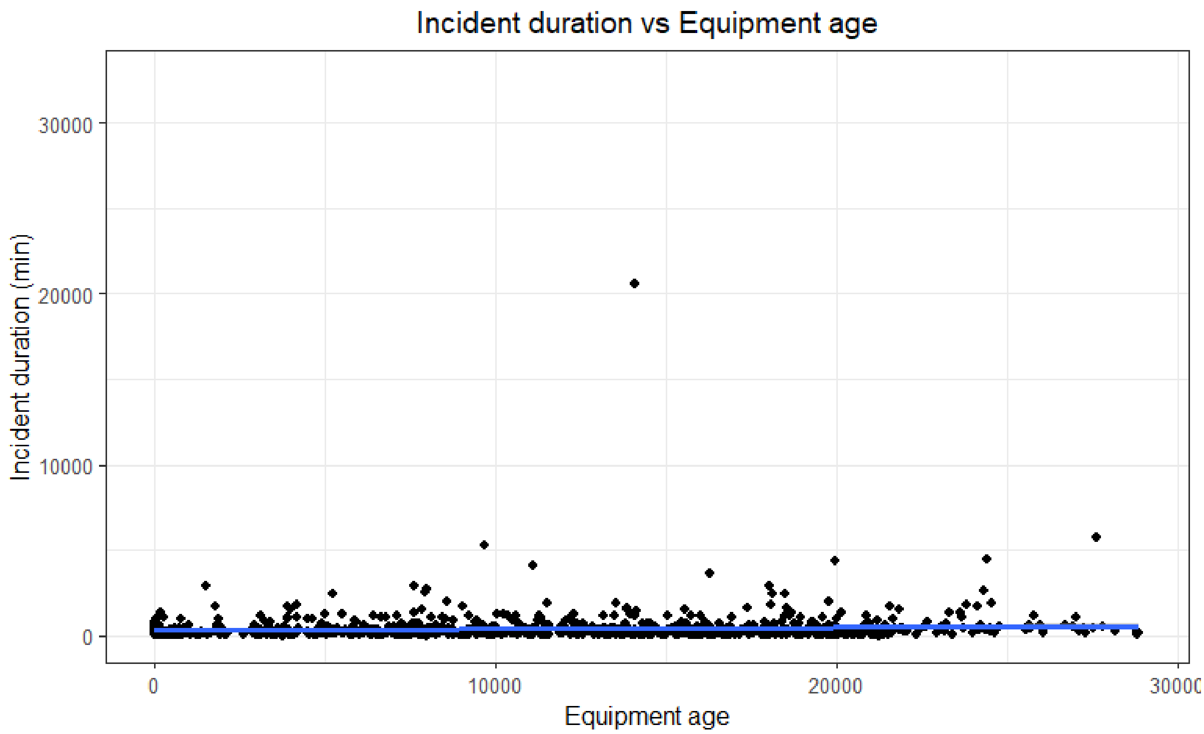

Incident duration vs Object type
Object type
Pole
Distran
Mvconduct
Crossarm
Isolink
Null
Other
Mvfuse
Lvfuse
Recloser
Sectliser
0
1000
2000
Incident duration (min)


Incident duration vs Equipment type
Equipment type
Pole
Distran
Null
Other
Mvfuse
Sectliser
0
400
800
1200
Incident duration (min)


Incident duration vs Asset condition label
Asset condition label
0 Unknown
3 Fatigued
2 Serviceable
4 Unreliable
Null
1 New
Other
0
500
1000
Incident duration (min)


Incident duration vs Extreme weather event
Extreme weather event
True
False
0
500
1000
1500
Incident duration (min)


Incident duration vs Icps
Incident duration (min)
30000
20000
10000
0
0
5000
10000
15000
20000
Icps


Incident duration vs Equipment age
Incident duration (min)
30000
20000
10000
0
0
10000
20000
30000
Equipment age

Appendix 7

21011 TOP 11kV Network Protection

Settings Review

Top Energy Ltd.

21011:1/ Revision C / 2-Feb-2023

INSPIRED. AGILE. GENUINE.

ERGO CONSULTING

Document history and status

Revision	Date	Author	Reviewed by	Approved by	Status
A	07/12/2021	A. Barrow	S. Timmins	S. Doar	For Issue
B	01/03/2022	A. Barrow	A. Barrow	S. Doar	For Issue
C	02/02/2023	A. Barrow	A. Barrow	S. Doar	For Issue

Revision details

Revision	Details
A	First issue to Client.
B	MOE updated to reflect different CT ratios found on site.
C	Updates per implementation findings.

Table of Contents

1. Executive Summary

A review of the 11kV network protection was carried out for Top Energy in 2019. The review identified a few grading anomalies and a number of opportunities to improve the protection coordination. In addition to these findings the report provided full proposed revisions of the grading schemes for consideration. Ergo met with Top Energy on 20 January 2021 to discuss the scope for implementation. Apart from specific items requiring attention, it was agreed to eliminate feeder and recloser hiset elements where possible in order to prevent possible overtripping. In the case of the reclosers, disabling of hiset elements also allows automatic reclosing to take place for faults that would otherwise result in a close lockout.

The defined scope of work has been carried out, as presented in the detailed per-substation calculation spreadsheets. The spreadsheets include notes describing the methodology followed and the decision-making process. Tabulated settings summaries are provided, both of the applied settings and the settings changes to be made. It is noted that removal of hiset elements has in most instances required changes to the grading schemes. This requirement was presented to Top Energy via email to ensure that this consequential aspect of the scope was acceptable.

Some of the settings reviews carried out previously were no longer applicable due to protection or network changes having been made subsequently. The reviews were therefore generally treated as "clean-sheet" exercises, with references to the earlier report as appropriate.

An accepted consequence of hiset removal is that close-in faults will take longer to be cleared. Close-in faults are relatively rare and the trade-off is therefore in favour of improving protection selectivity. Ergo nevertheless recommends that the number of autoreclosing attempts be reduced if/where practicable in order to minimise the impact on affected network components. A further consideration would be to implement sequential fast and slow trips (fuse-saving schemes) on the feeders and reclosers. This is considered as an option for the feeders because there are sections of small conductor quite close to the subs in some instances and these are potentially at risk with repeated reclosing onto heavy faults. Both of the above suggestions are subject to assessment by Top Energy's network team, as real-life performance history might indicate that the changes would be of little value. In some instances hiset elements have been retained on the feeders to protect at-risk conductors. Affected substations are Kaikohe, Kawakawa, Waipapa, Okahu and Northern Pulp.

2. Discussion

The agreed scope items for this project are itemised below. All of the items have been addressed, as detailed in the settings spreadsheets. Where the identified action is no longer relevant, this has been pointed out in the spreadsheets as well.

1. Eliminate feeder hiset elements unless they are required for a particular reason.

2. Waipapa aerodrome feeders: As these feeds are now from Kerikeri the feeders at Waipapa can revert to "normal" feeder settings with reduced pickups.

3. Check EF settings against cable screen ratings (typically applicable to first few hundred metres of the feeder).

4. Assume that current transformer continuous thermal limit is 1.2 p.u. of rated current for adequacy checks.

5. Settings to be provided in raw format, not as proprietary settings databases.

6. Omanaia now has new switchgear, protection and settings. The new settings have been provided to Ergo by Top energy. The review to include a general coordination review of the network downstream of the Omanaia 11kV feeder breakers.

7. The Pukenui transformer presently has an HV hiset overcurrent element set at CHT3322. As Pukenui is getting a 33kV busbar, the hiset at Church Road must be disabled, to be replaced by an element set at the Pukenui transformer HV breaker.

8. Only the specific issued identified in the 2019 report are to be addressed. General review changes shall not be applied.

9. No “special” protection (e.g. voltage-controlled overcurrent) is to be set.

Specific Items (from 2019 report):

1. Disable hiset elements for reclosers. Hisets are a valid means of reducing dip durations and fault impact on network components. They do however introduce a risk of overtripping and longer restoration times.

2. Check that transformer HV hisets do not look through the transformer. The problem is generally only present when transformers at a two-transformer substation are operated out of parallel (bus section open or one transformer out of service).

3. Retain existing definite-time earth fault regimes.

4. **Kaikohe**: Slow down the transformer HV and incomer to grade with slowest feeders when only one transformer is in service.

5. **Kaikohe:** The incomer O/C pickup is set to 600A (~ONAN full load). Projected maximum load is ~570A. Propose to raise the pickup to the CT thermal limit (720A).

6. **Waipapa:** Resolve the issue of the incomer O/C being set slower than the transformer HV O/C.

7. **Waipapa:** Address inadequate E/F grading margin between R-496 and CB407.

8. **Moerewa:** Reduce HV and incomer O/C pickups, which are currently substantially above the ONAF rating.

9. **Kerikeri:** Review HV hiset O/C as there is a small risk of this tripping for a through fault. Feeder O/C does not grade with R-024 for faults above ~1.5kA. Check if feeder can be slowed.

10. **Kawakawa:** Review transformer HV and incomer pickups as they appear to be unnecessarily high. These elements can also potentially be sped up.

11. **Kawakawa:** HV hiset may see through the transformer with only one transformer in service – setting to be reviewed.

12. **Haruru:** Review HV E/F pickup – currently set quite high.

13. **Omanaia:** O/C settings applied under recent switchgear replacement look OK – grading between the incomer and the feeders at maximum fault level is not ideal and will be reviewed with a view to increasing the margin slightly. E/F and reclosers not yet checked.

14. **Okahu:** HV hiset is currently in order but could be increased to remain stable for through faults in future. To be reviewed.

15. **Pukenui:** There is no grading between the HV and the incomer (and negative grading for phase-phase faults) – to be reviewed.

16. **Pukenui:** HV hiset is disabled – hiset tripping is at CHT3332. To be addressed per point g) above.

17. **Taipa:** There is no margin between KTA1162 and the transformer HV O/C. To be reviewed as this arrangement is not ideal. Introduce an HV hiset element.

18. **NPL:** R-400 E/F does not grade with the feeder – to be reviewed.

19. **Kaeo:** Settings not yet reviewed – review to be carried out under this project.

The general approach taken for this review (apart from addressing the specific items above) was to disable hiset elements and then review the protection grading based on the inverse-time elements only. Typically grading was compromised at fault levels beyond the hiset point, resulting in a need to revise upstream grading.

An accepted consequence of hiset removal is that close-in faults will take longer to be cleared. Close-in faults are relatively rare and the trade-off is therefore in favour of improving protection selectivity. Ergo nevertheless recommends that the number of feeder autoreclosing attempts be reduced where practicable in order to minimise the impact on affected network components. (It is noted that this may not be possible due to interference with downstream sectionaliser shot counts.) A further consideration would be to implement sequential fast and slow trips (fuse-saving schemes) on the feeders and reclosers. This is considered an option for the feeders because there are sections of small conductor quite close to the subs in some instances and these are potentially at risk with repeated reclosing onto heavy faults. Both of the above suggestions are subject to assessment by Top Energy's network team, as real-life performance history might indicate that the changes would be of little value. In some instances hiset elements have been retained on the feeders to protect at-risk conductors. Affected substations are Kaikohe, Kawakawa, Waipapa, Okahu and Northern Pulp. These hisets can be disabled at any time if the risk to conductors is considered acceptable or if other risk-mitigation methods are implemented. Overall grading will not be affected.

For the reclosers, it was found that inverse-time tripping for close-in faults was fairly fast, so that the hiset elements did not significantly improve clearance times. Fault levels at or beyond the reclosers are often quite low, meaning that multiple reclosures would not put excessive stress on the network. Existing definite-time earth fault grading is generally in order and it was usually only necessary to disable the hiset elements where they had been implemented. The reclosers do not have fuse-saving schemes (sequential fast and slow trips). Ergo recommends that these be considered if the fault history suggests that they might be beneficial.

3. Implementation of settings changes

While the currently-applied settings as captured are assumed to be accurate per the site settings, it is essential that they be checked against the applied settings prior to implementing changes. This applies to all associated settings, not only the ones that are being changed. If there are discrepancies, these must first be evaluated relative to the issued settings to determine if they will have any impact on the new grading schemes.

It is recommended that the relays and tripping be tested via secondary injection to prove correct operation once the settings have been updated. If this is not possible, correct operation is dependent on all tripping elements having been correctly identified and revised under the review, and on relay logic being per the provided applied settings. Any additional checks that can be carried out during the implementation process will reduce the risks associated with not testing.

Settings are issued in raw tabulated format. No logic settings changes have been proposed. Once a hiset element has been disabled, for example, it will still appear in the CB fail equation, SCADA indication, autoreclose initiate equation and possibly others as well. Whether this is acceptable has been left to TOP to decide.

4. Settings Summaries

4.1 Kaikohe

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Fdr Type	Grades With	Comment
Incomer 3	33 kV	IEC SI	1200 A	1 A	**1200/1**	0.98	0.22						
Incomer 2	33 kV	IEC SI	1200 A	1 A	**1200/1**	0.59	0.30						
Trfr. HV 1st	33 kV	IEC SI	500 A	1 A	**500/1**	0.48	0.13	2.94	0.00 s				F51
Trfr. HV 2nd	33 kV	IEC SI	500 A	1 A	**500/1**	0.48	0.13	2.94	0.00 cyc				F87
Incomer	11 kV	IEC SI	600 A	1 A	**600/1**	1.00	0.12						
Feeders	11 kV	IEC SI	200 A	5 A	**40/1**	5.00	0.10	40.00	0.00 cyc	except 105			
Slow Fdrs	11 kV	IEC SI	200 A	5 A	**40/1**	7.50	0.14	100.00	0.25 cyc	105			
R-587	22 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	0.60	0.016 s	105	Slow	105	
R-607	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	1.21	0.016 s	108		108	
R-106	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.075	0.10	0.33	0.016 s	108		R-607	
R-458	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.12	0.12			109		109	
R-432	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.08	0.10	0.90	0.016 s	110		110	
R-518	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.08	0.10	0.90	0.016 s	110		110	
R-1420	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10			105	Slow	R-587	
R-694	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	111		111	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Name	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment
HV EF 1st	500	100	0.20	0.00 s			F51
HV EF 2nd	500	78	0.16	7.50 cyc			F87
Inc. EF 1st	800	120	0.15	1.60 s			F51
Inc. EF 2nd	1200	120	0.10	70.00 cyc			F87
Feeder	40	20	0.50	50.00 cyc	except 105		
Slow Fdrs	40	40	1.00	50.00 cyc	105		
R-587	1000	12	0.012	0.60 s	105	105	
R-607	1000	10	0.01	0.50 s	108	108	
R-607	1000	320	0.32	0.016 s	108	108	hiset
R-106	1000	10	0.01	0.20 s	108	R-607	
R-106	1000	320	0.32	0.016 s	108	R-607	hiset
R-458	1000	15	0.015	0.60 s	109	109	
R-432	1000	15	0.015	0.60 s	110	110	
R-432	1000	480	0.48	0.016 s	110	110	hiset
R-518	1000	15	0.015	0.60 s	110	110	
R-518	1000	480	0.48	0.016 s	110	110	hiset
R-694	1000	15	0.015	0.60 s	111	111	
R-1420	1000	22	0.022	0.20 s	105	R-587	
R-694	1000	480	0.480	0.016 s	111	111	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Fdr Type	Grades With	Comment	Action
Incomer 3	33 kV			IEC SI	1200 A	1 A	**1200/1**	0.98	0.22							
Incomer 2	33 kV			IEC SI	1200 A	1 A	**1200/1**	0.59	0.30							
Trfr. HV 1st	33 kV	751A	51P1/50P1	IEC SI/Inst	500 A	1 A	**500/1**	0.56	0.22	4.13	0.00 s				F51	Change
Trfr. HV 2nd	33 kV	387A	51P1/50P11	IEC SI/Inst	500 A	1 A	**500/1**	0.56	0.22	4.13	0.00 cyc				F87	Change
Incomer	11 kV	351S	51P1	IEC SI	600 A	1 A	**600/1**	1.20	0.20							Change
Feeders	11 kV	351S	51P1	IEC SI	200 A	5 A	**40/1**	5.00	0.14	87.50	0.00 cyc	except 105 & 110				Change
Slow Fdrs	11 kV	351S	51P1/50P1	IEC SI/DefT	200 A	5 A	**40/1**	7.50	0.14	100.00	2.50 cyc	105				
Fdr 110	11 kV	351S	51P1/50P1	IEC SI/DefT	200 A	5 A	**40/1**	7.50	0.14	100.00	2.50 cyc	110				Change
R-587	22 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	Disable	Disable	105	Slow	105		Change
R-607	11 kV	Form 6	Inv	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	108		108		Change
R-106	11 kV	Form 6	Inv	IEC VI/DefT	1000 A	1 A	**1000/1**	0.075	0.10	0.33	0.016 s	108		R-607		
R-458	11 kV	Form 6	Inv	IEC VI	1000 A	1 A	**1000/1**	0.12	0.12	Disable	Disable	109		109		Change
R-432	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.08	0.10	Disable	Disable	110		R-1708		Change
R-518	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.08	0.10	Disable	Disable	110		R-1708		Change
R-1420	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10			105	Slow	R-587		
R-1708	11 kV		Inv	IEC VI	400 A	1 A	**400/1**	0.50	0.13			110		110		Change
R-694	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	111		111		Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Name	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment	Action
HV EF 1st	500	751A	50G1	100	0.20	0.15 s			F51	
HV EF 2nd	500	387A	50N11	78	0.16	7.50 cyc			F87	
Inc. EF 1st	800	351S	50N1	120	0.15	80.00 cyc			F51	
Inc. EF 2nd	1200	387A	50N2	120	0.10	75.00 cyc			F87	As left
Feeder	40	351S	50N1	20	0.50	50.00 cyc	except 105 & 110			
Slow Fdrs	40	351S	50N1	40	1.00	50.00 cyc	105			
Fdr 110	40	351S	50N1	30	0.75	60.00 cyc	110			
R-587	1000	Form 6	DefT	12	0.012	0.60 s	105	105		
R-587	1000	Form 6	hiset	Disable	-	Disable	105	105		Change
R-607	1000	Form 6	DefT	15	0.015	0.60 s	108	108		
R-607	1000	Form 6	hiset	Disable	-	Disable	108	108		Change
R-106	1000	Form 6	DefT	10	0.01	0.20 s	108	R-607		
R-106	1000	Form 6	hiset	320	0.32	0.016 s	108	R-607		
R-458	1000	Form 6	DefT	15	0.015	0.60 s	109	109		
R-432	1000	Form 6	DefT	15	0.015	0.60 s	110	110		
R-432	1000	Form 6	hiset	Disable	-	Disable	110	R-1708		Change
R-518	1000	Form 6	DefT	15	0.015	0.60 s	110	R-1708		
R-518	1000	Form 6	hiset	Disable	-	Disable	110	R-1708		Change
R-1420	1000	Form 6	DefT	22	0.022		105	R-587		
R-1708	400		DefT	20	0.050	0.90s	110	110		
R-694	1000	Form 6	DefT	15	0.015	0.60 s	111	111		
R-694	1000	Form 6	hiset	Disable	-	Disable	111	111		Change

`

4.2 Kerikeri

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Comment
KOE3672	33 kV	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 cyc	
KOE3602	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 cyc	
Trfr. HV 1st	33 kV	IEC SI	500 A	1 A	**500/1**	0.48	0.13	2.94	0.00 s	F51
Trfr. HV 2nd	33 kV	IEC SI	500 A	1 A	**500/1**	0.48	0.13	2.94	0.00 cyc	F87
Incomer	11 kV	IEC SI	750 A	1 A	**750/1**	0.80	0.12			
Feeders	11 kV	IEC VI	250 A	1 A	**250/1**	1.00	0.15	8.00	0.00 cyc	
R-024	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.14	0.10	1.00	0.00 s	Bypassed

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Name	CTR	Pickup Ap	Pickup As	Delay	Comment
HV EF 1st	500	100	0.20	0.15 s	F51
HV EF 2nd	500	80	0.16	7.50 cyc	F87
Inc. EF 1st	800	120	0.15	80.00 cyc	F51
Inc. EF 2nd	750	120	0.16	70.00 cyc	F87
Feeders	250	25	0.10	50.00 cyc	
R-024	1000	10	0.01	0.10 s	Bypassed

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Comment	Action
KOE3672	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 cyc		
KOE3602	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 cyc		
Trfr. HV 1st	33 kV	751A	51P1/50P1	IEC SI/Inst	500 A	1 A	**500/1**	0.48	0.18	3.88	0.00 s	F51	Change
Trfr. HV 2nd	33 kV	387A	51P1/50P11	IEC SI/Inst	500 A	1 A	**500/1**	0.48	0.18	3.88	0.00 cyc	F87	Change
Incomer	11 kV	351S	51P1	IEC SI	750 A	1 A	**750/1**	0.80	0.16				Change
Feeders	11 kV	351S	51P1	IEC VI	250 A	1 A	**250/1**	1.00	0.15	8.00	0.00 cyc		

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Comment	Action
HV EF 1st	500	751A	50G1	100	0.20	0.15 s	F51	
HV EF 2nd	500	387A	50N11	80	0.16	7.50 cyc	F87	
Inc. EF 1st	800	351S	50N1	120	0.15	80.00 cyc	F51	
Inc. EF 2nd	750	387A	50N21	120	0.16	70.00 cyc	F87	
Feeders	250	351S	50N1	25	0.10	50.00 cyc		

4.3 Kawakawa

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades With	Comment
KOE3692	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	3.75	0.00 s			
KOE3602	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s			
Bus Section	33 kV	C1	300 A	1 A	**300/1**	2.00	0.10	5.00	0.00 s			
Trfr. HV 1st	33 kV	C1	500 A	1 A	**500/1**	0.30	0.19	2.00	5.00 cyc			F51
Trfr. HV 2nd	33 kV	C1	300 A	1 A	**300/1**	0.60	0.19	2.50	0.00 cyc			F87T
Incomer 1st	11 kV	IEC SI	600 A	5 A	**120/1**	3.75	0.18					F51
Incomer 2nd	11 kV	IEC SI	600 A	1 A	**600/1**	0.75	0.18					F87T
Fdrs 9 & 10	11 kV	IEC SI	150 A	5 A	**30/1**	7.50	0.10					
Fdrs except 9 & 10	11 kV	IEC SI	150 A	5 A	**30/1**	6.25	0.10					
R-050	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	0.85	0.016 s	206	fdr	
R-131	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	0.85	0.016 s	206	fdr	
R-199	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.12	0.10	0.96	0.016 s	209	fdr	
R-1100	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.15	0.13	0.795	0.016 s	209	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment
HV EF 1st	500	100	0.20	10.00 cyc			F51
HV EF 2nd	300	100	0.33	5.00 cyc			F87
33kV Sect.	300	60	0.20	100.00 cyc			
Inc. EF 1st	600	450	0.75	75.00 cyc			F51
Inc. EF 2nd	600	60	0.10	90.00 cyc			F87
Feeder	30	15	0.50	50.00 cyc			
R-050 & R131	1000	10	0.01	0.50	206	fdr	
R-050 & R131	1000	320	0.32	0.016	206	fdr	hiset
R-199	1000	10	0.01	0.50	209	fdr	
R-199	1000	320	0.32	0.00	209	fdr	hiset
R-1100	1000	10	0.01	0.50	209	fdr	
R-1100	1000	320	0.32	0.016	209	fdr	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades With	Comment	Action
KOE3692	33 kV	311L	51PP/50P1	IEC SI/Inst	800 A	1 A	**800/1**	0.79	0.20	3.75	0.00 s				
KOE3602	33 kV	311L	51PP/50P1	IEC SI/Inst	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s				
Bus Section	33 kV	351S	51P1/2 50P2/3	C1/Inst	300 A	1 A	**300/1**	2.00	0.10	5.00	0.00 cyc				
Trfr. HV 1st	33 kV	451	51S/50P1	C1/DefT	500 A	1 A	**500/1**	0.36	0.19	2.00	5.00 cyc			F51	Change
Trfr. HV 2nd	33 kV	387-6	51PC1 50P11/50P21	C1/DefT	300 A	1 A	**300/1**	0.60	0.19	3.37	0.00 cyc			F87	Change
Incomer 1st	11 kV	351S	51P1	C1	600 A	5 A	**120/1**	3.75	0.18					F51	
Incomer 2nd	11 kV	387-6	51P3	C1	600 A	1 A	**600/1**	0.75	0.18					F87	
Fdrs 9 & 10	11 kV	351S	51P1/50P1	C1	150 A	5 A	**30/1**	7.50	0.13	66.67	0.00 cyc			New element	Change
Fdrs except 9 & 10	11 kV	351S	51P1/50P2	C2	150 A	5 A	**30/1**	6.25	0.13	66.67	0.00 cyc				Change
R-050	11 kV	Form 6	51P1/50P1	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	Disable	Disable	206	fdr		Change
R-131	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	Disable	Disable	206	fdr		Change
R-199	11 kV	Form 6	Inv	IEC VI	1000 A	1 A	**1000/1**	0.12	0.10	Disable	Disable	209	fdr		Change
R-1100	11 kV	Form 6	Inv	IEC VI	1000 A	1 A	**1000/1**	0.15	0.13	Disable	Disable	209	fdr		Change

Earth Fault:

(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment	Action
HV EF 1	500	451	50G1	100	0.20	10.00 cyc			F51	
HV EF 2	300	387-6	51N1C/ S1V2	100	0.33	5.00 cyc			F87	
33kV Sect.	300	351S	50N2/3 50G2/3	60	0.20	100.00 cyc				
Inc. EF 1	80	351S	50N1	60	0.75	75.00 cyc			F51	Change
Inc. EF 2	600	387-6	50N31	60	0.10	90.00 cyc			F87	Change
Feeder	30	351S	50N1	15	0.50	50.00 cyc				
R-050	1000	Form 6	DefT	10	0.01	0.50	206	fdr		
R-050	1000	Form 6	hiset	Disable	-	Disable	206	fdr	hiset	Change
R-131	1000	Form 6	DefT	10	0.01	0.500	206	fdr		
R-131	1000	Form 6	hiset	Disable	-	Disable	206	fdr	hiset	Change
R-199	1000	Form 6	DefT	10	0.01	0.50	209	fdr		
R-199	1000	Form 6	hiset	Disable	-	Disable	209	fdr	hiset	Change
R-1100	1000	Form 6	DefT	10	0.01	0.50	209	fdr		
R-1100	1000	Form 6	hiset	Disable	-	Disable	209	fdr	hiset	Change

4.4 Mt Pokaka

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Comment
KOE3602	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s	
KOE3672	33 kV	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 s	
Trfr. HV	33 kV	C2	100 A	1 A	**100/1**	1.66	0.20			F87 (787)
Incomer	11 kV	C2	400 A	1 A	**400/1**	1.00	0.20			F87 (787)
Feeders	11 kV	C2/Inst	400 A	1 A	**400/1**	0.50	0.20	3.00	0.00 cyc	F51 (351S)

Earth Fault:

(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Comment
HV EF	100	20	0.20	0.00	F87 (787)
Inc. EF 1^{st}	150	30	0.20	2.00 s	F87 (787) (NCT)
Inc. EF 2^{nd}	400	40	0.10	1.50 s	F87 (787) resid.
Feeders	400	20	0.05	50.00 cyc	F51 (351S)

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Comment	Action
KOE3602	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s		
KOE3672	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 s		
Trfr. HV	33 kV	787	51P1/50P11	C2	100 A	1 A	**100/1**	1.66	0.20	8.50	0.10 s	F87 (787)	Change
Trfr. HV	Note: The above 50P11 element is not currently enabled. It is advised to enable, set and test this element. It is currently in the HV tripping equation only.												Change
Incomer	11 kV	787	51P2	C2	400 A	1 A	**400/1**	1.00	0.20			F87 (787)	
Feeders	11 kV	351S	51P1/50P1	C2/Inst	400 A	1 A	**400/1**	0.50	0.20	Disable	Disable	F51 (351S)	Change

Earth Fault:

(Ap/As = Amps pri/Amps sec)

Panel	Relay	Element	CTR	Pickup Ap	Pickup As	Delay	Comment	Action
HV EF	787	50G11	100	20	0.20	0.00	F87 (787)	
Inc. EF 1^{st}	787	50N11	150	30	0.20	2.00 s	F87 (787) (NCT)	
Inc. EF 2^{nd}	787	50G21	400	40	0.10	1.50 s	F87 (787) resid.	
Inc. EF 2^{nd}	Note: To enable the above element 50G21TC must be set = 1.							Change
Feeders	351S	50N1	400	20	0.05	50.00 cyc	F51 (351S)	

4.5 Moerewa

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Feeder Type	Grades with	Comment
KOE3692	33 kV	311L	51PP/50P1	C1	800 A	1 A	800/1	0.79	0.20	3.75	0.00 s				F51
KOE3602	33 kV	311L	51PP/50P1	C1	800 A	1 A	800/1	0.79	0.20	9.38	0.00 s				F51
Trfr. HV 1st	33 kV	751A	51P1/50P1	C1	250 A	1 A	250/1	0.70	0.13	6.00	0.00 s				F51
Trfr. HV 2nd	33 kV	387A	51P1/50P11	C1	250 A	1 A	250/1	0.70	0.13	6.00	0.00 cyc				F87
Incomer	11 kV	351S	51P1	C1	800 A	1 A	800/1	0.50	0.12						F51
Feeders	11 kV	351S	51P1/50P1	C2	250 A	1 A	250/1	1.00	0.15	8.00	0.00 cyc		Other fdrs		F51
Feeders	11 kV	351S	51P1/50P1	C2	500 A	1 A	500/1	0.68	0.15	8.00	0.00 cyc		AFFCO 1&2, Spare		F51
R-481	11 kV	Form 6	Inv/DefT	IEC EI	1000 A	1 A	1000/1	0.10	0.21	1.00	0.016 s	Pokapu		fdr	F51
R-565	11 kV	Form 6	Inv/DefT	IEC-EI	1000 A	1 A	1000/1	0.10	0.21	1.00	0.016 s	Moerewa		fdr	F51

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Fdr Type	Grades With	Comment
HV EF 1st	250	751A	50N1	25	0.10	0.15 s				F51
HV EF 2nd	250	387A	50N11	32	0.13	7.50 cyc				F87
Inc. EF 1st	400	351S	50N1	120	0.30	80.00 cyc				F51 (NCT)
Inc. EF 2nd	800	387A	50N21	240	0.30	70.00 cyc				F87
Feeder	250	351S	50N1	25	0.10	50.00 cyc		Other fdrs		F51
Feeder	500	351S	50N1	25	0.05	50.00 cyc		AFFCO 1&2, Spare		F51
R-481	1000			10	0.01	0.60 s	Pokapu		fdr	
R-481	1000			320	0.32	0.016	Pokapu		fdr	hiset
R-565	1000			10	0.01	0.60 s	Moerewa		fdr	
R-565	1000			320	0.32	0.016	Moerewa		fdr	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Fdr Type	Grades with	Comment	Action
KOE3692	33 kV	311L	51PP/50P1	C1	800 A	1 A	800/1	0.79	0.20	3.75	0.00 s					
KOE3602	33 kV	311L	51PP/50P1	C1	800 A	1 A	800/1	0.79	0.20	9.38	0.00 s					
Trfr. HV 1st	33 kV	751A	51P1/50P1	C2	250 A	1 A	250/1	0.47	0.40	3.84	0.00 s					Change
Trfr. HV 2nd	33 kV	387A	51P1/50P11	C2	250 A	1 A	250/1	0.47	0.40	3.84	0.00 cyc					Change
Incomer	11 kV	351S	51P1	C2	800 A	1 A	800/1	0.38	0.38							Change
Feeders	11 kV	351S	51P1/50P1	C2	250 A	1 A	250/1	1.00	0.15	8.00	0.00 cyc		Other fdrs			
Feeders	11 kV	351S	51P1/50P1	C2	500 A	1 A	500/1	0.50	0.22	Disable	Disable		Spare			Change
R-481	11 kV	Form 6	Inv/DefT	IEC EI	1000 A	1 A	1000/1	0.10	0.21	1.00	0.016 s	Pokapu		fdr		
R-565	11 kV	Form 6	Inv/DefT	IEC-EI	1000 A	1 A	1000/1	0.10	0.21	1.00	0.016 s	Moerewa		fdr		

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Fdr Type	Grades With	Comment	Action
st											
nd											
st											
nd											
Feeder	250	351S	50N1	25	0.10	50.00 cyc		Other fdrs		F51	
Feeder	500	351S	50N1	25	0.05	50.00 cyc		Spare		F51	
R-481	1000	Form 6	DefT	10	0.01	0.60 s	Pokapu		fdr		
R-481	1000	Form 6	hiset	Disable	-	Disable	Pokapu		fdr	hiset	Change
R-564	1000	Form 6	DefT	10	0.01	0.60 s	Moerewa		fdr		
R-565	1000	Form 6	Hiset	Disable	-	Disable	Moerewa		fdr	hiset	Change

4.6 Waipapa

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.
Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Fdr Type	Grades with	Comment
KOE3672	33 kV	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 s				
KOE3602	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s				
Trfr.1 HV 1st	33 kV	C1	1000 A	1 A	**1000/1**	0.30	0.13	1.90	0.00 s				F51 (751A)
Trfr. 1 HV 2nd	33 kV	C1	1000 A	1 A	**1000/1**	0.36	0.13	1.80	0.00 cyc				F87 (387E)
Trfr. 2 HV 1st	33 kV	C1	300 A	1 A	**300/1**	1.00	0.13	6.33	0.00 s				F51 (751A)
Trfr. 2 HV 2nd	33 kV	C1	300 A	1 A	**300/1**	1.20	0.13	6.00	0.00 s				F87 (387E)
Incomers	11 kV	C2	1250 A	1 A	**1250/1**	0.64	0.40						F51 (351S)
Fdrs 1	11 kV	Recl C	1000 A	1 A	**1000/1**	0.20	1.00	2.00	0.00 cyc	405			
Fdrs 2	11 kV	Recl C	1000 A	1 A	**1000/1**	0.40	1.00	2.00	0.00 cyc	406			
Fdrs 3	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.30	0.18	2.00	0.00 cyc	408			
Fdrs 4	11 kV	IEC SI	1000 A	1 A	**1000/1**	0.40	0.20			409			
Fdrs 5	11 kV	Recl C	1000 A	1 A	**1000/1**	0.24	1.00	2.00	0.00 cyc	407			
Fdrs 6	11 kV	Recl C	1000 A	1 A	**1000/1**	0.28	1.00	2.00	0.00 cyc	410	Fdrs 6		
R-086	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.12	0.10	0.96	0.016 s	405	Fdrs 1	fdr	
R-113	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.20	1.40	0.016 s	408	Fdrs 3	fdr	
R-270	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	1.00	0.016 s	408	Fdrs 3	fdr	
R-067	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	1.00	0.016 s	409	Fdrs 4	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Curve	Delay	Fdr CB	Grades With	Comment
T1 HV EF 1st	1000	100	0.10		0.15 s			F51 (751A) measured
T1 HV EF 2nd	1000	100	0.10		0.15 s			F51 (751A) residual
T1 HV EF 3rd	1000	80	0.08		7.50 cyc			F87 (387E)
T2 HV EF 1st	300	20	0.067		0.15 s			F51 (751A) measured
T2 HV EF 2nd	300	30	0.10		0.15 s			F51 (751A) residual
T2 HV EF 3rd	300	78	0.26		7.50 cyc			F87 (387E)
Inc. EF 1st	600	60	0.10		80.00 cyc			F51 (NCT)
Inc. EF 2nd	1250	60	0.048		80.00 cyc			F51
Inc. EF 3rd	1250	125	0.10		70.00 cyc			F87
Fdrs 1	1000	25	0.025		30.00 cyc	405		
Fdrs 2	1000	25	0.025		30.00 cyc	406		
Fdrs 3	1000	30	0.030		50.00 cyc	408		
Fdrs 4	1000	25	0.025		50.00 cyc	409		
Fdrs 5	1000	25	0.025		30.00 cyc	407		
Fdrs 6	1000	25	0.025		30.00 cyc	410		
R-086	1000	15	0.015		0.10s		405	
R-086	1000	480	0.48		0.016s		405	hiset
R-113	1000	15	0.015		0.80s		408	
R-113	1000	100	0.10		0.016s		408	hiset
R-270	1000	10	0.01		0.10s		408	
R-270	1000	320	0.32		0.016s		408	hiset
R-067	1000	15	0.02		0.10s		409	
R-067	1000	480	0.48		0.016s		409	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Fdr Type	Grades with	Comment	Action
KOE3672	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.56	0.32	3.75	0.00 s					
KOE3602	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s					
Trfr.1 HV 1st	33 kV	751A	51P1/50P1	C1	1000 A	1 A	**1000/1**	0.36	0.19	2.00	0.10 s				F51	Change
Trfr. 1 HV 2nd	33 kV	387E	51P1/50P11	C1	1000 A	1 A	**1000/1**	0.36	0.19	2.00	0.00 cyc				F87	Change
Trfr. 2 HV 1st	33 kV	751A	51P1/50P1	C1	300 A	1 A	**300/1**	1.20	0.19	6.67	0.10 s				F51	Change
Trfr. 2 HV 2nd	33 kV	387E	51P1/50P11	C1	300 A	1 A	**300/1**	1.20	0.19	6.67	0.00 cyc				F87	Change
Incomer 1st	11 kV	351S	51P1	C1	1250 A	1 A	**1250/1**	0.64	0.19						F51	Change
Aerodrome Rd Fdr	11 kV	351S	51P1/50P1	C1	300 A	1 A	**300/1**	1.34	0.12	6.67	0.00 cyc				F51	Change
Other Fdrs	11 kV	351S	51P1/50P1	C1	300 A	1 A	**300/1**	1.34	0.12	13.33	0.00 cyc				F51	Change
R-086	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.12	0.10	Disable	Disable	405	Fdrs 1	fdr		Change
R-113	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.20	Disable	Disable	408	Fdrs 3	fdr		Change
R-270	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	408	Fdrs 3	fdr		Change
R-067	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	409	Fdrs 4	fdr		Change

Earth Fault:

(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment	Action
T1 HV EF 1st	1000	751A	50N1	100	0.10	0.15 s			F51 meas	
T1 HV EF 2nd	1000	751A	50G1	100	0.10	0.15 s			F51 resid	
T1 HV EF 3rd	1000	387E	50N11	100	0.10	7.50 cyc			F87	Change
T2 HV EF 1st	300	751A	50N1	100	0.33	0.15 s			F51 meas	Change
T2 HV EF 2nd	300	751A	50G1	100	0.33	0.15 s			F51 resid	Change
T2 HV EF 3rd	300	387E	50N11	100	0.33	7.50 cyc			F87	Change
Inc. EF 1st	600	351S	50N1	60	0.10	80.00 cyc			F51 (NCT)	
Inc. EF 2nd	1250	351S	50G1	60	0.048	80.00 cyc			F51	
Inc. EF 3rd	1250	387E	50N21	125	0.10	70.00 cyc			F87	
Fdrs	300	351S	50N1	30	0.10	50.00 cyc	All			Change
Fdrs	300	351S	50G1	30	0.10	50.00 cyc	All			Change
R-086	1000	Form 6	DefT	15	0.015	0.10s		405		
R-086	1000	Form 6	hiset	Disable	-	Disable		405	hiset	Change
R-113	1000	Form 6	DefT	15	0.015	0.60s		408		Change
R-113	1000	Form 6	hiset	Disable	-	Disable		408	hiset	Change
R-270	1000	Form 6	DefT	10	0.01	0.10s		408		
R-270	1000	Form 6	hiset	Disable	-	Disable		408	hiset	Change
R-067	1000	Form 6	DefT	15	0.02	0.10s		409		
R-067	1000	Form 6	hiset	Disable	-	Disable		409	hiset	Change

4.7 Haruru

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment
KOE3692	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	3.75	0.00 s			
KOE3602	33 kV	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s			
Trfr. HV 1st	33 kV	C1	1000 A	1 A	**1000/1**	0.24	0.13	1.47	0.00 s			F51
Trfr. HV 2nd	33 kV	C1	1000 A	1 A	**1000/1**	0.24	0.13	1.47	0.00 cyc			F87
Incomer	11 kV	C1	600 A	1 A	**600/1**	1.00	0.12					F51
Other fdrs	11 kV	C2	200 A	5 A	**40/1**	6.00	0.15	40.00	0.00 cyc			F51
Fdr 608	11 kV	C1	200 A	5 A	**40/1**	5.00	0.05	25.00	0.00 cyc			F51
R-071	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	1.30	0.016 s	609	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades with	Comment
HV EF 1st	1000	100	0.10	0.15 s			F51
HV EF 2nd	1000	80	0.08	7.50 cyc			F87
Inc. EF 1st	600	120	0.20	80.00 cyc			F51
Inc. EF 2nd	600	120	0.20	70.00 cyc			F87
Feeders	40	20	0.50	50.00 cyc			F51
R-071	1000	10	0.01	0.60 s	609	fdr	
R-071	1000	320	0.32	0.016 s	609	fdr	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KOE3692	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.79	0.20	3.75	0.00 s				
KOE3602	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.79	0.20	9.38	0.00 s				
Trfr. HV 1st	32 kV	751A	51P1/50P1	C1	1000 A	1 A	**1000/1**	0.24	0.18	2.00	0.10 s			F51	Change
Trfr. HV 2nd	33 kV	387A	51P1/50P11	C1	1000 A	1 A	**1000/1**	0.24	0.18	2.00	0.00 cyc			F87	Change
Incomer	11 kV	351S	51P1	C1	600 A	1 A	**600/1**	1.00	0.16					F51	Change
Other fdrs	11 kV	351S	51P1/50P1	C2	200 A	5 A	**40/1**	6.00	0.18	Disable	Disable			F51	Change
Fdr 608	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	5.00	0.05	Disable	Disable			F51	Change
R-071	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	1.30	0.016 s	609	fdr		

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades with	Comment	Action
HV EF 1st	1000	751A	50G1	100	0.10	0.15 s			F51	
HV EF 2nd	1000	387A	50N11	80	0.08	7.50 cyc			F87	
Inc. EF 1st	600	351S	50N1	120	0.20	80.00 cyc			F51	
Inc. EF 2nd	600	387A	50N21	120	0.20	70.00 cyc			F87	
Feeders	40	351S	50N1	20	0.50	50.00 cyc			F51	
R-071	1000	Form 6	DefT	10	0.01	0.60 s	609	fdr		
R-071	1000	Form 6	hiset	Disable	-	Disable	609	fdr	hiset	Change

4.8 Omanaia

Existing:

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment
KOE3582	33 kV	IEC SI	500 A	1 A	**500/1**	0.30	0.30	4.80	0.00 s			
Trfr. HV 1st	33 kV	C1	200 A	1 A	**200/1**	0.99	0.13	7.50	0.00 s			F51
Trfr. HV 2nd	33 kV	C1	200 A	1 A	**200/1**	0.89	0.13	7.50	0.00 cyc			F87
Incomer 1st	11 kV	C1	400 A	1 A	**400/1**	1.00	0.12					F51
Incomer 2nd	11 kV	C1	400 A	1 A	**400/1**	0.85	0.12					F87
Feeders	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15					F51
Gen Inc.	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15					F51 (reverse)
R-385	11 kV	IEC EI	Rogowski Coil			70A pri	0.10	500A pri	0.00 s	504	fdr	Intellirupter
R-460	11 kV	IEC EI	Rogowski Coil			70A pri	0.10	500A pri	0.00 s	506	fdr	Intellirupter

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades with	Comment
HV EF 1st	200	26	0.13	0.15 s			F51
HV EF 2nd	200	32	0.16	7.50 cyc			F87
Inc. EF 1st	400	120	0.30	80.00 cyc			F51
Inc. EF 2nd	400	120	0.30	70.00 cyc			F87
Feeders	200	20	0.10	50.00 cyc			F51
Gen Inc. 1st	200	60	0.30	75.00 cyc			F51 residual (Reverse)
Gen Inc. 2nd	200	80	0.40	80.00 cyc			F51 meas. (Reverse)
Gen Inc. 3rd	200	60	0.30	75.00 cyc			F51 meas. (Non-dir)
R-385	Rogowski Coil	10	-	0.60 s	504	fdr	Basler D curve
R-460	Rogowski Coil	10	-	0.60 s	506	fdr	Basler D curve

New:

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KOE3582	33 kV	311L	51PP/50P1	IEC SI	500 A	1 A	**500/1**	0.30	0.30	4.80	0.00 s				
Trfr. HV 1st	33 kV	751A	51P1/50P1	C1	200 A	1 A	**200/1**	0.50	0.23	4.00	0.10 s			F51	Change
Trfr. HV 2nd	33 kV	387E	51P1/50P11	C1	200 A	1 A	**200/1**	0.50	0.23	4.00	0.10 s			F87	Change
Incomer 1st	11 kV	351S	51P1	C1	400 A	1 A	**400/1**	0.63	0.20					F51	Change
Incomer 2nd	11 kV	387E	51P2	C1	400 A	1 A	**400/1**	0.63	0.20					F87	Change
Feeders	11 kV	351S	51P1	C2	200 A	1 A	**200/1**	1.00	0.17					F51	Change
Gen Inc.	11 kV	351S	51P2 (Rev)	C2	200 A	1 A	**200/1**	1.00	0.15					F51 (reverse)	
R-385	11 kV		Inv	IEC EI	Rogowski Coil			70A pri	0.10	Disable	Disable	504	fdr	Intellirupter	Change
R-460	11 kV		Inv	IEC EI	Rogowski Coil			70A pri	0.10	Disable	Disable	506	fdr	Intellirupter	Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades with	Comment	Action
HV EF 1st	200	751A	50G1	26	0.13	0.15 s			F51	
HV EF 2nd	200	387E	50N11	32	0.16	7.50 cyc			F87	
Inc. EF 1st	400	351S	50N1	120	0.30	80.00 cyc			F51	
Inc. EF 2nd	400	387E	50N21	120	0.30	70.00 cyc			F87	
Feeders	200	351S	50N1	20	0.10	50.00 cyc			F51	
Gen Inc. 1st	200	351S	50G3	60	0.30	75.00 cyc			F51 residual (Reverse)	
Gen Inc. 2nd	200	351S	50N3	80	0.40	80.00 cyc			F51 meas. (Reverse)	
Gen Inc. 3rd	200	351S	50N1	60	0.30	75.00 cyc			F51 meas. (Non-dir)	
R-385	Rogowski Coil			10	-	0.60 s	504	fdr	Basler D curve	
R-460	Rogowski Coil			10	-	0.60 s	506	fdr	Basler D curve	

