CLIMATE CHANGE FLOOD IMPACT ESTIMATION ON A NATIONAL SCALE

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ABSTRACT

As part of the Government's mandatory reporting on climate risks, large entities must prepare climate statements, that comply with Aotearoa New Zealand Climate Standards. In order to achieve this reporting, entities rely on a variety of datasets and modelling, based on different climate scenarios, to inform high level nationwide climate risk assessments. However, data gaps still exist for some key parameters in Representative Concentration Pathway (RCP) scenarios. Two tools that can be used to understand and disclose climate-related risks are CoreLogic flood data, which provides detailed information about flood risk at the property level for a range of Annual Exceedance Probabilities (AEP), and NZSeaRise projections, which estimate sea level rise. Data from these sources, which include estimates of sea level rise, as well as tidal, pluvial and fluvial flooding, enables companies to assess the potential impact of these hazards on their assets. Data from NIWA's regional climate model can also be used to inform projected change in precipitation across the country together with changes in wind severity, or extended drought risk. By analysing this data, companies can evaluate the effectiveness of their risk management strategies and identify opportunities for adaptation.

This paper focusses on how climate impacts can initially be addressed using existing tools, such as CoreLogic flood data, NZ SeaRise Programme national projections, and NIWA's regional climate projections derived from General Circulation Models (GCMs), which are available at nationwide scale regarding flood risk, and temperature/wind/precipitation/drought. Limitations in existing datasets and future forecasted improvements are also discussed. A case study was undertaken to demonstrate the use of these datasets using a geospatial platform to visually inform risk assessments for Z Energy Limited (Z) nationwide and to determine expected climate variation at each asset location. Results identified Z assets which may be exposed to sea level rise, pluvial/fluvial flood, increased precipitation intensity, drought or other risks. Estimated changes in risk exposure for each site were extracted as point sources for each asset location and reported using an online geospatial tool. This information has allowed Z to further investigate asset vulnerability at 'higher' risk asset locations for the identified increased climate impact risks.

By leveraging these resources and other climate related models as they become available, large entities can better understand and manage their climate-related risks and provide transparent and consistent information to stakeholders about their efforts to address these risks. This along with utilising geospatial tools has enhanced communication of identified risks and improved understanding of these climate impacts.

KEYWORDS

Climate change, impact assessment, flood risk, sea level rise, CoreLogic, NIWA, NZ SeaRise, geospatial analysis

PRESENTER PROFILE

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INTRODUCTION

As part of the Government's mandatory reporting on climate risks, large entities must prepare climate statements, that comply with Aotearoa New Zealand Climate Standards. This paper introduces and discusses a methodology which was developed with available climate data to deliver a climate impact assessment for Z Energy Limited (Z). Z has adopted the reporting recommendations from the Task Force on Climate-related Financial Disclosures (TCFD) and will report against the Aotearoa New Zealand Climate Standards from 2024. Z has completed work to qualitatively and quantitively assess the transitional and physical climate change risks and opportunities to the business. This paper focuses on the approach taken to assess physical risks across Z's assets.

Physical assets were assessed for risks from wind, precipitation, drought, flooding and sea level rise. This assessment was a first pass climate change impact assessment (i.e. screening level) which is undertaken on a national scale to gain a preliminary understanding of climate change related risks and opportunities. This report discusses a methodology for this type of assessment with a specific focus and discussion on the limitations of estimating flooding from precipitation and sea level rise.

BACKGROUND

Z is an integrated energy company that is focused on meeting the needs of their customers now and into the future. Z operate the largest network of the most strategically important fuel storage assets in Aotearoa New Zealand (NZ), including more than 50% of NZ's bulk fuel storage terminals, representing 189 million litres of fuel storage. They also operate a network of 194 Z-branded retail service stations, 126 commercial truck stops and several commercial refueling stations across the county to help keep NZ moving and ensure security of supply for NZ.

Z wished to review climate change impacts to their assets and are looking to mature their approach to meet the Aotearoa New Zealand Climate Standards. In October 2021, the Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act amended the Financial Markets Conduct Act (FMCA), making it a mandatory requirement for specified entities to prepare climate statements. The requirement applies to large publicly listed companies, insurers, banks, non-bank deposit takers and investment managers. The ultimate aim of Aotearoa New Zealand Climate Standards is to support the allocation of capital towards activities that are consistent with a transition to a low-emissions, climate-resilient future.

Since adopting reporting recommendations from the Task Force on Climate-related Financial Disclosures (TCFD), the New Zealand External Reporting Board (XRB) has released the Aotearoa New Zealand Climate Standards. These Climate Standards will require entities to disclose, among other matters:

- a description of current climate-related impacts;
- a description of the climate-related risks and opportunities identified over the short, medium, and long term;
- a description of the anticipated impacts of climate-related risks and opportunities.

This paper outlines a methodology which acts as a high-level screening model for nationwide distribution of physical climate risk as well as available climate impact models and projections available to undertake this work in 2022. The limitations of the existing national flood datasets are also addressed. It is noted that currently new models, climate projections and data are being developed and made available frequently as this knowledge area grows. These new datasets will improve understanding of climate impacts as well as this climate impact assessment methodology as the industry upskills on how to respond to climate change.