`

4.9 Kaeo

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.
Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment
KAO3672	33 kV	C1	500 A	1 A	**500/1**	0.66	0.18	0.70	125.00 cyc			F51 (311L)
Trfr.1 HV 1st	33 kV	C1	250 A	1 A	**250/1**	0.89	0.13	3.20	0.00 s			F51 (751A)
Trfr. 1 HV 2nd	33 kV	C1	250 A	1 A	**250/1**	0.89	0.13	3.20	0.00 cyc			F87 (387E)
Incomers	11 kV	C1	800 A	1 A	**800/1**	0.85	0.12					F51 (351S)
Fdr 1712	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15	8.00	0.00 cyc			F51 (351S)
Fdr 1722	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15	8.00	0.00 cyc			F51 (351S)
Fdr 1732	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15	8.00	0.00 cyc			F51 (351S)
Fdr 1772	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15	8.00	0.00 cyc			F51 (351S)
Fdr 1782	11 kV	C2	200 A	1 A	**200/1**	1.00	0.15	8.00	0.00 cyc			F51 (351S)
R-450	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	CB1732	fdr	
R-496	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	CB1722	fdr	
R-293	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	Dip Rd.	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Curve	Delay	Fdr CB	Grades With	Comment
T1 HV EF 1st	250	25	0.10		0.15 s			F51 (751A) residual
T1 HV EF 2nd	250	25	0.10		7.50 cyc			F87 (387E) residual
Inc. EF 1st	400	96	0.24		80.00 cyc			F51 (351S) NCT
Inc. EF 2nd	800	80	0.10		70.00 cyc			F87 (387E)
Fdr 1712	200	20	0.10		50.00 cyc			F51 (351S)
Fdr 1722	200	20	0.10		50.00 cyc			F51 (351S)
Fdr 1732	200	20	0.10		50.00 cyc			F51 (351S)
Fdr 1772	200	20	0.10		50.00 cyc			F51 (351S)
Fdr 1782	200	20	0.10		50.00 cyc			F51 (351S)
R-450	1000	10	0.01	107	0.10	CB1732	fdr	
R-450	1000	320	0.32		0.016 s	CB1732	fdr	hiset
R-496	1000	15	0.015	DefT	0.60 s	CB1722	fdr	
R-496	1000	480	0.48		0.016 s	CB1722	fdr	hiset
R-293	1000	10	0.01	107	0.10	Dip Rd.	fdr	
R-293	1000	320	0.32		0.016 s	Dip Rd.	fdr	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KAO3672	33 kV	311L	51PP/50P1	C1	500 A	1 A	**500/1**	0.66	0.18	0.70	125.00 cyc			F51	
Trfr.1 HV 1st	33 kV	751A	51P1/50P1	C1	250 A	1 A	**250/1**	0.89	0.13	5.00	0.00 s			F51	Change
Trfr. 1 HV 2nd	33 kV	387E	51P1/50P11	C1	250 A	1 A	**250/1**	0.89	0.13	5.00	0.00 cyc			F87	Change
Incomers	11 kV	351S	51P1	C1	800 A	1 A	**800/1**	0.72	0.13					F51	Change
Feeders	11 kV	351S	51P1/50P1	C2	200 A	1 A	**200/1**	1.00	0.12	Disable	Disable			F51	Change
R-450	11 kV	Form 6	Inv/DefT	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	CB1732	fdr	F51	Change
R-496	11 kV	Form 6	Inv/DefT	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	CB1722	fdr	F51	
R-293	11 kV	Form 6	Inv/DefT	IEC VI	1000 A	1 A	**1000/1**	0.10	0.10	0.70	0.016 s	Dip Rd.	fdr	F51	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Curve	Delay	Fdr CB	Grades With	Comment	Action
T1 HV EF 1st	250	751A	50N1	25	0.10		0.15 s			F51 residual	
T1 HV EF 2nd	250	387E	50N11	25	0.10		7.50 cyc			F87 residual	
Inc. EF 1st	400	351S	50N1	96	0.24		80.00 cyc			F51 NCT	
Inc. EF 2nd	800	387E	50N21	80	0.10		70.00 cyc			F87	
Feeders	200	351S	50N1	20	0.10		50.00 cyc			F51	
R-450	1000	Form 6	DefT	10	0.01	107	0.10	CB1732	fdr		
R-450	1000	Form 6	DefT	Disable	-		Disable	CB1732	fdr	hiset	Change
R-496	1000	Form 6	DefT	15	0.015	DefT	0.60 s	CB1722	fdr		
R-496	1000	Form 6	DefT	480	0.48		0.016 s	CB1722	fdr	hiset	
R-293	1000	Form 6	DefT	10	0.01	107	0.10	Dip Rd.	fdr		
R-293	1000	Form 6	DefT	Disable	-		Disable	Dip Rd.	fdr	hiset	Change

4.10 Okahu

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment
KTA1122	33 kV	IEC SI	800 A	1 A	**800/1**	0.48	0.25					F51 (311L)
KTA1082	33 kV	IEC SI	800 A	1 A	**800/1**	0.48	0.25					F51 (311L)
KTA1142	33 kV	IEC SI	400 A	1 A	**400/1**	1.25	0.26					F51 (311L)
Trfr.1 HV 1st	33 kV	C1	200 A	5 A	**40/1**	6.00	0.13	36.75	0.00 s			F51 (751A)
Trfr. 1 HV 2nd	33 kV	C1	200 A	5 A	**40/1**	6.00	0.13	36.75	0.00 cyc			F87 (387A)
Incomers	11 kV	C1	600 A	5 A	**120/1**	5.00	0.12					F51 (351S)
Fdr 1105	11 kV	C1	200 A	5 A	**40/1**	6.25	0.10	50.00	0.00 cyc			F51 (351S)
Fdr 1106	11 kV	C1	400 A	5 A	**80/1**	2.50	0.10	25.00	0.00 cyc			F51 (351S)
Fdr 1107	11 kV	C1	200 A	5 A	**40/1**	5.00	0.10	50.00	0.00 cyc			F51 (351S)
Fdr 1108	11 kV	C1	200 A	5 A	**40/1**	5.00	0.10	50.00	0.00 cyc			F51 (351S)
Fdr 1109	11 kV	C1	200 A	5 A	**40/1**	5.00	0.10	50.00	0.00 cyc			F51 (351S)
Fdr 1110	11 kV	C1	200 A	5 A	**40/1**	5.00	0.10	50.00	0.00 cyc			F51 (351S)
R-750	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.12	0.10	1.20	0.016 s	105	fdr	
R-1462	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10			105	R-750	
R-656	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.34	0.90	0.016 s	108	fdr	
R-126	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.34	0.90	0.016 s	109	fdr	
R-426	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	0.90	0.016 s	108	fdr	
R-464	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	12.10	0.016 s	109	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment
T1 HV EF 1st	40	60	1.50	0.15 s			F51 (751A) residual
T1 HV EF 2nd	40	32	0.80	7.50 cyc			F87 (387A) residual
Inc. EF 1st	120	120	1.00	80.00 cyc			F51 (351S)
Inc. EF 2nd	120	120	1.000	70.00 cyc			F87 (387A)
Fdr 1105	40	20	0.50	50.00 cyc			F51 (351S)
Fdr 1106	80	20	0.25	50.00 cyc			F51 (351S)
Fdr 1107	40	20	0.50	50.00 cyc			F51 (351S)
Fdr 1108	40	20	0.50	50.00 cyc			F51 (351S)
Fdr 1109	40	20	0.50	50.00 cyc			F51 (351S)
Fdr 1110	40	20	0.50	50.00 cyc			F51 (351S)
R-750	1000	12	0.012	0.70 s	105	fdr	
R-750	1000	320	0.320	0.016 s	105	fdr	hiset
R-1462	1000	10	0.01	0.40 s	105	R-750	
R-656	1000	10	0.01	0.50 s	108	fdr	
R-126	1000	10	0.01	0.50 s	109	fdr	
R-426	1000	15	0.015	0.60 s	108	fdr	
R-426	1000	120	0.120	0.016 s	108	fdr	hiset
R-464	1000	10	0.01	0.60 s	109	fdr	

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KTA1122	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.48	0.25					F51	
KTA1082	33 kV	311L	51PP/50P1	IEC SI	800 A	1 A	**800/1**	0.48	0.25					F51	
KTA1142	33 kV	311L	51PP/50P1	IEC SI	400 A	1 A	**400/1**	1.25	0.26					F51	
Trfr.1 HV 1st	33 kV	751A	51P1/50P1	C1	200 A	5 A	**40/1**	6.00	0.20	36.75	0.00 s			F51	Change
Trfr. 1 HV 2nd	33 kV	387A	51P1/50P11	C1	200 A	5 A	**40/1**	6.00	0.20	36.75	0.00 cyc			F87	Change
Incomers	11 kV	351S	51P1	C1	600 A	5 A	**120/1**	5.00	0.19					F51	Change
Fdr 1105	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	6.25	0.12	50.00	0.00 cyc			F51	Change
Fdr 1106	11 kV	351S	51P1/50P1	C1	400 A	5 A	**80/1**	3.13	0.12	25.00	0.00 cyc			F51	Change
Fdr 1107	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	6.25	0.12	50.00	0.00 cyc			F51	Change
Fdr 1108	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	6.25	0.12	50.00	0.00 cyc			F51	Change
Fdr 1109	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	6.25	0.12	50.00	0.00 cyc			F51	Change
Fdr 1110	11 kV	351S	51P1/50P1	C1	200 A	5 A	**40/1**	6.25	0.12	50.00	0.00 cyc			F51	Change
R-750	11 kV	CAPM2	Inv	IEC EI	1000 A	1 A	**1000/1**	0.12	0.14	Disable	Disable	105	fdr		Change
R-1462	12 kV	CAPM3	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10						
R-656	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.20	Disable	Disable	108	fdr		Change
R-126	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.26	Disable	Disable	109	fdr		Change
R-426	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	108	fdr		Change
R-464	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	109	fdr		Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment	Action
T1 HV EF 1st	40	751A	50G1	60	1.50	0.15 s			F51 (751A) residual	
T1 HV EF 2nd	40	387A	50N11	32	0.80	7.50 cyc			F87 (387A) residual	
Inc. EF 1st	120	351S	50N1	120	1.00	80.00 cyc			F51 (351S)	
Inc. EF 2nd	120	387A	50N21	120	1.000	70.00 cyc			F87 (387A)	
Fdr 1105	40	351S	50N1	20	0.50	50.00 cyc			F51 (351S)	
Fdr 1106	80	351S	50N1	20	0.25	50.00 cyc			F51 (351S)	
Fdr 1107	40	351S	50N1	20	0.50	50.00 cyc			F51 (351S)	
Fdr 1108	40	351S	50N1	20	0.50	50.00 cyc			F51 (351S)	
Fdr 1109	40	351S	50N1	20	0.50	50.00 cyc			F51 (351S)	
Fdr 1110	40	351S	50N1	20	0.50	50.00 cyc			F51 (351S)	
R-750	1000	CAPM2	DefT	12	0.012	0.70 s				
R-750	1000	CAPM2	Inst	Disable	-	Disable			hiset	Change
R-1462	1000	Form 6	DefT	10	0.01	0.40 s				
R-656	1000	Form 6	DefT	10	0.01	0.50 s				
R-126	1000	Form 6	DefT	10	0.01	0.50 s				
R-426	1000	Form 6	DefT	15	0.015	0.60 s				
R-426	1000	Form 6	Inst	Disable	-	Disable			hiset	Change
R-464	1000	Form 6	DefT	10	0.01	0.60 s				

4.11 Pukenui

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment
KTA1142	33 kV	C1	400 A	1 A	**400/1**	1.25	0.26					F51 (311L)
CHT3332	33 kV	C1	1000 A	1 A	**1000/1**	0.15	0.18	0.65	0.15 s			F51 (311L)
Trfr.1 HV 1st	33 kV	C1	1000 A	1 A	**1000/1**	0.15	0.10	2.00	10.00 cyc			F51 (351S)
Trfr. 1 HV 2nd	33 kV	C1	1000 A	1 A	**1000/1**	0.15	0.10	2.00	0.00 cyc			F87 (387E)
Incomer 1st	11 kV	C1	1000 A	1 A	**1000/1**	0.45	0.10					F51 (351S)
Incomer 2nd	12 kV	C1	1000 A	1 A	**1000/1**	0.45	0.10					F87 (387E)
Feeders	11 kV	C2	1000 A	1 A	**1000/1**	0.20	0.20					F51 (351R)
R-354	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.075	0.11	2.40	0.016 s	Te Kao	fdr	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment
T1 HV EF 1st	1000	20	0.02	5.00 cyc			F51 (351S) measured
T1 HV EF 2nd	1000	50	0.05	20.00 cyc			F51 (351S) measured
T1 HV EF 3rd	1000	20	0.02	5.00 cyc			F51 (351S) residual
T1 HV EF 4th	1000	50	0.05	20.00 cyc			F51 (351S) residual
T1 HV EF 5th	1000	50	0.05	5.00 cyc			F87 (387E)
Inc. EF 1st	600	120	0.20	75.00 cyc			F51 (351S) NCT
Inc. EF 2nd	1000	120	0.12	80.00 cyc			F51 (351S) residual
Inc. EF 3rd	1000	120	0.12	80.00 cyc			F87 (387E)
Feeders	1000	20	0.02	50.00 cyc			F51 (351R)
R-354	1000	15	0.015	0.50 s	Te Kao	fdr	
R-354	1000	480	0.480	0.016 s	Te Kao	fdr	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KTA1142	33 kV	311L	51PP	C1	400 A	1 A	**400/1**	1.25	0.26					F51	
CHT3332	33 kV	311L	51PP	C1	1000 A	1 A	**1000/1**	0.15	0.26	Disable	Disable			F51	Change
Trfr.1 HV 1st	33 kV	351S	51P1/50P1	C1	1000 A	1 A	**1000/1**	0.15	0.18	0.60	10.00 cyc			F51	Change
Trfr. 1 HV 2nd	33 kV	387E	51P1/50P11	C1	1000 A	1 A	**1000/1**	0.15	0.18	0.60	0.00 cyc			F87	Change
Incomer 1st	11 kV	351S	51P1	C1	1000 A	1 A	**1000/1**	0.40	0.16					F51	Change
Incomer 2nd	11 kV	387E	51P2	C1	1000 A	1 A	**1000/1**	0.40	0.16					F87	Change
Feeders	11 kV	351R	51P1	C2	1000 A	1 A	**1000/1**	0.20	0.20					F51	
R-354	11 kV	Form 6	Inv	IEC VI	1000 A	1 A	**1000/1**	0.075	0.11	Disable	Disable	Te Kao	fdr		Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Fdr CB	Grades With	Comment	Action
T1 HV EF 1st	1000	351S	50N1	20	0.02	5.00 cyc			F51 meas.	
T1 HV EF 2nd	1000	351S	50N2	50	0.05	20.00 cyc			F51meas.	
T1 HV EF 3rd	1000	351S	50G1	20	0.02	5.00 cyc			F51 resid.	
T1 HV EF 4th	1000	351S	50G2	50	0.05	20.00 cyc			F51 resid.	
T1 HV EF 5th	1000	387E	50N11	50	0.05	5.00 cyc			F87	
Inc. EF 1st	600	351S	50N1	120	0.20	75.00 cyc			F51 NCT	
Inc. EF 2nd	1000	351S	50G1	120	0.12	80.00 cyc			F51 resid.	
Inc. EF 3rd	1000	387E	50N21	120	0.12	80.00 cyc			F87	
Feeders	1000	351R	50N1	20	0.02	50.00 cyc			F51	
R-354	1000	Form 6	DefT	15	0.015	0.50 s	Te Kao	fdr		
R-354	1000	Form 6	DefT	Disable	-	Disable	Te Kao	fdr	hiset	Change

4.12 Taipa

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Comment
KTA1162	33 kV	C1	400 A	1 A	**400/1**	0.75	0.31	8.00	0.00 cyc	From SEL 2017 Database
Trfr. HV	33 kV	C1	1000 A	1 A	**1000/1**	0.18	0.15			
Incomer	11 kV	C1	300 A	5 A	**60/1**	6.00	0.20			
Gen Inc.	11 kV	C1	300 A	5 A	**60/1**	6.00	0.15			
CB1205/6/8	11 kV	C1	200 A	5 A	**40/1**	5.00	0.10	15.00	0.00 cyc	
CB1207	11 kV	C1	200 A	5 A	**40/1**	7.00	0.10	25.00	0.00 cyc	
R-363	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	0.90	0.016 s	
R-017	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.40	0.90	0.016 s	
R-519	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.20	0.80	0.016 s	
R-135	11 kV	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	0.80	0.016 s	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay (s)	Comment
HV EF	1000	10	0.01	0.00 cyc	
Inc. EF	60	72	1.20	75.00 cyc	F51
Gen. EF 1st	60	60	1.00	80.00 cyc	F51 measured
Gen. EF 2nd	60	30	0.50	75.00 cyc	F51 residual
Feeders	40	20	0.50	50.00 cyc	F51
R-363	1000	10	0.01	0.60	
R-363	1000	320	0.32	0.016 s	hiset
R-017	1000	10	0.01	0.50 s	
R-519	1000	10	0.01	0.60	
R-519	1000	320	0.32	0.016 s	hiset
R-135	1000	18	0.018	0.60 s	

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Feeder CB	Grades with	Comment	Action
KTA1162	33 kV	311L	51PP/50P1	C1	400 A	1 A	**400/1**	0.75	0.31	8.00	0.00 cyc			From SEL 2017	
Trfr. HV	33 kV	351R	51P1	C1	1000 A	1 A	**1000/1**	0.12	0.28	1.00	0.00 cyc			F51	Change
Incomer	11 kV	351S	51P1	C1	300 A	5 A	**60/1**	6.00	0.20					F51	
Gen Inc.	11 kV	351S	51P1	C1	300 A	5 A	**60/1**	6.00	0.15					F51	
CB1205/6/8	11 kV	351S	51P1/50P1	C2	200 A	5 A	**40/1**	6.00	0.14	Disable	Disable			F51	Change
CB1207	11 kV	351S	51P1/50P1	C2	200 A	5 A	**40/1**	6.00	0.14	Disable	Disable			F51	Change
R-363	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.07	0.10	0.90	0.016 s	1206	fdr		
R-017	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.18	Disable	Disable	1206	fdr		Change
R-519	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.20	Disable	Disable	1207	fdr		Change
R-135	11 kV	Form 6	Inv	IEC EI	1000 A	1 A	**1000/1**	0.10	0.10	Disable	Disable	1207	fdr		Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay (s)	Fdr CB	Grades With	Comment	Action
HV EF	1000	351R	50N1	10	0.01	5.00 cyc				
Inc. EF	60	351S	50N1	72	1.20	75.00 cyc			F51	
Gen. EF 1st	60	351S	50N1	60	1.00	80.00 cyc			F51 measured	
Gen. EF 2nd	60	351S	50G1	30	0.50	75.00 cyc			F51 residual	
Feeders	40	351S	50N1	20	0.50	50.00 cyc			F51	
R-363	1000	Form 6	DefT	10	0.01	0.60	1206	fdr		
R-363	1000	Form 6	DefT	Disable	-	Disable	1206	fdr	hiset	Change
R-017	1000	Form 6	DefT	10	0.01	0.50 s	1206	fdr		
R-519	1000	Form 6	DefT	10	0.01	0.60	1207	fdr		
R-519	1000	Form 6	DefT	Disable	-	Disable	1207	fdr	hiset	Change
R-135	1000	Form 6	DefT	18	0.018	0.60 s	1207	fdr		

4.13 Northern Pulp

Existing:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Grades With	Comment
KTA1122	33 kV	IEC SI	800 A	1 A	**800/1**	0.48	0.25				
KTA1082	33 kV	IEC SI	800 A	1 A	**800/1**	0.48	0.25				
KTA1142	33 kV	IEC SI	400 A	1 A	**400/1**	1.25	0.26				
Trfr. HV 1st	33 kV	IEC SI	300 A	5 A	**60/1**	5.00	0.15	24.50	0.00 s		F51
Trfr. HV 2nd	33 kV	IEC SI	300 A	5 A	**60/1**	8.00	0.13	24.50	0.00 cyc		F87
Incomer	11 kV	IEC SI	1200 A	5 A	**240/1**	3.35	0.10				
CB1405	11 kV	IEC VI	300 A	5 A	**60/1**	5.00	0.05	33.33	0.00 cyc		
CB1406	11 kV	IEC VI	200 A	5 A	**40/1**	7.00	0.10	40.00	0.00 cyc		
CB1407	11 kV	IEC VI	400 A	5 A	**80/1**	3.75	0.05	25.00	0.00 cyc		
CB1408	11 kV	IEC VI	200 A	5 A	**40/1**	5.00	0.10	50.00	0.00 cyc		
CB1409	11 kV	IEC VI	400 A	5 A	**80/1**	3.75	0.05	25.00	0.00 cyc		
CB1410	11 kV	IEC VI	300 A	5 A	**60/1**	5.00	0.05	37.00	0.00 cyc		
R-1381	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.13	0.10	0.520	0.016 s	R-1405	
R-1405	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.23	0.10	1.00	0.016 s	CB1406	forward
R-1405	11 kV	IEC SI	1000 A	1 A	**1000/1**	0.08	0.10	0.300	0.016 s	R-1381	reverse
R-400	11 kV	IEC VI	1000 A	1 A	**1000/1**	0.12	0.30	0.996	0.016 s	CB1406	

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Pickup Ap	Pickup As	Delay	Grades With	Comment
HV EF 1st	60	30	0.50	0.20 s		F51
HV EF 2nd	60	30	0.50	7.50 cyc		F87
Inc. EF 1st	240	96	0.40	75.00 cyc		F51
Inc. EF 2nd	240	96	0.40	75.00 cyc		F51
Inc. EF 3rd	240	60	0.25	70.00 cyc		F87
CB1405	60	24	0.40	50.00 cyc		
CB1406	40	24	0.60	50.00 cyc		
CB1407	80	40	0.50	50.00 cyc		
CB1408	40	24	0.60	50.00 cyc		
CB1409	80	40	0.50	50.00 cyc		
CB1410	60	24	0.40	50.00 cyc		
R-1381	1000	10	0.01	0.30 s	R-1405	
R-1381	1000	320	0.32	0.016 s	R-1405	hiset
R-1405	1000	20	0.02	0.60 s	CB1406	fwd
R-1405	1000	8	0.008	0.04 s	R-1381	rev
R-400	1000	20	0.02	1.50 s	CB1406	
R-400	1000	640	0.64	0.016 s	CB1406	hiset

New:

In the tables below recloser hiset pickups are shown as multiples of the CT secondary.

Overcurrent:

Name	Voltage	Relay	Element	Curve	CT Prim	CT Sec	CT Ratio	Pickup	Time	Hiset Pickup	Hiset Delay	Grades with	Comment	Action
KTA1122	33 kV	311L	51PP	IEC SI	800 A	1 A	**800/1**	0.48	0.25					
KTA1082	33 kV	311L	51PP	IEC SI	800 A	1 A	**800/1**	0.48	0.25					
KTA1142	33 kV	311L	51PP	IEC SI	400 A	1 A	**400/1**	1.25	0.26					
Trfr. HV 1st	33 kV	751	51P1/50P1	IEC SI	300 A	5 A	**60/1**	5.00	0.15	26.50	0.10 s		F51	Change
Trfr. HV 2nd	33 kV	387E	51P1/50P11	IEC SI	300 A	5 A	**60/1**	5.00	0.15	26.50	0.00 cyc		F87	Change
Incomer	11 kV	351S	51P1/50P11	IEC SI	1200 A	5 A	**240/1**	3.35	0.17					Change
CB1405	11 kV	351S	51P1/50P1	IEC VI	300 A	5 A	**60/1**	5.00	0.05	Disable	Disable			Change
CB1406	11 kV	351S	51P1/50P1	IEC VI	200 A	5 A	**40/1**	7.00	0.14	100.00	0.00 cyc			Change
CB1407	11 kV	351S	51P1/50P1	IEC VI	400 A	5 A	**80/1**	3.75	0.05	Disable	Disable			Change
CB1408	11 kV	351S	51P1/50P1	IEC VI	200 A	5 A	**40/1**	5.00	0.10	Disable	Disable			Change
CB1409	11 kV	351S	51P1/50P1	IEC VI	400 A	5 A	**80/1**	3.75	0.05	Disable	Disable			Change
CB1410	11 kV	351S	51P1/50P1	IEC VI	300 A	5 A	**60/1**	5.00	0.05	Disable	Disable			Change
R-1381	11 kV	Form 6		IEC VI	1000 A	1 A	**1000/1**	0.13	0.10	0.52	0.016 s	R-1405		
R-1405	11 kV	Intellirupter		IEC VI	1000 A	1 A	**1000/1**	0.23	0.09	1.00	0.016 s	CB1406	forward	Change
R-1405	11 kV	Intellirupter		IEC SI	1000 A	1 A	**1000/1**	0.08	0.08	Disable	Disable	R-1381	reverse	Change
R-400	11 kV	Form 6	Inv/Inst	IEC VI	1000 A	1 A	**1000/1**	0.12	0.20	2.50	0.016 s	CB1406		Change

Earth Fault:
(Ap/As = Amps pri/Amps sec)

Panel	CTR	Relay	Element	Pickup Ap	Pickup As	Delay	Grades With	Comment	Action
HV EF 1st	60	751	50G1	30	0.50	0.20 s		F51	
HV EF 2nd	60	387E	50N11	30	0.50	7.50 cyc		F87	
Inc. EF 1st	240	351S	50N1	96	0.40	75.00 cyc		F51	
Inc. EF 2nd	240	351S	50G1	96	0.40	75.00 cyc		F51	
Inc. EF 3rd	240	387E	50N21	60	0.25	70.00 cyc		F87	
CB1405	60	351S	50N1	24	0.40	50.00 cyc			
CB1406	40	351S	50N1	24	0.60	50.00 cyc			
CB1407	80	351S	50N1	40	0.50	50.00 cyc			
CB1408	40	351S	50N1	24	0.60	50.00 cyc			
CB1409	80	351S	50N1	40	0.50	50.00 cyc			
CB1410	60	351S	50N1	24	0.40	50.00 cyc			
R-1381	1000	Form 6	DefT	10	0.01	0.20 s	R-1405		Change
R-1381	1000	Form 6	Inst	Disable	-	Disable	R-1405		Change
R-1405	1000	Intellirupter	DefT	20	0.02	0.60 s	CB1406	fwd	
R-1405	1000	Intellirupter	DefT	8	0.008	0.04 s	R-1381	rev	
R-400	1000	Form 6	DefT	20	0.02	0.60 s	CB1406		Change
R-400	1000	Form 6	Inst	Disable	-	Disable	CB1406	hiset	Change

Appendix 8

Cyclone Gabrielle Review
Completed June 2023

Cyclone Gabrielle review – OFI’s

- 150+ OFI’s reported either directly or via a supervisor/manager
- 96 OFI’s remaining after the duplicates/similar OFI’s were merged
- Multiple meetings with managers/executives to discuss the OFI’s then agree on a solution and a timeframe
- 16 OFI’s have either already been completed, are being dealt with outside of the storm Action Requests or were deemed not relevant
- 34 of the remaining 80 OFI’s will be resolved by reviewing/releasing the TEN Emergency Preparedness Plan, the TEN Emergency Response Plan and the TECS Storm Response Plan

Cyclone Gabrielle review – Remaining OFI’s

Highlights of the remaining 46 OFI’s;

- Review the vehicles that are allocated to staff members, internal department vehicle changes need to be kept up to date.
- De-escalation/conflict training for dealing with angry/frustrated consumers.
- Developing a patrol assessment form that lists the required information.
- Isolating equipment is being added to Field Maps on the tablets.
- Refresher training for contact protocols - communications with the TECC.
- Investigate having stores staff available for more hours through events.

Cyclone Gabrielle review – Remaining OFI’s cont.

- Confirming our fatigue policy covers external contractors and their fatigue policies.
- Review of the fatigue recording system and training more staff on how it works.
- Investigating and implementing “storm mode” in the ADMS
- Ongoing improvements to the ADMS Outage Management System (OMS) including dashboard(s) and incident tracking and resource scheduling/planning.
- Review when the Crisis Management Team (CMT) is implemented. General feeling that the CMT would have helped coordinate non-operational support response

A reminder: When we have an event, managers should make sure that their remaining staff cover the people who are involved in the event response, the same way they do when their staff are on leave or sick.
This is how the people who aren’t directly involved with the event assist. One Top Energy.

Cyclone Gabrielle review – Action Request Timeline

Mar 23	Jun 23	Sep 23	Dec 23	Mar 24	Jun 24	Sep 24	Dec 24	Mar 25

- EPP and ERP Release
- SRP Release
- Contact Protocols Refresher Training
- De-Escalation Training
- Vehicle Allocation Review
- Review Fatigue Policy and Monitoring
- Isolation Points Visible in Field Maps
- Line Patrol Assessment
- Stores Staff Availability
- Develop Storm Mode and Full Implementation of OMS

Appendix 9

Assura

AU #17966 - Network Fault Audit - FAR NORTH ROAD, 11kV RECL R354 - SAIDI (3.79) - Fault Response Audit -

Overview

State	2. Completed	ID	17966
Lodged By	Reporting, Assura	Date Lodged	13-Jul-2022 6:31 AM
Last Changed By	[redacted]	Date Changed	24-Nov-2022 2:27 PM
Start Date	11-Jul-2022 10:20 PM	Category	Compliance
Recurrence	(None)		

Details

Audit Work Instruction	SS06-02-033W - Touchline Audit Workflow Work Instruction		
Audit Type	Fault Response Audit		
Fault Report Location	Record Centre - Fault Response Reports and Attachments		
Planned Audit Date	13-Jul-2022	Actual Assessment Date	13-Jul-2022
Title	Network Fault Audit - FAR NORTH ROAD, 11kV RECL R354 - SAIDI (3.79)		
Audit Reference Number	INCD-13646-F | F-5789-F	Order Reference	40082355

Assessing Organisation

List Name
No records to display.

Assessor

List Name
[redacted]

Findings

Assessment Finding

ADMS Incident Details:

Tree fell into lines during storm event. Site to hazardous to repair at night crews stood down for safety and returned next day. High winds and dark.

Saidi Actual - 3.793948998703357
Report Description - FAR NORTH ROAD, 11kV RECL R354
Substation - PUKENUI
Feeder - TE KAO
Item Type Effected - Conductor Span
Orientation - Line
Cause - Tree Contact
Location - R354
General Area - PUKENUI
Confirmed Date - 2022-07-11 22:20:02.0000000
Start Date - 2022-07-11 22:20:02.0000000
End Date - 2022-07-12 10:36:00.0000000
SAP - 40082355
Voltage - 11kV
Incident Details - Trees on line Pole 431562
Completed By - [redacted]
ICPS - 328

Enter reporting findings into report and raise Action Requests as required.

Actions Required

Execution of Work - Planning and Coordination

Was auto reclose a contributing factor?	No
Communication / Instruction Issue?	No
Escalations / Notifications	No
Restricted Access?	No
Field Resource Availability?	No
Dispatch Management?	No
Field Response?	No
Field Device Failure?	Yes
Field Device Failure Notes	S1012 requires cellular access to work remotely. The cell tower [redacted] does not have long reserve batteries. Cell site batteries went flat during outage causing loss of coms to S1012. This required Field responder to operate device locally. Caused 30min delay to restore final section of line to restore last 138icps.
Network Controllers Switching / Fault management?	No
Was protection failure a contributing factor?	No

Attachments

Attachments

	Title	Attached Date	Attached By
	S1012 Tangoake.msg	29-Sep-2022 5:30 PM	[redacted]
	S1012 Te Kao.msg	24-Nov-2022 2:28 PM	[redacted]

Related Items

Type: --- All

No related items found.

Assignment

Urgency	Low
Action Officer	Division.Network.Operations.FaultReview (Group)
Escalation 1	
Escalation 2	
Escalation 3	
Also Notify	
Calendar Profile	24 Hours, 7 Days

Action Log

State	Actual Date	Logged By	
0	13-Jul-2022 6:31 AM	Reporting, Assura	*Workflow added, assigned to Division.Network.Operations.FaultReview (Group)* Hide section
1	29-Sep-2022 5:30 PM	[redacted]	*Progressed to 1. In Progress, assigned to Division.Network.Operations.FaultReview (Group)* Hide section Refer attached email requesting Engineering decision for proposed solution to comm constraint
2	24-Nov-2022 2:27 PM	[redacted]	Progressed to 2. Completed, assigned to Division.Network.Operations.FaultReview (Group) Hide section See attached email dated 7/11/22. Comms tech installed booster ariel from Henderson Bay cell site to create alternative comms path in the event of loss of supply to Paua cell site at Tangoake. TECC confirms this appears to of resolved, improved the comms blockage to S1012 during outages.

Appendix 10

SAIDI Analytics Deep Dive

Summary Report

Prepared for Top Energy

12 May 2023

Table of Contents

Glossary of terms

Term	Definition
Incident	An electricity outage incident. In this report, we are primarily focused on unplanned outages.
SAIDI	System Average Interruption Duration Index $$S = \frac{\sum U_i N_i}{N_T}$$ Where S is the SAIDI, U and N are the incident time and number of affected customers for location i respectively, and N_T is the total number of customers served. This is typically measured in minutes.
ADMS	Advanced Distribution Management System
SAP	Systems Applications and Products
Regulatory Year	SAIDI regulatory years run from April to March.
SA2	Statistical Area 2 as defined by Stats NZ in 2022. The SA2 geography aims to reflect communities that interact together socially and economically. In populated areas, SA2s generally contain similar sized populations.

Executive summary

The System Average Interruption Duration Index (SAIDI) metric is defined as the sum of all customer interruption durations divided by the total number of customers served. Previously, Harmonic has been commissioned to explore factors that might explain high SAIDI numbers from Top Energy's internal datasets, and, with updated data, examine the causes of SAIDI and compare with previous findings. This new report is a deeper-dive into the factors associated with SAIDI and the connection between SAIDI, weather conditions, and network asset age and type.

A selection of data extracts were previously determined and provided to Harmonic. These include extracts from the ADMS, SAP, Smartrak and FieldGo systems. The extracts provide information relating to incidents from YE2020 up until September 2022 (mid-YE2023), and corresponding details on the relevant equipment affected and employee responses. In addition to this, more data on network assets was provided, and publicly available weather data was obtained by Harmonic.

This investigation has uncovered several key findings that helped shed light on SAIDI, with a particular emphasis on explaining the impact of adverse weather on outage incident frequency and duration, and asset condition in relation to outage incidents.

- Peak wind gusts can be correlated to daily incident counts, while neither daily rainfall nor cumulative rainfall over the past 10-21 days has a noticeable connection to this.
- Most frequently, incidents occur when there are strong gusts from the prevailing South-Westerly wind or from Northerly or Easterly directions of ex-tropical cyclones.
- Average incident duration is higher for very high levels of rainfall. There is a weaker correlation between gust strength and incident duration.
- Overhead conductors are associated with the second highest average incident duration.
- There is a correlation between daily rainfall amounts and delay time to respond to an incident.
- Weather measurements are increasing over the years, with more rainfall observed in Winter months during YE2023 compared to previous Winter months. Maximum gust speeds throughout YE2022 and YE2023 are consistently higher than in previous years and there is less variation in maximum gust speeds.
- Northland tends to experience extreme wet days and days with extreme peak wind gusts with a higher frequency than average for similar regions of the North Island.
- Conductors have the highest failure rates compared to other device types, with 57.5% of all asset failures being conductor failures.

- Asset failures are more likely to occur when weather conditions are severe or extreme. In particular, conductors tend to be the most affected.

Introduction

The System Average Interruption Duration Index (SAIDI) metric is commonly used by electric power utilities as a measure of network reliability. SAIDI is defined as the sum of all customer interruption durations divided by the total number of customers served. It is desirable to reduce SAIDI minutes as they represent an increase in maintenance costs to the organisation and are a regulated metric.

Top Energy operates in one of New Zealand's most challenging Energy Distribution environments. Covering a large area with a small population relative to other EDBs, Top is also exposed to severe impacts of climate change, particularly fierce storms and flooding.

Top is increasingly breaching SAIDI regulatory caps, sometimes exceeding 400 SAIDI minutes. While weather is a legitimate reason for these breaches, Top is seeking to understand other underlying causes, particularly asset related issues. To support this understanding, Harmonic performed an analysis of SAIDI performance with 2021 data, then refreshed it in 2022.

Top is now interested in a deeper dive to identify actionable insights that will help Top prioritise remedial activities that will have the greatest impact on SAIDI performance. There are two key parts to the deep dive analysis covered in this report; weather-related incident analysis and asset condition investigation.

Methodology

The R programming language was used to load, transform, explore and analyse the data.

Data Sources

Top Energy provided Harmonic with extracts from the following data sources:

Data Source Name	Extracts Provided
Advanced Distribution Management System (ADMS)	• *Incident Data sheet:* A master list of incidents and their associated properties. • *switching_log_view.xlsx :* Timestamped worker events associated with particular jobs.
Systems Applications and Products (SAP)	• *Jobs and Equip sheet:* Equipment properties associated with a particular incident. • *Notif Time sheet:* Actual notification time to the worker of the incident. • *Condition History sheet*: Timestamped equipment condition measurements. • *Timesheet Info sheet*: Timesheet entries for each worker. • *Vehicle Hours sheet*: Logged vehicle hours.
FieldGO	• *JSA SignOn sheet*: Sign in / sign off times for workers.
Smartrak	• *V1-EVENTS-xxxx.xlsx* : Timestamped vehicle event data provided in four Excel files labelled 2019 to 2022.
Misc.	• *EmployeeList sheet*: A list of employees and employee attributes. • *Vehicle Info sheet*: A list of vehicles

	and vehicle attributes. ● *Asset Information.xlsx:* Several sheets containing information on Distribution Poles, Transmission Poles, Transformers, Conductors, CrossArms, and incident locations.

Weather data across Northland was extracted from the NIWA CliFlo weather database. These data sets are daily rainfall (in mm), daily peak wind gust (speed in km/h, direction in degrees) and surface wind at 9 am (speed in km/h, direction in degrees). These are widely available across most weather stations, and earlier analysis had seen them to be related to incident frequency and incident duration.

Incidents are matched to the nearest weather station which can provide the most accurate weather data for that incident, as described in Mapping incidents to weather stations.

Cleaning and Subsetting

The following steps were performed:

ADMS

- Due to issues with date formatting affecting incidents recorded prior to February 2022, the original incident data from the original report had to be spliced with the latest incident data (up to November 2022). Specifically
  - All incidents prior to April 2020 will be sourced from the phase 1 data (Incidents_by_Date.xlsx, uploaded Feb 17 2022), as there were no date issues there.
  - All incidents post April 2020 will be sourced from the updated incidents data Incidents_by_Date_v2.xlsx sheet (uploaded Nov 22 2022), since that version had the date issue fixed.
- Incidents were filtered to only unplanned incidents, leaving 1543 incidents spanning 2019 to 2022 (regulatory years ending 2020 to 2023).
- A duplicated incident ID (INCD-6304-F) was removed.
- Combined the 6.6 and 6.35kV voltages into one (replaced all instances of 6.6 with 6.35). Top Energy had indicated that these two voltages although recorded differently actually represented the same real-life value.
- Additionally, several locations had different names and had to coalesced:
  - Kaitaia, Kaitaia Transmission and Kaitaia 33kv were renamed to **Kaitaia**

    - Kaikohe 33kv was renamed to **Kaikohe Transmission**
    - Okahu was renamed to **Okahu Rd**

SAP

- Duplicated order numbers in the notification times data were removed, keeping the earliest recorded notification time for each order number.

Smartrak

- The cleaned data was joined onto FieldGo by vehicle identifier (the “work centre” field), and this was subsequently joined with the cleaned ADMS dataset.
- Orders that could not be matched to a vehicle were filtered out.
- It was also observed that vehicle trips associated with an order could span multiple days, not just the timeframe in which the incident occurred. To address this, only vehicle events with “rt_date” timestamps within the incident start and end datetime, were kept.

General

- Variables with information stored as characters were converted to lower-case, fixing inconsistencies in the data such as kilovolts being written as “kV” in one instance, and “KV” in another.

Weather-related Incidents

To accurately assess the impact of weather on incidents, the analysis of outage incidents alongside the concurrent weather conditions is performed with incidents which are likely connected to the weather.

- Incidents are filtered by “outage_type” and outage “cause” to analyse only incidents associated with adverse weather, lightning, or tree fall. One of the below conditions must be satisfied:
    - ***Outage Type*** is one of: "weather", "adverse weather", "adverse environment", "lightning"
    - ***Cause*** is "tree (fall on line)"
- There are very few observations with the outage type “weather” or “adverse environment”, and thus due to the similar denotation, these are corrected to “adverse weather”.

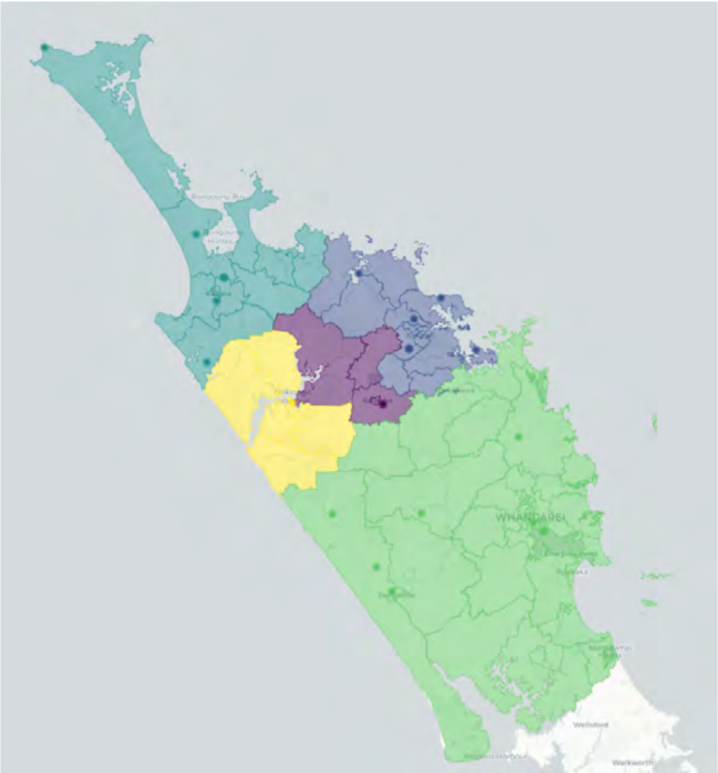
Feature Generation

Processing Geographic Data

Generating Custom Geographic Regions

Northland covers a large area of the North Island, and weather conditions can vary across the region. To avoid producing overly generalised analysis about weather trends, the region was split into smaller sections with reasonably similar climate conditions.

Boundaries were loosely provided by Top Energy, and manually mapped into custom regions using SA2 regions as a base.



Mapping Incidents to Custom Regions

Incident addresses provided in the ADMS were used to geocode incident data (convert to latitude and longitude). Incidents matched to the region it resided within.

Mapping incidents to weather stations

Incident addresses provided in the ADMS were used to geocode incident data (convert to latitude and longitude). Weather stations for each weather metric (surface wind speed, daily peak gust speed, daily rainfall) were then matched to the closest incidents.

Classifying events as weather related

An outage can be considered weather related if:

Outage type is one of:

- "weather"
- "adverse weather"
- "adverse environment"
- “lightning”

Or the **cause** is listed as “tree fall on line”.

Classifying Asset Ages

To classify an asset as a young or old asset, the following steps were followed:

1. Age was calculated based on either age at day of failure, or current year.
2. Assets were then flagged as young or old depending on their expected lifespan. If they failed before the expected lifespan, they were classified as young. If they failed after their expected lifespan, they were classified as old.

Device Type	Expected Lifespan
Cross-arms	30 years
Concrete Poles	60 years
Wooden Poles	45 years
Lines (Overhead Conductors)	55 years
Transformers	45 years

Approach to Analysis

The goal of the analysis discussed in this report was:

1. To continue exploration of the weather data, and delve deeper into the effect weather has on incidents and SAIDI.
2. To gain insights to aid with the prioritisation of asset replacement that produces the maximum reduction in SAIDI.

This report aims to address the relationship between weather conditions and the incidents and high SAIDI observed, and also the connection between asset condition and incidents and SAIDI. SAIDI is associated with two aspects:

- The number (frequency) of incidents
- The duration of incidents (and time to respond)

The main goals of the weather deep-dive analysis were:

- Development of a clear definition of “extreme weather” events based on parameters such as rainfall and wind gust speed and direction.
- Investigation of the impacts of adverse weather on incident frequency, incident duration and employee response times.
- Analysis of weather geographically, by custom geographical region, based on SA2 regions.
- Comparison of extreme weather event frequency in Northland vs the rest of the North Island, to determine if Northland is disproportionately represented.
- Investigation of potential changes in weather over time.

There were two key aspects to the asset condition investigation:

- Investigation of asset component failure by location, and how the frequency of failure compares by region.
- Investigation of the relationship between extreme weather and component failure.

Results

Extreme Weather and Weather-Related Incidents

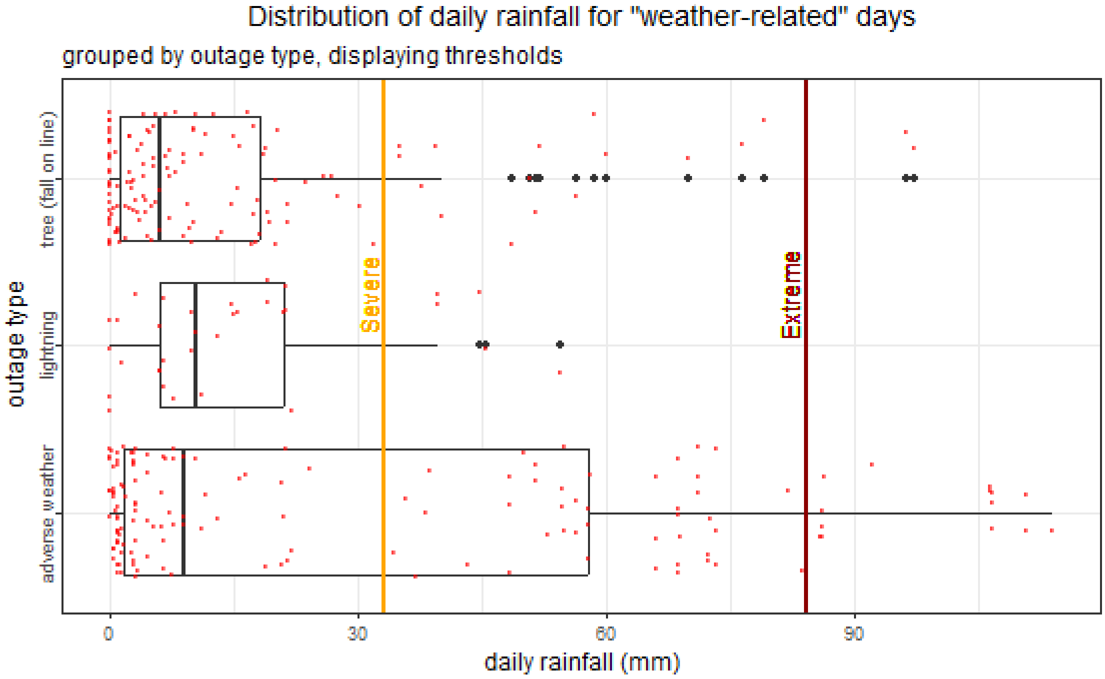
Incident data contains an “extreme weather event” flag, raised by employees manually if they responded to an incident believed to be associated with extreme weather. Previous investigation indicated that this was subjective. There may be utility in a more objective extreme weather definition based on weather data.

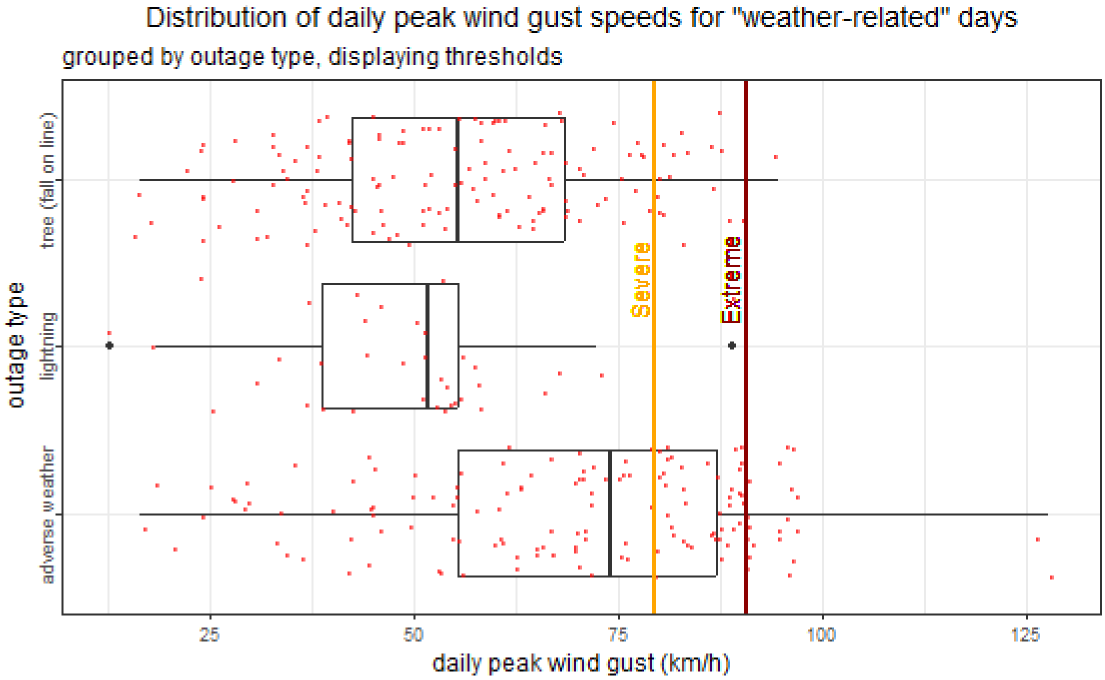
Analysis of weather data alongside *weather-related incidents* helped define a “severe” and an “extreme” threshold for both daily rainfall amounts and daily peak wind gust speeds. This is based purely on the weather conditions at the time, rather than severity of impact. The thresholds are the levels which the weather metrics are expected to exceed only on the top 25% and 5% most severe weather-related incident days.

	Severe *(75th percentile)*	***Extreme*** *(95th percentile)*
Daily Peak Wind Gust (km/h)	79.6	90.7
Daily Rainfall (mm)	33.2	84.1

There is no catch-all way of looking at weather data and identifying a threshold for weather which could guarantee widespread damage and multiple outage incidents. However, these thresholds can help guide the analysis of how adverse weather conditions may impact outages in the Top Energy distribution area.

The figures on the following page indicate where these thresholds are with respect to the distribution of weather metrics measured on weather-related incident days in Northland between April 2019 and August 2022.





The distributions of the weather metrics are shown relative to the "severe" and "extreme" thresholds in the figures above. There is clearly a higher density of 'adverse weather' outage types, seen on the bottom box plot in each figure, exceeding the "severe" or "extreme" weather thresholds. This is logical, and shows that when the weather is noticeably more severe, the cause of the incident is likely to be adverse weather.

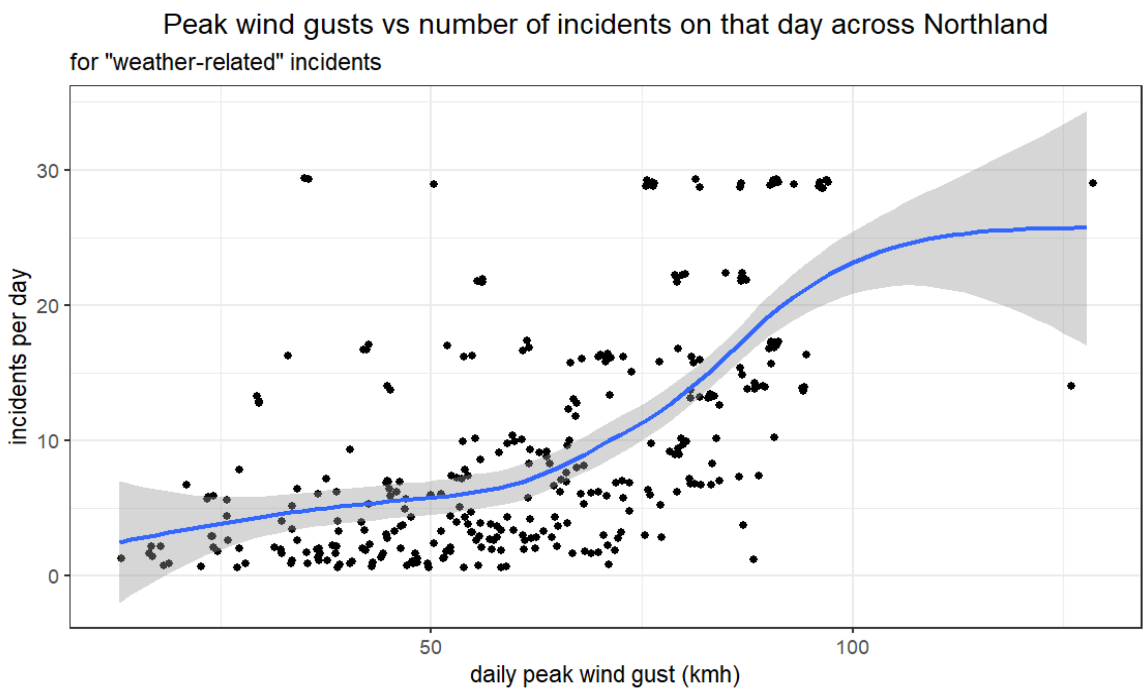
The “severe” and “extreme” thresholds are much closer together for daily rainfall. There is a very high proportion of days with little or no rainfall, and a long right tail of days of higher rainfall that has very low frequency. In comparison, daily peak wind gusts have a less spread out distribution and the majority of peak gust speeds sit within the range of 30-70 km/h.

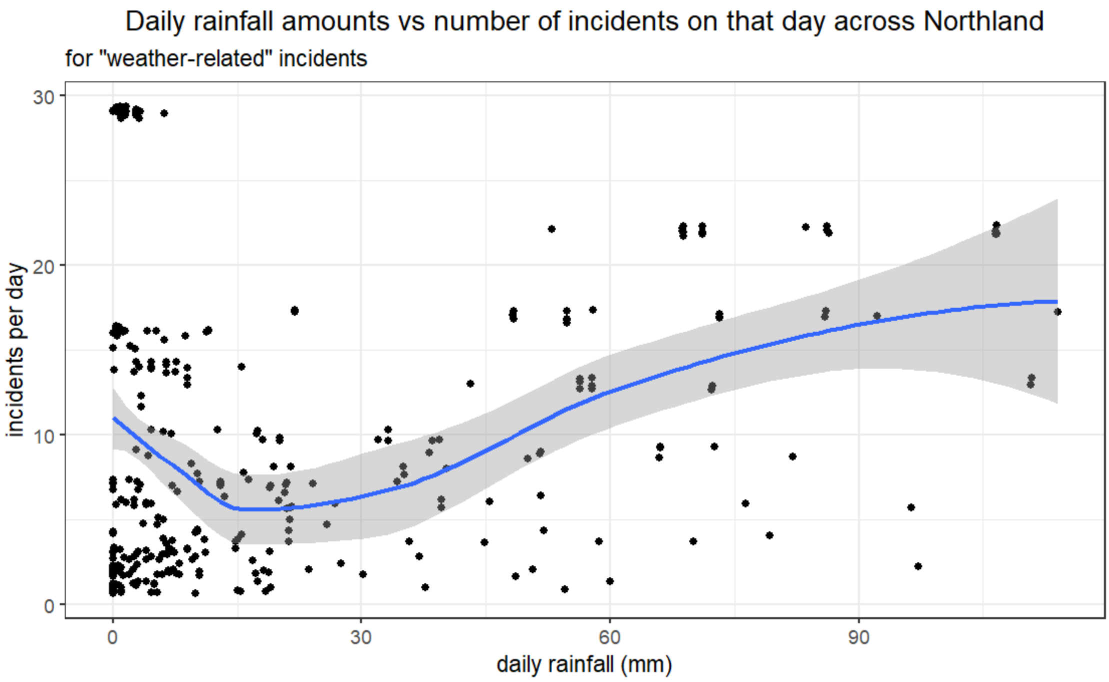
Adverse Weather Conditions

Effect on Incident Frequency

Weather conditions are correlated with the daily number of incidents across Northland. There is a stronger relationship between daily incident frequency and daily peak wind gust speed, compared to daily rainfall. This is concordant with domain experts believing high wind gusts to have a greater impact on the number of incidents, and high rainfall having a greater impact on response time.

In the two following figures, the lines of best fit indicate positive correlations between the severity of the weather and the number of incidents across Northland on that day.





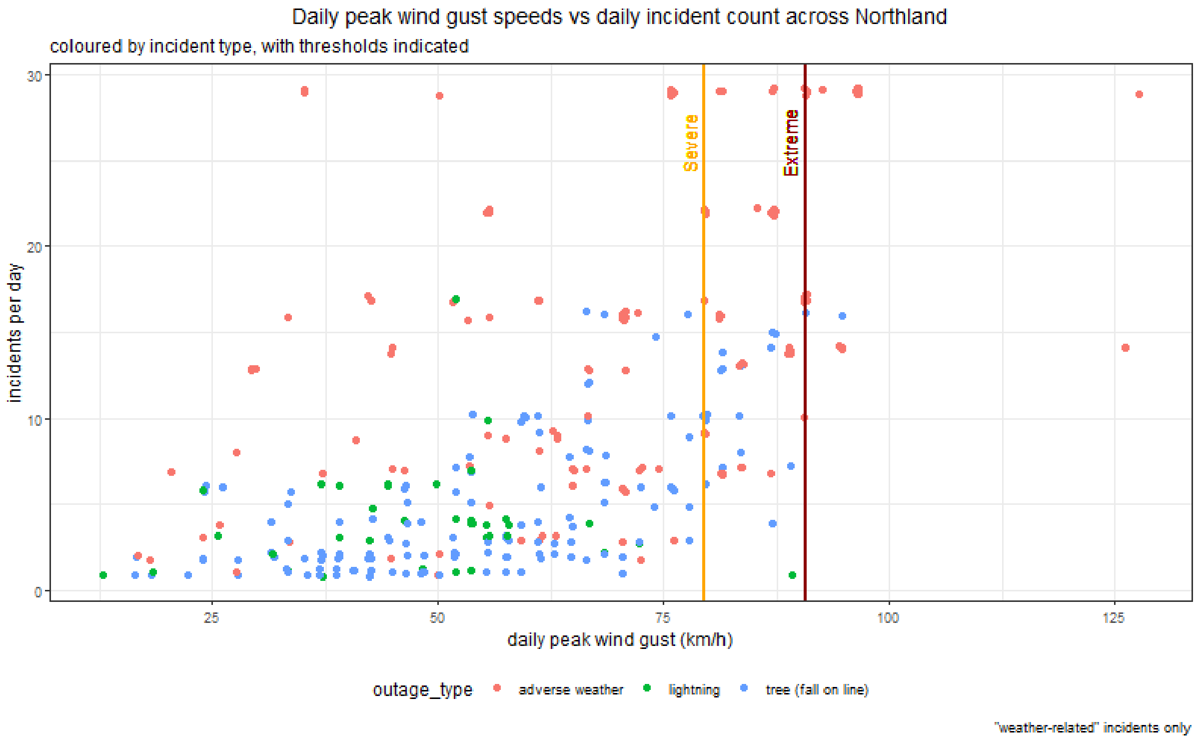
The relationship between daily peak wind gust speed and the daily incident count is of moderate strength. The scatter generally follows the trend across the whole range of peak wind gust speeds.

The relationship between daily rainfall and the daily incident count shows a weaker correlation. There are many days with very low rainfall but high incident counts. The positive correlation between daily rainfall and incidents only is seen for daily rainfall amounts above 15mm, and the scatter following this trend is sparse.

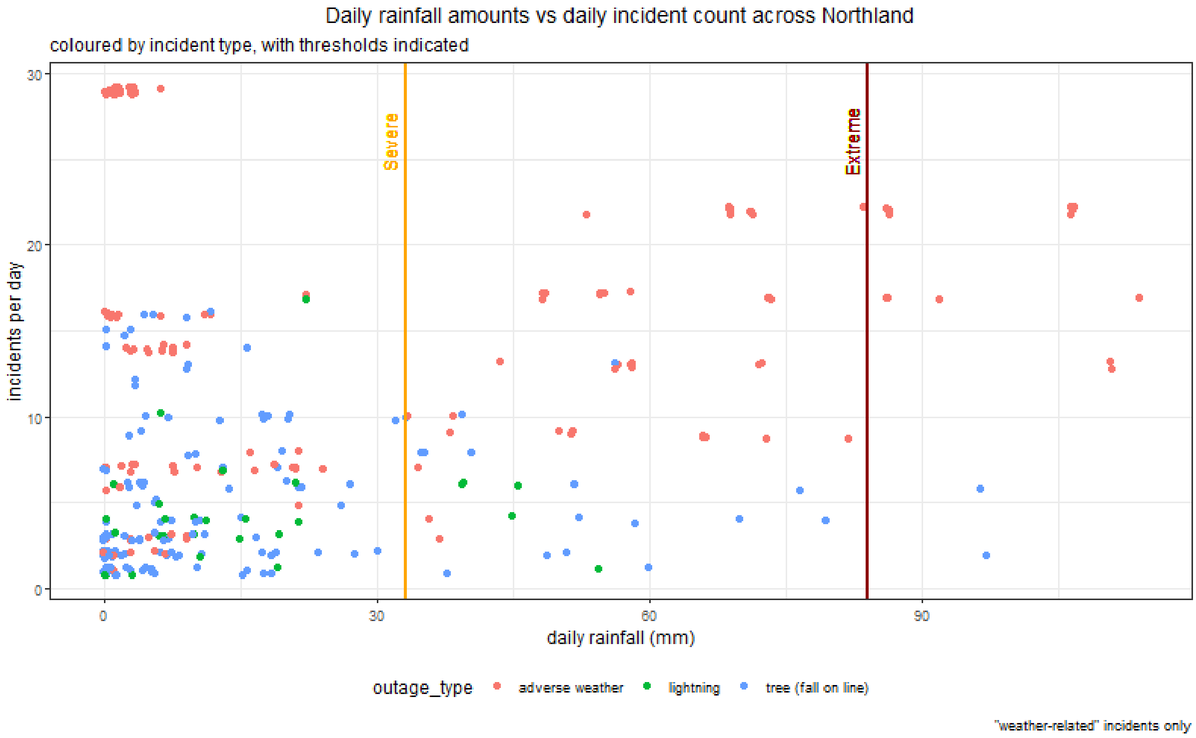
Incident Frequency with Severe and Extreme weather, by outage type

The “severe” and “extreme” weather thresholds are included on the figures on the following page. The points also coloured the recorded incident outage type. There are two main aspects of the graphs below which stand out:

- Most instances of “severe” or “extreme” peak wind gusts are associated with higher numbers of incidents on that day (i.e. 5 or more incidents). The same is not seen for daily rainfall amounts.
- Not all incidents with “adverse weather” outage type meet the “severe” weather thresholds. This can be for two reasons:
  - They may only meet the threshold for one of gust or rainfall, but not both.
  - The outage type is currently recorded manually, and there are no quantified rules to determine the impact from weather.



One particular anomaly is the cluster in the top left corner of the 'Daily Rainfall vs Incident Count' figure below. There are almost 30 incidents on this day, but negligible rainfall. To these outages, rainfall was not a factor at all, but they are still flagged as "adverse weather" incidents. This is due to other weather conditions. Most of these data points are associated with "severe" or "extreme" gusts.



Combined Effect of Gust and Rainfall

The figures in the section above showed that not all “adverse weather” incidents meet the “severe” weather thresholds. However, this is considering only a single aspect of the weather at a time. Investigation of the combined effect of rainfall and wind gusts on incident frequency produced the plots and insights below.

In the figure above, and those on the following pages, three key patterns can be identified:

1. **A higher number of incidents on the same day can be linked to higher wind gusts:**
    a. Most days in the ‘more than 10 incidents’ group, in the figure above, have peak wind gust speeds above 50 km/h,

    b. *Almost* all “extreme” wind gust instances occur within the ‘more than 10 incidents’ group. That said, days with a single incident, but still peak gust speeds above the “severe” threshold of 80 km/h, can occur.

        → see the “severe” and “extreme” thresholds included in a figure at the bottom of page 19.

2. **The amount of rainfall on a day does not have a significant impact on the number of incidents:**

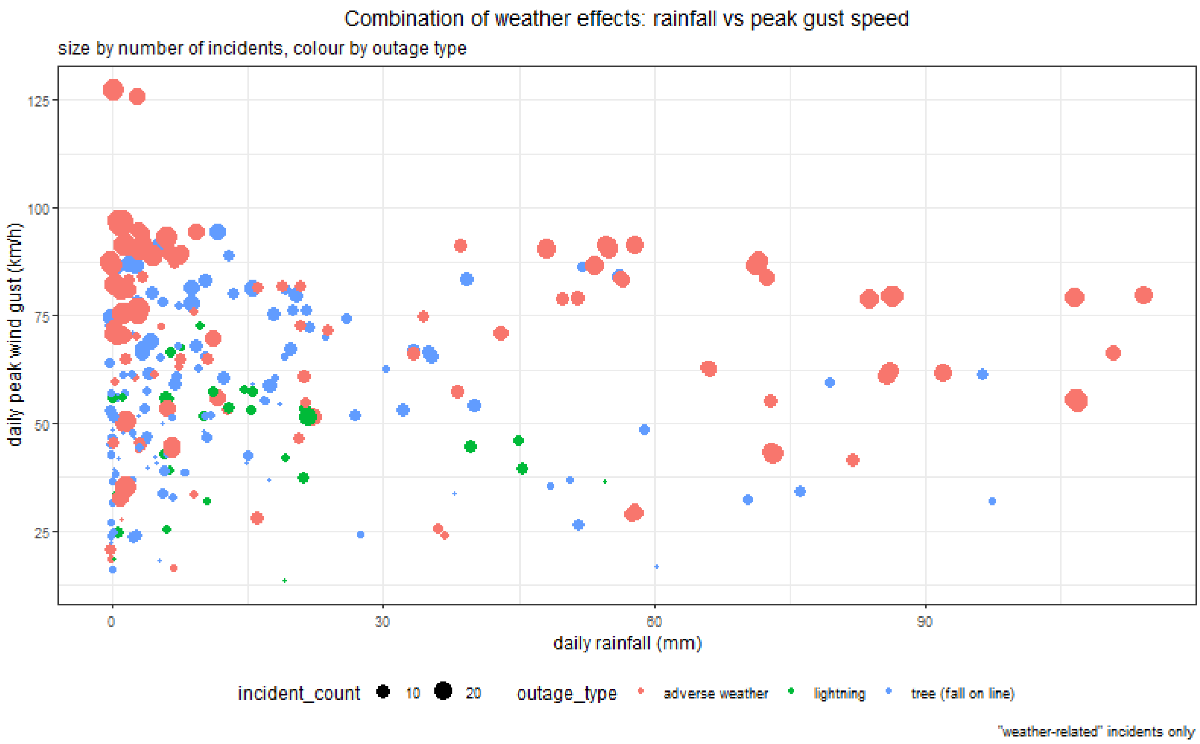
a. In the figure above there is a slightly higher density of "severe" and "extreme" rainfall days for the '5 - 9 incidents' and the 'more than 10 incidents' groups,

b. There are multiple instances of only 2-4 incidents on a day with "extreme" rainfall.

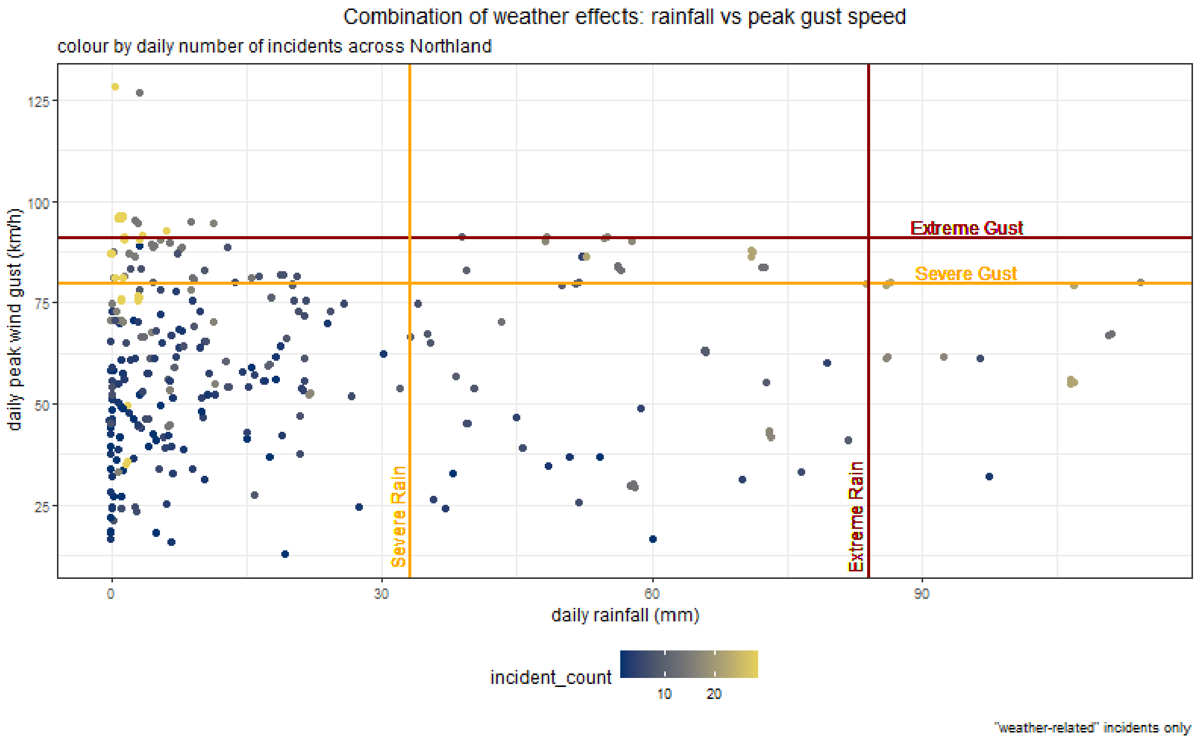
3. **Overall, the 'adverse weather' outage type is associated with more multiple-incident days:**
   a. More incidents with outage types of 'adverse weather' (red) are seen in the 'more than 10 incidents' and '5-9 incidents' groups.

It is also of interest to note patterns which are not identified. Most importantly, in terms of incident frequency, **there is no clear interaction between peak wind gust and rainfall.**

These patterns are further demonstrated in the figure below and on the following page.



The "severe" and "extreme" rainfall and gust thresholds are included on the figure on the following page. This allows for an interpretation of the extent to which daily incident count corresponds to one or both weather metrics being more severe.

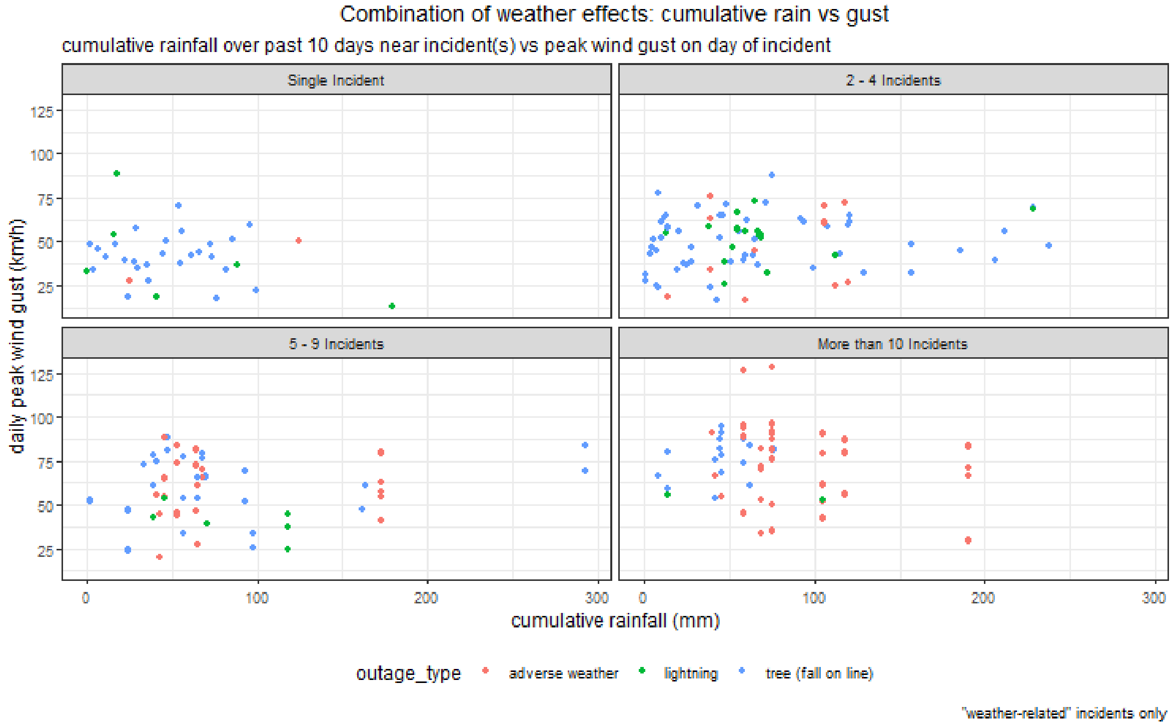


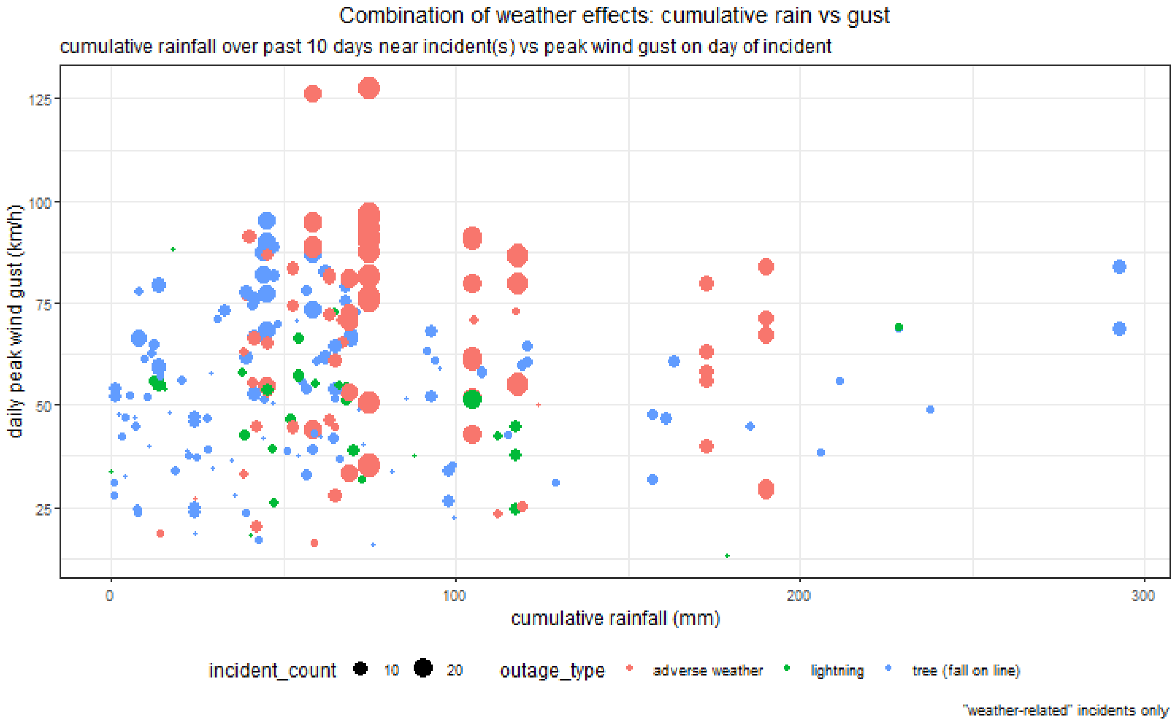
There is a significantly higher proportion of days with very high incident counts (yellow points) when the peak wind gust speed is over the "severe" threshold, and more so for the "extreme" threshold. There are still days with weather-related incidents which are above these thresholds, but in comparison experience very few incidents.

These same observations are not made for the "severe" daily rainfall and "extreme" daily rainfall thresholds, and there is no notable interaction between "severe" and "extreme" gust and rainfall with respect to the daily incident numbers.

Cumulative Rainfall combined with Wind Gusts

Anecdotally, a large amount of rainfall in a short time span could lead to more incidents, with saturated ground increasing the likelihoods of landslides. An investigation of cumulative rainfall over the past 10-21 days was performed. Similar plots to those above, but with cumulative rainfall over the past 10 days, instead of daily rainfall, are displayed below. Plots indicating the amount of rainfall in the past 14 and 21 days can be found in the Appendices.





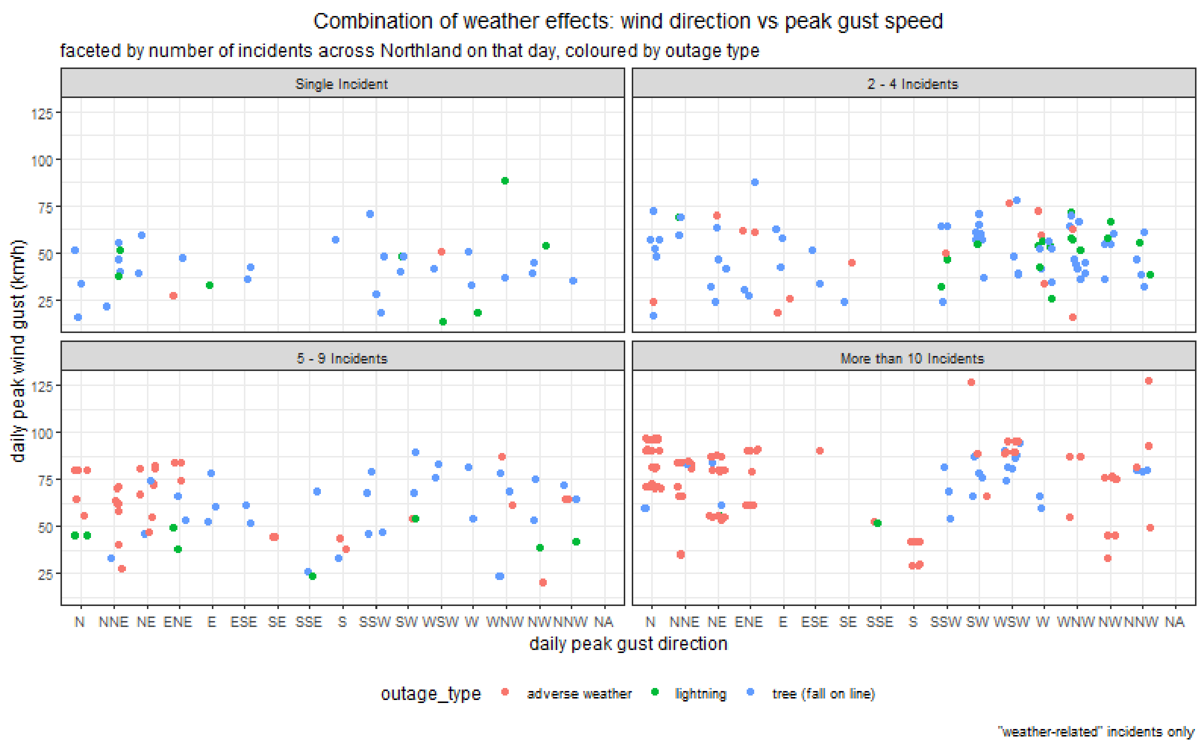
In the figures above, cumulative rainfall over the past 10 days is plotted against the daily peak wind gust on the day of the incident. There are two key observations:

- There are no clearer patterns with cumulative rainfall and incident frequency, compared to the previous figures which just have daily rainfall on the x-axis.
- In general, there are more incidents on days with higher peak wind gusts, and days with 'adverse weather' outage type.

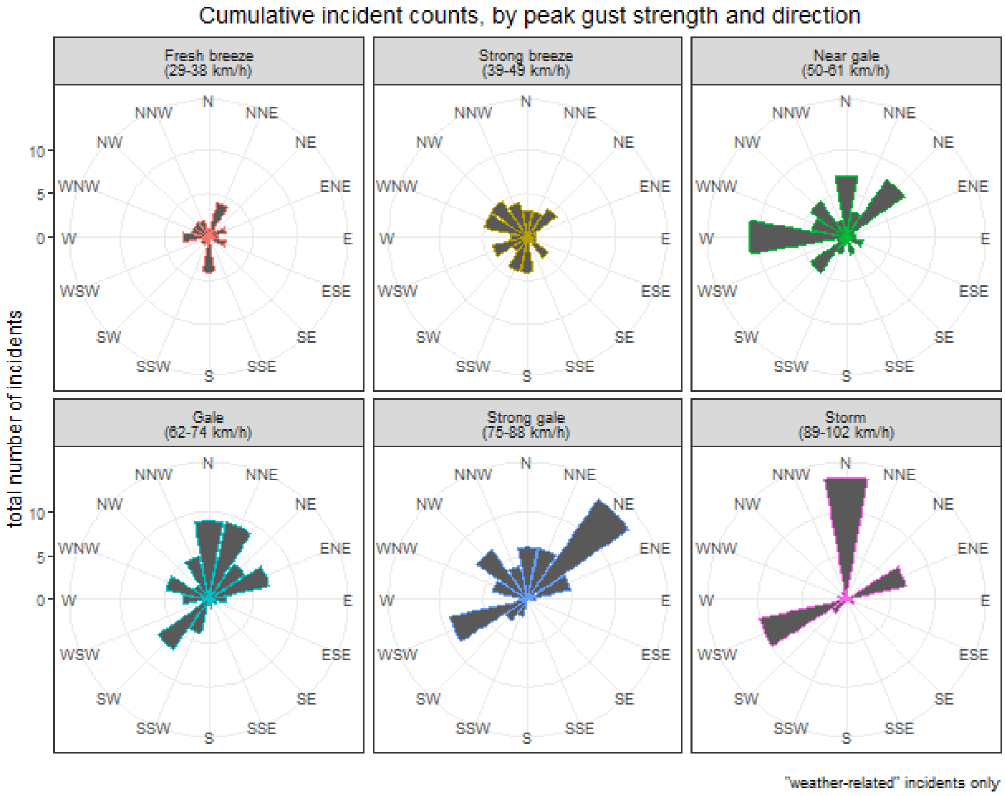
Wind gust directions

An investigation incorporating the peak wind gust direction, alongside the peak wind gust speed and the daily incident count was conducted. The main finding is that North to North-Easterly gust directions or South-Westerly and West South-Westerly gust directions are more common on higher-incident days.

On the figure below, it is clear that for all weather-related incident days, Easterly to Southerly gusts are far less common. There is a clear gap in the 'more than 10 incidents' group for these gust directions. Northerly to North-Easterly and West or South-Westerly gusts seem to cause the highest density of multiple-incident days.



Considering groupings of gust speed, based on the Beaufort scale, the figure below shows the total number of incidents between April 2019 and August 2022 by both peak gust speed and peak gust direction.



The gust directions and speeds which cause the highest number of outages are:

- North and North-East gusts in the "Strong Gale" and "Storm" categories. These exceed the "severe" wind gust threshold (~80 km/h).
- In the "Gale" category (nearing the "severe" threshold), North, North-North-East and South-West are the most common in terms of incidents.
  - These are of similar overall incident frequency to the West-South-West gusts of "Strong Gale" and "Storm" speeds.

Overall, these wind directions mentioned are either broadly from the prevailing South-Westerly wind or from more Northerly or Easterly directions from ex-tropical cyclones.

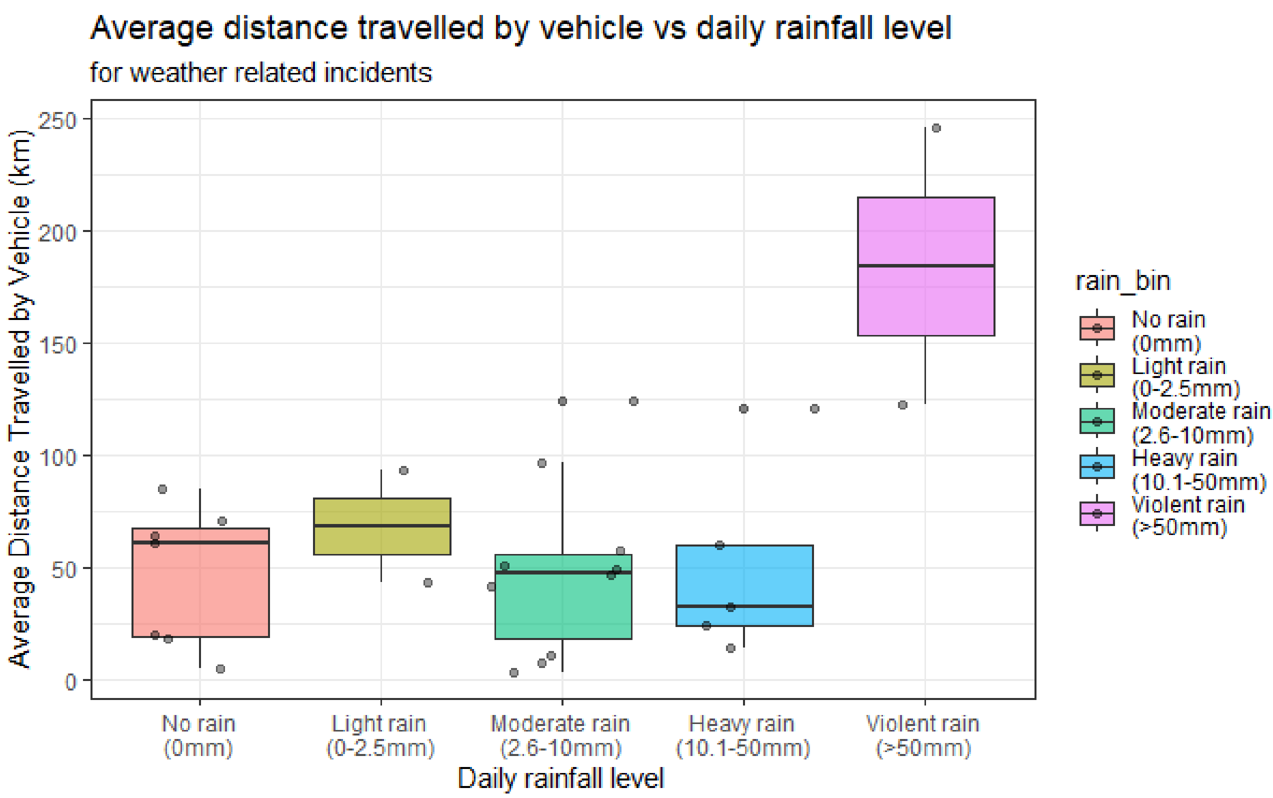
It is reassuring that far fewer incidents occur on days with peak wind gusts less than 50km/h ("Fresh Breeze" and "Strong Breeze" categories).

Effect of weather on Incident Response

Anecdotally, rainfall was observed to impact incident response time more than heavy wind or gust speeds. This was based on the intuition that rain could lead to flooding, thereby disrupting travel and repair work.

For this analysis, only weather related incidents were chosen (see Classifying events as weather related) to eliminate the effect of other factors. Peak daily gust speed, daily rainfall and combinations of the two were then examined. It should be noted that vehicle tracking data could not be exactly matched with incidents which meant that only 52% of incidents could be used for vehicle analysis.

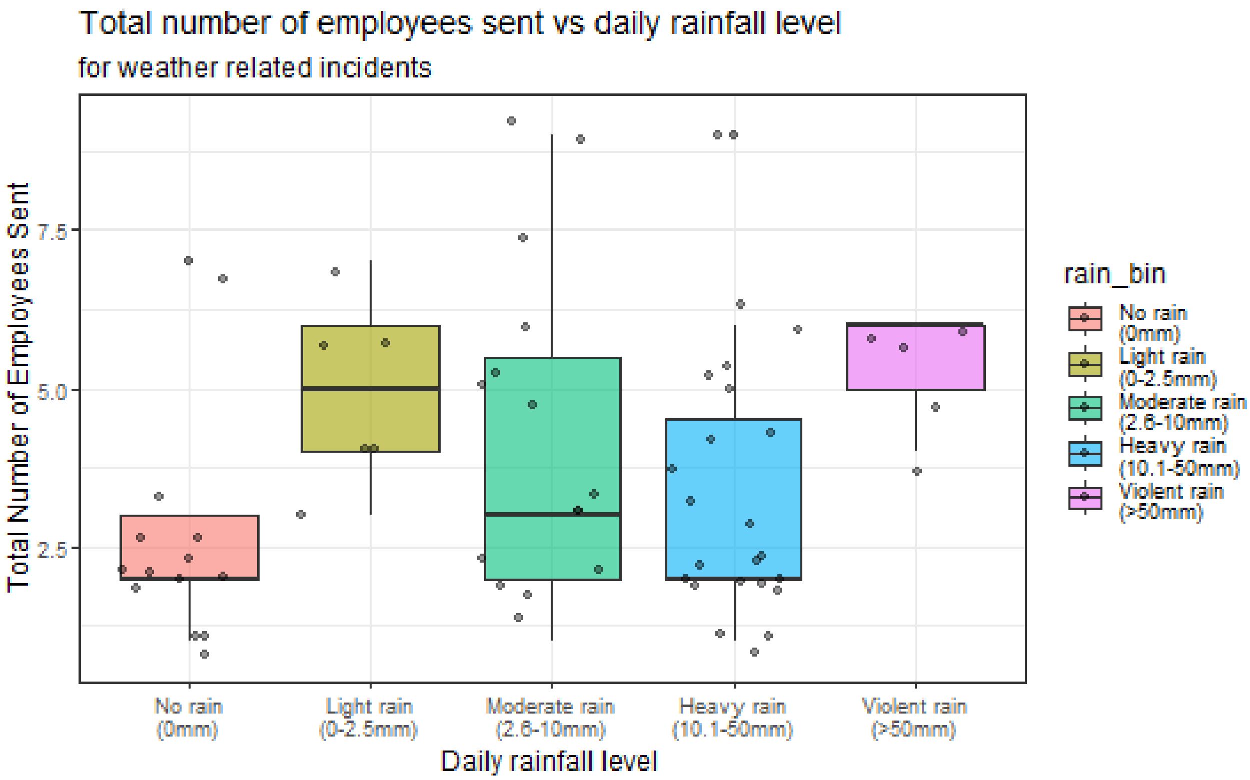
Rainfall



Binned daily rainfall levels against average distance travelled (km/per job) on each incident. The horizontal black lines represent the median vehicle distance travelled.

As depicted in the above figure, rainfall above a certain threshold appears to have a significant impact on staff movements. Incidents occurring on days with “Violent rain” are associated with the furthest distance travelled by repair crew. Despite these findings, the relationship between rainfall amounts and distance travelled by vehicle does not follow a consistent trend.

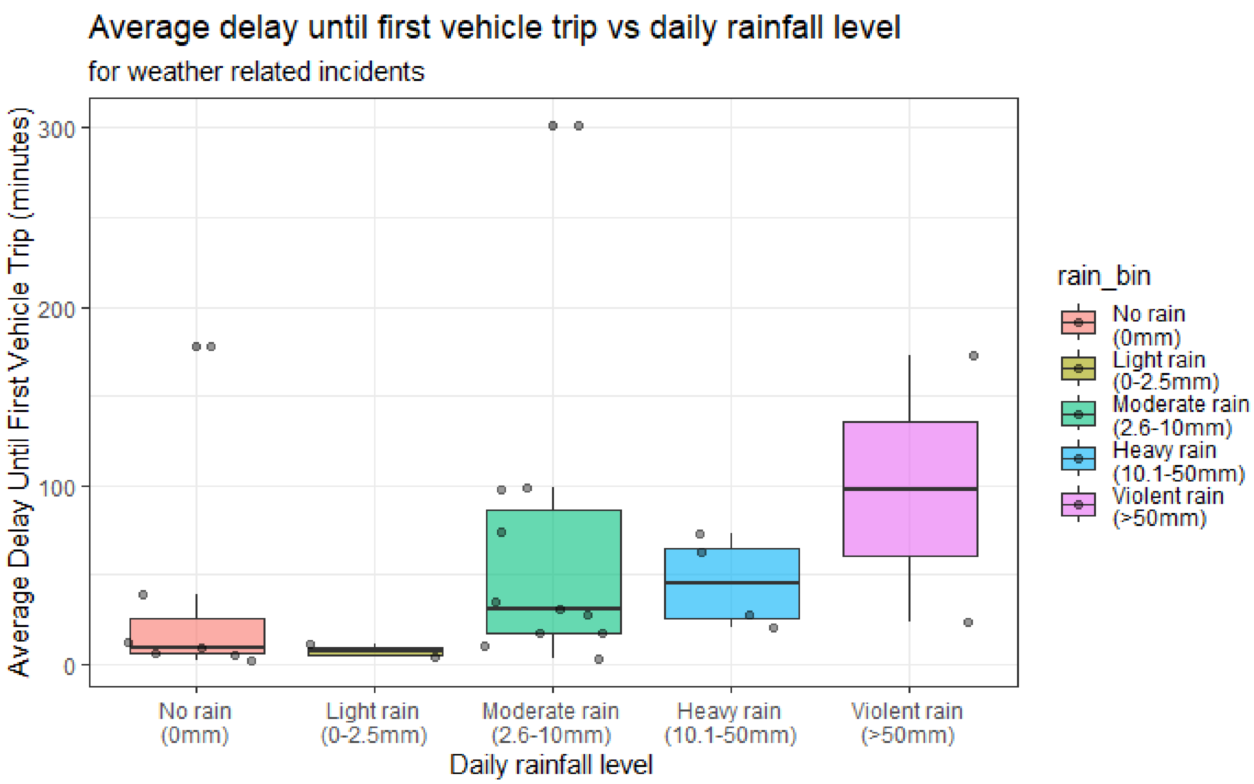
Nevertheless, caution must be taken when inferring increase in distance travelled, as there are relatively few observations of extreme rainfall that could be matched to vehicle data.



There is an observed relationship between the number of employees sent and rainfall level.

- 'Violent" rain days are associated with the most employees being dispatched on average, with approximately 6 staff members being dispatched.
- The relationship does not appear to be linear as the number of staff, with average number of staff sent falling from 5 crew to (approximately) 2 during "Light" rain to 2 crew in "heavy" rain
- Although "violent" rain days recorded the most staff

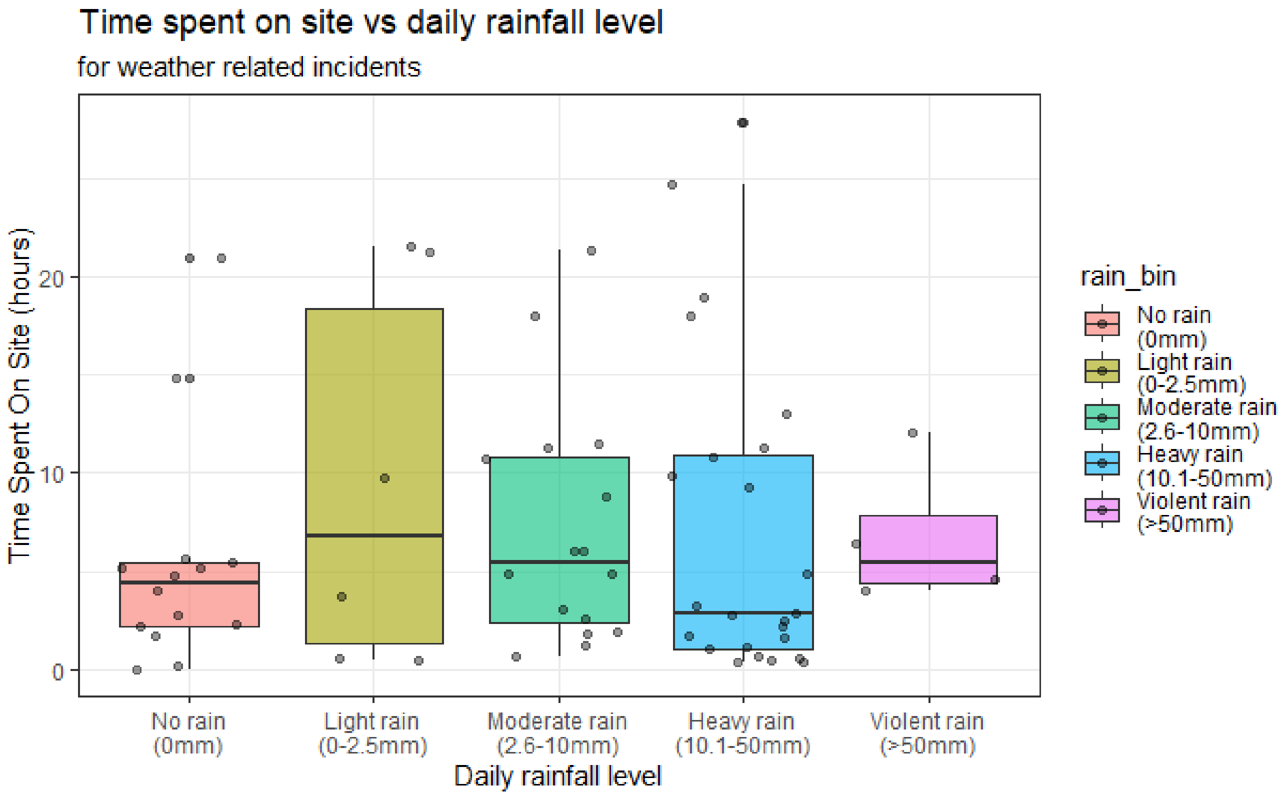
Whilst there is evidence of a relationship between daily rainfall and employee numbers, this is not an indication of causality. One possible reason for this apparent relationship is that severe weather is associated with an increased frequency. Hence, more staff will be dispatched to respond. Nevertheless, this is only one possible explanation and more information is needed to confirm.