METHODOLOGY

CLIMATE RISK AND IMPACT DEFINTIONS

The Intergovernmental Panel on Climate Change (IPCC) defines a climate impact driver as "natural or human-induced climate events or trends that may have an impact (detrimental or beneficial) on an element of society or ecosystems". (Reisinger, et al., 2020). Climate impact drivers are the changes in the climate system itself which may cause a climate hazard, and depending on the vulnerability and exposure of the asset in question, a climate risk on the asset as interpreted below:

Climate risk = climate related hazard x exposure x asset vulnerability

The assessment approach used here identifies climate impact drivers at the location of each asset but does not incorporate a vulnerability assessment to determine the resilience of assets in tolerating climate impact drivers. In some instances, data was able to indicate the hazard and exposure, however, was limited in the assignment of a clear increased risk. Note further assessment would be required to properly assign vulnerability and subsequent risk to assets in accordance with best practice assessment.

ASSESSMENT PARAMETERS

TIMEFRAMES

An entity must select the projected timeframes of interest. For this initial assessment, Z selected the following timeframes for the assessment as follows:

- Present Day
- Short-term: 2025
- Mid-term: 2030
- Long-term: 2040

CLIMATE IMPACT DRIVERS

An early qualitative assessment was undertaken for Z to determine which climate impact drivers were most material in causing potential high risks to assets. These were identified as drought, precipitation, and sea level rise (including flooding from precipitation and sea level rise). Wind was later included in this scope after reviewing asset maintenance data.

CLIMATE SCENARIOS

Under the Climate Standards an entity must disclose the risks and opportunities to their business over the short, medium, and long term across three different climate scenarios: a 1.5 degrees Celsius climate-related scenario; a 3 degrees Celsius or greater climate-related scenario; and a third climate-related scenario. Z selected three scenarios for the initial assessment (Table 1) with the Representative Concentration Pathway 2.6 (RCP2.6) meeting the required 1.5 degrees scenario, the RCP8.5 meeting the required 3 degrees or greater scenario and the RCP4.5 meeting the 'additional' scenario. AR5 RCP scenarios were chosen to as these aligned with NIWAs NIWA's regional climate model projection grids applied in this assessment.

Table 1: Temperature Scenarios. Source: (IPCC, AR5, 2014)

RCP Scenario	Long-term RCP estimate of (2080 – 2100) compared to a 1986 – 2005 base period	Long-term RCP estimate adjusted for an 1850 – 1900 base year (as per Climate Standards)
RCP2.6	1.0 °C	1.5°C
RCP4.5	1.8 °C	2.3°C
RCP8.5	3.7 °C	4.5°C

It should be noted that the IPCC Sixth Assessment Report, Working Group 1 (AR6 WG1) presents projected changes in the global climate corresponding to several Shared Socioeconomic Pathways (SSPs). Noting that AR6 SSPs and AR5 RCPs are not strictly comparable, the global mean warming projections compare as follows in Table 2. The AR5 values are originally relative to the mean temperature of

1986-2005. Following AR5, 0.6°C has been added to represent warming between 1850-1900 and 1986-2005. 'Summary for Policy Makers' refers to the WG1 Summary for Policymakers reports for AR5 and AR6.

Table 2: Projected global mean warming in 2081-2100, relative to 1850-1900, in AR5 and AR6 (Bodeker, 2022)

End-of-century nominal radiative forcing (Wm-2)	Warming in 2081-2100 (°C) under RCP scenarios (likely range; AR5 table SPM.2)	Warming in 2081-2100 (°C) under SSP scenarios (very likely range; AR6 SPM table B.1.2)
2.6	1.6 (0.9-2.3)	1.8 (1.3-2.4)
4.5	2.4 (1.7-3.2)	2.7 (2.1-3.5)
8.5	4.3 (3.2-5.4)	4.4 (3.3-5.7)

It is noted in most cases the RCP climate impact modelled scenarios do not deviate significantly from one another in terms of effects until after 2040. Therefore, the data assessment focuses on the RCP8.5 scenario for 2040 as the furthest timeframe within this report.

CLIMATE DATA

Climate datasets were obtained from the National Institute of Water and Atmosphere (NIWA). The climate datasets covered the following climate impact indicators: mean temperature, mean maximum temperature, extreme Hot Days (temperature over 30 degrees Celsius), extreme Heatwave Days (temperature over 30 degrees Celsius for more than three days), rainfall totals, heavy rain days, 99th percentile daily precipitation, maximum 1-day rainfall, maximum 5-day rainfall, snow days, potential evapotranspiration deficit (PED), 10-day dry spell days, 99th percentile daily mean wind speed and windy days. A nomenclature of terms for these indicators is given at the end of this paper.