In the case of average vehicle delay, there appears to be a positive correlation between daily rainfall levels and delay time. Incidents occurring on days of violent rain suffered the greatests delay, whilst “Light” or “No” levels of rainfall were associated with the least amount of delay.

It also appears that variation in delay times is generally larger when there are higher amounts of rain, but this is not proportional to rainfall levels. Unexpectedly, the longests observed delays occur during “Moderate” levels rainfall.

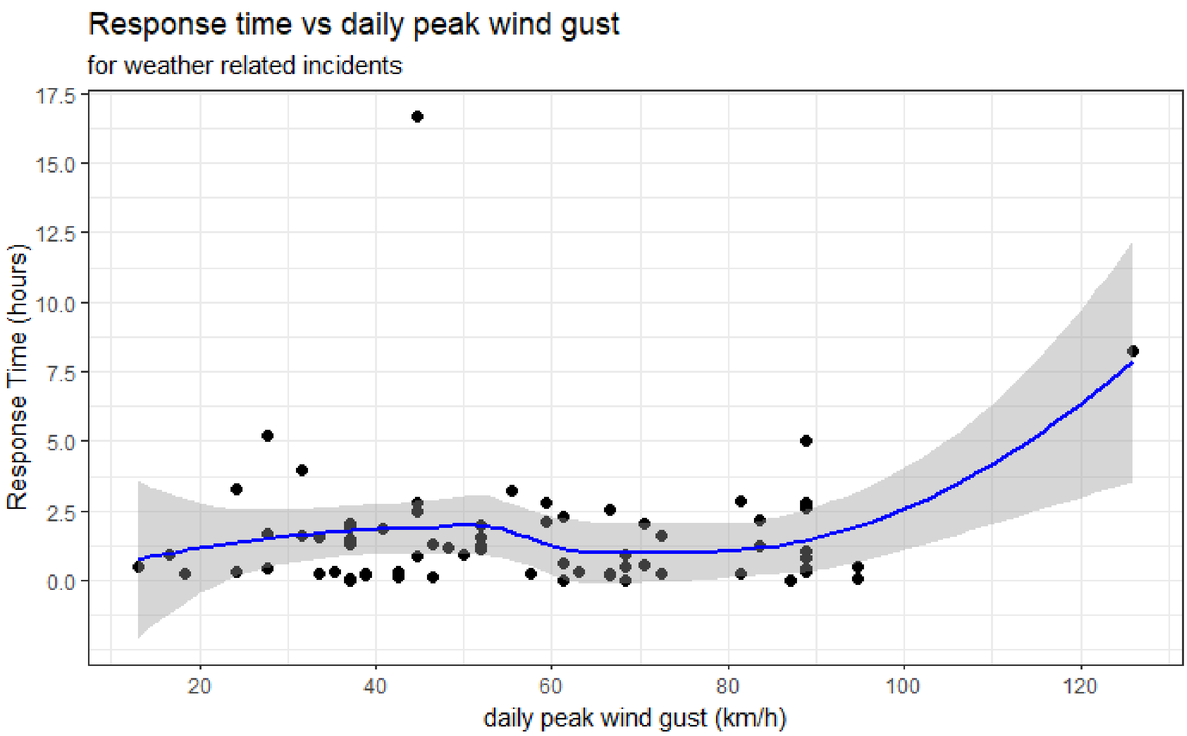
Once again, it is worth mentioning that despite the observed connection between delay in vehicle dispatch and rainfall, this is not necessarily causal. Considering that there is generally an increase in incidents and the number of staff during severe weather, it is likely that a lack of available staff could be partly responsible for these findings.



There does not appear to be a relationship between average time on site and rainfall level. For instance, the average time on site is higher for light rain than heavier levels of rainfall, and the "heavy" rain incidents record the lowest average time onsite. In contrast to this "light" rain incidents have the highest average time spent on site.

The variation is not consistent across the different rain levels, and there is no strong correlation between the variation in time onsite and rainfall level. The maximum onsite time is also lowest for the "violent rain" category - despite the expectation that weather of this nature would most impact work. Based on these findings it is difficult to assess the degree to which rainfall levels affect the duration of repair work.

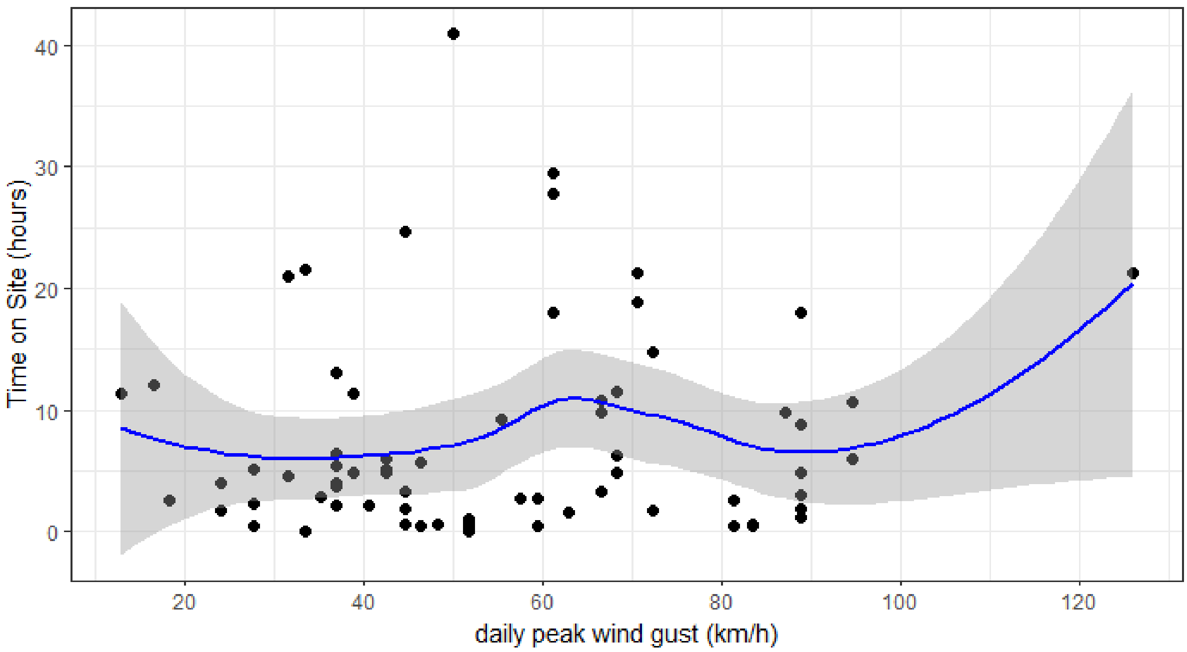
Gust Speed



The time to respond to an incident appears to be uncorrelated by daily peak gust speeds - indicated by a mostly horizontal trendline.

- Across all gust speeds near zero response times can be observed.
- Furthermore, there is a sudden uptick in average response time between speeds of 90km/h and 130km/h.
- This suggests that for extremely high peak gust speeds there *could* be an effect on the response time, but more data is required to confirm this trend.

Time on site vs daily peak wind gust
for weather related incidents



Like with response time, average time on site is relatively consistent across different gust speeds, but with significant variation for all gust speeds, ranging between 1 and 20 hours for the majority of incidents. Data points are scattered quite sparsely around the trendline, which suggests little correlation between gust speeds and time on site.

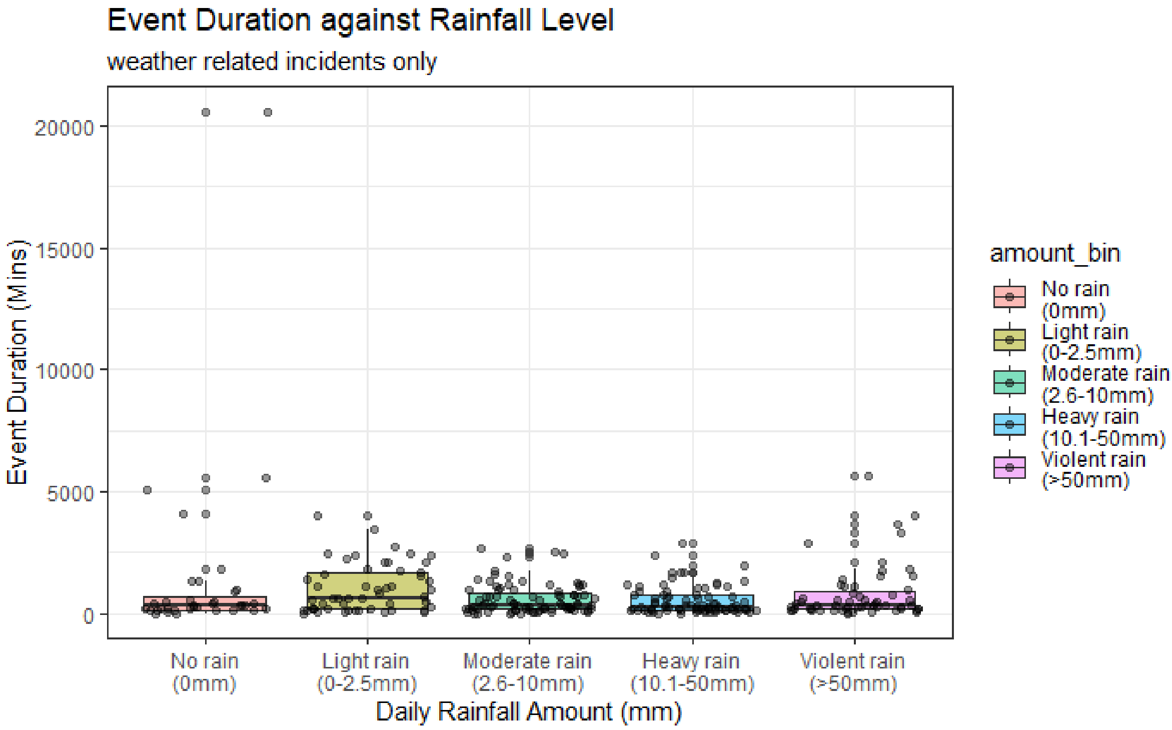
For gusts around 60-70 km/h there is a slight spike in the time spent on site, but this appears to be an outlier.

Effect of weather on Incident Duration

It was of interest to investigate the link between incident duration and weather conditions, so that Top can better understand how vulnerable their overall incident response time is to adverse weather.

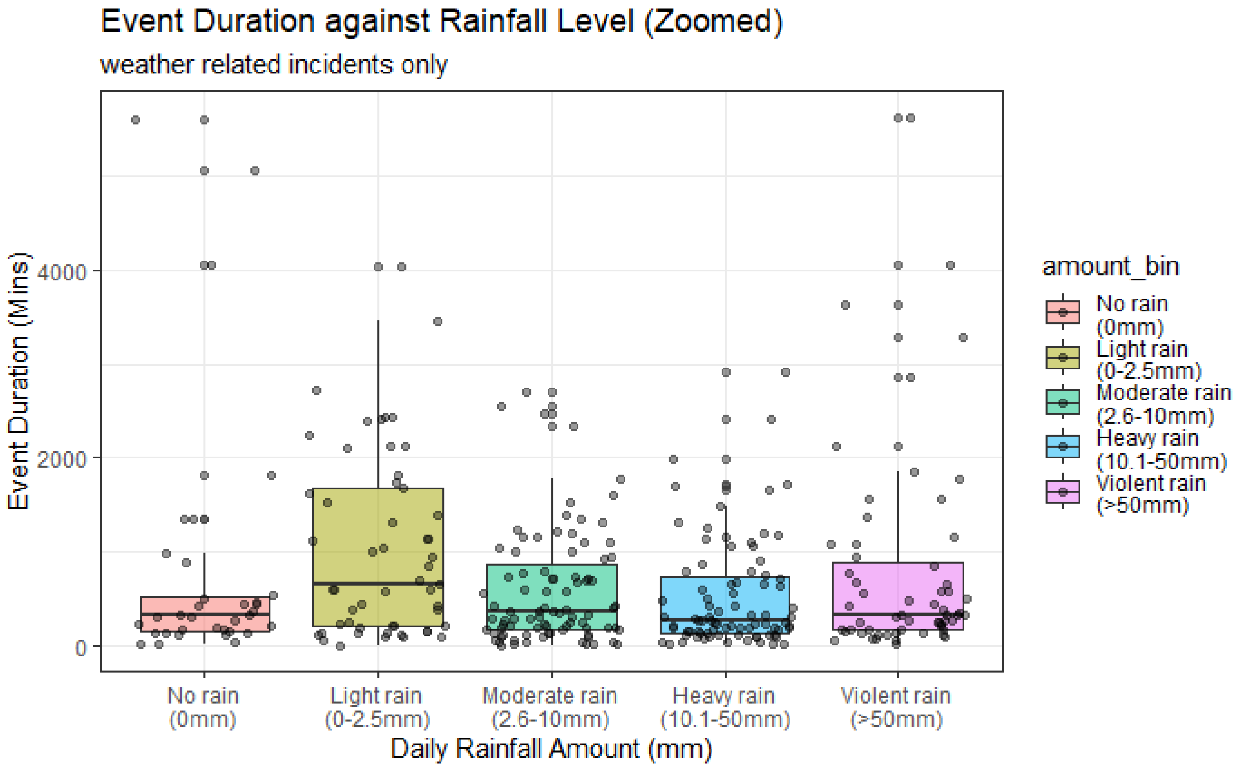
For the purpose of this analysis, we focused our investigation on outages caused by adverse weather (see Classifying events as weather related) in order to limit the influence of other factors on event time.

Rainfall



The figure above shows incident outage duration distributions for groupings of rainfall amounts. However, there are two outliers of extremely long incident durations, on days with little-to-no rainfall.

The figure on the following page ignores these outliers, and provides a zoomed-in view to allow closer inspection of the distributions.

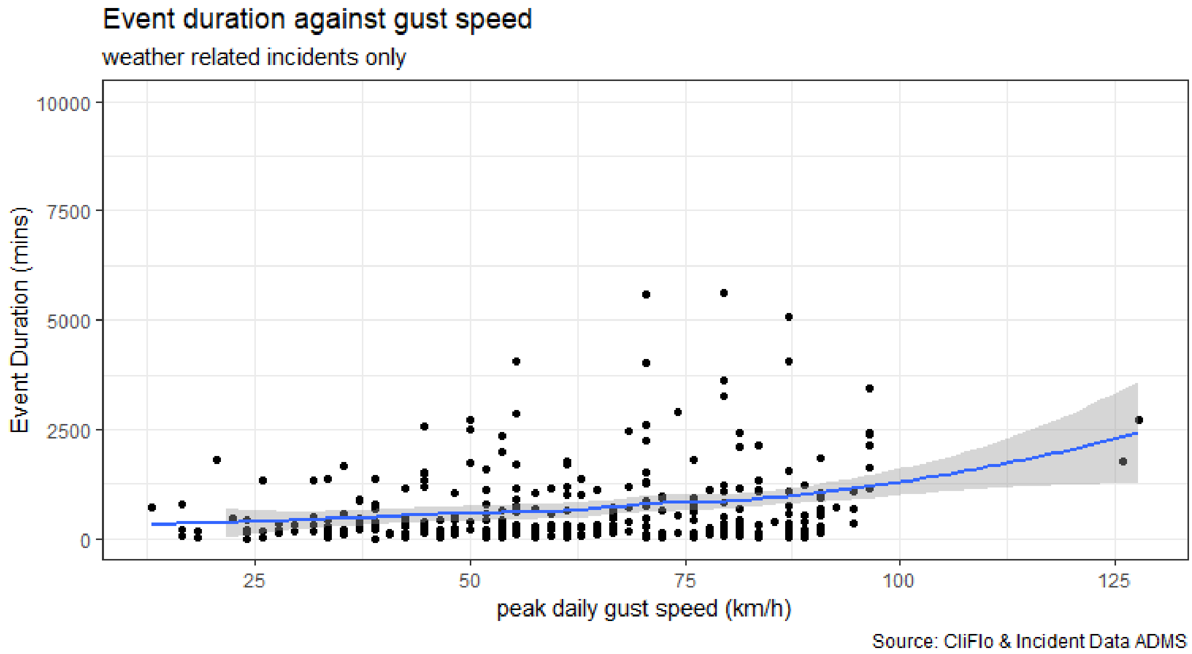


The Event duration in minutes vs binned daily rainfall amounts. The horizontal black lines represent the median duration of each rainfall category.

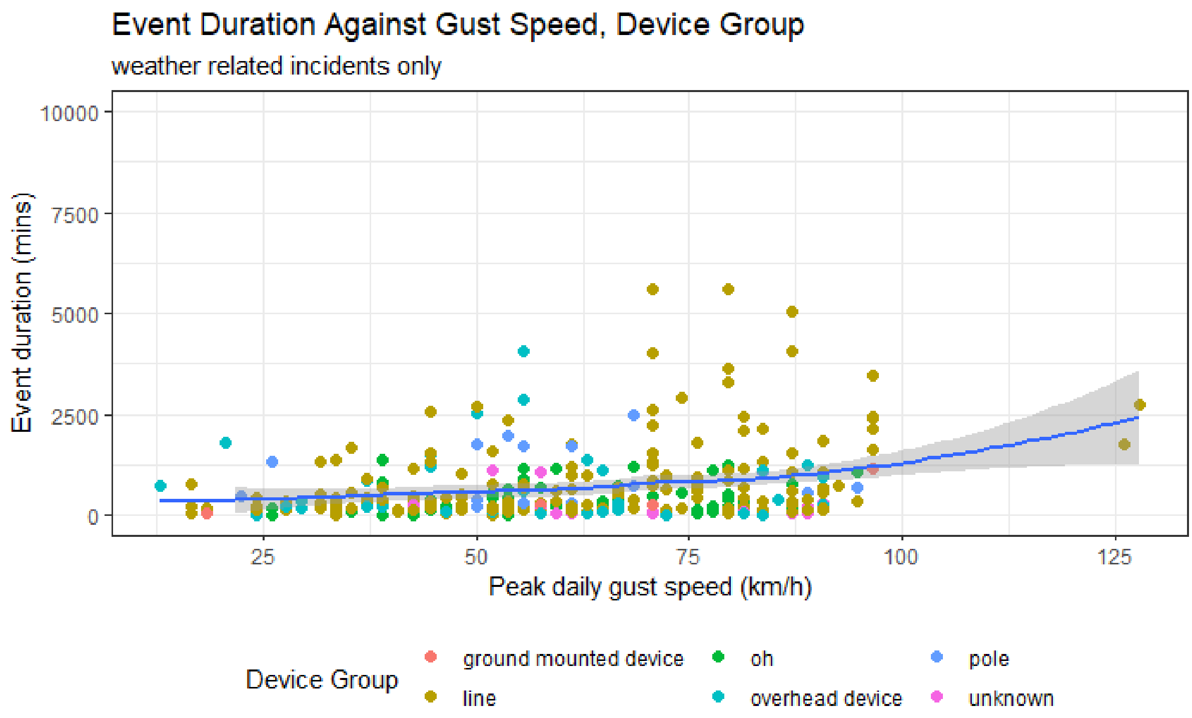
There does not appear to be a strong correlation between event duration and rainfall amounts.

- The average event duration is similar across all rainfall categories, except for light rain which records the highest median event duration.
- Incidents on days with “Violent” rainfall is more right skewed than other categories, with more events exceeding 3000 minutes
- Interestingly the longest events tend to occur for both days with 0 mm of rain and “Violent” rain.

Gust

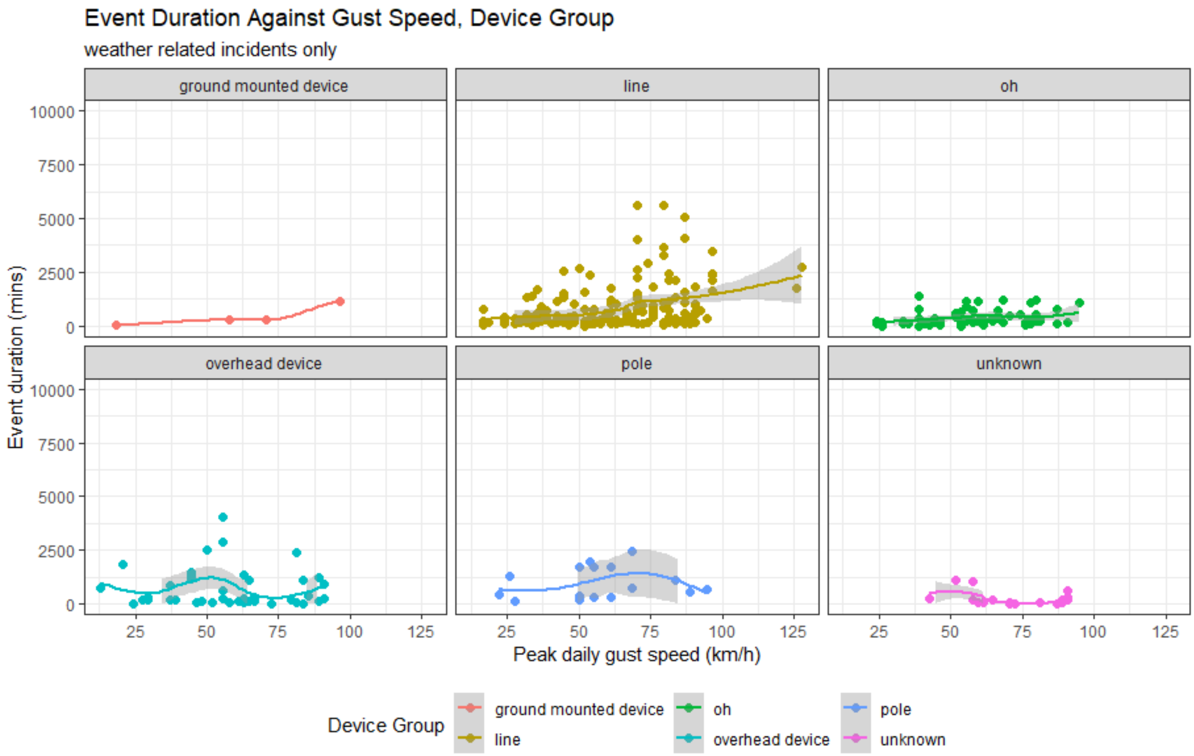


There is a weak correlation between wind gust speed and incident duration. The figure above shows both average incident duration and variation in average incident duration gently increase as the daily peak gust speed increases. Event duration peaks when there are wind gusts of approximately 75 km/h.



Event duration tends to increase with peak gust speeds, as seen in the figure at the top of the previous page. Breaking this down by device group, it can be seen that longer outages are more common when overhead conductors (lines) are affected and there appears to be a higher incidence of line related outages at gust speeds of approximately 70 km/h and above.

The following plot demonstrates the relationship between gust speed and event duration, broken down into each one of the device groups. Here the interaction between gust speeds and device groups is more clearly illustrated.



Here the difference between device groups is more stark. Devices belonging classed as "line" (overhead conductors) show a dramatic increase in event duration gust speeds increase whereas all other groups demonstrate little correlation.

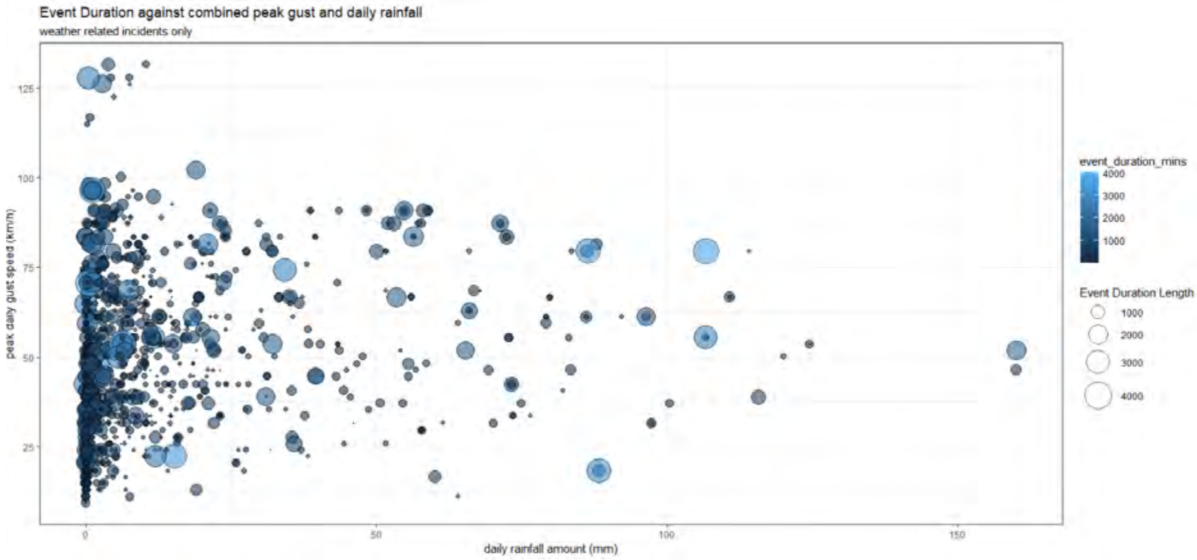
Device Group	Average Event Duration (mins)	% of Overall incidents	% of weather related incidents
cable	2739.2	0.9	0.0
line	573.6	34.4	53.8
pole	415.4	13.8	5.2
Overhead (conductor)/lines	350.8	14.7	12.9
oh	342.3	24.4	21.5
Ground mounted device	276	2.9	1.2

Device groups, ranked by associated event duration. Devices labelled "unknown" are missing from this table.

Overhead conductors have the 2nd highest associated average event duration, and are affected 56% more frequently when weather conditions are likely responsible.

These findings may indicate that link between gust speeds and event duration is actually due to the effect gust speeds have on specific components, which in turn affects the time taken to repair.

Combined effect of gust and rain



A brief analysis was conducted into the combined effect of rainfall and wind gusts on incident durations.

The figure above shows a very high density of incidents close to the y-axis, with little-to-no rainfall occurring on that day. In this cluster there is a high proportion of dark blue small points, indicating relatively short incident durations, however, higher duration incidents (larger, pale blue points) also occur in this cluster. The scatter generally becomes more sparse as the daily rainfall amount becomes more extreme. Looking closer, it is in fact the low-duration small points which become less common, and there remains a similar density of larger points indicating higher duration. Thus, for weather-related incidents of occuring on days with very high daily rainfall amounts, there is a higher likelihood that the incident will have a long duration and cause a large increase in SAIDI.

Despite this, any trends in the figure above, do not show any interaction between rain and gust influencing durations.

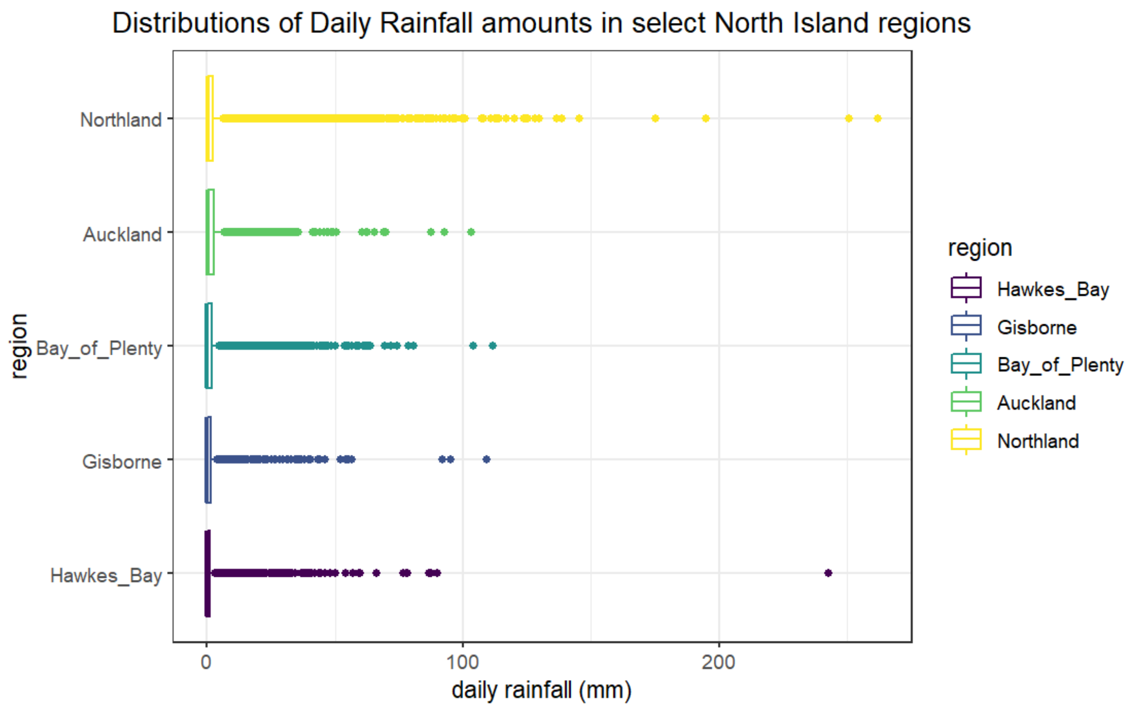
Comparison of Adverse Weather in Northland to other North Island regions

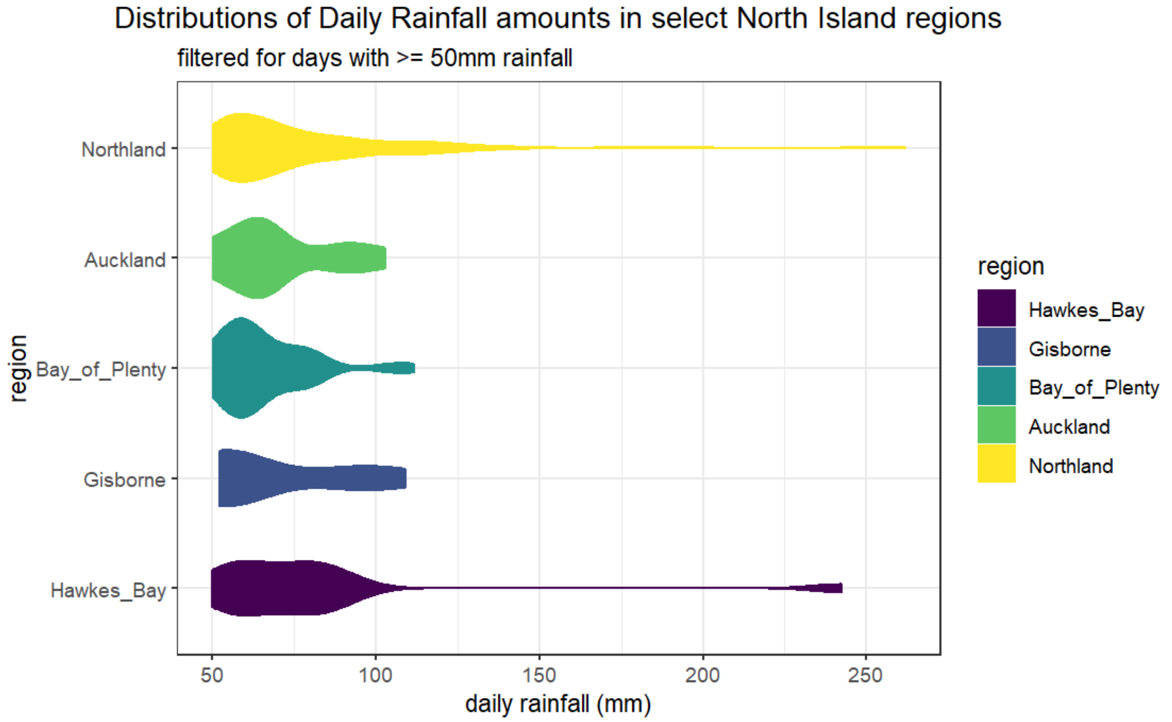
In the Top Energy distribution region, we have analysed data from 25 weather stations. For this comparison, other geographic regional councils in the North Island were represented by 2 - 4 weather stations.

A focus group of Auckland, the Bay of Plenty, Gisborne, and the Hawkes Bay was selected, as these regions are considered to be the most geographically and meteorologically similar to Northland. Weather data was extracted from the NIWA CliFlo weather database from April 2019 to August 2022.

Rainfall

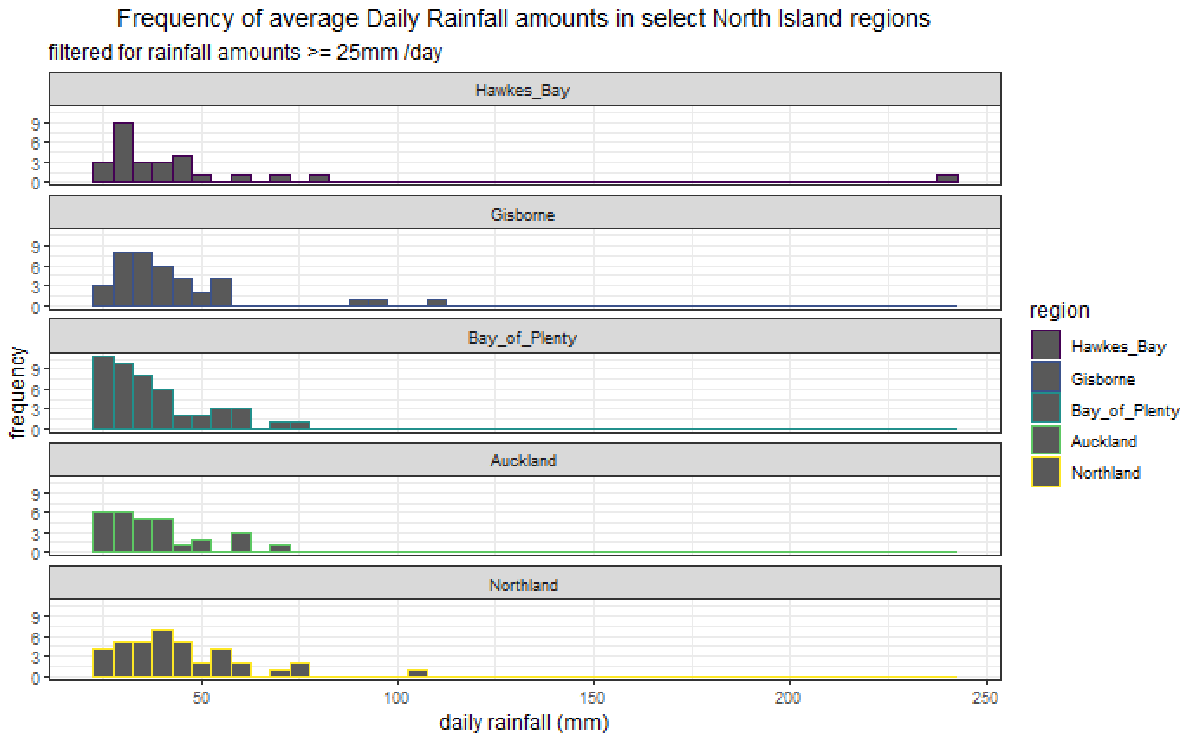
The figure below indicates all regions have the vast majority of days with little or no rainfall. With an interest in extremes, the figure on the following page is filtered for days with more than 50mm of rainfall.





Northland clearly has the longest tail of high rainfall days, followed by Hawkes Bay.

The figure below has data filtered for days with rainfall amounts exceeding 25mm, and then binned into groups, to see the frequency of bands of daily rainfall amounts.

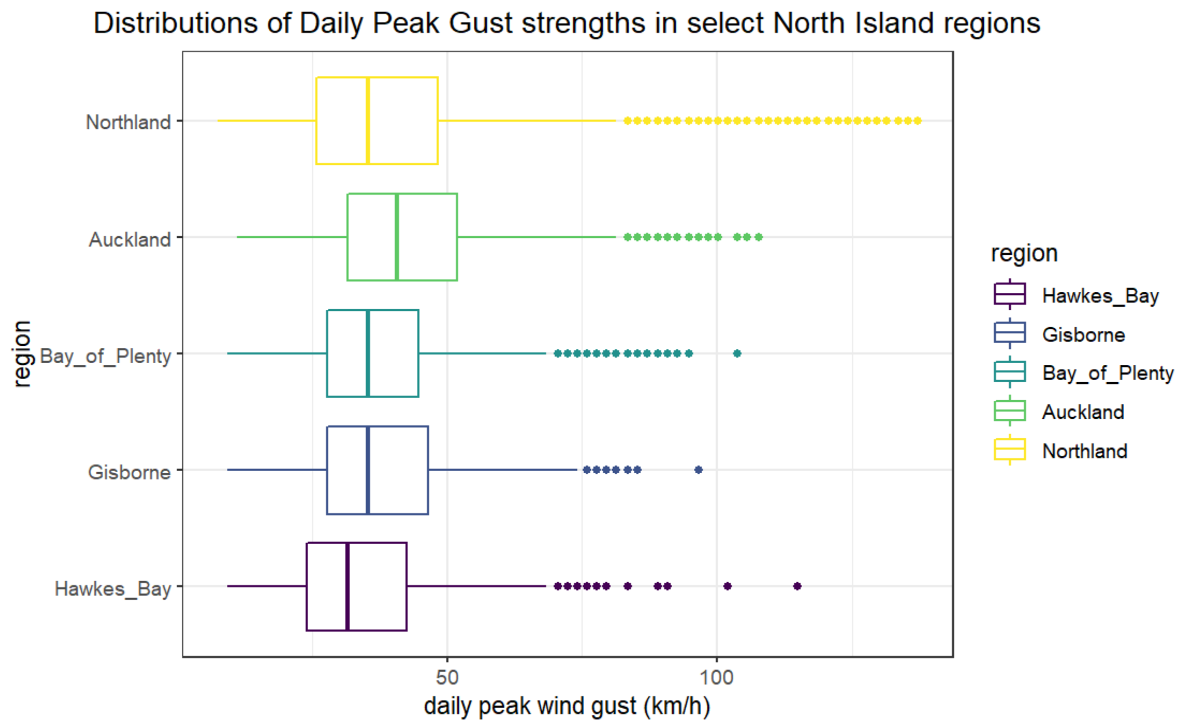


Looking just at Northland, this region experiences days with 37.5 - 42 mm of rainfall with the highest frequency. In comparison, the peak frequencies seen in other regions are at lower amounts of rainfall, between 25 and 37.5 mm of rainfall per day. Note that these approximate most-common-groupings exclude all days with less than 25mm of rainfall.

Northland, Hawkes Bay, and Gisborne have longer right tails of more days occurring with higher amounts of rainfall, compared to the other regions in the focus group.

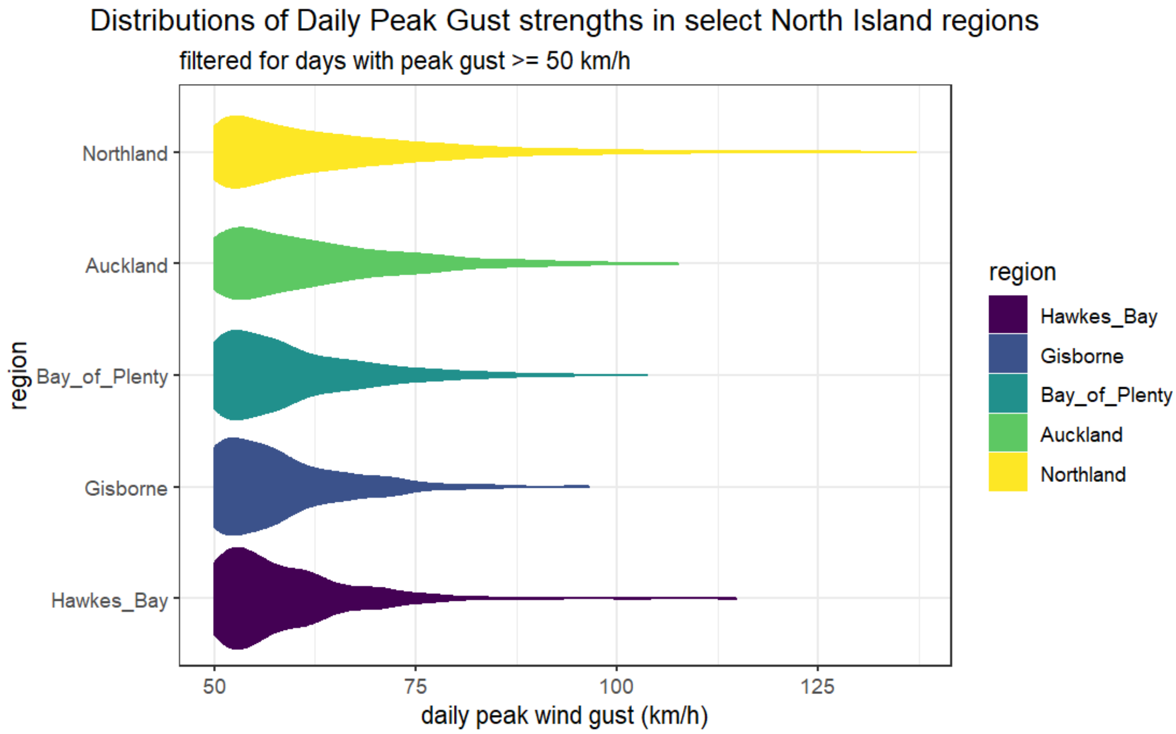
Gust Speed

There is significant overlap between the most common daily peak gust speeds across the regions.

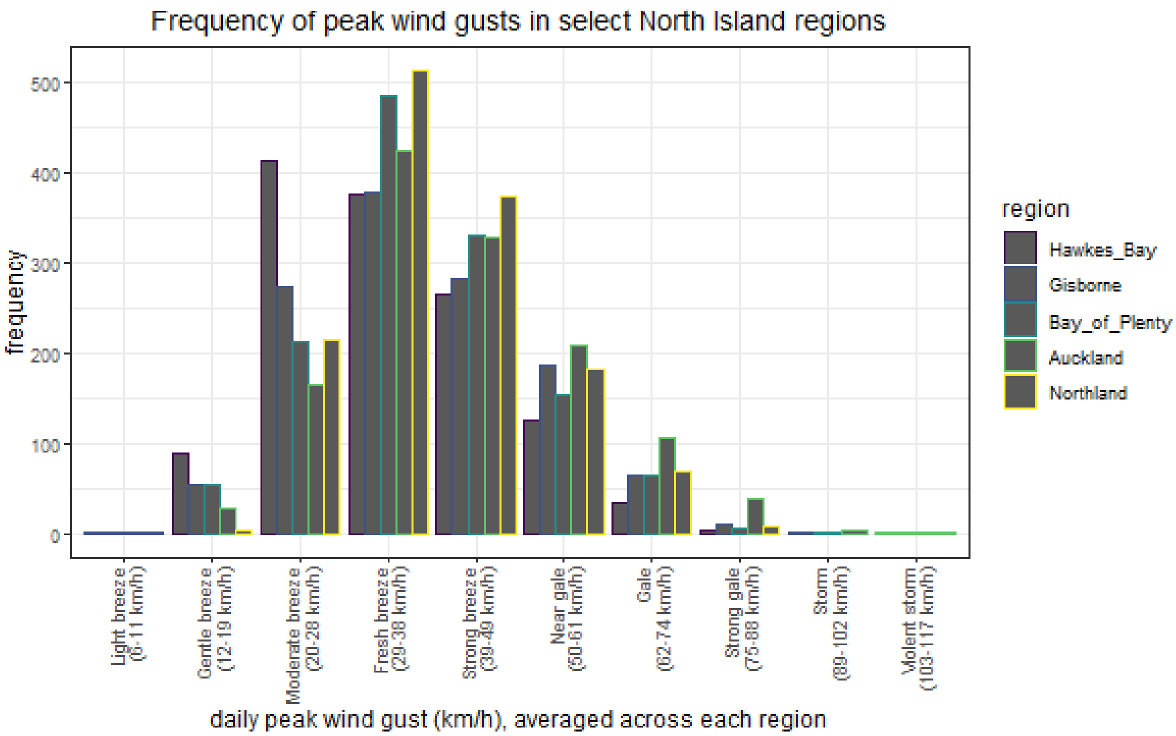


Again the figures are filtered for days with greater than 50km/h peak gust, to focus on the frequency of more severe weather days.

In the figure below, Northland has a narrower and longer distribution shape. This suggests it experiences fewer 'medium' amounts of peak gusts, and more frequent very high peak gusts, seen in the long right tail.



The figure below has the data binned into wind speed groups from the Beaufort scale, to be able to see the frequency of more interpretable groupings of windspeed.



In the figure above, of all the regions, Northland has the most days with a peak gust in the ‘Strong breeze’ (39 - 49 km/h) and Fresh Breeze (29 - 38 km/h) groups. It also has the 3rd highest frequency for Near Gale (50 - 61 km/h) (after Auckland and Hawkes Bay), and 2nd highest in Gale (62 - 74 km/h).

Overall, this analysis of Northland rainfall and wind gust metrics in comparison to a focus group of Auckland, the Bay of Plenty, Gisborne, and the Hawkes Bay, has shown:

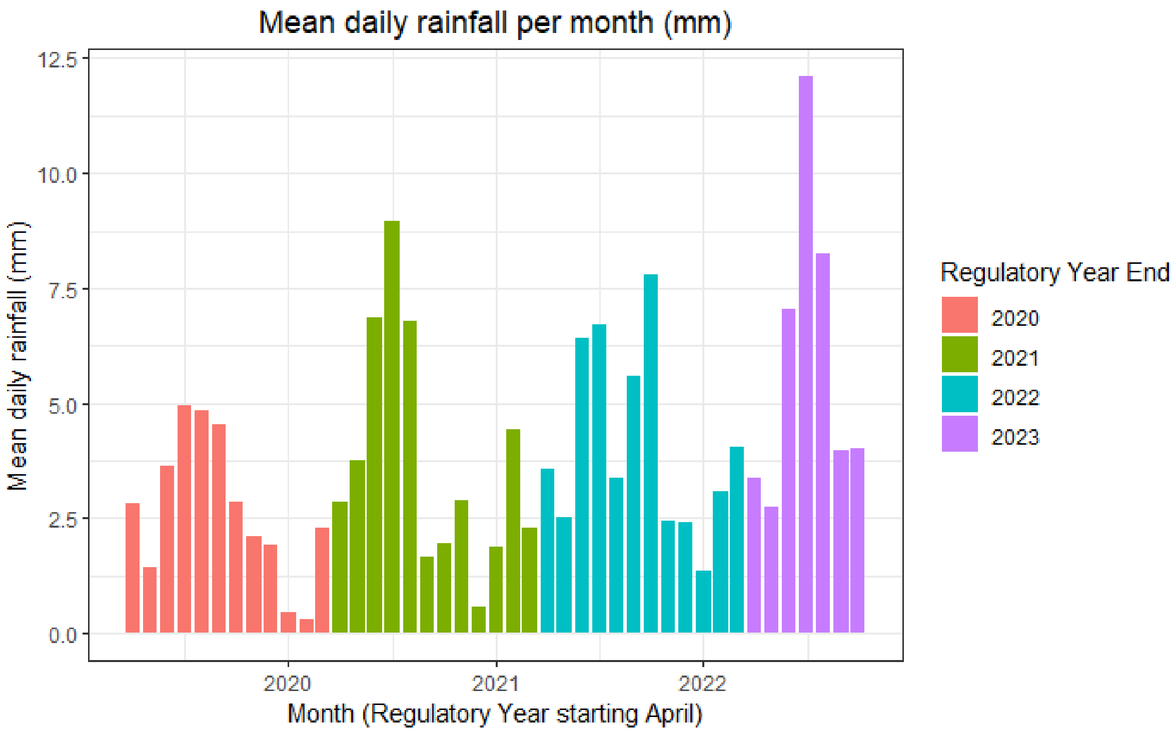
- Northland, Hawkes Bay and Gisborne in general experience days of high rainfall with greater frequency.
- Northland, Auckland, and Hawkes Bay are the more windy regions in this group, experiencing high peak gust speeds with greater frequency. .

Weather trends over time

Previously, it was suggested that Winter months and bad weather had an impact on incident frequency. We also observed that usage of the manually input Extreme Weather Event flag was increasing in YE2023 as more adverse weather events were recorded per month on average, and that changes in rainfall and gust speeds coincided with increases in SAIDI and/or incident frequency. Therefore, this section of the report seeks to outline changes in rainfall and maximum gust speeds throughout Northland throughout YE2020 to YE2023, at different levels of regional aggregation.

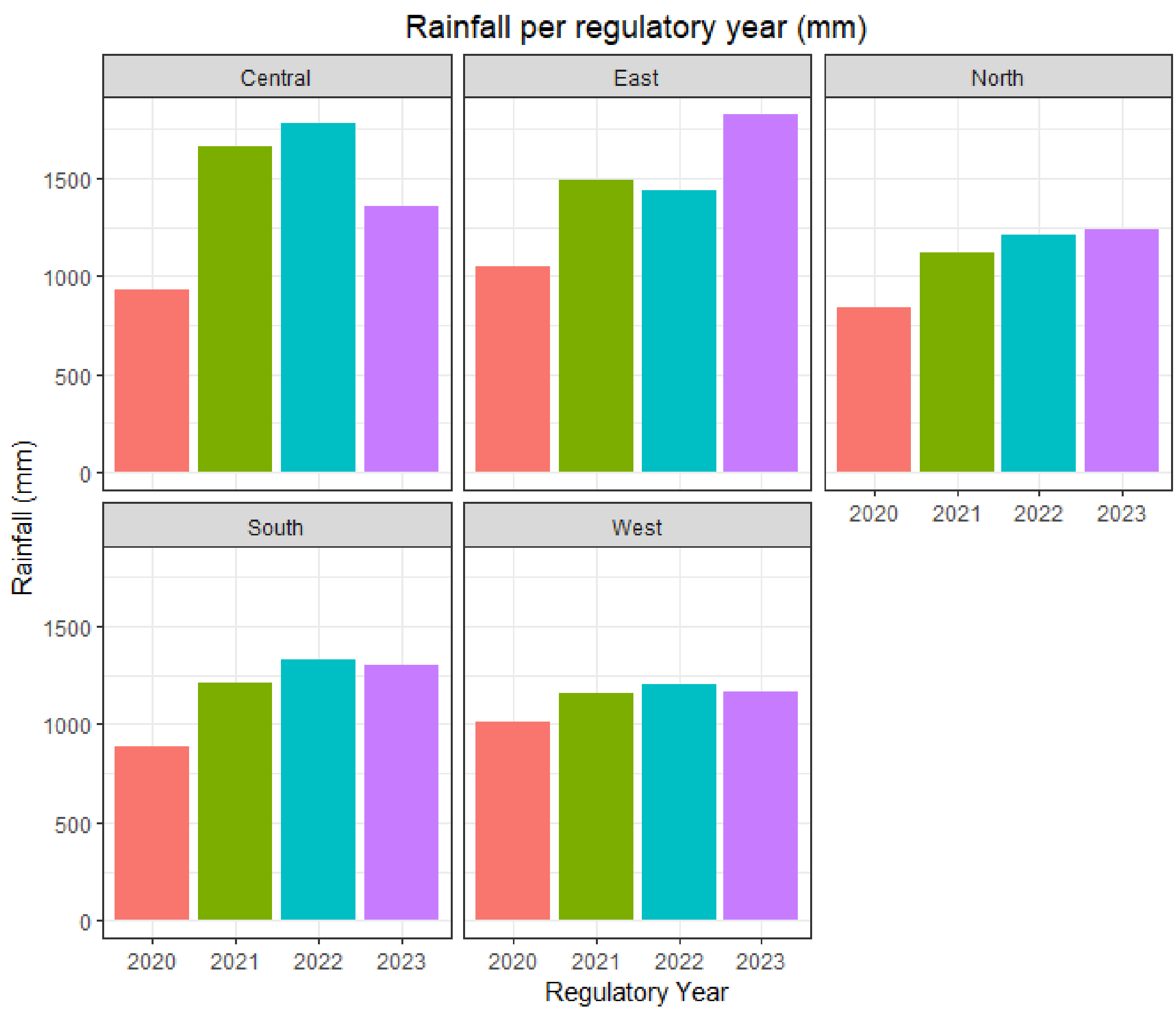
Annual patterns

Rainfall

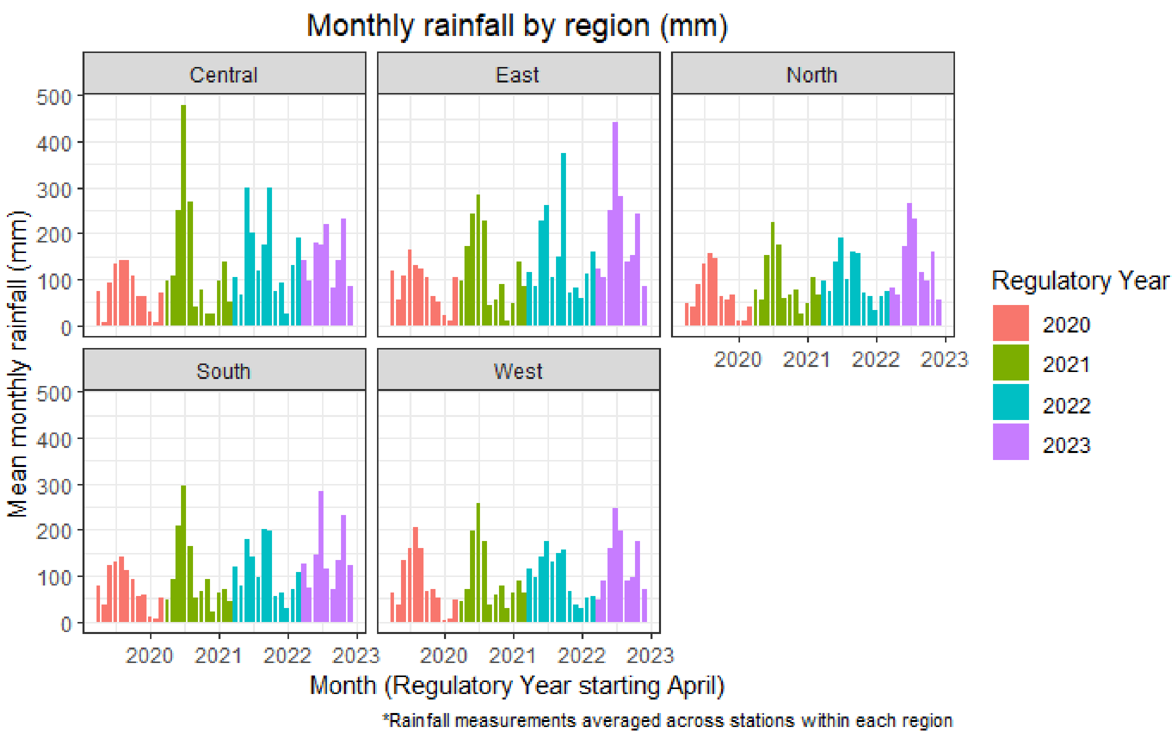


The graph above shows the daily amount of rainfall in Northland, averaged across all weather stations in Northland per month. Each year exhibits similar seasonal patterns, where the average daily amount is higher over Winter months, and generally lower in Summer months. The average daily rainfall amount for each month generally increases each year, with YE2023 showing a marked increase in average daily rainfall in Winter compared to previous Winter months.

YE2023 exhibited a record level of average rainfall per day by month in July, averaging to 12mm/day. Each year shows relatively similar patterns of average daily rainfall throughout the months, though YE2023's lowest average daily rainfall in May of 2.7mm/day is much higher than lowest average measurements in previous years. This suggests that though there may be some daily fluctuations not captured in the graph above, YE2023 on average appears to be wetter than previous years per month.

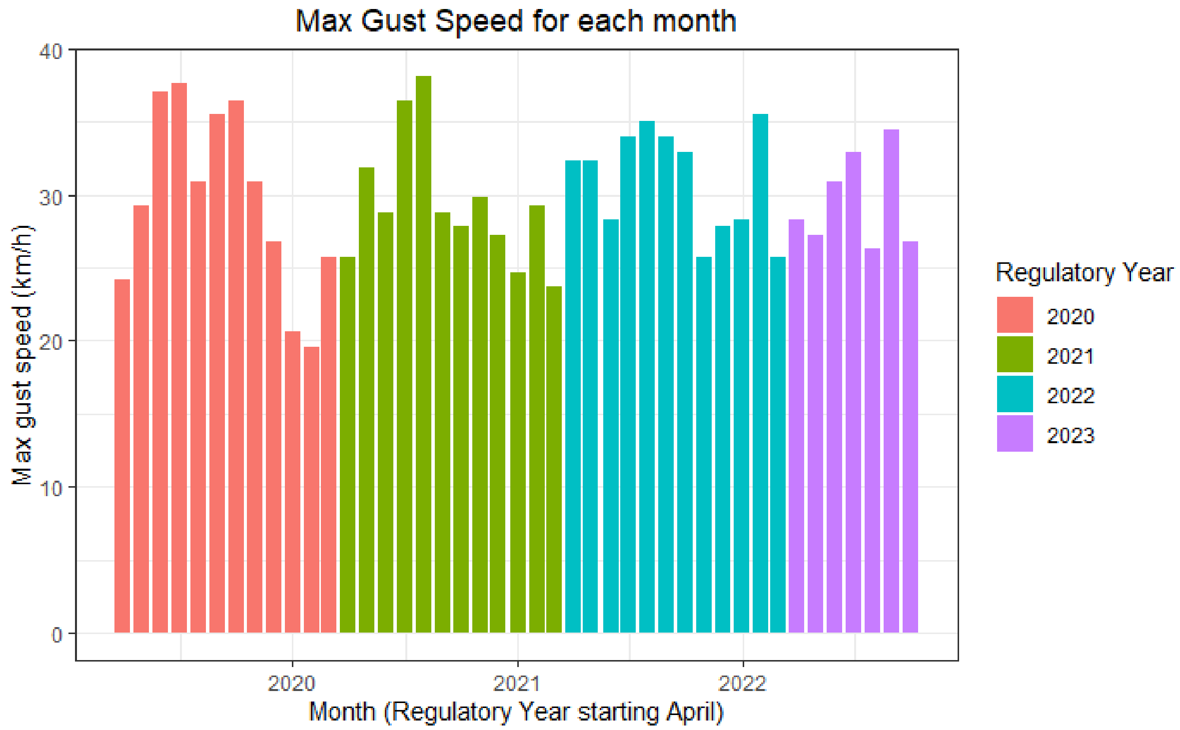


In YE2023, the eastern side of Northland had the highest amount of rainfall, measuring at 1818 mm of rainfall - approximately 385 mm more than YE2022. This is contrary to the patterns seen in previous years, where the central areas in Northland saw the highest amount of rain overall. Interestingly, central Northland experienced much less rainfall compared to previous years in YE2023, approximately 422mm less than YE2022. The other regions in Northland experienced similar levels of rainfall to previous years, although YE2020 notably experienced less rainfall than the following years.

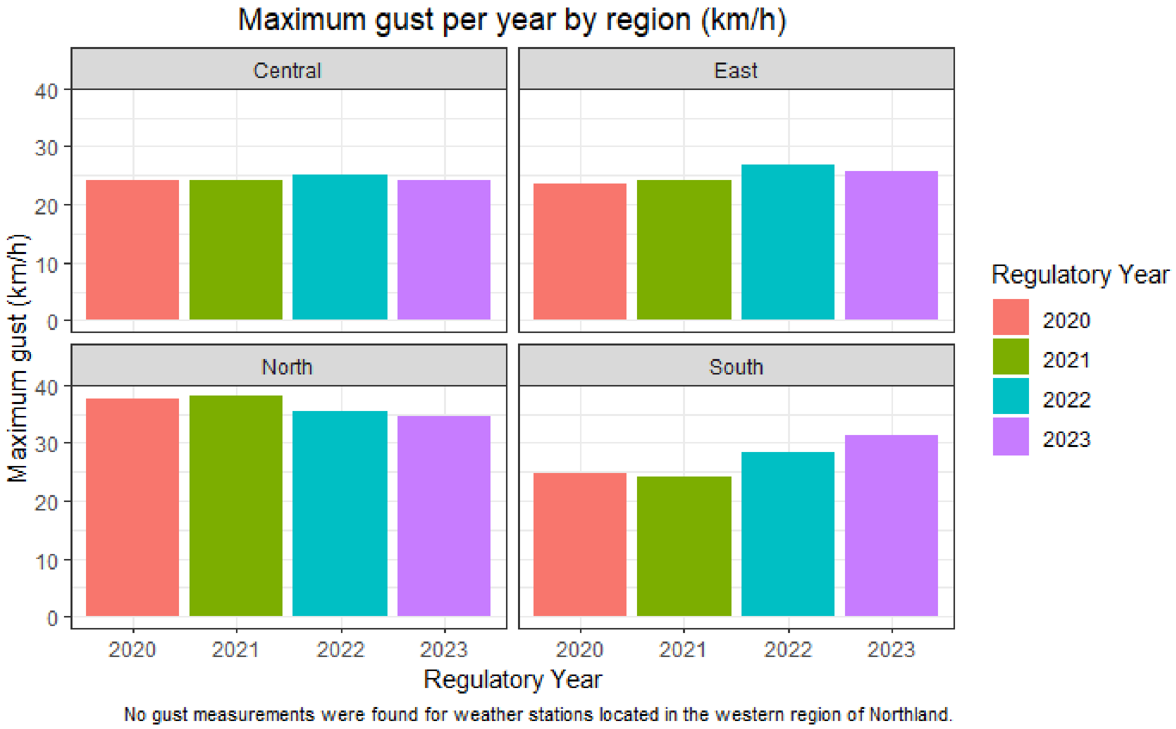


The mean rainfall per month across stations within the eastern region of Northland consistently trends upwards over time during the observed period, with peaks appearing in Winter months. Particularly, July YE2023 exhibits a peak measurement of 423 mm in a month, which exceeds YE2022's peak in October of 373 mm by 50 mm. The peak in July YE2023 coincides with a spike in SAIDI minutes. Most regions roughly follow a seasonal pattern, with more rainfall occurring during Winter months and less rainfall in Summer months. Overall, the trend for monthly rainfall generally increases each year except for central Northland which experiences more variation year to year.

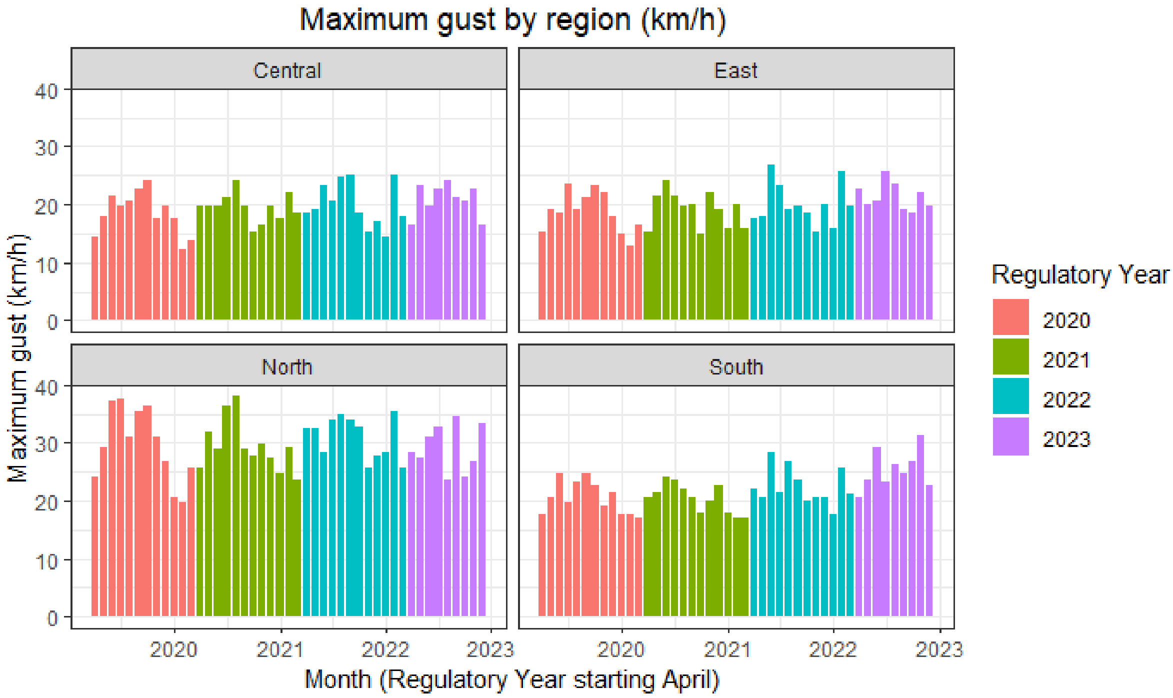
Gust



The above figure regarding gust speed indicates a slight deviation from gust speed patterns in YE2023, compared to previous years. A seasonal pattern can be observed throughout the years, but it is interesting to observe that maximum gust speeds are consistently high across each month in YE2022 and YE2023 to date.



Maximum gust speeds for central and east Northland are roughly the same at around 24 to 25 m/s. In the southern parts of Northland, the maximum observed gust speed increases from 25 m/s in YE2020 to 31 m/s in YE2023. Meanwhile, the maximum observed gust speed varies between 34 to 37 m/s. There is seemingly a downward trend, but it is not strong enough to conclude that there is a conclusive change in gust speeds for that area. Overall, maximum gust speeds per year in the northern parts of Northland remain quite high compared to other parts of Northland.

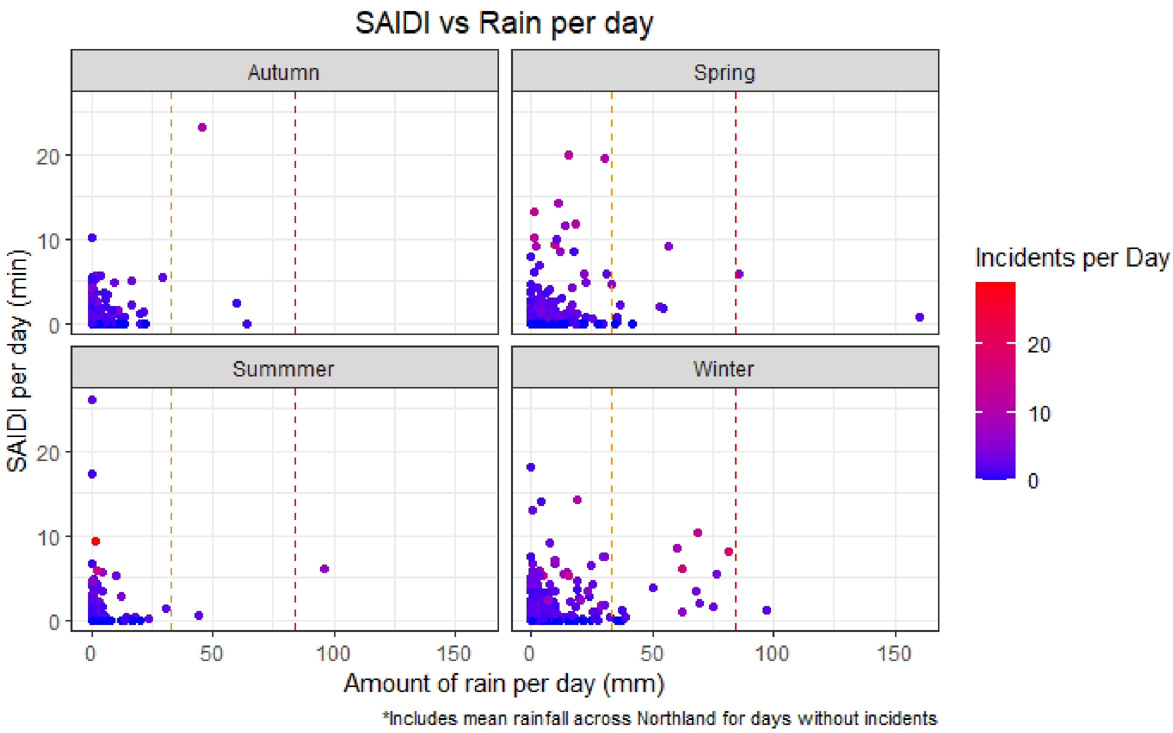


*No gust measurements were found for weather stations located in the western region of Northland.

The graph above matches what we expect to see, with overall higher maximum gust speeds in northern parts of Northland compared to other regions. Central and East appear to have similar gust patterns.

Overall, the average maximum gust speed appears to increase yearly by each region, except for in the northern area where gusts remain consistently strong.

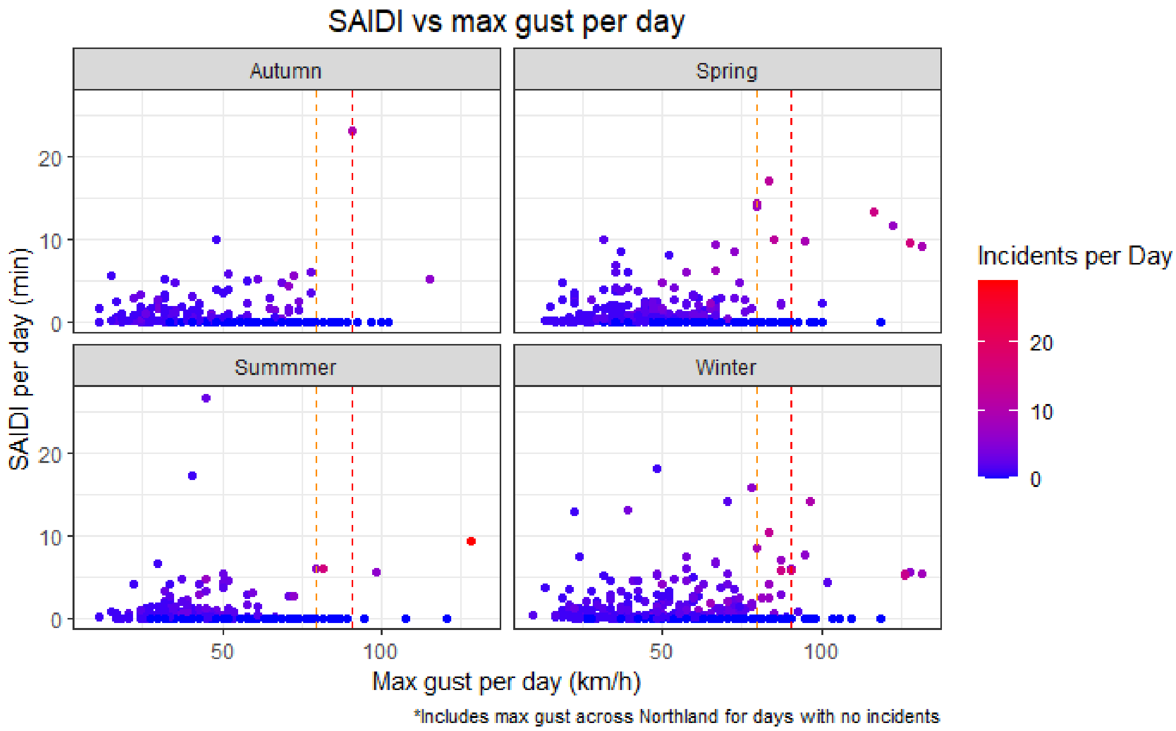
Seasonality



For this plot, the mean rainfall across all of Northland was taken on days where 0 incidents occurred.

When looking at accumulation of SAIDI per day plotted against rainfall per day, we don't see a strong relationship between the two variables. This is expected, as anecdotally we know that heavy rain and flooding has more of an impact on response time than SAIDI directly.

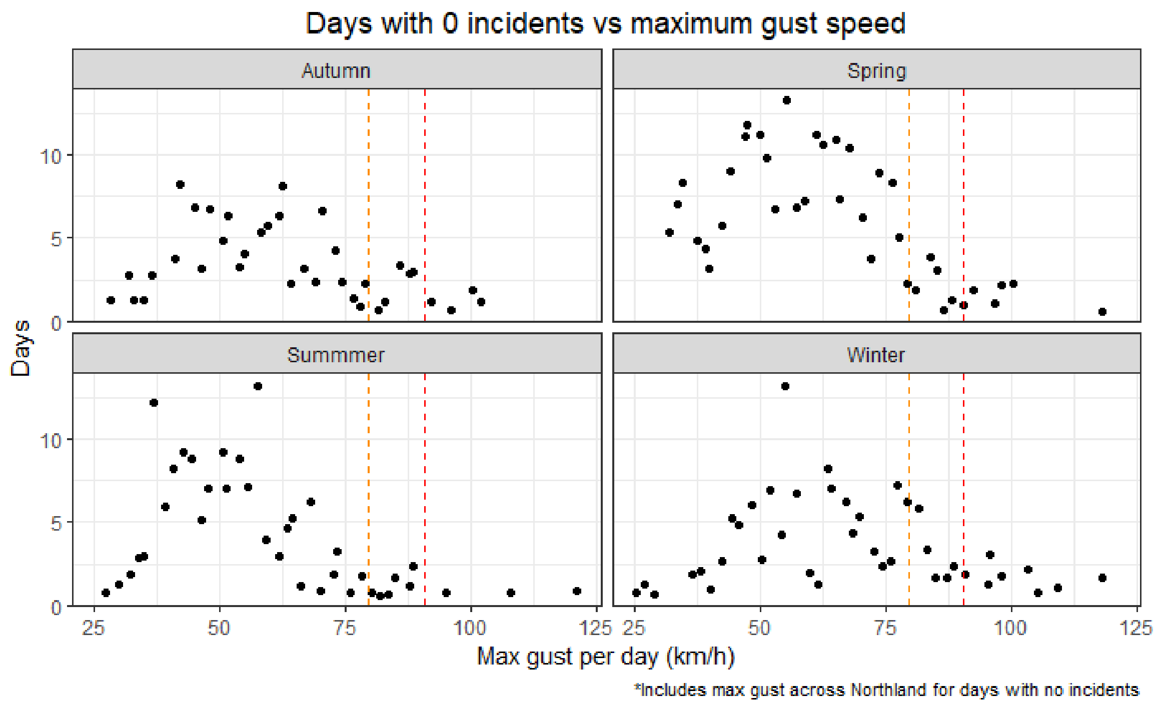
As noted previously, 28 days within our observation period have had severe rainfall, and 4 days have had rainfall classified as extreme. There were only 4 days where no incidents occurred when rainfall was considered extreme. All days with severe rainfall have at least 2 incidents.



For this and the following plots, the max gust across all of Northland was taken on days where 0 incidents occurred.

Looking at accumulation of SAIDI per day plotted against maximum gust speeds per day, it is interesting to note that there are quite a few days with strong gusts where no incidents occurred despite previous understanding of the correlation between gust speeds and incidents.

58 days within our observation period have had severe maximum gust speeds, and 51 days have had gust speeds classified as extreme. Of these, there were 75 days where no incidents occurred.

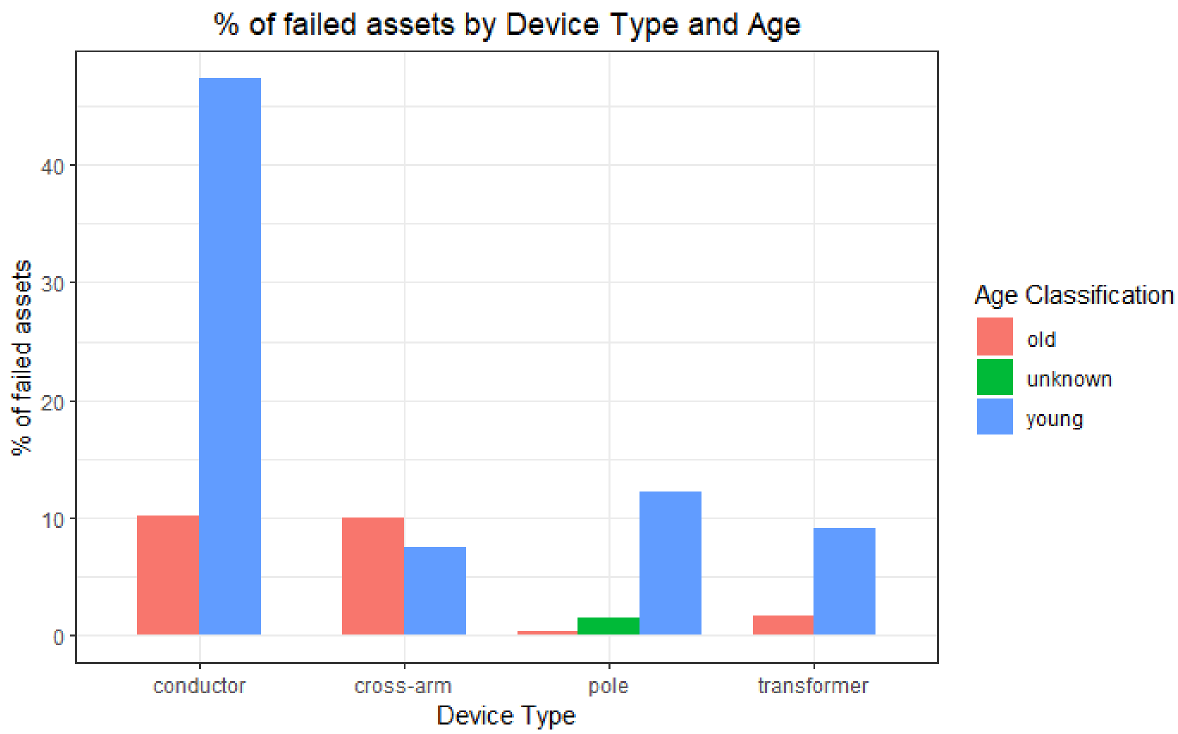


For days when there are no incidents, maximum gust speeds throughout Northland can vary quite a bit. However, the plot above shows that there were 574 days without incidents when maximum gust speeds were less than 79.6 km/h - less than what is classified as severe. In severe conditions, there were 44 days without incidents. There were 31 days without incidents when the maximum gust speed across Northland was at extreme levels.

Asset Condition Analysis

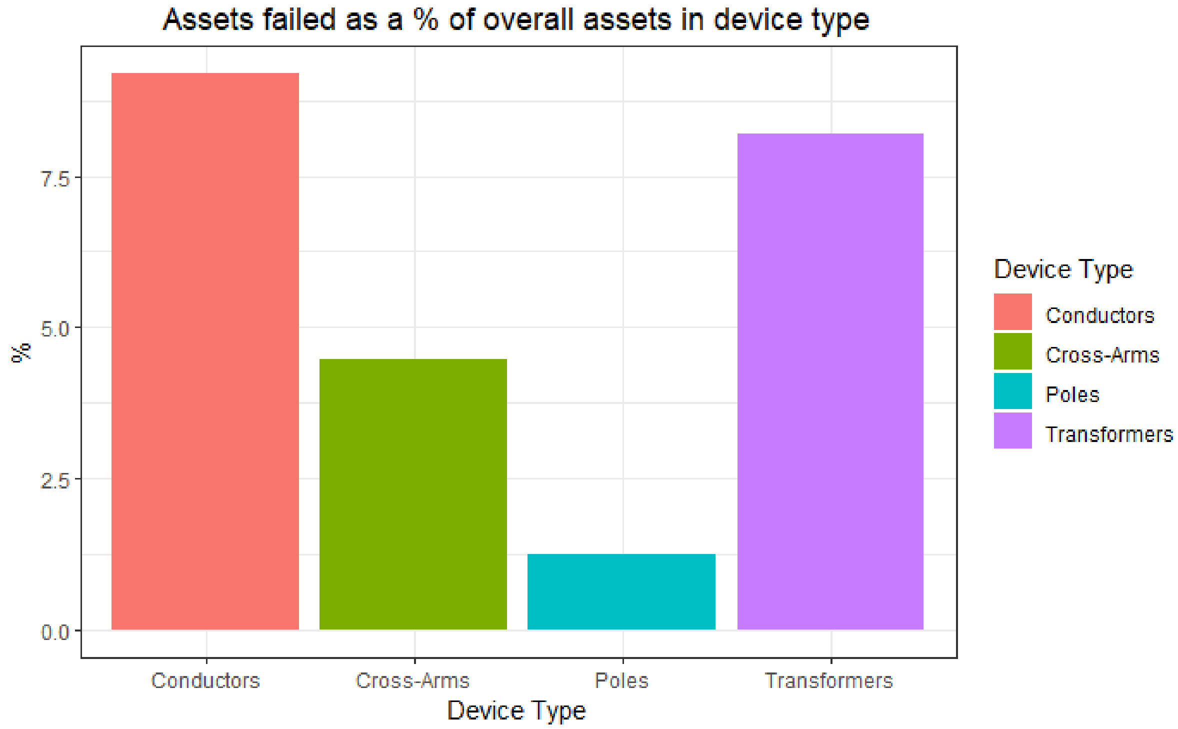
This report focuses exclusively on the following device types:

- Conductors
- Cross-arms
- Poles
- Transformers



Overall there were 588 incidents which were linked to asset failures. Of these, 57.5% of those were related to conductors. 17.5% were related to cross-arms, 14% to poles and 11% were linked to transformers.

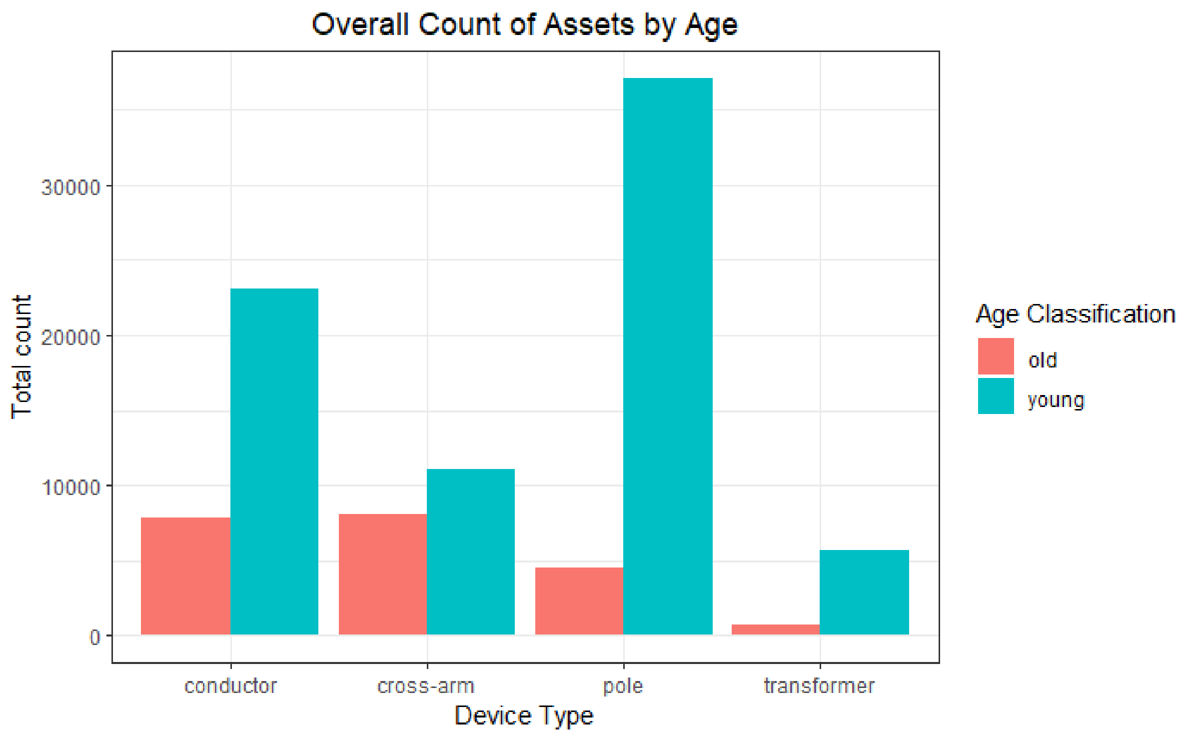
76% of all failed assets failed before their expected lifespan (referred to henceforth as 'young' assets), while 22% were past their life expectancy (referred to henceforth as 'old' assets). 1.5% of pole incidents were unable to be classified into age groupings and were therefore classed as unknown. These poles are all between 45 to 60 years old.

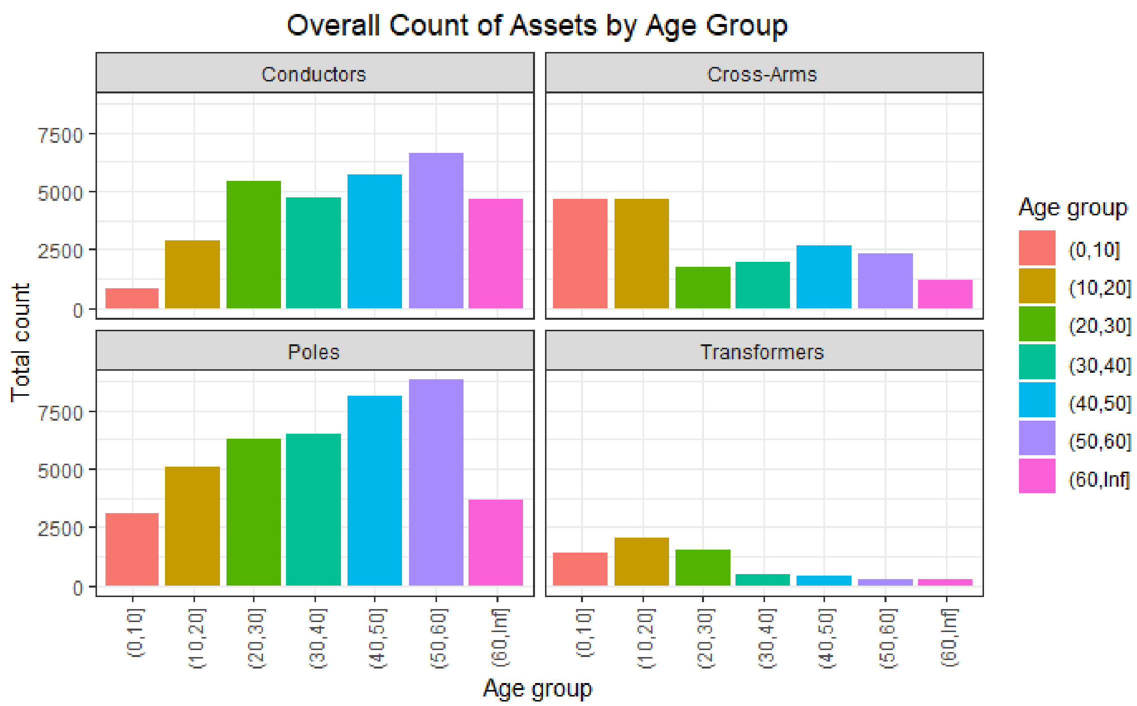


The two assets with the highest rate of failure are conductors and transformers.

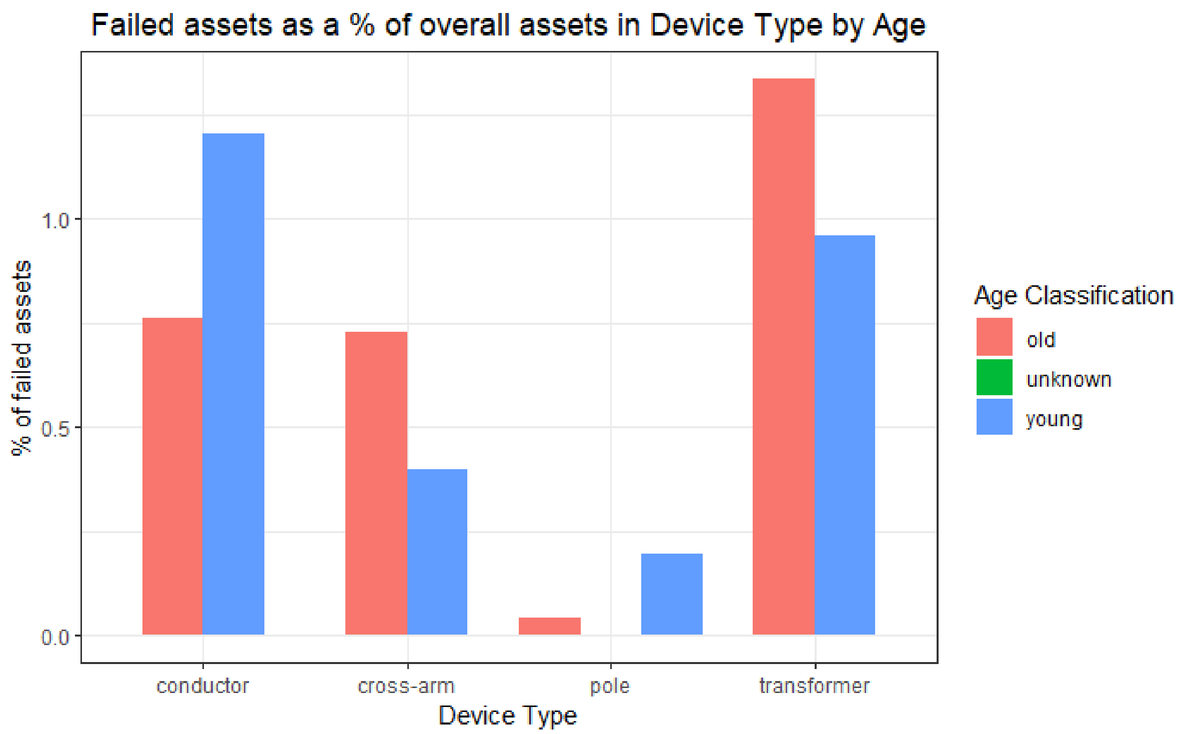
Conductors make up the second most amount of assets at just over 30,000 assets, which is 32% of all assets. They also have the highest failure rate, at 9% of all conductors being involved with an incident.

Although transformers make up the least number of assets compared to other device types - 6,359 transformers, or 6.5% of all assets - it has the second highest failure rate, with 8% of all transformers being involved with an incident.


Overall Count of Assets by Age
Total count
30000
20000
10000
0
conductor
cross-arm
pole
transformer
Device Type
Age Classification
old
young


Overall Count of Assets by Age Group
Conductors
Cross-Arms
Poles
Transformers
Total count
7500
5000
2500
0
(0,10]
(10,20]
(20,30]
(30,40]
(40,50]
(50,60]
(60,Inf]
Age group
Age group

A majority of assets owned are classified as young assets, which could explain the over-representation of young assets involved with incidents. It is interesting that almost half of all the cross-arms and transformers are younger than 20 years old - specifically, 49% of all cross-arms and 54% of all transformers. There are a wide range of pole ages, resulting in 89% of all poles being classified as young poles.

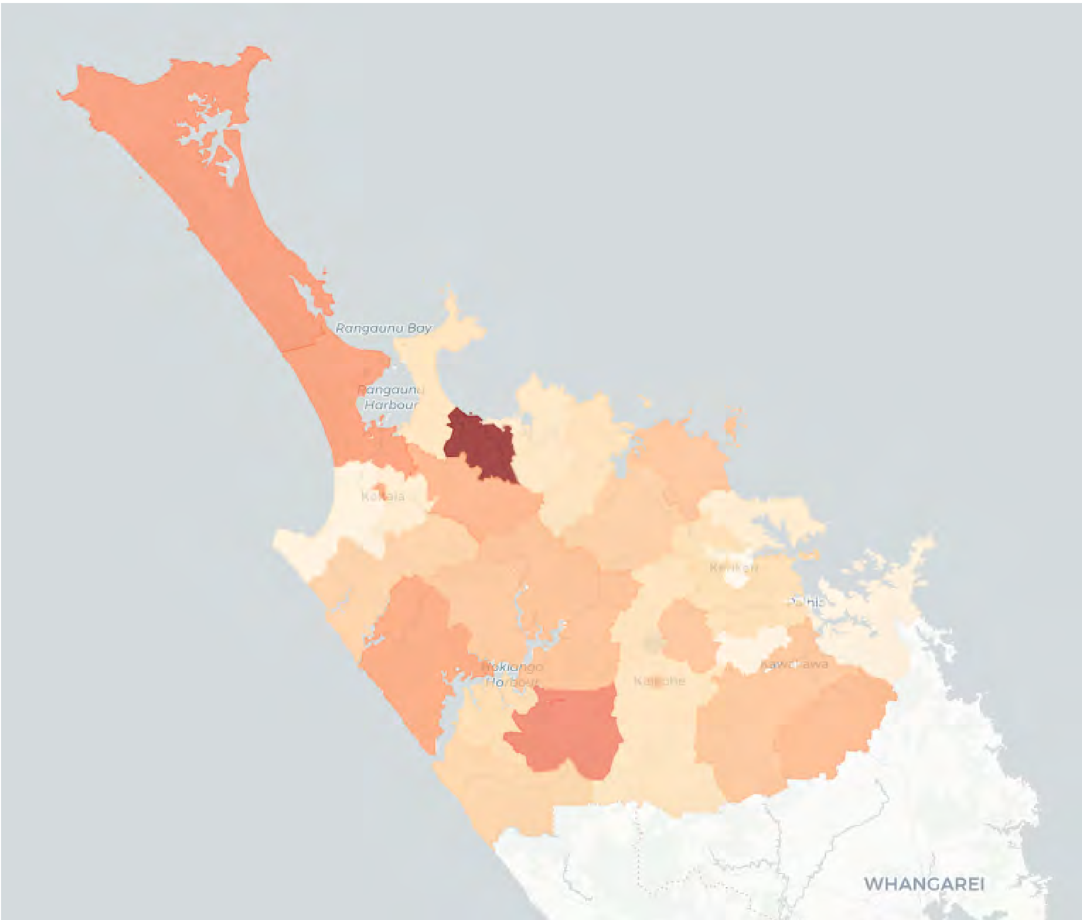


Taking the different populations of age classes into account, 1.2% of all young conductors fail, whereas 0.76% of all older conductors fail. This suggests that there could be other reasons besides reaching end-of-life which contribute towards conductors failing.

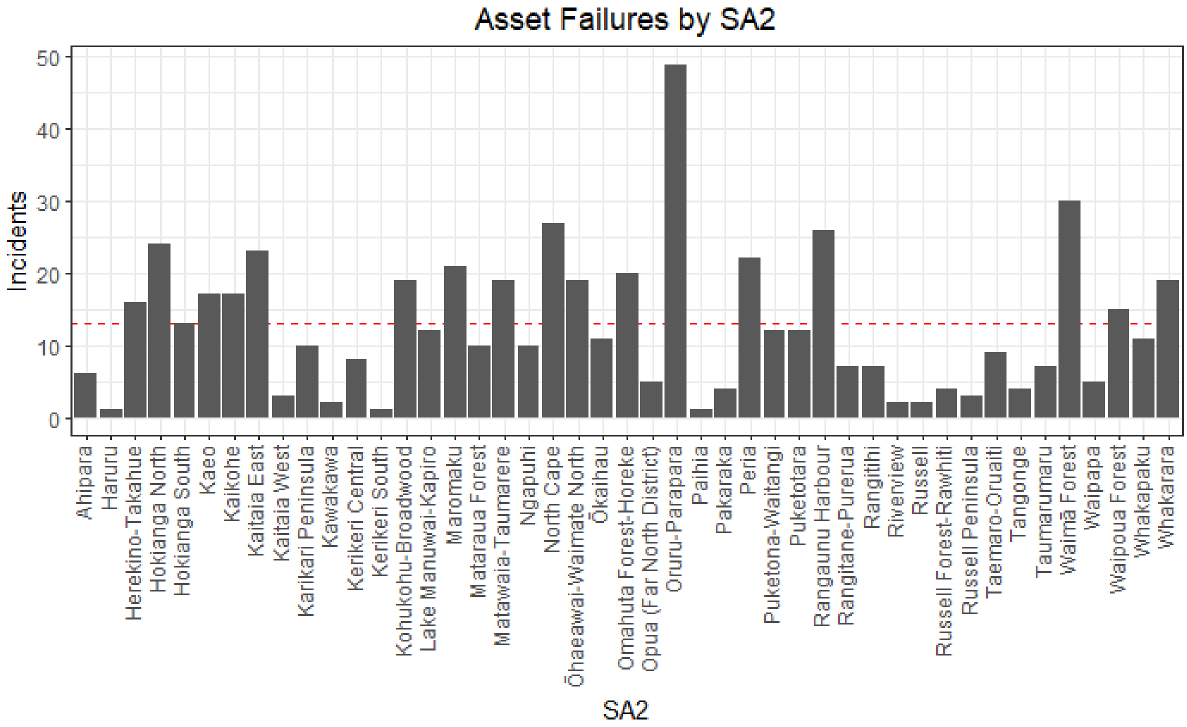
While there are a significant number of young cross-arms and transformers failing, it is reflective of the large population of young cross-arms and transformers.

Asset component failure by location

The following analysis concerns breakdowns of SAIDI by their geographical location, grouped by Statistical Area 2 (SA2) definitions by Stats NZ. Incidents were placed in a SA2 by matching the provided incident address and area to coordinates. Note that this process relied on reverse geocoding, which although properly limited to the correct area of New Zealand, may be occasionally inaccurate in terms of coordinates.



Incidents involving asset failure by SA2 across 2022, 2021, 2022 and 2023

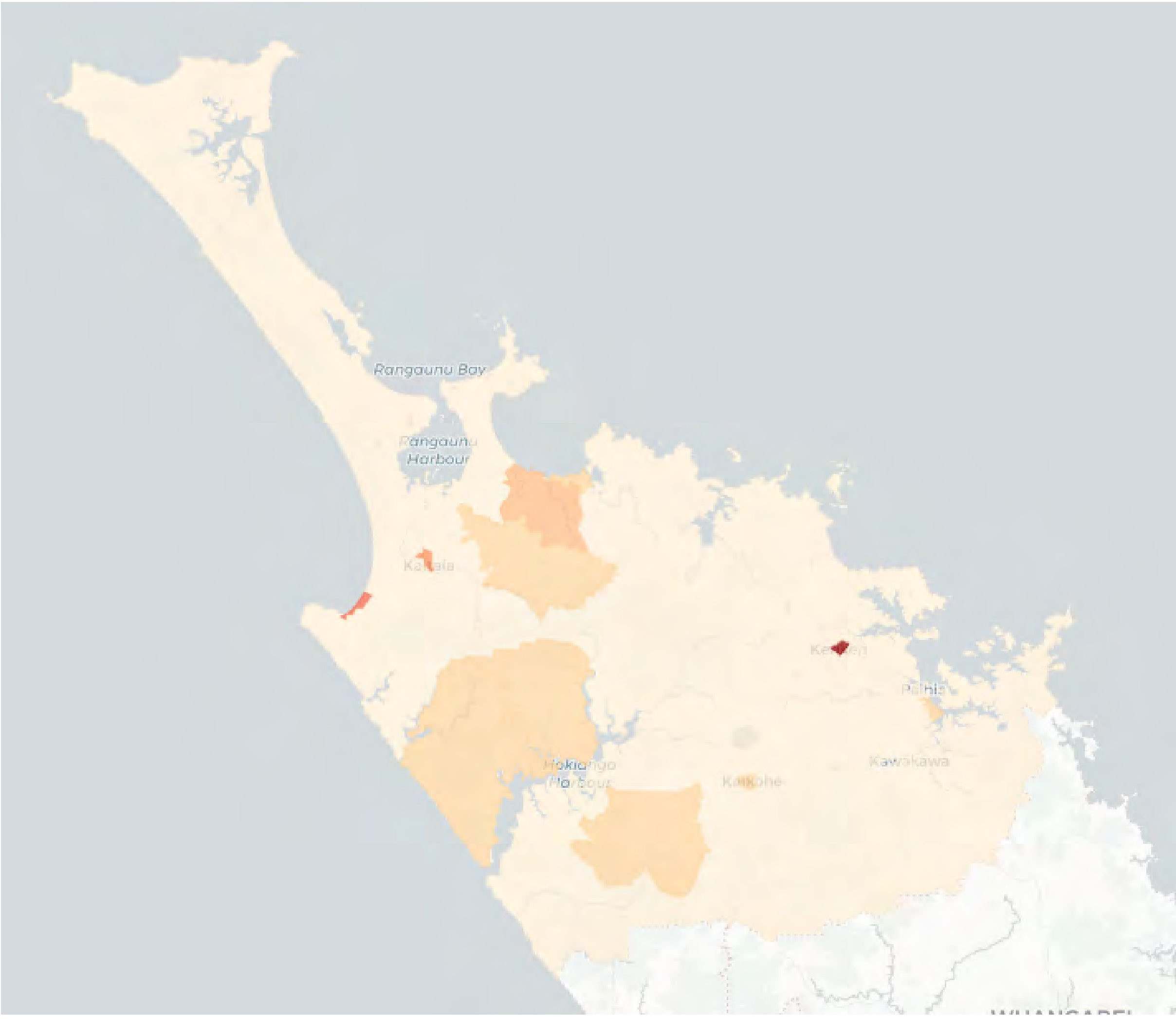


Number of incidents across each SA2 in 2022, 2021, 2022 and 2023. The red line represents an expected number of asset-related incidents if incidents were spread uniformly across SA2s in Northland, ignoring differences in population and geography.

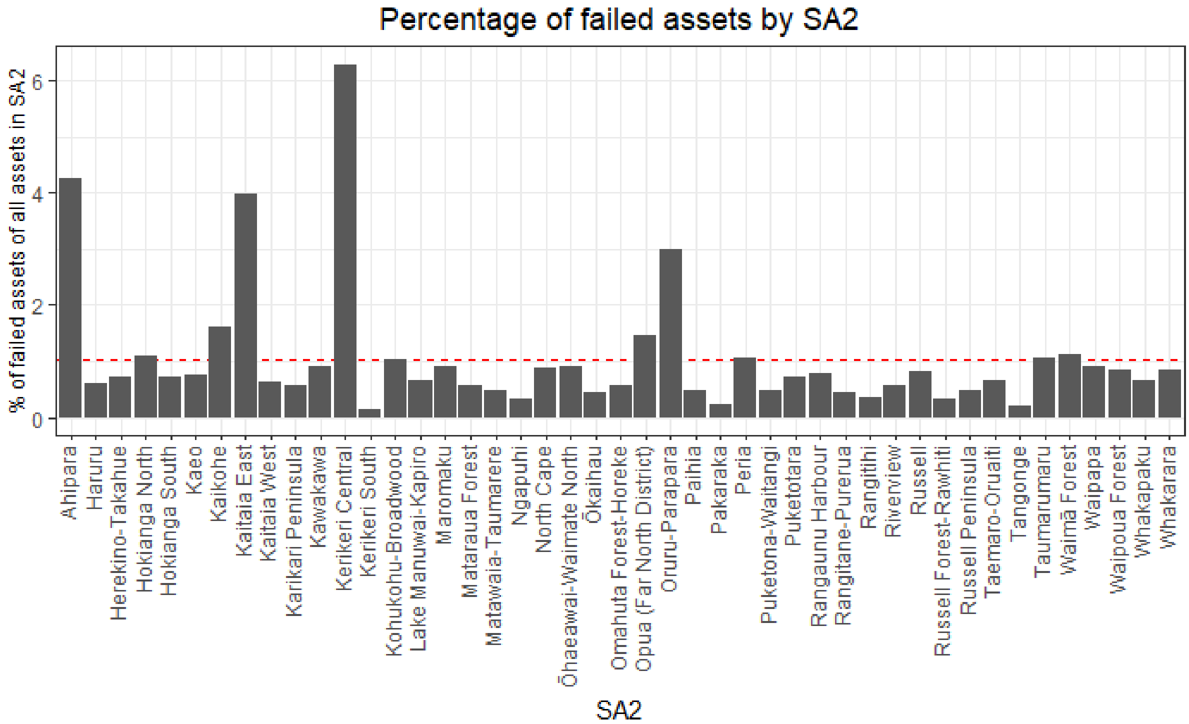
SA2	Incidents	# devices in region	Incidents as a % of all devices in region
Oruru-Parapara	49	1638	3.0%
Waima Forest	30	2676	1.12%
North Cape	27	3081	0.88%
Rangaunu Harbour	26	3350	0.78%
Hokianga North	24	2224	1.08%

Top 5 SA2s by number of incidents across 2022, 2021, 2022 and 2023

Most incidents involving assets were in Oruru-Parapara, where there were 49 incidents over the observed period. This is approximately 48% more incidents than Waima Forest with 30 incidents - the SA2 with the second highest incidents. Interestingly, this also makes up 8% of all asset-related incidents in the observed time period.



Incidents involving asset failure by SA2 across 2022, 2021, 2022 and 2023



Percentage of incidents across each SA2 in 2022, 2021, 2022 and 2023. The red line represents the mean (average) asset failure rate across SA2s in Northland.

SA2	Incidents	Assets in region	% of all assets in region
Kerikeri Central	8	127	6.3%
Ahipara	6	141	4.3%
Kaitaia East	23	576	4.0%
Oruru-Parapara	49	1638	3.0%
Kaikohe	17	1045	1.6%

Top 5 SA2s by percentage of incidents of all assets in region across 2022, 2021, 2022 and 2023

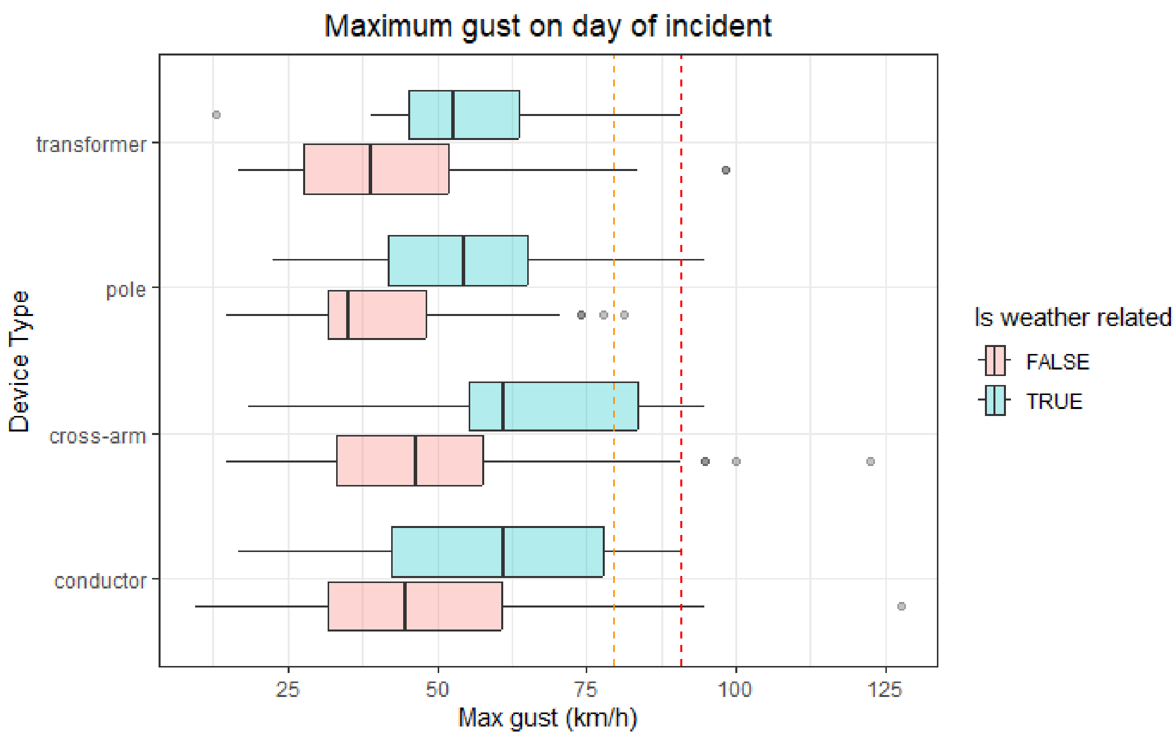
During our analysis we determined that it was also useful to consider incident count in relation to the density of assets within each SA2, to understand if there were regions where the rate of asset failure is higher than others.

The top 4 SA2s all exhibit a considerably higher percentage of percentage asset failure compared to other SA2s in Northland, with Kerikeri Central showing that 6.3% of all assets in the region experienced some form of failure during the observation period. This is approximately 5% higher than our mean of 1.04% of assets across all of Northland's SA2s. Ahipara follows closely with 4.3% of all assets in Ahipara experiencing some form of failure.

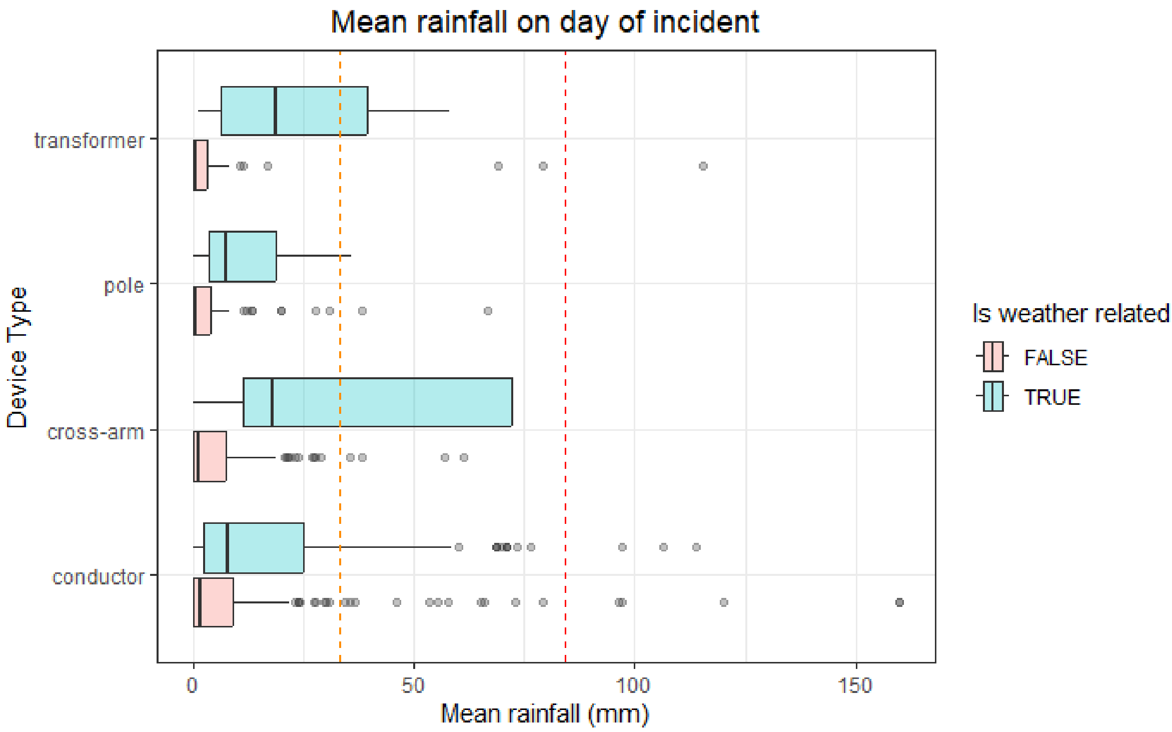
While obviously some SA2s are more asset-dense than others, it is interesting to note how the top two SA2s are quite small geographically and thus have a lot less assets within them. Despite this, they experience a higher percentage rate of asset failures.

Adverse weather and component failure

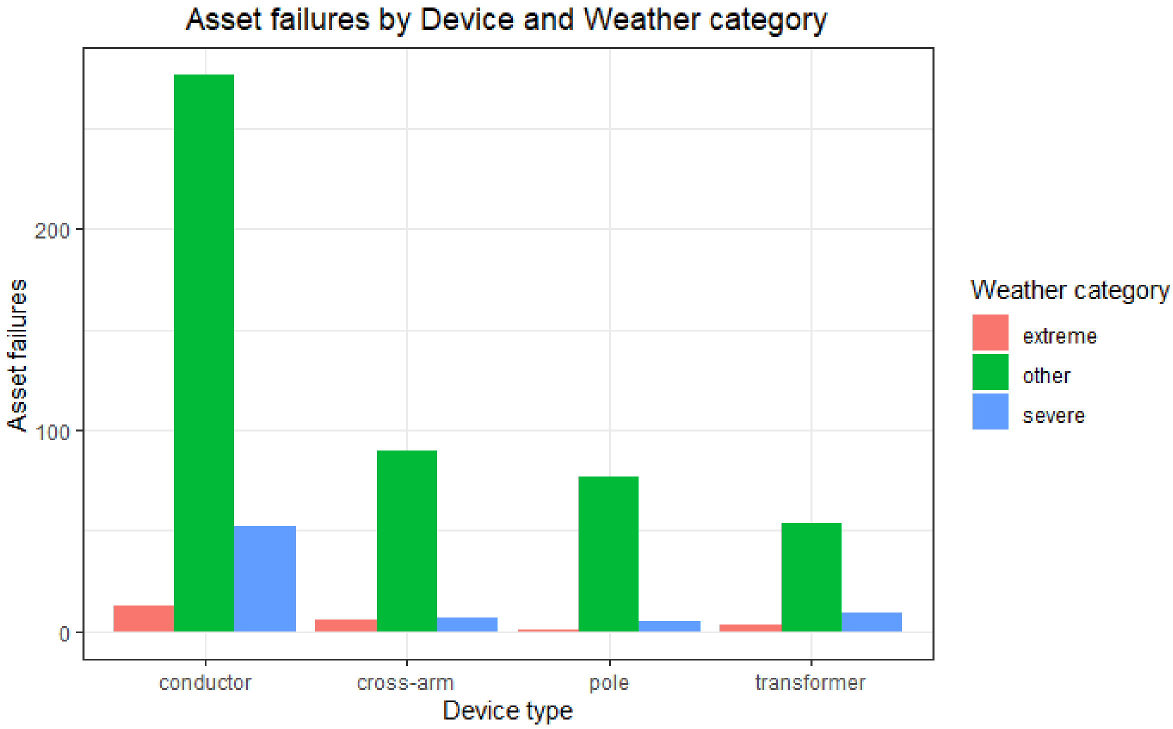
There was interest in if adverse weather conditions had a relationship with component failure. To investigate this, weather conditions were determined as "severe" or "extreme" using the definitions previously defined in this report, and a cause was marked 'weather related' if the outage type was either "weather", "adverse weather", "adverse environment", "lightning", or the cause was listed as "tree fall on line".



Overall, median max gusts across all device types are higher for asset failures marked as weather related, as opposed to asset failures not associated with weather. This relationship is stronger for poles and cross-arms than for transformers and conductors.



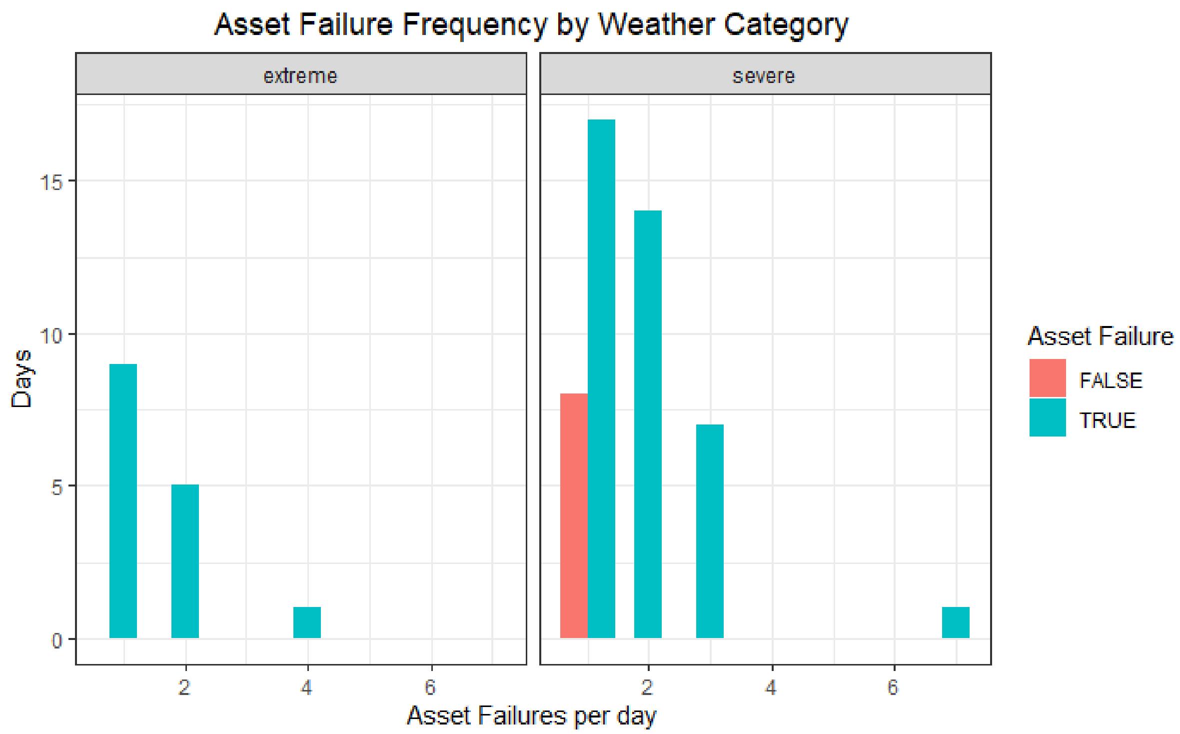
Interestingly, examining mean rainfall on the day of an asset-related incident shows a much clearer difference between averages for weather and non-weather related asset failures. However, this association is not as strong for conductors.



Overall, the majority of asset failures are not related to severe or extreme weather events, with 84% of all asset failures falling under the 'other' category. 12% of all asset-related incidents occur under severe weather conditions, while 4% occur under extreme conditions.

71% of all asset failures that occurred under severe weather conditions were conductors. 57% of all asset failures that occurred under extreme weather conditions were also conductors, with cross-arms following at 26% of all asset failures that occurred under extreme conditions.

While a large majority of incidents occur under non-severe or non-extreme weather conditions, severe and extreme weather conditions tend to affect conductors the most.

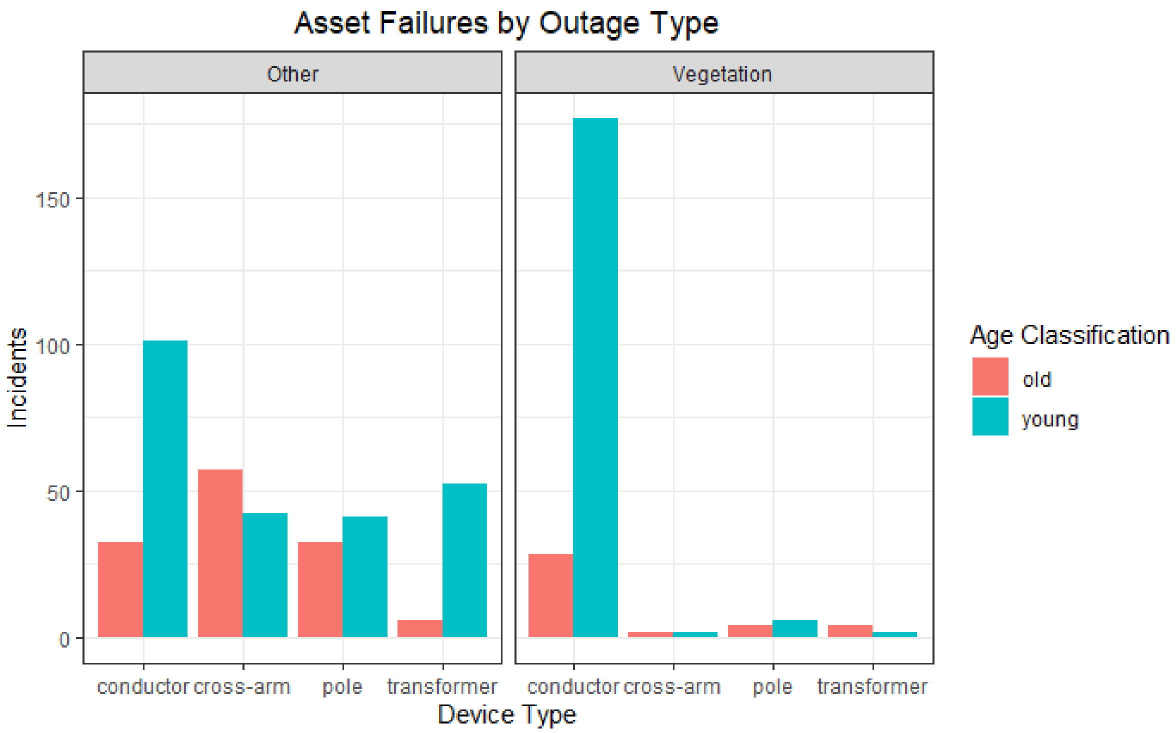


When weather conditions averaged across Northland are severe, there are only 8 days where no incidents occur. On the 39 other days where weather conditions are severe, there are 73 individual asset failure incidents.

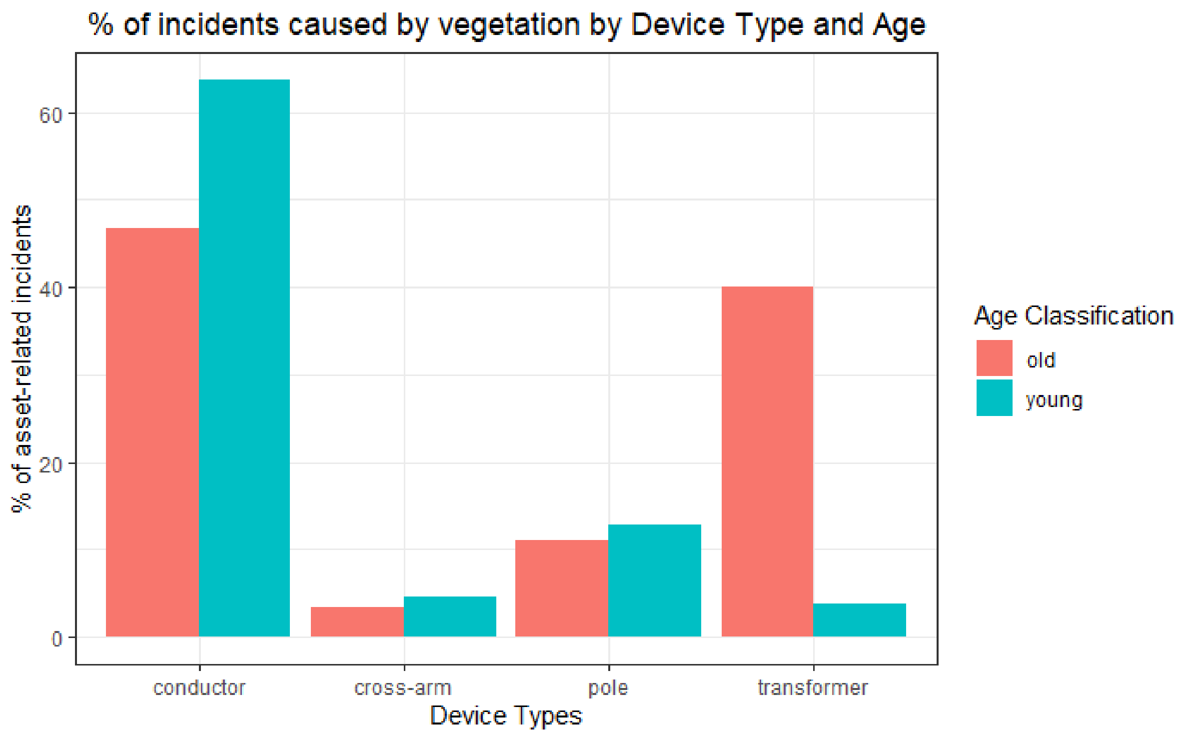
Averaging weather conditions across Northland results in 47 days which meet the criteria for severe weather. Of these, there are only 8 days where no incidents occur. On the other 39 days, when incidents do occur, there are 73 individual asset failure incidents.

There are 15 days with extreme weather conditions across Northland, and all of these days result in at least one asset failure. This indicates that severe or extreme weather conditions are highly likely to result in asset failures.

Other causes of component failure



Vegetation has a large impact on conductors, and not so much on other device types. Of all asset failures, 30% are young conductors failing due to vegetation. 91% of all vegetation incidents affect conductors overall, and 79% of all vegetation incidents affect young conductors.



63% of all incidents relating to young conductors were caused by vegetation, while 47% of all incidents relating to older conductors were caused by vegetation. This indicates that despite the differences in population between device types, we can reasonably conclude that the over-representation of conductors is not an issue; there is a clear relationship between vegetation and conductor failures.

Conclusions and Recommendations

Key Findings

Definitions of “severe” and “extreme” adverse weather conditions in Northland

- There is no catch-all way of looking at weather data and identifying a threshold for weather which could guarantee widespread damage and multiple outage incidents. However, the thresholds below can help guide the analysis of how adverse weather conditions may impact outages in the Top Energy distribution area.

	Severe *(75th percentile)*	***Extreme*** *(95th percentile)*
Daily Peak Wind Gust (km/h)	79.6	90.7
Daily Rainfall (mm)	33.2	84.1

Wind gust correlates with incident frequency, while there are some correlations between rainfall, gust speeds and incident duration

- Peak wind gust speed can be correlated with incident frequency, while rainfall and cumulative rainfall cannot. Conversely, both rainfall and peak gust speed can be correlated to incident duration to a certain extent.
- The wind gust directions associated with the most incidents are the prevailing South-Westerly wind or Northerly to Easterly directions from ex-tropical cyclones.
- There is some evidence of interaction between gust speeds and the device group affected, which impacts incident duration.
- Outage incidents involving overhead conductor (line) devices are more likely to have long incident durations. There appears to be a higher incidence of “line” related outages at gust speeds of approximately 70 km/h and above.
- The response to an incident cannot easily be correlated to the weather, due to insufficient data. However, it appears that delays in incident response are higher when rainfall is higher.

Recommendation: As there is an observed relationship between wind gusts and incident frequency, particularly from South-Westerly or Northern to Easterly winds, it is recommended to investigate further what design or environmental factors can be implemented to strengthen assets, particularly overhead conductors.

Higher rainfall levels interfere with the ability of crew to travel to an incident

- "Violent" rain (>50mm/day) was associated with repair crews travelling longer routes, possibly to avoid flooding. However, rainfall levels below this amount did not appear to have a significant impact on the distance travelled. It appears that only rainfall above a threshold (e.g. "Violent") has a severe impact on vehicle travel.
- The delay in vehicles being dispatched tends to occur during heavy rainfall and vehicles that are dispatched on "Violent" rainfall days experience the greatest delay. A possible explanation for this could be staff shortages during extreme weather, although further research is required to confirm this.
- Examining time on site, there is no observable increase in time spent on site for higher levels of rain.

Recommendation: Due to the observed relationship between delay in vehicle dispatch and rainfall level, it is recommended that further investigation into fleet and staff availability during more intense rainfall conditions be undertaken.

A relationship between gust speeds and employee response could not be established

- This investigation could not establish a strong correlation between employee response metrics (time on site and response time) and peak daily gust speeds.

Northland tends to experience extremely wet days and days with extreme peak wind gusts with a higher frequency than average.

- Northland is in the top 3 for both frequency of high rainfall days and frequency of high peak wind gust days in the focus group of Northland, Auckland, Bay of Plenty, Hawkes-Bay, and Gisborne.

Weather measurements are increasing over the years

- While each year experiences some variation in rainfall amounts, there is a marked increase in rainfall amounts in Winter YE2023 compared to previous Winter months.
- The amount of rainfall within each region has increased since YE2020.
- Maximum gust speeds are consistently higher through YE2022 and YE2023, while YE2020 and YE2021 showed more variation in maximum gust speeds.

Conductors have the highest failure rates compared to other device types

- 57.5% of all asset failures were conductor failures. Taking into account the overall number of conductors within Top's network, they have the highest failure rate, with 9% of all conductors being involved with an incident.
- The device type with the second highest failure rate are transformers, with 8% of all transformers being involved with an incident.
- 1.2% of all young conductors were involved with an incident, which is the highest rate of failure for young asset types. This is more than older conductors, of which 0.76% of all older conductors were involved with an incident.
- 30% of all asset failures are young conductors failing due to vegetation. Of all vegetation incidents associated with asset failures, 91% affect conductors, and 79% affect young conductors particularly.

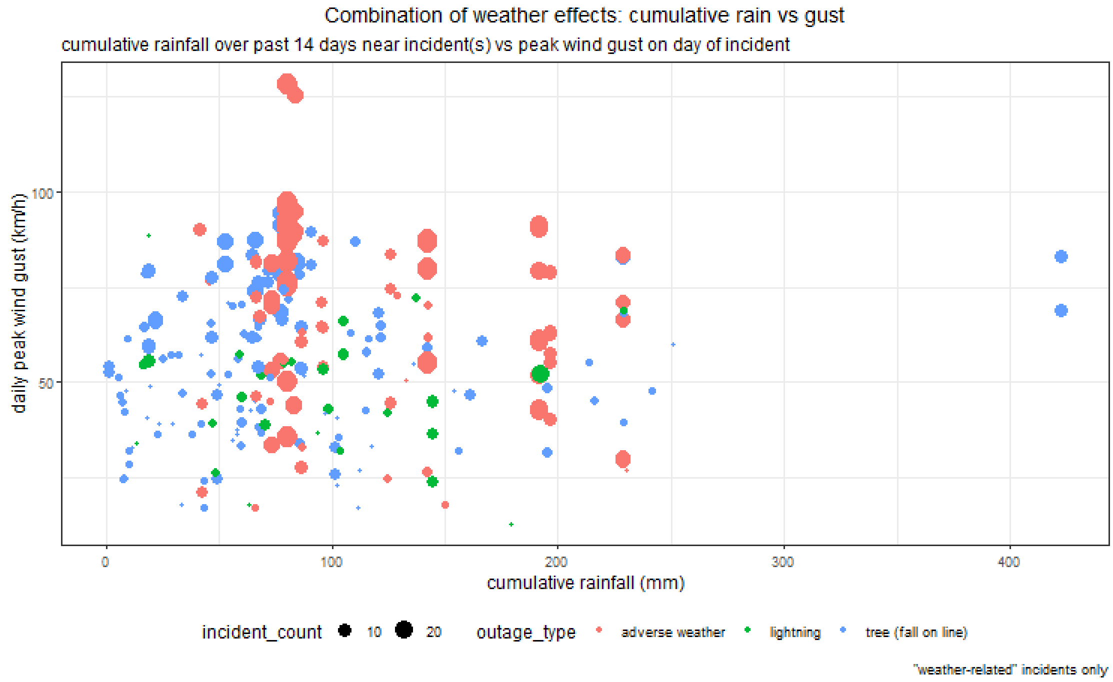
Asset failures are likely to occur when weather conditions are severe or extreme

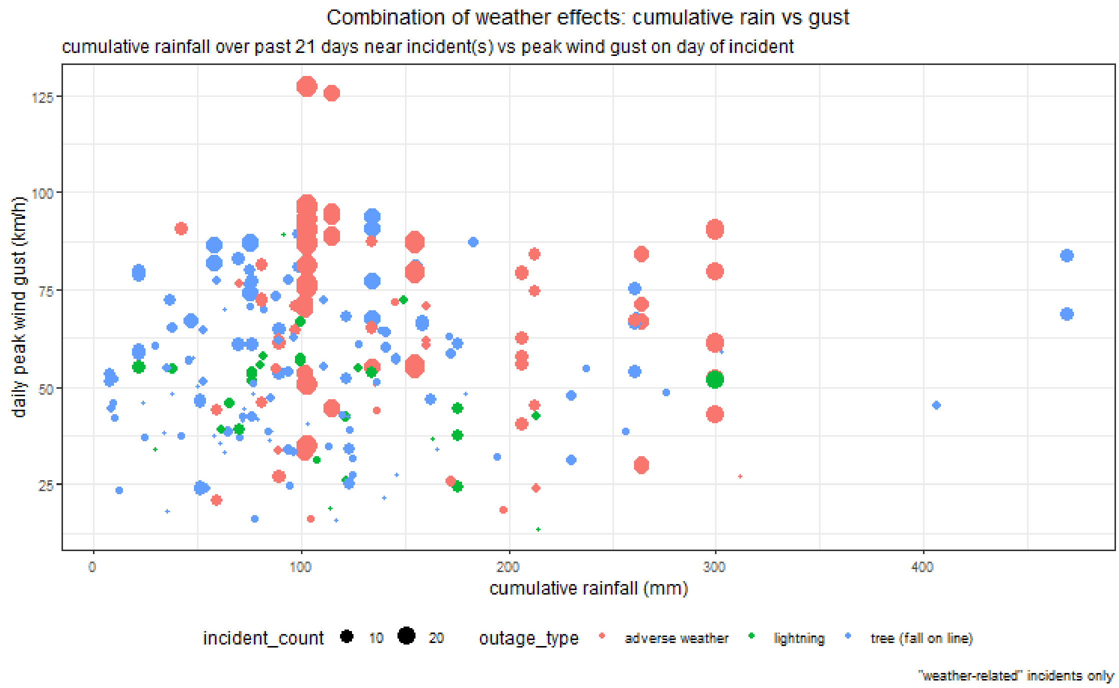
- Over the observed period, there were only 8 days where no asset-related incidents occurred when weather conditions were severe.
- All days with extreme weather conditions result in at least one asset failure.
- Severe and extreme weather conditions tend to affect conductors more than other device types.

Recommendation: Due to the high rates of failure for conductors, particularly when vegetation and/or adverse weather conditions are involved, it is recommended to investigate further what design or environmental factors can be managed to mitigate the rate of failure.

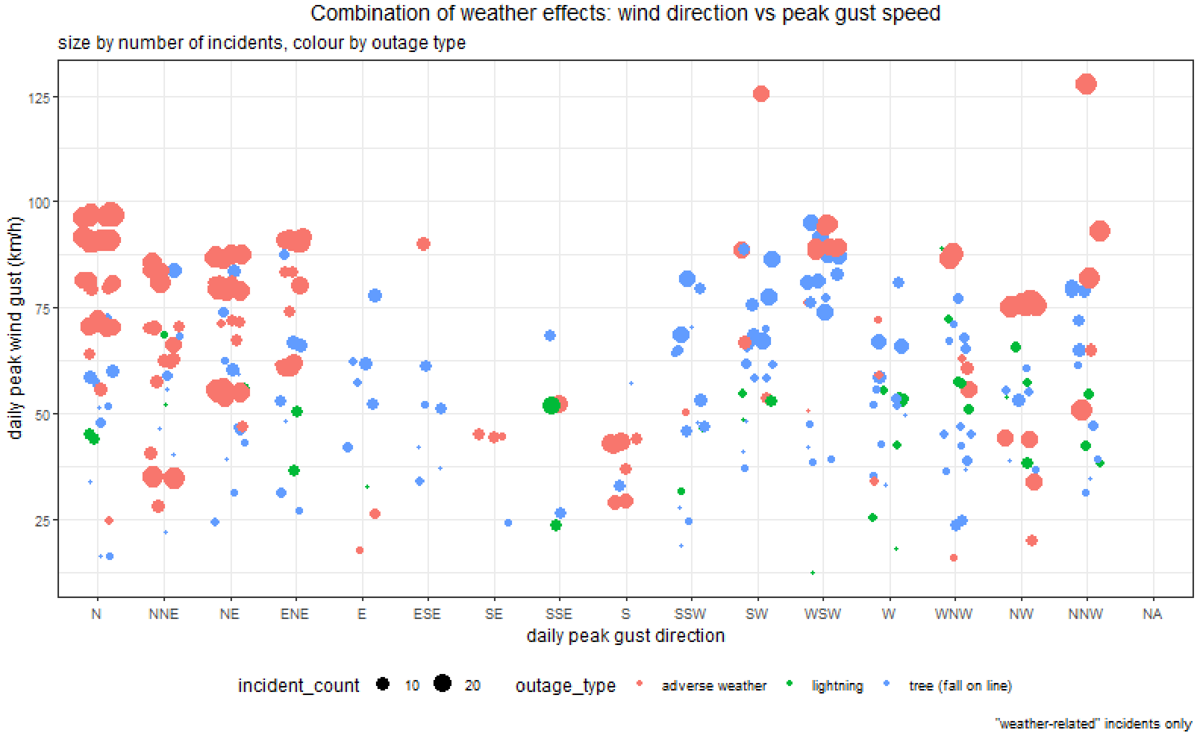
Appendices

Cumulative Rainfall (14 days and 21 days) vs Peak Wind Gust

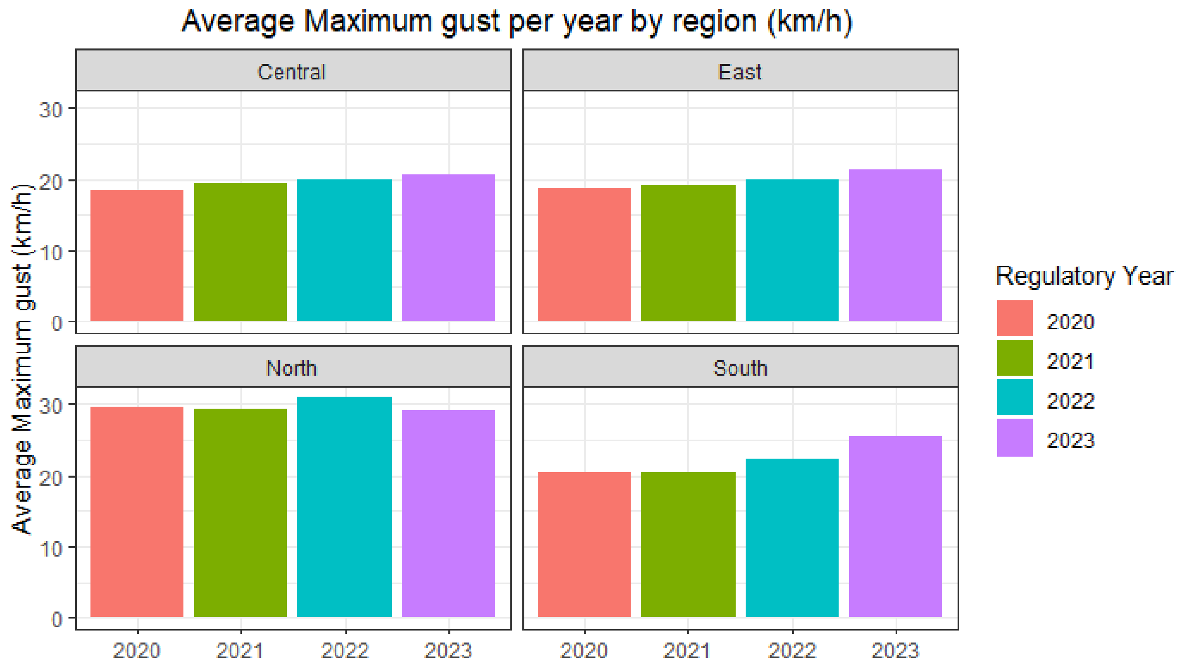




Wind Direction vs Peak Wind Gust Speed, with point size indicating incident number

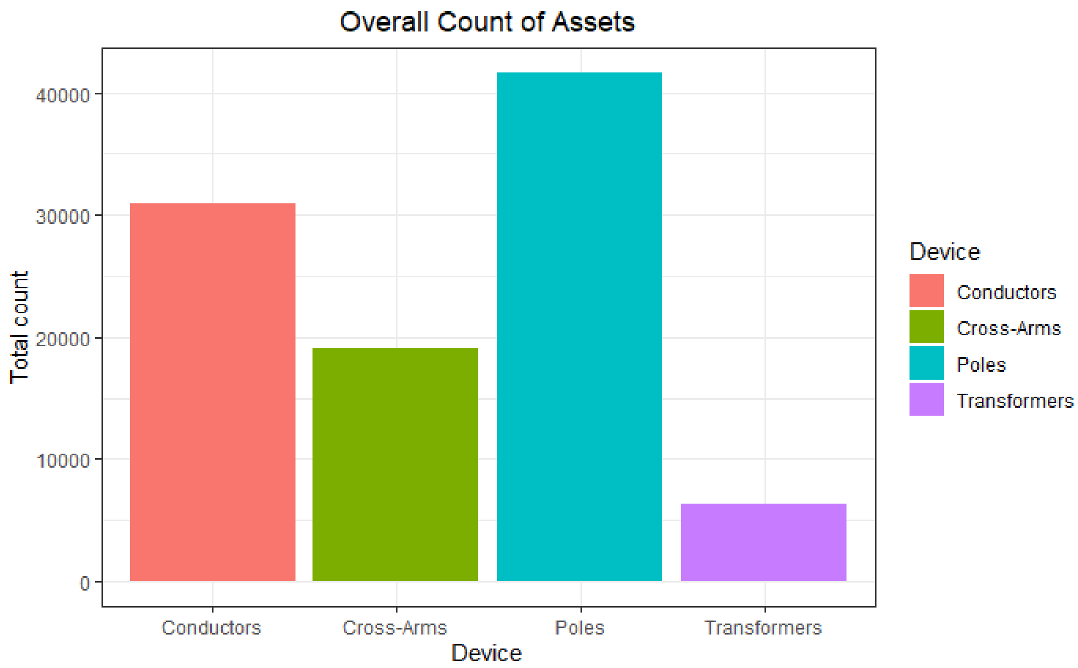


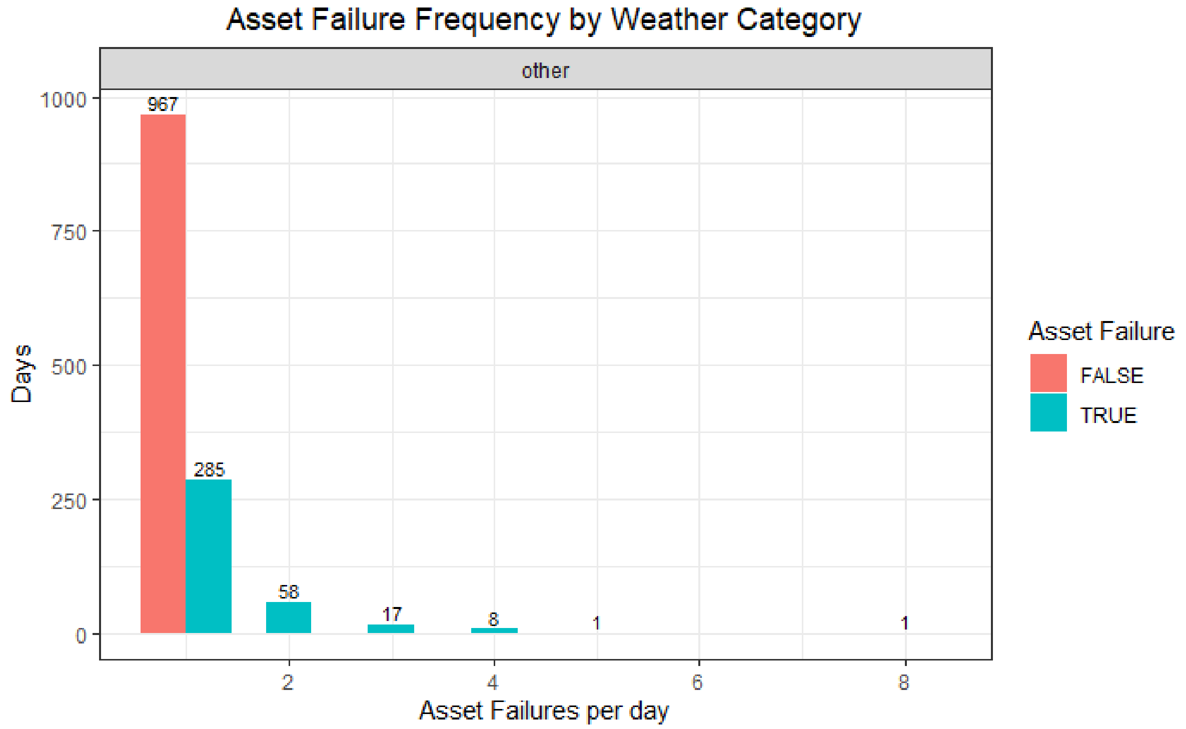
Gust Plots



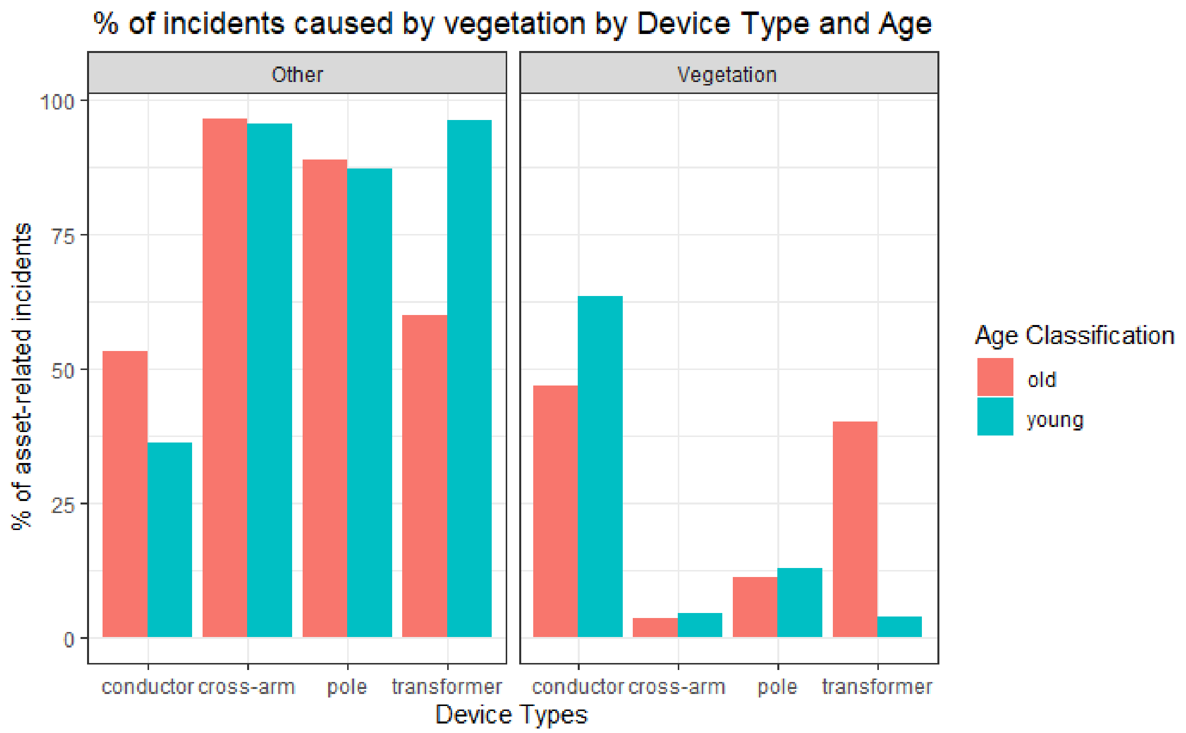
*No gust measurements were found for weather stations located in the western region of Northland.

Asset Plots





Asset Failure Plots



Appendix 11

TOP ENERGY
Te Puna Hihiko
www.topenergy.co.nz

Top Energy Limited
Level 2, John Butler Centre
60 Kerikeri Road
P O Box 43
Kerikeri 0245
New Zealand
PH +64 (0)9 401 5440
FAX +64 (0)9 407 0611

Memo to	**David Sullivan** **Nicole Anderson** **Jon Nichols** **Steve Sanderson** **Simon Young**
From	**Russell Shaw**
Date	**August 2022**
Subject	**AMP Due Diligence Part 1 - Asset Performance and Review**

PURPOSE

This is an information paper. It is part 1 of a 2-part Asset Management Plan (AMP) Due Diligence review. The document is to inform the Board of the analysis, decisions and direction being taken by Network management with focus on changes from last year.

BACKGROUND

Top Energy recently published the 2022 AMP Update to the 2021 AMP. As required by the Commerce Commission a new AMP is due for release on 31 March 2023. In order to understand the trade-offs and decisions made in covering capital and maintenance expenditure drivers the Board, as part of due diligence, has asked for information on past and future performance presented in this, and a second paper (Part 2) in September.

EXECUTIVE SUMMARY

The topics raised and questions answered in this paper are presented in the following order:

1. *Review of FYE 2022 reliability*
2. *Changes to network risk (emerging technologies and climate change)*
3. *Proposed Changes to fleet plans for key asset classes*

Review of FY22 Reliability

- There were two major SAIDI events in FYE 2022, a short sharp storm on 3 August 2021 and Cyclone Dovi in mid-February 2022. This latter event had the most severe impact on our network reliability of any storm that we have experienced since 2014. Fortunately, we were able to normalize the impact of these two events using the normalization methodology approved by the Commerce Commission, so that we remained below our price-path threshold of 380 minutes. The first storm was a major SAIDI event but did not trigger a major SAIFI event, so we were not able to normalize out SAIFI performance. Cyclone Dovi was both a major SAIDI and major SAIFI event.
- Nevertheless, our normalized unplanned network SAIDI of 342 minutes was our highest since FYE 2015 (after normalizing our historic performance in accordance with the Commission's current methodology). Our normalized unplanned SAIFI of 4.47 was below our SAIFI threshold of 5.07.
- There were no interruptions of our incoming 110kV supply from Maungatapere and no

unplanned interruptions of our own 110kV transmission system. Using our backup diesel generation, we successfully completed our annual maintenance outage of the 110kV transmission system without interrupting supply to consumers in our northern area.

- The normalized unplanned SAIDI due to faults on the 33kV network was 30 minutes, 9% of the total network SAIDI of 343 minutes. Going forward, we are aiming to reduce the annual normalized unplanned SAIDI on our subtransmission network to below 20 minutes through the remote control of our generation at Taipa and Omanaia.
- The normalized unplanned SAIDI and SAIFI of our 11kV distribution network were 312 minutes and 3.3 respectively. Due to this trend we have identified our worst performing feeders, and these are targeted in the 11kV Reliability Improvement Plan that was approved by the Board last April.

Changes to Network Risk (emerging technologies and climate change)
New solar farms to our network. The connection of solar farms is rapidly approaching, and the 2023 AMP will update the commentary in the 2021 AMP and the 2022 AMP Update. Assuming the solar farm projects for which connection agreements have already been signed proceed, as is highly likely, the amount of generation embedded in our network will be more than double the total consumer demand. The penetration of embedded generation, relative to the size of the network, is currently second highest of New Zealand EDB's. The network will become a hybrid generation-distribution network with two-way energy flows and generation management will likely dominate control room activity. We will need new skills with experience in the operation and management of generation, and these are currently being recruited.

The 2023 AMP will also provide an update on the renewable energy zone (REZ) initiative. Northland is the pilot project for this initiative, which is being led by Transpower. Transpower has released a consultation document and feed-back has been generally supportive of the concept. There is still the problem of funding such a venture to be worked through as with export capacity assigned to current applicant's, any potential renewable generation developers would currently need to fund the cost of the transmission network upgrades required before more renewable generation can be connected. There is potential that the cost of the Wiroa-Kaitaia line would be funded through capital contributions, and provision for the construction of this line will be removed from the capital expenditure forecast in the 2023 AMP. The funds released will be reallocated to the deferred Wiroa substation build, which will almost certainly be required before the end of the ten-year AMP planning period, and to continuation of the 11kV reliability improvement programme. Assuming the line is built, Top Energy will still likely need to fund some of the cost, as it will also eventually be used to supply the new substation at Garton Rd, Oruru, which will replace the existing Taipa substation, where the site is likely to become increasingly vulnerable to flooding as a result of sea level rise.

The 2022 AMP Update noted that with the completion of the Wiroa 110/33kV Wiroa substation, there would be sufficient capacity in the subtransmission network to support a doubling of the current load, subject to the installation of a switching station at Oromahoe and voltage support at Haruru and Kawakawa zone substations. We will therefore have the capacity to connect large new block loads where the cost of connecting to the network will be funded by capital contributions from the developer.

However much of the forecast load growth will be incremental in nature, driven (in part) by electrification of the transport fleet and subdivision growth. Augmentation of network capacity to support this growth cannot be fully funded by capital contribution.

This growth is likely to unevenly spread across the network and by 2050 demand in some areas could be higher than double the current localized peak demand. Supplying these additional loads would require reinforcement of the 11kV distribution network, which could involve the construction of new lines and zone substations. Our current stance is to ensure we investigate providing for increased capacity when replacing or installing new distribution infrastructure.

Management of the Asset Base

The capital expenditure forecast in the 2022 AMP Update accurately reflected the current year (FYE 2023) workplan, as it was at the time the AMP was prepared and before the decision was taken to defer the Wiroa substation build and reallocate this expenditure to improving the reliability of the 11kV distribution network.

However, the forecast for FYE 2024 and beyond was unchanged from the forecast in the 2021 AMP, apart from an increase in the provision for customer driven capital expenditure. Therefore:

- The cost of projects and programmes may be understated since the abnormally high-cost escalations experienced in FY2021/22 and built into the FYE 2023 work were not carried forward to subsequent years.

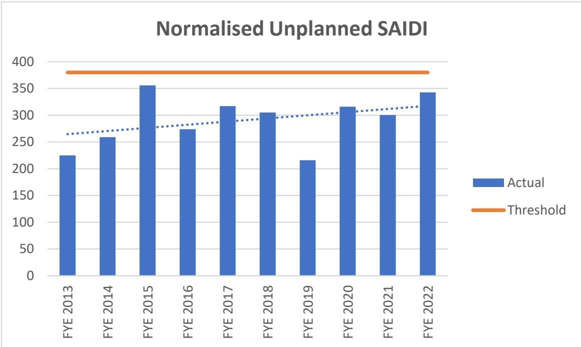
- It made no provision for the projects and programmes that were deferred either to accommodate work in the approved FYE 2022 work programme that was not completed or to ensure that the abnormally high-cost escalations were accommodated without exceeding the budget envelope.

The capital expenditure budget in the 2022 AMP Update did not account of the deferral of the Wiroa build or the removal of the provision for the construction of the Wiroa-Kaitaia 110kV line. The 2023 AMP capital expenditure budget will therefore need be revised to take account of all these factors.

The revised budget will also have an increased provision for the proactive replacement of crossarms and renewal of pole top hardware as part of the 11kV Reliability Improvement Plan , as failure of these asset components currently accounts for almost 60% of all defective equipment SAIDI.

REVIEW OF FYE 2022 NETWORK RELIABILITY

In FYE 2022 the unplanned reliability of our network, after normalization in accordance with the Commerce Commission's currently approved methodology was 343 SAIDI minutes and 3.96 SAIFI interruptions. A comparison with our historic performance (after normalization using the current methodology) and our current price-path thresholds is shown in Figure 1.



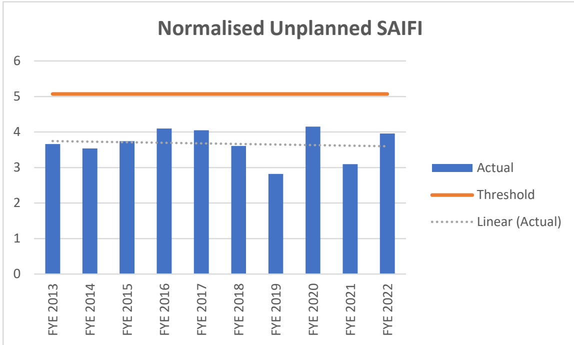


Figure 1: Impact of Unplanned Network Interruptions after Normalization

Major SAIDI Events

There were two major SAIDI events in FYE 2022, a storm on 3 August 2021 and Cyclone Dovi in mid-February 2022. Cyclone Dovi was also a major SAIFI event.

The August event lasted 16 hours and affected the north-west of our supply area, including the far-north peninsula, Kaitaia and Hokianga areas. Over that time there were 14 storm-related 11kV faults with an aggregate raw SAIDI and SAIFI impact of 34.0 and 0.13. As the aggregate raw SAIDI for the event exceeded our boundary value of 27.92 we were able to normalize the SAIDI impact down to 5.5 minutes for assessment against our price path. The SAIFI impact did not exceed the boundary value of 0.23 and so could not be normalized.

Cyclone Dovi took us by surprise as it was forecast to have largely run out of steam by the time it reached New Zealand and was expected to pass east of our supply area. The event affected our whole supply area and had the most severe impact on our network reliability of any storm that we have experienced since 2014. There were 50 faults reported between 3pm on Saturday 12 February and 9pm on Monday 14 February. The storm had a raw SAIDI impact of 390.2 minutes, which we were able to normalize back to 19.8 minutes. The SAIFI impact was 0.63, which we normalized to 0.12.

The only interruption of our 33kV network during Dovi was a tripping of the incoming circuit to the Taipa substation at 1.30am on Sunday 13th, an event which had a raw SAIDI of 53 minutes. While the downstream generation at Taipa was available to mitigate this impact, it was not used until after daylight the next morning for two reasons:

- At the time the tripping occurred the operators were overwhelmed – a total of 17 faults were reported in the four-hour period between 11pm and 4 am.
- There were safety concerns about livening the 11kV without first patrolling the network, as at least one report was received of a wire in the area after it had been isolated by the 33kV fault.

Fortunately, we were able to normalize the impact of these two events using the normalization methodology approved by the Commerce Commission, so our normalized FYE 2022 SAIDI remained below our price-path threshold of 380 minutes. Our FYE 2022 raw SAIFI was 3.96, so the normalization wasn't needed to ensure we remained below the price-quality path threshold of 5.07.

Transmission Network
There were no unplanned interruptions of the 110kV transmission system in 2022. When the system was taken out of service for its annual maintenance shutdown, supply to consumers in the northern part of our supply area was maintained by using our diesel generation.

Sub transmission Network
Figure 2 shows the raw and normalized unplanned SAIDI and SAIFI due to faults on our 33kV network in FYE 2022. In addition to the fault during Cyclone Dovi, there were five faults that exceeded our threshold of 2 SAIDI minutes for detailed investigation into the cause of the fault.

- On 2 July 2021 a fault on the single circuit Kaitaia-Taipa line had a SAIDI of 11.60 minutes. The cause of the fault was not found. At the time the Taipa generation was out of service due to the replacement of a generator transformer.

- On 3 August 2021 there was an outage of the Kaitaia-Pukenui line due to a broken binder securing the conductor on a pole at Waiharara. This fault occurred during the severe August storm and had a SAIDI of 8.41 minutes. This was normalized to 0.58 minutes for assessment against our SAIDI target.

- On 23 May 2021 a tree fell on to the Kaikohe-Omanaia line at Waima, causing a fault with a SAIDI impact of 5.17 minutes. The Electricity (Hazards from Trees) Regulations 2003 limits our ability to manage the risk of tress falling into our lines, where the trees are located outside the clearance zone specified in the Regulations.

- On 1 October 2021 there was another tripping on the Kaikohe-Omanaia line with a SAIDI impact of 3.56 minutes. The cause of this fault was never found.

- On 11 July 2021 there was a bird strike on the Kaikohe-Omanaia line with a SAIDI impact of 2.77 minutes.

These faults all occurred on lines supplying substations with a single incoming 33kV supply. We have now implemented remote control of the generators at Omanaia, and if this had been in place when the faults occurred, we should have been able to mitigate the impact of the faults on this line. We have allocated funds for the refurbishment of the Kaikohe-Omanaia 33kV line, and the first stage of this project is being implemented in the current year.

Going forward, we would expect the normalized SAIDI impact of unplanned interruptions of the sub transmission system to be lower than 20 minutes, provided we are successful in remotely starting generators at Taipa and Omanaia once an interruption occurs at these substations. However, the installation of standby generation will have no impact on SAIFI, as the generators are only started after an interruption occurs. The Pukenui generator is a second-hand unit and has still to be commissioned due to ongoing defects.

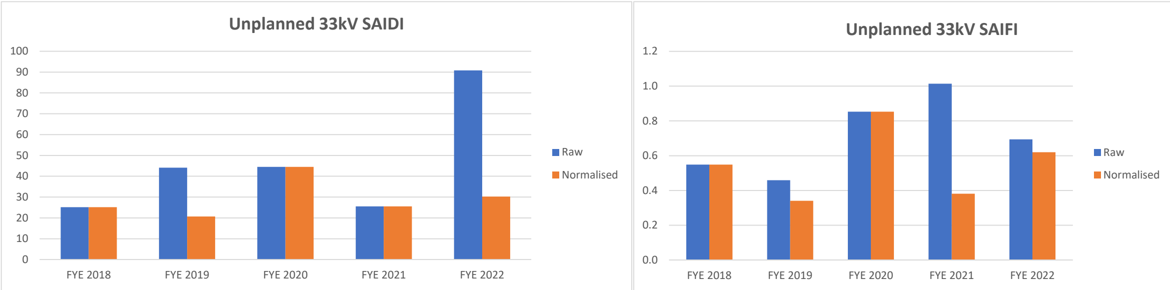


Figure 2: Impact of Unplanned 33kV Interruptions

Distribution Network

Overall Impact of Unplanned Interruptions

Figure 3 compares the impact of unplanned interruptions of the distribution network in FYE 2022 with that experienced over the previous four years. The distribution network accounted for 91% of the total normalized unplanned network SAIDI and 84% of unplanned network SAIFI. The trendlines in Figure 2 confirm our earlier advice to the Board that due to this trend we are addressing it with our recently formulated 11kV reliability improvement programme.

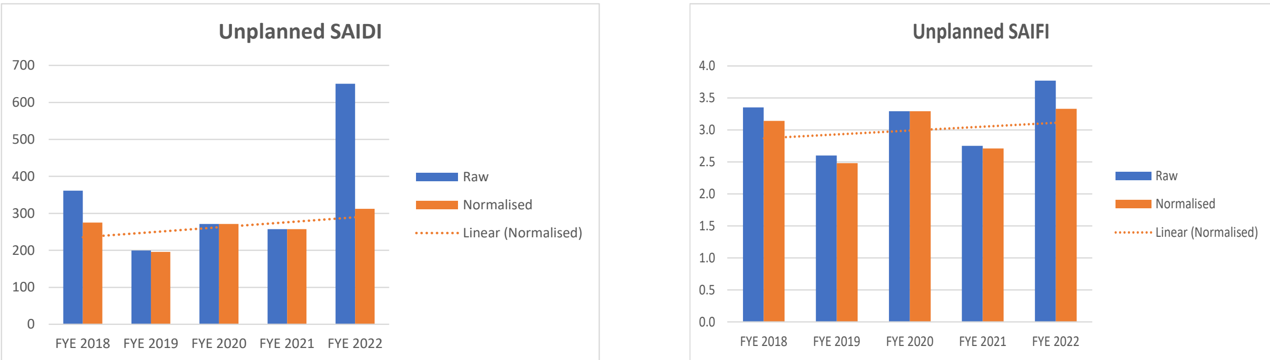


Figure 3: Impact of Unplanned 11kV Interruptions

Causes of Unplanned Distribution Network Interruptions

Over FYE2022, defective equipment accounted for 31% of normalized unplanned SAIDI and 32% of normalized unplanned SAIFI. Similarly, vegetation contributed 29% of SAIDI and 24% of SAIFI. The other major causes of interruptions were third party interference (17% of SAIDI) and faults where the cause could not be found (14% of SAIDI). Car vs pole incidents accounted for 82% of third-party interference SAIDI.

Figure 4 shows the trend of the two main fault causes over the five-year period FYE 2018-22.

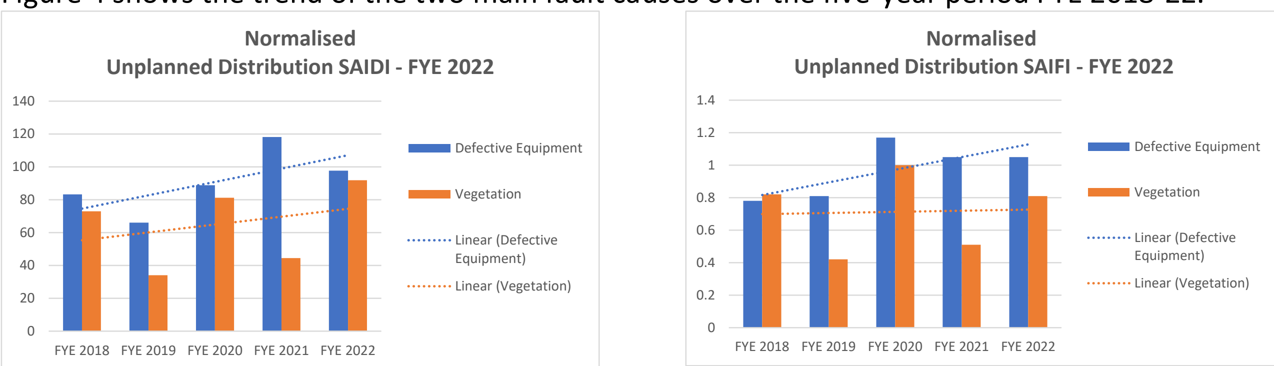


Figure 4: Normalized Impact of Distribution Network Defective Equipment and Vegetation Faults

Worst Served Feeders

Table 1 lists the ten worst served feeders on our network, ranked by normalized unplanned SAIDI in FYE 2022 and, where applicable, describes the strategies that we are putting in place to improve the performance of each feeder. While these feeders represent only 16% of the 63 feeders currently on our network, they caused 59% of the total normalized unplanned distribution network SAIDI in FYE 2022.

Rank	Feeder	SAIDI	Improvement Strategy
1.	South Road	28.88	We are implementing a protection upgrade in the current FYE 2023 year. In FYE 2025 we are planning to install a new injection point at the Kaitaia 110kV substation and also complete an interconnection to the Rangiahua feeder at Broadwood.
2.	Rangiahua	22.10	In FYE 2025 we plan to complete an interconnection to the South Road feeder at Mangamuka.
3.	Whangaroa	20.55	In the current FYE 2023 year we are constructing an interconnection between the end of the Whangaroa feeder and the end of the Mangamuka feeder.
4.	Oruru	20.38	We plan to implement a protection upgrade in FYE 2026.
5.	Te Kao	18.24	We are implementing an accelerated pole and pole top hardware replacement programme in FYE 2023 and 2024 and are planning a protection upgrade in FYE 2025.
6.	Tokerau	18.12	We are implementing an accelerated pole and pole top hardware replacement programme in the current FYE 2023 year and are planning a protection upgrade on this feeder in FYE 2024.
7.	Ohaeawai	15.40	-TBA
8.	Russell Express	14.66	In the current year we are completing the final stage of the Russell Reinforcement project, which will move half the load on the feeder to the Joyce's Rd feeder.
8.	Totara North	13.85	-TBA
10.	Waima	13.04	-TBA

Table 1: Worst Served Feeder Improvement Strategies

CHANGES TO NETWORK RISK

Emerging New Technologies

Renewable Generation

Our 2022 AMP Update noted that we have signed connection agreements for the connection of 63MW of utility scale solar farm capacity in our northern area and 9MW on a site close to the Ngawha geothermal power station. This capacity is the maximum the network can handle due to the limited capacity of the Kaikohe-Kaitaia 110kV line.

At the time of writing, no solar farm developer had accepted our proposal for the construction of the connection assets required to connect their solar farms to the network, so all applications remain on hold. However, we remain in contact with all the developers with whom connection agreements have been signed and the expectation is that all solar farms will proceed to construction.

In signing the connection agreements, we relied on our consultant's modelling that confirmed that all three solar farms can be connected to the northern network without adversely impacting the quality of supply provided to other network users. The consultant has noted that, in all three cases, the equipment to be installed at each site had still to be confirmed and so its modelling used typical electrical parameters for the type of equipment proposed. The consultant recommended that the modelling be reviewed using the design parameters of the actual equipment to be installed at each site, once this data was available. These reviews have still to be undertaken, but no issues are anticipated provided the new generation complies with the applicable industry standards and our own policies on the connection of distributed generation to our network.

The consultant also recommended that the commissioning of the solar farms be closely monitored to confirm that the generation performs in accordance with its approved design parameters. This will assist our operation team familiarize itself with the equipment and its impact on the performance of the network under different network operating conditions. We will engage an independent consultant to assist with this process.

Renewable Energy Zone

The 2022 AMP Update discussed the initiative with Northpower and Transpower to investigate the establishment of a REZ in Northland, with the objective of increasing the capacity of the transmission network to accommodate the connection of additional renewable distributed generation within the Top Energy and Northpower supply areas. These changes could include the construction of the planned Wiroa-Kaitaia 110kV line and a thermal upgrade to increase the capacity of Transpower's double circuit Kaikohe-Kaitaia line.

Transpower has taken responsibility for progressing the REZ.

In the expectation that the Wiroa-Kaitaia line will now be funded (if not fully, then partially) by renewal energy developers, rather than Top Energy, provision for the construction of this project will no longer be included in the capital expenditure forecast in the 2023 AMP. The expenditure will be reallocated to the construction of the 110/33kV Wiroa substation and to projects targeted at improving the reliability of the 11kV distribution network.

Impact of Distributed Generation

Assuming the solar farm capacity in the northern area and OEC5 at Ngawha proceed there will be a total of 164MW of generation embedded in our network comprising:

- 84MW of geothermal plant at Ngawha, operating continuously as a base load generator.
- 63MW of utility scale solar generation in the northern area. This generation output is intermittent and not routinely controlled by the plant operator.
- 17MW of standby diesel generation, which can be run in islanded mode during abnormal network operating conditions.

This is more than double the current peak demand on our network by consumer offtake users. In addition, there is currently almost 8MW of small-scale solar generation connected to our network, most of which is connected to the low voltage network. There is no sign that interest in the installation of small scale, rooftop solar generation will abate.

We are therefore transitioning from a passive network with one-way energy flows to a hybrid generation-distribution network where energy can flow in either direction. We likely already have the highest level of connected distributed generation relative to the size of our network of any EDB in the country. As this trend accelerates, the management of connected generation is going to dominate our control room activity and the skills required to develop and manage our network will change. We are preparing for this transition through the recruitment of a distribution system operations manager with experience in in generation management, and we have installed a state-of-the-art Advanced Distribution Management System (ADMS) to assist with the real time management of both facets of our operation.

Climate Change
Section 7.6 of our 2021 AMP discussed the two main impacts of climate change on the development and operation of our network.

Changes in weather patterns
The main impacts of the change in weather patterns were identified as:

- *An increase in the intensity of ex-tropical cyclones,* which could have a detrimental impact on network reliability. We now have a better understanding the drivers of our network reliability and we have developed the distribution network reliability improvement programme.

- *Sea level rise,* which will progressively increase the flood risk of the Taipa substation site. Our current strategy to mitigate this risk is to relocate the substation to a new site at Garton Rd, Oruru, which would be supplied by a deviation to the planned 110kV Wiroa-Kaitaia line. While the construction of this line will not be included in the 2023 AMP capital expenditure forecast, we still expect the line to proceed, funded by the developers of utility scale solar farms wanting to connect to our network. If the Garton Rd site is to be used for a new substation, we may need to make a contribution to the cost of this line.

Decarbonisation of the Economy
Decarbonisation of the economy is expected to increase the demand for electricity, due to the electrification of transport and process heat. This was discussed in Section 3.5.1 of our 2020 AMP Update where it was noted that Transpower in its Whakamana i Te Mauri Hiko report forecast that electricity demand would increase by 68% by 2050. Since then, the Climate Change Commission has issued its recommendations on decarbonisation of the economy and the Government has released it decarbonisation plan. It is not clear whether this plan will materially change the Transpower demand forecast. We will continue to monitor developments in the national climate change policy and their likely impact on our network.

On the generation side, decarbonization is the main driver for the connection of renewable generation to our network. As noted elsewhere in this paper, our ability to full accommodate this will be dependent on whether we can mitigate our transmission constraints. This is the objective of the REZ initiative discussed above. This situation is still evolving, and we expect to be able provide an update in our 2023 AMP.

On the demand side, we expect to see demand increase due to the electrification of transport (in part) and growth as the eastern seaboard of our supply area is expanding quickly and there is no indication that the rate of growth will reduce. Subdivision demand in the Kerikeri area remains strong. Our supply area has significant untapped potential for economic growth, particularly in the horticulture, industrial and tourism sectors.

As discussed in our 2022 AMP Update, we have tested the capacity of our transmission and sub transmission networks to supply double our current level of demand. We found that there will be sufficient capacity in the network subject to:

- The construction of the 110/33kV substation at Wiroa. While this build has been deferred in the short term, it will almost certainly be required before the end of the ten-year AMP planning period.

- The establishment of a 33kV switching station at Oromahoe and the installation of voltage support at the Kawakawa and Haruru substations to support demand growth at Paihia, Opua and on the Russell peninsula.

Our network backbone is therefore well placed to supply large new block loads, where the cost of connecting to the network will be paid for by the developer.

We think that most of the network augmentation that we will need to fund to support demand growth of this magnitude will be reinforcement of the 11kV network to support incremental demand growth. This will be determined by the nature and location of such growth. While a doubling of demand has been assumed for this exercise, localized growth in some areas could be much higher. Growth driven by the demand for electric vehicle charging is incremental and, while dispersed across the network, is likely to be higher in the higher socio-economic areas.

There is a risk that high incremental growth rates could occur in areas, such as Omapere, the Karikari, Purerua and Russell peninsulas that are not well served by our existing 11kV distribution infrastructure.

These will be monitored as increasing network capacity to supply such areas would require the construction of new lines, which could initially be constructed at 33kV and operated at 11kV, with a view to later installing a new 33/11kV zone substation.

Electrification of existing industrial process heat is less likely as most process heat in our area is associated with wood processing industries and already uses wood-based biofuel. The [redacted] recently replaced it coal fuelled boiler with a wood fired unit.

FLEET MANAGEMENT

AMP Capital Expenditure Forecast

The 10-year capital expenditure forecast in our 2022 AMP Update and submitted to the Commission in Regulatory Schedule 11a can be characterized as follows:

- The forecast capital expenditure on network assets was $192.5 million (at constant FYE 2023 prices) over the 10-year period. However, while the current year forecast was adjusted from the 2021 AMP forecast to account for abnormally high labour and materials cost increases (estimated at 7% and 15% respectively), no changes have been made to the forecasts for FYE 2024 and beyond. The forecasts for these years:
    - The cost of projects and programmes may be understated since the abnormally high-cost escalations experienced in FY2021/22 and built into the FYE 2023 work were not carried forward to subsequent years.
    - Made no provision for the projects and programmes that were deferred either to accommodate work in the approved FYE 2022 work programme that was not completed or to ensure that the abnormally high-cost escalations were accommodated without exceeding the budget envelope

- The forecast included $38.3 million over FYE 2025-30 for the construction of the Wiroa-Kaitaia line. It is now probable that this line, if constructed, will be largely funded through capital contributions by solar farm developers. The $38.3 million provision is now known to be significantly lower than the likely construction cost and the build would likely need to be funded by additional construction costs being spread over more years.

- The forecast included $9.6 million for the construction of the new 110kV Wiroa substation over FYE 2023-25. $3.1 million of this provided for in the current year has now been reallocated to the new 11kV reliability improvement programme. Due to the high labour and materials cost increases (estimated at 7% and 15% respectively) the remaining $6.5 million understates the cost the work it was intended to provide for. While the decision has been made to defer this project, given the load growth in the Kerikeri area there is little doubt that the substation will be required at some stage within the ten-year AMP planning period. However, the timing of the build is uncertain and will depend on the rate of growth in demand.

- A total of $73.6 million in the forecast (38%) has been provided for asset renewal and replacement. Of this $25.3 million is allocated to the distribution network, $10.8 million of which is reactive expenditure incurred responding to faults and the remediation of urgent defects identified during asset inspections.

- A total of $2.4 million has been allocated to the proactive replacement of crossarms. This programme was budgeted to begin until FYE 2026.

The 2023 AMP is required to be a full AMP rather than an update and the capital expenditure forecast will need to be well supported in the text. The forecast will be revised to include the following changes from the forecast in the 2022 AMP Update.

- All years of the constant price forecast will be based on expected FYE 2024 costs.

- Construction costs for the 110kV line will be removed on the understanding that the line will be constructed as a customer driven asset largely funded by capital contributions. Residual costs to fully secure the route will still be included but these are not a material amount.

- The construction of the Wiroa substation will be included as a “placeholder”, based on updated information on demand growth and quantitative modelling of the impact of a loss of the Kaikohe-Wiroa line at time of peak demand. The supporting text will clarify that the build may be brought forward or further deferred.

- The forecast will include an updated 11kV reliability improvement plan funded by the deferral of Wiroa substation build and the removal of the Wiroa-Kaitaia line. The need for this plan and its expected impact will be discussed in the text. The new plan will include provision for the proactive replacement of crossarms and other pole top hardware starting FYE 2024.

Impact of Defective Equipment Faults

We monitor the condition of our asset base through our regular asset inspections. All assets are inspected in accordance with a time-based inspection schedule but the interval between the inspection of individual assets will vary. This is determined by:

- The probability of an asset failure. Assets early in their expected life will be inspected less frequently than assets nearing the end of their life that are showing signs of accelerated deterioration, where the inspection interval is determined by an assessment of the assets likely remaining life as determined by the asset’s condition.

- The consequences of an asset failure. Consequences are determined primarily in terms of safety risk and the impact of an asset failure on the reliability of the network. Assets with a high consequence of failure are replaced early, while assets where the consequences of failure are low are likely to be left in service until the asset finally fails.

The results of our regular asset inspection are used to formulate an overall assessment of the health of our network asset base using the methodology set out in the Electricity Engineers’ Association (EEA) Asset Health Indicator Guide. This Guide categorizes the asset base by asset type and requires an assessment of the number of assets of each asset type that are nearing the end of their expected life and are due for replacement. Where possible the assessment is based on the condition of that asset as determined from our asset inspections. However, for some asset types, such as conductor and cable, asset condition cannot be determined from a visual inspection and asset age is used as a proxy for condition.

This approach assists us utilize an asset replacement and renewal programme that ensures:

- The allocation of expenditure to asset replacement and renewal is sufficient to ensure that the asset base is maintained to a level that will meet our asset management objectives and ensure that our reliability of supply does not deteriorate to a level that is unacceptable to stakeholders.

- This expenditure is appropriately prioritized and targeted appropriately.

The success of our fleet management plans can be determined by evaluating the impact of faults caused by defective equipment on overall network reliability, as measured by SAIDI and SAIFI.

A shortcoming of this approach is that the EEA Guide categorizes the asset base into the asset types generally used for financial reporting when, for some assets, a higher level of disaggregation is more appropriate. Table 2 provides a breakdown of the average annual SAIDI impact of defective equipment failures on the 11kV over the five-year period FYE 2018-22.

Cause	**SAIDI (minutes)**	**Percent of Total**
Crossarms	27.23	30%
Other pole top hardware	25.40	28%
Conductor	14.56	16%
Transformer (incl. regulators)	9.08	10%
Cables	3.63	4%
Switch	3.01	3%
Reclosers / sectionaliser	0.79	1%
Poles	0.34	0%
Circuit breaker	0.24	0%
Other	6.59	7%
Total	**90.88**	**100%**

Table 2: SAIDI Impact of 11kV Defective Equipment Faults

The table shows that 58% of the reliability impact defective equipment faults on the 11kV distribution network were caused by the failure of crossarms or other pole top hardware, which are not categorized as assets under the EEA methodology. However, our proactive asset renewal programme largely focuses on the replacement of “assets” as categorized in the EEA Guide and used for financial reporting purposes. Hence a pole inclusive of its crossarms and other pole top hardware are categorized as an “asset” but the hardware that it supports are merely considered components. This creates an anomaly in that the pole top hardware generally has a shorter life than the associated pole, particularly when the pole is concrete. Until now, we have not had proactive asset renewal programmes specifically targeted at pole top hardware.

While the recently developed 11kV reliability improvement programme does not explicitly include provision for proactive pole top hardware replacements, it allocates $1.75 million for the replacement of concrete poles on the Te Kao and Tokerau feeders in FYE 2023-24. These two feeders had the highest SAIDI impact of crossarm and pole top hardware failures over the FYE 2018-22 period of all the feeders on the network and together accounted for 5.2% of this total impact. Pole replacements routinely include the replacement of pole top hardware. As indicated above, the 2023 AMP expenditure forecast will include provision for an asset renewal programme targeted at the proactive replacement of pole top hardware.

Recommendation
That the Directors accept this paper for information.

Russell Shaw
Chief Executive
Top Energy Group

Prepared by:
Ian Robertson
Network General Manager

Appendix 12

www.topenergy.co.nz

Top Energy Limited

Level 2, John Butler Centre
60 Kerikeri Road
P O Box 43
Kerikeri 0245
New Zealand
PH +64 (0)9 401 5440
FAX +64 (0)9 407 0611

Memo to	**David Sullivan** **Nicole Anderson** **Jon Nichols** **Steve Sanderson** **Simon Young**
From	**Russell Shaw**
Date	**August 2023**
Subject	**AMP Due Diligence Part 1 - Asset Performance and Review**

PURPOSE

This is an information paper. It is part 1 of a 2-part Asset Management Plan (AMP) Due Diligence review. The document is to inform the Board of the analysis, decisions and direction being taken by Network Management with focus on changes from last year.

BACKGROUND

Top Energy published the 2023 AMP on 31 March 2023, which covered a ten-year planning period from 1 April 2023 to 31 March 2033. As required by the Commerce Commission an AMP Update, is due for release on 31 March 2024. In order to understand the trade-offs and decisions made in covering capital and maintenance expenditure drivers the Board, as part of due diligence, has asked for information on past and future performance presented in this, and a second paper (Part 2) in September.

EXECUTIVE SUMMARY

The topics raised and questions answered in this paper are presented in the following order:

1. Review of FYE 2023 reliability
2. Changes to network risk
3. Proposed changes to fleet plans for key asset classes

Review of FYE2023 Reliability

In FYE2023 the raw unplanned SAIDI impact was 1791.6 minutes and 7.05 SAIFI interruptions per consumer. After normalisation in accordance with the Commerce Commission's approved methodology, the normalised measures were 513.96 SAIDI minutes and 5.50 SAIFI interruptions. These were both higher than the Commerce Commission's quality thresholds of 380.24 SAIDI minutes and 5.07 SAIFI interruptions. This was the first year that Top Energy Top Energy failed to comply with the annual Unplanned Interruptions reliability assessments

- There were four major SAIDI events in FYE2023, two storms in July and August 2022 and Cyclone Gabrielle in mid-February 2023. There was also a separate major SAIDI event in August 2022 when a tree fell onto the 33kV Taipa line and we could not start the Taipa generators remotely because of a software fault. Cyclone Gabrielle was our only major SAIFI event. Due to the impact of normalisation, these four events did not appear to make a significant contribution to our normalised SAIDI/SAIFI measures their total normalised SAIDI impact was 52.52 minutes. However the Commerce Commission classifies periods of time as major events that have accrued greater than 27.92 SAIDI minutes over any 24-hour period so Major Events exclude any long tail, which (for example) in Cyclone Gabrielle case extended for an additional two weeks over which 40 SAIDI minutes were accrued.

- During FYE2023, there were 66 interruptions, outside of major events with a SAIDI impact of greater than 2 minutes. Together these interruptions had a SAIDI impact of 246 minutes, which accounted for 48% of our total normalised Unplanned SAIDI for the year. Many of these were attributable to adverse weather.

- There were no interruptions of our incoming 110kV supply from Maungatapere and no unplanned interruptions of our own 110kV transmission system. Using our backup diesel generation, we successfully completed our annual maintenance outage of the 110kV transmission system without interrupting supply to consumers in our northern area.

- The normalized unplanned SAIDI due to faults on the 33kV sub transmission network was 18.99 minutes, 4% of the total network Unplanned SAIDI of 513.96 minutes. As a result of the investment in the sub transmission network, sub transmission faults are no longer a major contributor to our normalised network SAIDI. Going forward, we are aiming to reduce the annual normalized unplanned SAIDI on our sub transmission network to below 20 minutes.

- The normalised SAIDI impact of faults on our 11kV distribution network in FYE2023 was 480.1 minutes, up 54% from the FY2022 impact of 312.43 minutes.

- The three major contributors to our normalised SAIDI impact were faults caused by adverse weather, defective equipment, and vegetation. The aggregated SAIDI impact of these three measures was 380.7 minutes, 77% higher than the corresponding measure in FYE2022.

- The SAIDI impact of vegetation faults on the normalised reliability of the network increased at a significant rate. We estimate from our records that 68 trees fell across and through our 11kV network during Cyclone Gabriele alone. Although the impact of tree contact events is increasing at a faster rate than tree fall events, it is hard to ascertain anything from this due to how the events are reported by individuals. Assuming no improvement in weather patterns however, the normalised reliability of the network is likely to deteriorate further unless we are able to implement a more effective vegetation management strategy not bound by current legislation.

Network Risk

The widespread power outages experienced throughout our supply area during Cyclone Gabrielle have highlighted the need for the electricity distribution sector to increase its focus on resilience and the need to be better prepared for high impact-low probability (HILP) events. We have assessed the maturity of our resilience management using an industry-standard assessment tool and are currently investigating the potential for improvement.

- Land slips that occurred during Cyclone Gabrielle in the vicinity of the route of our 110kV line where it crosses the Maungataniwha Range have highlighted the vulnerability of this line to the failure of a structure foundation. We have completed a geotechnical survey of the route and are planning to relocate two structures considered particularly vulnerable. We are also increasing our preparedness for such an event by developing firm plans and procedures for the restoration of supply following a structure failure.

- While the planned 110kV line would relieve the transmission constraint between Kaitaia and Kaikohe, there is still a constraint south to Maungatapere. We continue to work with Transpower on the establishment of a renewable energy zone (REZ) to overcome these constraints, but progress is slow. We suspect that we will not be able to build the line until the Government develops a policy on the funding of the transmission and distribution system upgrades that will be needed if sufficient renewable generation is to be built to enable New Zealand to meet its 2050 net-zero decarbonisation target.

Fleet Management

We are progressively introducing a more structured and granular approach to the management and use of fleet data, which in time we anticipate will provide a more accurate and complete picture of the condition of our network assets, a more effective asset inspection programme and a robust basis for determining the optimal level of expenditure on the renewal and replacement of each asset fleet.

- We have purchased the software tools we need for this initiative (DataFrame software from Asset Dynamics) and are currently populating these tools with data on our overhead line assets. Data on other asset fleets will be added to the models in due course.

- In parallel with this, we are reviewing our processes for capturing asset condition data and are planning to introduce an asset inspection auditing regime. We are also developing a structured approach to measuring asset criticality so this can be included in the models.

- In the current FYE2024 year, we have increased the resources allocated to our low voltage data capture project, which is currently planned to be completed over a three-year period.

- An external review of our zone substation power transformer fleet has indicated that the condition of some older transformers is worse than indicated by the results of our regular power transformer monitoring tests. We are developing a comprehensive fleet plan for our power transformer assets, which will include a power transformer renewal and replacement strategy, the cost of which will be included in our 2024 AMP expenditure forecast. We have contingency plans in place should a power transformer fail unexpectedly and, while the review has identified an emerging issue that we need to act on, we are well placed to manage the short-term risk.

- Top Energy currently uses an Open Platform Communications (OPC) protocol to control field devices (reclosers, sectionalisers, remote controlled switches and voltage regulators). OPC is unsupported and has been identified for replacement with a modern replacement to address known stability issues. A project has been set up to investigate, fund, and implement a modern DNP3 digital field device communication protocol, for all new devices and the migration of existing equipment and field devices to the new protocol. A business case will be presented to the Board and will be included in the AMP update.

REVIEW OF FYE2023 NETWORK RELIABILITY

A comparison of our normalised network SAIDI and SAIFI in FYE2023 with our historic performance is shown in Figure 1, which shows that we failed to Comply with the Annual Unplanned Interruptions Reliability Assessments:

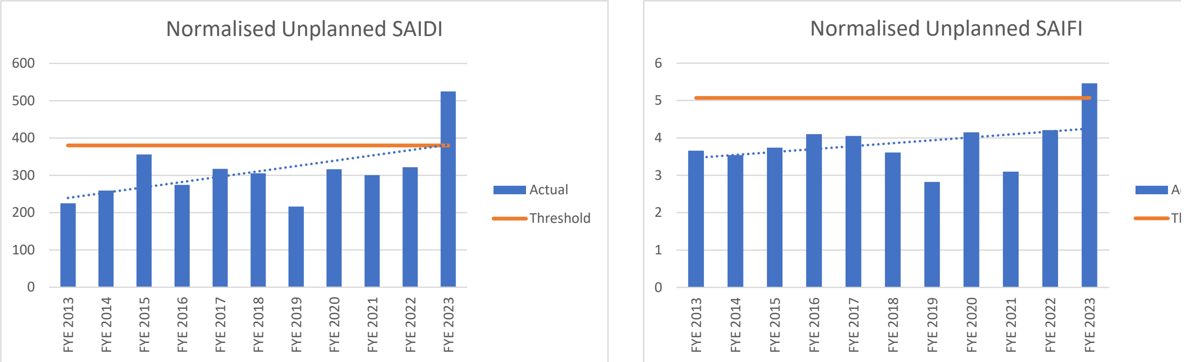


Figure 1: Impact of Unplanned Network Interruptions after Normalization

Major SAIDI and SAIFI Events

There were four major SAIDI events during FYE2023, of which Cyclone Gabrielle had the greatest impact. Cyclone Gabrielle was the only major SAIFI event we experienced. The impacts of these events is shown in Table 1.

Note that with major weather events such as Cyclone Gabrielle not all SAIDI is normalised. The Commerce Commission classifies periods of time as major events that have accrued greater than 27.92 SAIDI minutes over any 24-hour period. So Major Events exclude the long tail which with Cyclone Gabrielle, extended for an additional two weeks over which 40 more Unplanned SAIDI minutes were accrued.

Month	Duration (hrs)	No. Faults	Major Event		SAIDI		SAIFI		Comment
			SAIDI	SAIFI	Raw	Normalised	Raw	Normalised	
July	28	18	Y	N	43.2	8.46	0.243	0.243	Storm
August	34	27	Y	N	42.17	11.71	0.215	0.215	Storm
August	43	5	Y	N	53.83[1]	2.19	0.214	0.2.14	Tree fall on 33kV Taipa line. Control room unable to start generators due to software fault.
February	84	98	Y	Y	1190.9	30.16	1.084	0.215	Cyclone Gabrielle.

Table 1: Major SAIDI/SAIFI Events FYE2023

Note 1: For this table, only those faults that occurred within the rolling 24-hour normalisation window are included. There were also a small number of high SAIDI impact events that occurred in the aftermath of the storms that could not be normalised because they fell outside the rolling 24-hour window defined in the normalisation methodology approved by the Commission.

The storms in July and August were widespread and affected the whole of our supply area. The tree fall event on the Taipa line had a raw SAIDI of 53.83 minutes. An equipment related issue (software) problem prevented the Taipa generators being started remotely. This has now been rectified.

The normalisation process has the effect of eliminating the most severe storms such as Cyclone Gabrielle as major contributors to the unreliability of our network as measured by the Commission for assessment against its quality threshold. The four events with the highest

[1] This includes the SAIDI impact of unrelated faults that occurred within the rolling 24-hour normalisation window.

individual SAIDI impact in FYE2023 had a total raw SAIDI impact of 1,330.1 minutes, but normalisation reduced this to 52.52 minutes.

High Impact Interruptions

Our high normalised SAIDI in FYE2023 was due to the large number of faults with a raw SAIDI impact greater than two minutes that occurred outside of the weather events that triggered normalisation. As shown in Table 2, there were 66 faults with an individual SAIDI impact of greater than 2 minutes that could not be normalised because they occurred outside a normalised storm event. These had an aggregated SAIDI impact of 246 minutes, which was 48% of the total normalised Unplanned SAIDI impact for the year and almost five times the total normalised SAIDI impact of all the interruptions that occurred during Cyclone Gabrielle (if you exclude Cyclone Gabrielle's long tail).

SAIDI Range	No of Interruptions	Total SAIDI
8-9	2	17.03
7-8	2	14.45
6-7	2	13.28
5-6	8	41.93
4-5	8	35.63
3-4	15	52.51
2-3	29	71.18
Total	**66**	**246.01**

Table 2: High SAIDI Impact Faults

Table 3 analyses these 66 faults by fault type. It can be seen that the total normalised SAIDI impact of adverse weather events was 85.98 minutes (33.46 minutes from Table 2 and 52.52 minutes from Table 1[2]).

Fault Type	No of Interruptions	Total SAIDI
Defective Equipment	21	76.96
Vegetation	19	76.07
Adverse Weather	10	33.46
Unknown	7	21.6
Third Party	4	15.05
Lightning	2	13.28
Wildlife	2	5.25
Adverse Environment	1	4.34
Total	**66**	**246.01**

Table 3: High SAIDI Impact Faults

2 The tree fall event on the Taipa line was categorised as vegetation rather than adverse weather.

Overall SAIDI Impacts by Voltage

Table 4 shows the raw and normalised SAIDI impact over the period FYE2018-23, disaggregated by year and voltage.

FYE	110kV Transmission		33kV Sub transmission		11kV Distribution	
	Raw SAIDI	Normalised SAIDI	Raw SAIDI	Normalised SAIDI	Raw SAIDI	Normalised SAIDI
2018	90.40	4.18	25.17	25.17	361.37	275.25
2019	-	-	44.08	20.69	199.62	195.65
2020	-	-	44.50	44.50	271.74	271.40
2021	18.01	18.01	25.51	25.51	257.30	257.30
2022	-	-	90.83	30.27	650.68	312.43
2023	-	-	123.14	21.18	1,639.12	570.81

Table 4: Disaggregation of SAIDI Impacts by Voltage (FYE2018-23)

It can be seen from the table that:

- There were no supply interruptions in FYE2023 caused by faults on our transmission assets. Nevertheless, the high rainfall over the last two years has exposed the vulnerability of this line to a high-impact, low-probability (HILP) failure, most likely due to ground movement over the Maungataniwha Range undermining a structure foundation.

- The 33kV sub transmission network is also not a major contributor to normalised network SAIDI – in FYE2023 faults on our sub transmission network contributed less than 4% of our total normalised network Unplanned SAIDI. While there was little variation in the impact of these faults on our normalised SAIDI over the period, there was a significant increase in our raw 33kV SAIDI in FYE2022 and FYE2023. These faults mostly occurred during severe weather events and their raw impact was therefore largely normalised out.

- In FYE2023 the normalised 11kV SAIDI was 83% higher than in FYE2022.

Causes of Unplanned Network Interruptions

Table 5 shows the normalised SAIDI Impact of unplanned interruptions over the FYE2018-23 period, disaggregated by the standard fault causes used by the Commission for information disclosure.

FYE	2018	2019	2020	2021	2022	2023
Lightning	2.67	22.19	7.67	3.77	5.64	18.47
Vegetation	83.22	34.68	81.24	44.43	96.97	150.84
Adverse weather	21.48		2.52	0.28	20.76	93.82
Adverse environment		0.04				7.95
Third party interference	66.44	61.70	76.31	56.80	52.60	36.49
Wildlife				1.44	4.29	17.93
Human error	6.09	0.03	4.26	13.57	0.81	0.37
Defective equipment	94.89	66.08	122.12	140.46	97.68	139.22
Unknown	29.81	31.61	21.78	40.07	163.96	48.85

Total	304.60	216.33	315.90	300.82	342.71	513.96

Table 5: Breakdown of Network SAIDI by Fault Cause (FYE2018-23)

Insights from the data in Table 5 are discussed below.

- *Adverse weather*

The Far North experienced two states of emergency, a La Nina weather system, and 12 Notified Severe Weather Events (Table 6). These triggered vegetation damage due to increased soil moisture levels, high winds, and rain. Meteorological data suggests that the weather in both years was abnormally severe. An indication of this can be seen from Table 7, which shows the monthly rainfall recorded by the Kerikeri Weather Station, a private weather station within the Kerikeri town area over the six-year FYE2018-23 review period[3]. While the table only shows data over the six-year review period, the annual rainfall in both CY2021 and CY2022 were both higher than in any full calendar year since the station was established in 2007.

Severe Weather	Date
Cyclone Gabrielle (2nd State of Emergency in Northland)	12th February 2023
Storm (1st State of Emergency in Northland)	31st January 2023
Storm	27th January 2023
Cyclone Hale	10th January 2023
Storm	4th January 2023
Storm's	10th and 23rd November 2022
Storm	27th October 2022
Flooding	5th September 2022
Storm (Loss of State Highway 1 through Mangamuka Gorge)	18th August 2022
Storm's	12th and 25th July 2022
Storm	28th of May 2022
Cyclone Fili	12th April 2022

Table 6 Severe Weather Events (MetService)

	FYE2018	FYE2019	FYE2020	FYE2021	FYE2022	FYE2023
Apr	277.8	89.4	81.0	107.8	157.8	169.6
May	113.4	123.6	63.2	217.0	111.8	171.8
Jun	166.4	206.0	125.2	177.0	287.0	192.2
Jul	153.2	92.8	189.8	253.8	303.2	467.4
Aug	177.2	98.6	124.8	215.8	147.0	316.4
Sept	149.6	107.6	116.4	51.6	239.2	149.4
Oct	80.2	47.2	127.6	59.4	420.8	180.0
Nov	106.2	75.6	75.0	128.8	104.2	284.8
Dec	27.2	71.8	57.0	14.0	88.4	100.8
Jan	141.6	6.8	20.6	68.2	95.2	276.8

3 www.kerikeriweather.co.nz/wxrainsummary.php?r=wxrainsummary.php

Feb	192.6	93.4	14.8	167.4	168.6	223.1
Mar	206.4	88.2	119.8	130.6	198.2	27.4
Total	**1791.8**	**1101.0**	**1115.2**	**1591.4**	**2321.4**	**2559.7**

Table 7: Monthly Rainfall (mm) in Kerikeri FYE2018-23

The normalised SAIDI impact of adverse weather faults was almost five times higher than in FYE2022. Normalisation does not remove either the long tail of major events or the impact of smaller but frequent severe weather fronts, due to the FY23 La Nina weather system. Table 7 is indicative only and does not purport to be the outcome of a comprehensive analysis of the weather conditions in our supply area, The normalised FYE2023 SAIDI attributed to adverse weather is 567% higher than in FYE2022 as reporting was undertaken to capture the prime reason causing faults.

Note that the adverse weather categories do not fully reflect the adverse weather damage.
The Commerce Commission requires that an outage have one cause. Often adverse weather causes vegetation to fall on or contact lines. In order to record accurate vegetation damage they define adverse weather as follows:

*…all unplanned interruptions where the primary cause is adverse weather, **other than those caused directly by lightning, vegetation contact or adverse environment*** [our emphasis].[4]

So much of the vegetation damage can be attributed to severe weather.

The criteria used to categorise an "adverse weather" event has not been consistent over time. In FYE2022 only interruptions that occurred during the rolling 24-hour normalisation window of a major SAIDI/SAIFI event were categorised as adverse weather, whereas in FYE2023 this categorisation was broadened to include the impact of many events outside the normalisation window. If events are not categorised consistently, then trending SAIDI data by cause over time may not be valid. This could lead to inefficient expenditure allocation if trend data is to be used as the basis for the allocation of available financial resources.

The SAIDI "Deep Dive" report by Harmonic Analytics noted:

> *Incident data contains an "extreme weather event" flag, raised by employees manually if they responded to an incident believed to be associated with extreme weather. Previous investigation indicated that this was subjective. There may be utility in a more objective extreme weather definition based on weather data.*[5]

This was due to change in personnel in 2022, and the data was subsequently corrected. However if reading the Hamonic Analytic's report this needs to be taken into consideration.

- *Defective equipment*

  The second major SAIDI impact in FYE2023 was defective equipment. Figure 2 trends the SAIDI impact of defective equipment faults on the network over the period FYE2018-23. The figure shows that while there was a step jump in SAIDI input between FYE2019 and FYE2020,

---

4 The Information Disclosure Determination gives slips and earthquakes as examples to fault causes that should be categorised as adverse environment.

5 *SAIDI Analytics Deep Dive – Summary Report:* Harmonic Analytics, 12 May 2023, p12

there has been little change in the SAIDI impact of defective equipment faults since then. The reason for the significant jump between FYE2019 and FYE2020 is not clear.

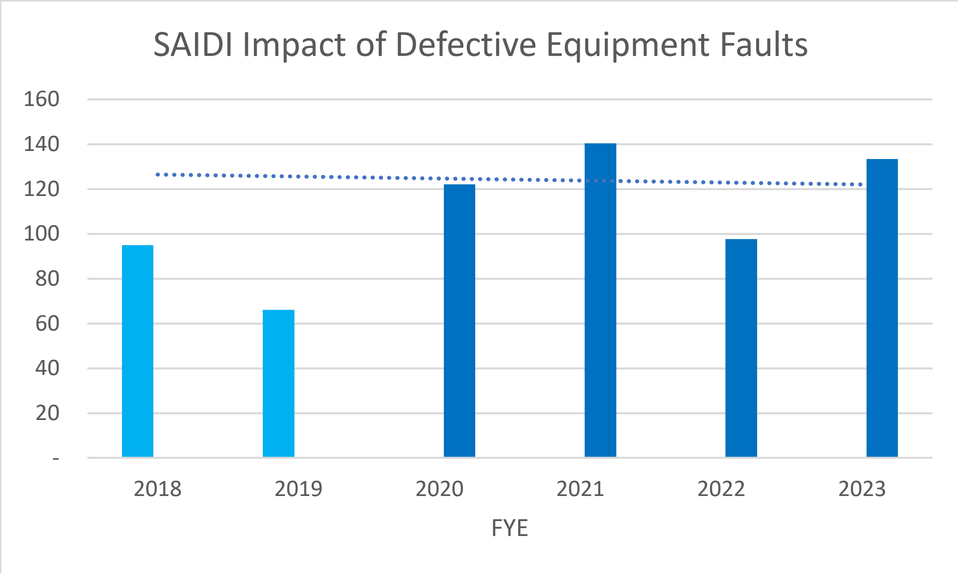


Figure 2: SAIDI Impact of Defective Equipment Faults

- *Vegetation*

The largest fault cause in FYE2023 was vegetation. Figure 3 trends the SAIDI impact of vegetation faults on the network over the period FYE2018-23, further disaggregated into tree contact and tree fall impacts. We estimate we suffered 68 trees fall through or across out lines during Cyclone Gabrielle alone.

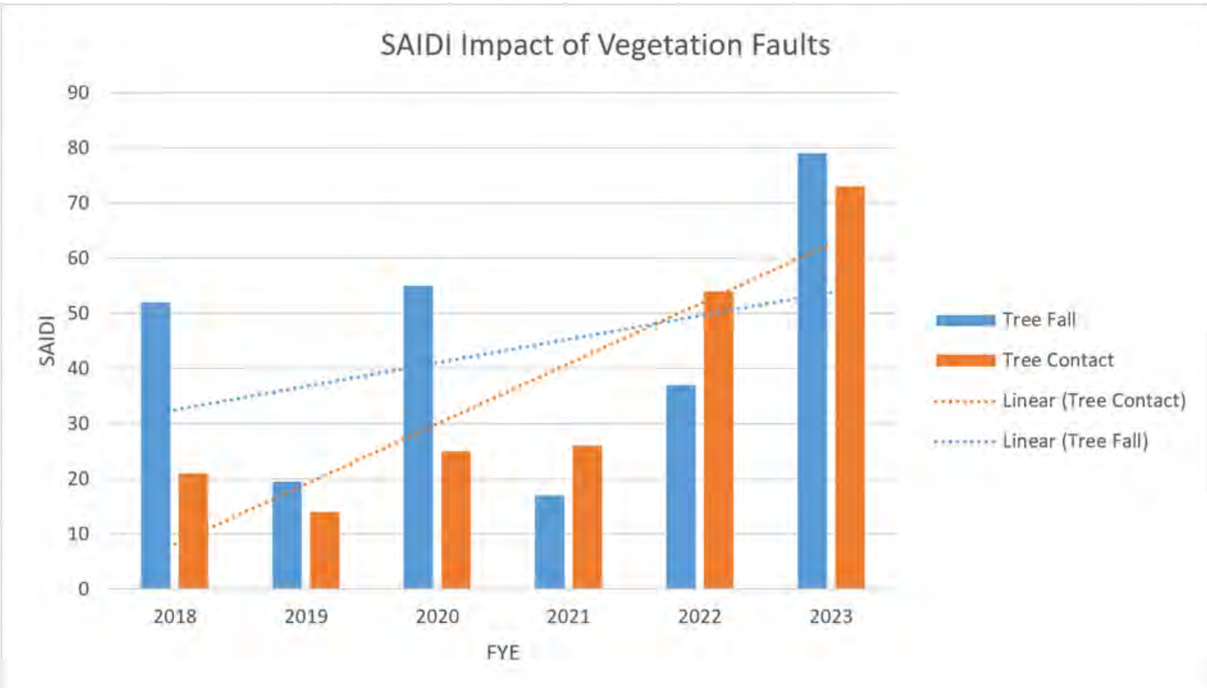


Figure 3: SAIDI Impact of Vegetation Faults

The graph shows a significant increase in both the SAIDI impact of tree-contact events over the review period and an increase in the impact of tree fall events.

Stabilisation Of Distribution Network Reliability

In May 2022 the Board approved management's 11kV network development plan, funded by reallocating the expenditure in the original FYE2023 work plan for the construction of the deferred Wiroa 110/33kV substation. The objective of this changes was to arrest the deterioration in the reliability of the 11kV network and stabilise it to meet the revised network reliability targets set out in the 2023 AMP.

For the current FYE2024 year we went out to open tender with a work package made up of the larger, more significant projects in our works programme. We have identified a suitable external contractor and are currently negotiating a final contract.

NETWORK RISK

Resilience

The normalised measure of reliability discussed above is designed as a measure of how well our asset management strategy meets the expectations of stakeholders, given events that can reasonably be expected to occur in the normal course of business and weather conditions that are typical for our supply area. Cyclone Gabrielle was a timely reminder that atypical events stress the network beyond its design envelope and beyond our fault response capacity. While such events have a severe impact on customers and other stakeholders, the normalisation process means that the impact of such events on the normalised reliability that we measure and report on is generally relatively small.

Nevertheless, we are a lifeline utility providing an essential service and our stakeholders expect us to be prepared and to respond effectively to such events when they do occur. The Electricity Engineers' Association (EEA) has prepared a Guideline on resilience, based on the following 4R's framework.

- **Reduction.** Identifying and analysing long-term risk to human life and property from hazards; taking steps to eliminate these risks if practicable, and, if not, reducing the magnitude of their impact and the likelihood of them occurring.

- **Readiness.** Developing operational systems and capabilities before a major loss event or emergency happens; including self-help and response programmes for the general public, and specific programmes for emergency services, Lifeline Utilities, and other agencies.

- **Response.** Actions taken immediately before, during, or immediately after a major loss event to save lives and protect property, and to help communities recover. In many cases this means activating pre-prepared readiness plans to enable lifeline utility services to be restored to communities.

- **Recovery.** The coordinated efforts and processes to bring about the immediate, medium-term, and long-term holistic regeneration of a community following a major loss event.

The EEA Resilience Guide includes a *Resilience Management Maturity Assessment Tool (RMMAT),* which has a very similar format to the *Asset Management Maturity Assessment Tool (AMMAT)* that is included in our AMP as Schedule 13. We have used this tool to assess our asset management maturity and are currently analysing our weaknesses and developing a programme to improve our resilience maturity. This will involve:

- **Reduction:** We are currently identifying credible high impact events, as well as practicable and economic investments to mitigate their impact that can be incorporated into our expenditure forecasts. It seems clear that the frequency of extreme weather events such as Cyclone Gabrielle is increasing, and climate change predictions for our supply area are that the intensity of such events will be higher. There is an overlap between mitigating the impact of severe weather events such as Gabrielle and managing BAU reliability in that investments designed to manage reliability will also reduce the impact of extreme weather events when they occur.

- **Readiness:** Developing in-house procedures and processes and formalising arrangements and contracts with external parties to enable us to be better prepared for such events, so that we can respond more effectively when they do occur. Lessons learnt from the review of our response to Cyclone Gabrielle be a useful input to this. This will largely involve refocusing our existing network management effort. It will also involve, amongst other things, considering whether we should purchase small diesel generators, which could be used to provide emergency power to community “refuges” in areas that are expected to be without supply for an extended period following a high impact event.

We have documented management’s assessment of our current resilience management maturity in a separate Board paper for the August meeting. We are also preparing a separate paper in September that will set our plan for increasing our preparedness for HILP events and improving our response capability.

Vulnerability of the Kaikohe-Kaitaia 110kV Line

This line is arguably our most critical network asset as it is the only connection to the grid for the more than 11,000 consumers in the northern part of our supply area. As indicated in Table 4 the reliability of this line has been excellent - the SAIDI impact of 110kV line faults was very low compared to the impact of our 33kV and 11kV assets.

However, the significant rain in our supply area over the last year has resulted in land slips near two structures where the line crosses the Maungataniwha Range. This has highlighted the vulnerability of this line to the failure of a structure due to its foundation being undermined by unstable ground.

Should such an event occur and cause a loss of supply, the diesel generation in the northern area is available to restore supply to all consumers (apart from the [redacted] until temporary repairs are made to the line. However, while the generators at Taipa have been in place for some years, we have still to test our ability to start the generators at our Kaitaia depot and the Bonnets Rd generator farm when no external power supply is available.[6] In a worst-case scenario it is likely to be days, possibly weeks, before a grid supply can be restored. Operation on diesel for this length of time will be expensive and the generators are designed as standby units and not rated for extended operation.

6 To date these generators have only been used to cover for a planned interruption. In this situation the procedure is to start the generators before the line is disconnected, so an external supply is available.

One of the lessons from Gabrielle and other recent storm events is that, under storm conditions, generators often cannot be used until the network that it supplies has been patrolled. If a fault such as a tree fall occurs on a line that is already without power due to an upstream fault, our operators will likely be unaware of the situation unless it has been reported by a member of the public.

We are taking the following steps to mitigate this risk.

- We have developed a standard operating procedure for starting the generators when no grid supply is available.

- We have undertaken a geotechnical survey and are planning to relocate two structures located close to ground at risk of erosion.

- We are working toward formalising an arrangement with Transpower for the supply and installation of a temporary structure (tower) at short notice should such an event occur. This arrangement will address and allocate responsibility for all relevant procedures including liaison with the Department of Conservation, transport of the tower, lifting it into position (presumably by helicopter), erection of the tower, attachment of the conductors, and energisation of the line. We also have in stock, suitable poles and conductor to replace many of the structures in the line, without the need for a specialist temporary "tower."

Renewable Generation

Our 2023 AMP noted that we have signed connection agreements for the connection of three utility scale solar farms in our northern area with a total capacity of 67MW. The construction of the 23MW Kaitaia Solar Farm by Loadstone Energy has commenced and we have started construction of the 33kV line that will connect this solar farm to our NPL zone substation. We remain in contact with the developers of the other two solar farms, which we expect to proceed in due course. When commissioned, these three solar farms will fully utilise the capacity of our existing Kaikohe-Kaitaia 110kV line.

The 2023 AMP also deferred the planned 110kV line between Wiroa and Kaitaia from the capital expenditure forecast on the basis that the cost of the line had escalated to the point where it cannot be justified purely on the basis of providing a resilient and reliable electricity supply to consumers in our northern area. While a route for this line has now been confirmed, the installation of diesel generation in the Kaitaia area has addressed some of the issues that triggered our original decision to construct the line.

As the sunshine hours in our northern area are amongst the highest in the country, we continue to receive applications to connect additional solar farm capacity to our network. However, we are unable to connect any further generation since there is no spare transmission capacity available to export the electricity south. There are two constraints – a constraint within our network between Kaitaia and Kaikohe and a constraint in the Transpower network between Kaikohe and Maungatapere.

We continue to work with Transpower and Northpower on the development of a Northland Renewable Energy Zone (REZ), which would assess the transmission system upgrade requirements to meet the demand for the connection of additional renewable generation in Northland from a holistic, area-wide perspective. However, Transpower has identified that further consideration and development is required to develop a REZ concept that is right for New Zealand. Funding of the system upgrades that will be needed if the REZ concept is to be progressed is likely to be a problem and we suspect that we will not be able to build the line until the Government develops a policy on the funding of the transmission and distribution system upgrades that will be needed if sufficient renewable generation is to be built to enable New Zealand to meet its 2050 net-zero decarbonisation target.

The 110/33kV transformer capacity at the Kaitaia substation is a further constraint. The substation has two transformers, a relatively new 40/60MVA unit and an older 22MVA unit. Should the larger unit fail, which is unlikely since it has given reliable service and our power transformer testing programme has shown it to still be in as-new condition, the 22MVA unit has insufficient capacity to accommodate the three new solar farms. Our 2023 AMP expenditure forecast provides for the replacement of this transformer in FYE2030.

FLEET MANAGEMENT

Approach

Fleet plans for our asset classes, (as high-level summaries) are included in Chapter 6 of our AMP. Each of these summaries includes an assessment of asset health, using the five-point framework in the EEA Asset Health Indicator Guide, and a replacement strategy expressed as the number of assets in each fleet that we plan to replace each year. However, the basis on which this replacement strategy was developed requires more attention as our health assessment currently takes no account of asset criticality. The assessment over the overall health of an asset fleet can therefore be misleading if the assets known to be in poor condition are non-critical assets that we would normally run to failure.

We are embarking on a multi-year strategy to develop a more robust and structured approach to our lifecycle asset management. To this end:

- We have purchased the DataFrame software from Asset Dynamics, which we will use to monitor the completeness of the data on each asset component. The software will aggregate this data and assess data completeness “scores” for the various sub-fleets. This will provide our asset managers a more robust assessment of the completeness of the data on different segments of our asset base, highlight those areas where data is less complete and likely less reliable.

  The software will initially be populated with data on our sub transmission and high voltage distribution lines. In particular, it is planned to treat crossarms as a separate asset component, which we don’t currently do. Crossarm faults account for over half of our defective equipment failures. While the expected life of a crossarm is about half that of the concrete pole to which they are attached, they are currently not separately monitored, which makes it difficult to develop an effective crossarm replacement strategy. Monitoring crossarm condition separately from that of their associated pole will, over time, lead to more robust management of the asset sub-fleet and a reduction in the number of supply interruptions caused by crossarm failures.

- The data in the DataFrame software will feed directly into our new condition-based risk management (CBRM) model, which was discussed in Section 8.3 of our 2023 AMP. The model will create a risk score for each individual asset, which is the product of the asset's probability of failure and the consequence of failure (criticality). The risk scores for each asset are then aggregated to create a risk profile for each asset class. Based on the rate of deterioration generally observed for each asset type, the model can track the change in risk profile of each asset class over time. We will use the model as a tool that will enable us to evaluate how different rates of asset replacement will impact the risk profile, and this will allow us to quantify the optimal rate of asset replacement to maintain the asset fleet in a condition that is fit for purpose. Over time, a separate CBRM model will be developed for each asset fleet.

- We plan to further develop our documented fleet plans to underpin the CBRM models. These will provide information on, but not necessarily be limited to, the characteristics the assets that make up the fleet (e.g. conductor types and standard sizes), failure modes, fleet management strategy, preventive maintenance, and corrective and reactive maintenance. The fleet plans and their associated CBRM models will drive our asset inspection plans, proactive and reactive maintenance, as well as our capitalised asset renewal and replacement strategy.

Asset Condition Data Quality

The data to be included in the DataFrame software platform relates to an asset's specification, its age, and other known factors, such as distance from the coast, which could influence an asset's expected rate of deterioration.

Data on the condition of an individual asset is maintained in our SAP asset management software platform and is derived from our asset management inspection programme. In parallel with the implementation of the DataFrame and CBRM software platforms, we are reviewing our asset condition data capture processes. This review is looking at:

- Whether the inspection templates for each asset type can be improved and whether the criteria on which inspectors base their assessment of an asset's condition is appropriate.
- The extent to which the asset inspection data should be audited. Currently no formal audits are undertaken. We plan to introduce a formal regime for auditing asset inspections once these positions are filled.
- The framework for defining asset criticality. The CBRM model will require criticality to be defined and assessed in a structured way.

We envisage that the strengthening of our maintenance management support capability, the introduction of the DataFrame and CBRM software platforms and the review of the robustness and appropriateness of our asset condition data will over time provide the information we need to develop a more cost-effective maintenance and asset renewal strategy. However this is a multi-year initiative – purchasing the software and populating it with the data we already have is only the first step in the process. It will be followed by an ongoing process of refinement that will include both improving the quality of asset data and learning to use the software tools more effectively.

Low Voltage Asset Data

A known limitation in the completeness and quality of our asset data relates to our low voltage assets. In FYE2023, we initiated an LV data capture project, which will capture accurate data on our LV assets and their connectivity across the network. As the data comes in, it is being input into our GIS and SAP asset management systems. The project includes opening all service pillars to confirm LV connectivity and has been useful in identifying issues that require remediation, but which would otherwise have gone unnoticed. In the current FYE2024 year, we have increased the resources allocated to this project, which we have planned to be completed over a three-year period.

Power Transformers

Our first comprehensive fleet plan will be for zone substation power transformers. Earlier this year we had an external review undertaken of the condition of our power transformer fleet, which found that many transformers were in worse condition than indicated by our regular condition assessment and testing programme. We are validating the findings of the external report which, when confirmed, will be used as the basis for the new fleet plan, which will include a multi-year power transformer renewal and replacement strategy. The cost of this will be included in our 2024 AMP expenditure forecast.

Power transformers are critical and expensive assets. As the number of units in the fleet is small and each transformer can be assessed individually, a CBRM model is not needed.

While the transformers in the poorest condition have all been assessed as having some finite residual life, there is always a risk that one might fail unexpectedly. The biggest concern is the condition of the transformers at Pukenui and Taipa substations, which both have only one transformer. However, we can cover the unexpected failure of either transformer using the mobile substation in the first instance and then relocating the second transformer at the Moerewa and Kaeo substations respectively to replace the failed unit. The other transformers in poor condition are at two-transformer substations, where the second transformer is available as cover.

Our view is that while the review has identified an emerging issue that we need to act on, we are well placed to manage the short-term risk.

Communication Protocol

Top Energy currently uses an Open Platform Communications (OPC) protocol to control field devices (reclosers, sectionalisers, remote controlled switches and voltage regulators). This protocol is separate from the Distributed Network Protocol 3 (DNP3) that is used to operate sub-station equipment.

OPC is unsupported and has been identified for replacement with a modern replacement to address known stability issues highlighted by a recent incident whereby workshop-based pre-commissioning testing on a new remote terminal unit resulted in an unexpected change in the state the auto reclose function of an in service recloser.

A project is to be set up to investigate, fund and implement a modern DNP3 digital field device communication protocol, for all new devices and the migration of existing equipment and field devices to the new protocol. This protocol will eventually replace both the existing OPC and the proposed Modbus protocols.

The targeted outcome is that all field devices to communicate across a modern supported communications protocol common to similar industry Networks.

Recommendation

That the Directors accept this paper for information.

Russell Shaw
Chief Executive
Top Energy Group

Prepared by:
Ian Robertson
Network General Manager

Appendix 13

www.topenergy.co.nz

Top Energy Limited
Level 2, John Butler Centre
60 Kerikeri Road
P O Box 43
Kerikeri 0245
New Zealand
PH +64 (0)9 401 5440
FAX +64 (0)9 407 0611

Memo To:	**Richard Krogh** **Nicole Anderson** **Jon Nichols** **Steve Sanderson** **David Sullivan** **Simon Young**
From:	**Russell Shaw**
Date:	**April 2022**
Subject:	**Management of Distribution Network Reliability**

Purpose

This is an information paper that discusses an asset management strategy review that we are currently undertaking to improve the reliability of supply provided by our 11kV distribution network.

Introduction

In the FYE22 financial year our network experienced two severe weather events, the first in August 2021 and the second in February 2022. After the first event, there was a concern of the risk of breaching the quality threshold set by the Commerce Commission under our price-quality path for the RP3 regulatory period Ergo were engaged to undertake a critical review of the then current and past 2 years unplanned network outage performance. This report was presented to the Board in November 2021.

Following the subsequent weather event, we undertook a further internal review of how successful our current asset management strategy has been in achieving its reliability objective. We found that there is no potential to further improve the reliability of our subtransmission network and that any further reliability improvement will come from improvements in the reliability of the 11kV distribution network.

This paper advises the Board that we are reviewing our asset management work programme that would accelerate the improvement in the reliability of the 11kV distribution network without exceeding the approved network expenditure level. This will involve deferring the Wiroa substation build and possibly implementing interim measures to manage the network capacity risk. The expenditure allocated to Wiroa, less the cost of any interim measures, would be reallocated to the maintenance and development of the 11kV network.

Background

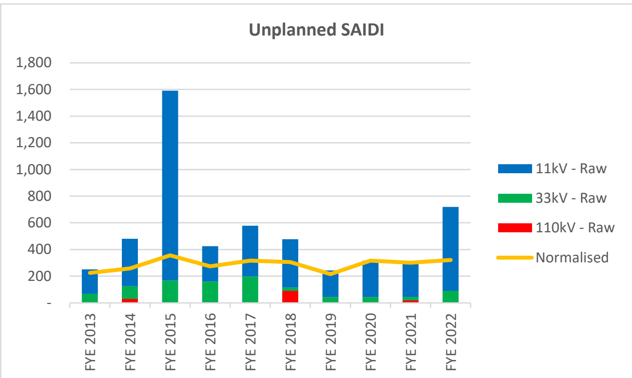
In 2011 the Board approved TE2020, a network development plan designed to achieve three overarching objectives:

- Elimination of annual nine-hour planned supply interruptions in the northern area to allow maintenance on the incoming 110kV line. This has been achieved through the installation of diesel generation, rather than though the second incoming circuit envisaged when TE2020 was conceived.

- Increasing network capacity as required to meet the localised growth in demand in the Kerikeri area. Our network was developed at a time when economic activity in our supply area was centred around Kaikohe and Kaitaia, and the transmission substations in our supply area were located accordingly. Over the last thirty years there has been a significant demographic shift and demand growth on our eastern seaboard has been substantial. We have built a new double circuit 110kV line between Kaikohe and Wiroa (currently operating at 33kV), a 33kV switching station at Wiroa and new 33/11kV substations at Kerikeri and Kaeo. However, localised load growth in the area remains high and, notwithstanding these investments, there remains an emerging constraint where there could be insufficient network capacity to supply the peak demand in the Kerikeri area under a worst-case N-1 contingency. A new 110/33kV substation at Wiroa would address this constraint and provide ample network capacity to meet the foreseeable network demand well beyond our 10-year AMP planning period. Engineering design of this new substation is in progress and construction work is planned to commence in the current year.
- Improvement in network reliability to a level comparable to that provided by other New Zealand EDBs supply rural communities. Expenditure to date has focused on improving the reliability of the 33kV network and we have been very successful in achieving this objective. The price quality trade off means that we would not increase reliability to those target levels over the RP3 period, however the next logical step is to increase the development of the 11kV distribution network.

Overall Network Reliability

Figure 1 shows the actual (raw) reliability of the network over the period FYE2013-22[1] and compares it with the normalised metric currently used by the Commission in assessing compliance with the quality threshold in our regulated price-quality path. Normalisation is used to limit the impact of extreme weather conditions and the normalised measure is designed to better reflect the level of reliability that can reasonably controlled by network managers. Top Energy uses the Commission's normalised measure for setting reliability targets and reporting reliability outcomes.[2]



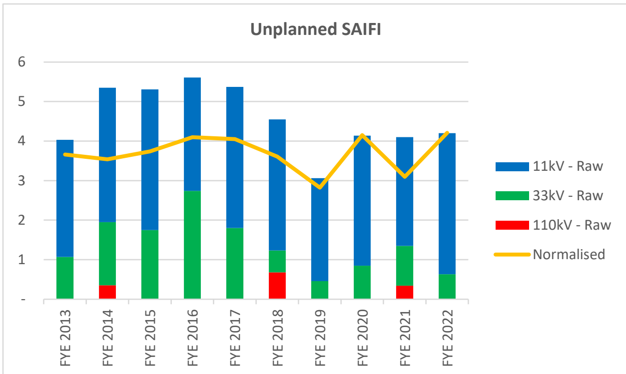


Figure 1: Raw and Normalised Network Reliability FYE 2013-22

---

1 FYE 2022 reliability does not include the impact of interruptions that occurred in March 2022.

2 The current normalisation methodology was developed by the Commission in late 2019 to apply for the RYE 2021-25 regulatory period (RP3). We have "reverse engineered" prior year reliability by applying the currently approved normalisation algorithm to the actual reliability experienced each year.

The graphs in Figure 1 indicate the following:

- The high levels of raw SAIDI experienced in FYE 2015 and FYE 2022 were due to abnormally severe storm events. If these are treated as outliers, there has been an overall improvement in actual network reliability over the period. However, this improvement is not reflected in the normalised measure, or in the raw reliability experienced in the most recent four-year period.
- Unplanned interruptions of the 110kV network are infrequent, and expenditure on eliminating extended planned 110kV line maintenance interruptions in the northern area have not had a material impact on unplanned network reliability.
- Almost all the reliability improvement experienced to date is due to the significant improvement in the reliability of the 33kV subtransmission network experienced after FYE 2017. This was due to the completion of a programme to upgrade to the protection systems on the 33kV network to allow two 33kV lines supplying a single substation to operate in parallel. As most of our zone substations have two incoming supplies, most 33kV faults no longer cause a supply interruption.[3]
- We have now reached the point where the reliability of the 33kV network is as good as we can realistically achieve. *Any further improvement in overall network reliability will come from an improvement in the performance of the 11kV distribution network.*

Distribution Network Reliability

In its last two regulatory reviews the Commission has set its reliability thresholds on the basis that an EDB should not allow its reliability, on average, to fall below the average reliability delivered during the most recent 10-year historic period for which data is available. Figure 2 shows the trend in the impact of 11kV interruptions (outside of major event periods) over the review period. Using only 11kV data, both SAIDI and SAIFI exhibit a rising trend. With that in mind we are looking at focusing on replacement and development of the 11kV network.

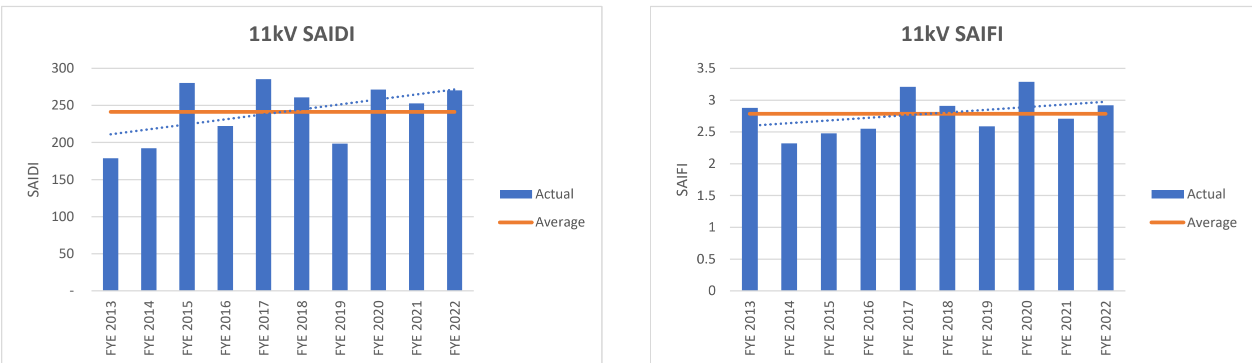


Figure 2: 11kV Reliability FYE 2013-22

---

[3] This is the reason that most major events requiring normalisation occurred in the early years of the period. Prior to FYE 2018, a 33kV fault would likely have triggered a major event requiring normalisation whereas, after completion of the protection upgrade, the same fault does not even cause a supply interruption.

Interruptions caused by faults on the distribution network now account for more than 80% of our normalised SAIDI and SAIFI. Improving the reliability of our 11kV distribution network is challenging for the following reasons:

- The distribution network has a much higher fault exposure than the subtransmission network. We have approximately 2,600km of overhead distribution line compared to 330km of subtransmission line. Reliability improvement initiatives such as asset renewal or vegetation management have only a localised incremental impact on overall reliability.
- The network in rural areas is characterised by long feeders, each with a high number of connected customers. The network has a total of 60 feeders, 18 of which have more than 1,000 connected consumers. This is a legacy issue; the network was designed to provide an electricity supply to a remote, sparsely populated rural area, with little regard to measuring supply reliability.
- Much of our rural network has always been uneconomic to serve. This has made it difficult to justify substantial investment in this part of the network. There is little evidence that customers in the more remote, less well served parts of our supply area are prepared to pay more for an increased reliability of supply.

The Ergo report recommended that we initiate a programme that focuses on the worst SAIDI performing distribution feeders and provided as a guide, various recommendations and initiatives.

These options have differing levels of cost and effectiveness. We are in the process of preparing a distribution network reliability improvement plan that will optimise the application of the different options to suit the specific requirements of our network balancing reliability improvement and cost. The rate at which we can implement this improvement plan will depend on the availability of funding.

Reallocation of Expenditure

The capital expenditure forecast in the 2022 AMP Update is heavily weighted toward the transmission and subtransmission network. A total of $80.3 million (59%) of the $136.3 million capital expenditure (excluding customer driven expenditure relating to new connections and reactive expenditure on fault and defect remediation) over the period FYE 2023-32 is on the transmission and subtransmission network. The bulk of this expenditure is allocated to two large projects, the Wiroa 110/33kV substation and the construction of the Wiroa-Kaitaia 110kV line.

The design of the Wiroa substation is well advanced, and construction is due to start this year. The cost of this project in the 2022 AMP Update capital expenditure forecast is $9.6 million to be spent over the period FYE 2023-25. However, this cost does not include known cost increases after FYE 2023. If construction of this project could be deferred the funding would be immediately available for the development and renewal of the 11kV network. If the substation was constructed later in the planning period it could be then funded from expenditure allocated to the new 110kV Wiroa-Kaitaia line, which now appears likely to be largely funded by capital contributions. Based on the actual cost of construction of the 110kV line to evacuate the power from OEC4 at Ngawha, the provision in the forecast for the construction of the 110kV line is likely understated by a significant margin.

The following section considers the implications of deferring the Wiroa substation build and evaluates the risk of this strategy to Top Energy.

Deferral of Wiroa Substation

The driver for the construction of the Wiroa substation is Top Energy's deterministic planning criterion for the subtransmission network, which requires there be sufficient network capacity to ensure that supply is not interrupted during an outage of a single transmission element. We presented a paper to the Board in August 2020 that demonstrated how the 33kV voltage at Kaeo was affected if the 110kV construction line between Kaikohe and Wiroa was removed from service. This is shown in Figure 3. The paper forecast that by 2024 the voltage at Kaeo would fall below the voltage limit in this scenario, which would mean that the voltage supplied to consumer on the fringe of the network would fall below the statutory minimum. The construction of the Wiroa substation has been timed to prevent this situation arising.

Peak demand in the Kerikeri area has been growing since FYE2016. In the 2015 winter the sum of the actual peak demands of the substations in the Kerikeri Area was 17.4MVA but by 2020 this had risen to 20.9MVA[4], a growth rate of 4%. There is no sign of this growth abating, and we are aware of a number of potential developments in the Kerikeri area that will increase the electricity demand if they proceed.

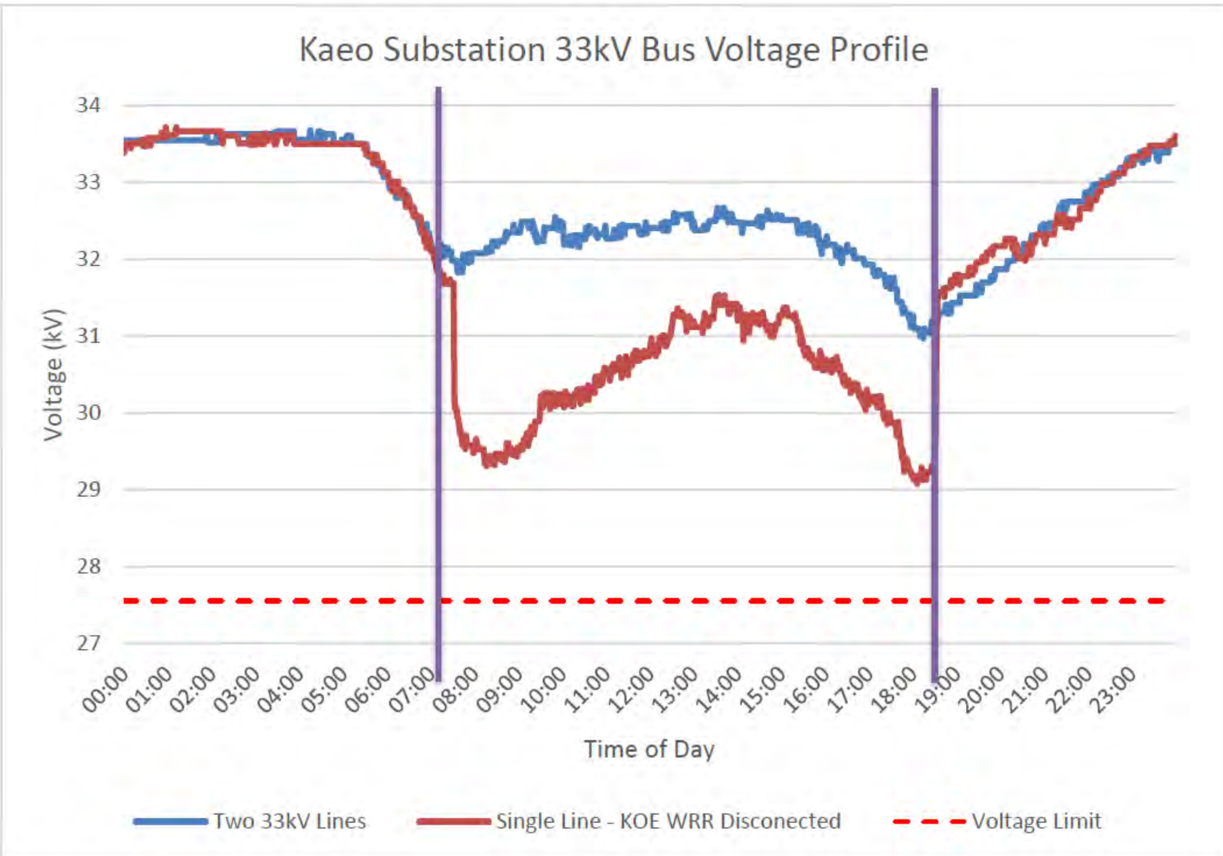


Figure 3: Impact of Kaikohe-Wiroa Line Fault on Kaeo 33kV Voltage

4 Data taken from the 2016 and 2021 AMPs.

While good electricity industry practice has traditionally required this type of deterministic assessment to drive development, best practice is now to take a probabilistic approach to network planning. This risk-based approach permits deterministic planning criteria to be breached, provided a proper risk assessment is undertaken and any residual risk, after mitigation, is acceptable to the business and its stakeholders. Risk is a combination of both probability and consequence. In this case, the following factors are relevant.

Probability

- The situation does not arise if the lower capacity Kaikohe-Mt Pokaka-Wiroa line is out of service, as the direct 110kV construction line has ample capacity to supply the load.
- There is only a concern if the direct 110kV construction line supply is lost at times of peak demand. This is for a period of about six weeks in July/August and then only between about 8-10am and 5-7pm on weekdays. Outside this window, the Kaikohe-Mt Pokaka circuit has sufficient capacity to meet the demand.
- The probability of an unplanned Kaikohe-Wiroa line outage at any time, is very low. The most probable fault causes are vegetation or a pole top hardware failure. The vegetation risk can be actively managed, and the risk of a pole top hardware failure is low as all hardware is relatively new.

Consequence

Should there be an unplanned interruption of the Kaikohe-Wiroa line at a time of peak demand the control room operator would need to ensure that the maximum demand on the Kaikohe-Mt Pokaka-Wiroa circuit was not exceeded. Some load, such as the load on the Totara North feeder, could be transferred to substations not normally supplied from Wiroa, but this transfer capacity is limited. The operator would also ensure that all controllable load, such as water heating was turned off, but this is likely to be the case during peak demand periods. Any further excess demand would need to be shed by the operator until the peak demand period was over, but there would be potential to rotate the interruptions to limit the time any one consumer is without power. The maximum demand that would need to be interrupted would be the difference between the actual demand and the demand that could be supplied through the Mt Pokaka circuit.

Comment

In the short term (3 to 5 years) we consider the risk to Top Energy of deferring the Wiroa build to be low, given the small probability of an event occurring, the limited amount of load that would need to be shed and the relatively short window before demand would drop below the reduced network capacity. In the unlikely event that a situation did arise where load shedding was required, the impact on consumers would be minimal. It is unlikely such an event that would cause widespread stakeholder concern.

The consequences will increase as demand in the area increases over time, as more load would need to be shed potentially for a longer period and there is little doubt that a 110kV substation will eventually be required.

However, it may be possible to mitigate the risk and even further defer the need for the Wiroa build by installing a switched 33kV capacitor bank to provide voltage support. We are investigating the cost of this and modelling the impact. Once the 110kV Wiroa substation was commissioned, the capacitor bank would be redeployed to Kaikohe to replace the existing bank there, which will be due for replacement in about ten years.

A possible non-network solution that could also defer the need for the Wiroa substation build would be a battery installed in conjunction with a solar farm connected to the 33kV subtransmission network supplied from Wiroa.

Recommendation
That the Directors accept this paper for information and endorse our plan to revise our 11kV network asset replacement and development plan to be funded by deferring the Wiroa build.

Russell Shaw
Chief Executive
Top Energy Group

Prepared by:
Ian Robertson
General Manager Network

Appendix 14

Appendix 14 – Director's certificate

We, David Alexander Sullivan and Jon Edmond Nichols being directors of Top Energy Limited certify that, having made all reasonable enquiry, to the best of our knowledge and belief, the attached unplanned interruptions reporting of Top Energy Limited and related information, prepared for the purposes of the Electricity Distribution Services Default Price-Quality Path Determination 2020 has been prepared in accordance with all the relevant requirements

D A Sullivan

J E Nichols

29 August 2023