All NIWA climate data (NIWA, 2022) was in the form of climate change Geographic Information System (GIS) grids from NIWA's regional climate model. For all indicators, projected changes against the baseline (1986 – 2005) for the 2031 – 2050 period for RCP2.6, RCP4.5, RCP8.5 scenarios were provided, where all data points are the averages over the 20-year period. The associated 1986 – 2005 modelled historic climate layer was also provided for all indicators except the 99th percentile wind (for which it is not available). This modelled historic data is a proxy for the present day. For 99th percentile wind, an alternative 1986 – 2005 layer was provided, based on modelled historic climate data derived from the interpolation of observational data within the National Climate Database.

Climate change grids from NIWA's High Intensity Rainfall Design System (HIRDS) were also provided for 24 hour and 1 hour 100-year and 50-year magnitude rainfall depths.

To interpolate for 2025 and 2030 timeframes, NIWA approved the use of a linear interpolation approach to estimate average climate change values for time periods in between NIWA's 1986 – 2005 and 2031 – 2050 regional climate model outputs.

The data selected for use in this assessment is further discussed below.

DROUGHT

Drought can be defined as a "period of abnormally dry weather long enough to cause a serious hydrological imbalance" (IPCC, 2019). It is a relative term as different locations have different amounts of normal rainfall and dry days. There are different types of droughts (e.g., agricultural, hydrological, meteorological etc.), and this assessment focused on meteorological drought which is based on the degree and duration of the dry period.

NIWA monitors drought conditions using the New Zealand Drought Index (NZDI) which is a combination of four indices, including Potential Evapotranspiration Deficit (PED) (NIWA, 2022). The standardised PED and NZDI approximately align (Figure 1) and a threshold of 300 mm PED is commonly used as a measure of drought risk (i.e., Ministry for the Environment (2018) etc.). As projections for the NZDI are not available with climate change, the PED has been used here as a measure of potential drought risk, with PED data separated into categories of 0-200 mm PED, 200 – 300 mm PED and 300 mm + PED.

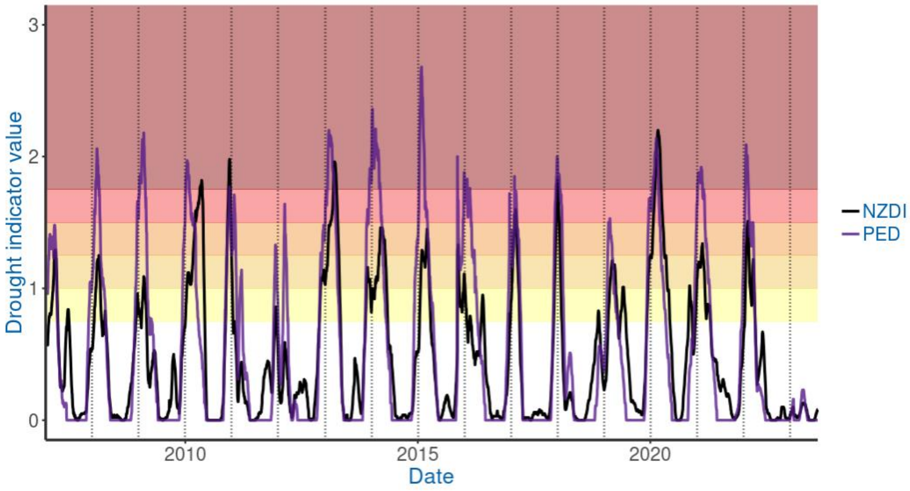


Figure 1: The NZDI and standardised PED shown for Auckland from 2007 – 2022. Source: (NIWA, 2022).

In addition, a '10-day dry spells' dataset was also assessed. This gives the number of days over the year which occur in a dry spell of 10 or more days (a 'dry day' being a day with less than 1 mm of rainfall). 10-day dry spells can be an indication of drought frequency and/or length. However, there is no common threshold for the number of dry days after which a drought is classified. A statistical metric has been applied based on the average number of dry days for New Zealand which is 56 days (or 15% of the year). The data was split into that being equal to or less than average, that being above average (15% - 25%) and that being more than a quarter of the year (>25%).

The PED and 10-day dry days data was combined into a 'drought score metric' as per Table 3.

Table 3: Matrix used for drought risk score

PED (mm)	No. of 10-day dry days as a percentage of the year		
	0-15%	15-25%	25%+
<200	Low	Low	Medium
200 - 299	Low	Medium	High
300+	Medium	High	High

WIND

The data available consisted of:

- a windy day is defined as a day where the mean wind speed is over 10 m/s (36 km/h); and
- the 99th percentile wind speed being the daily average wind speed that occurs on the top 1% of windy days.

However, most wind damage occurs during gusts of much higher wind speed – for example wind speeds of 20 m/s (72 km/h) can cause small branches to break, while construction damage can occur at wind speeds of over 30 m/s (108 km/hr) (NIWA, 2006). Both datasets were used to determine whether windiness with projected climate change over all scenarios was expected to increase, decrease or remain similar.

Because of the limitations in data, it is difficult to determine a risk category. However, assumptions can be made that increased extreme gusts are associated with increased wind. Therefore, any assets in regions with increased windiness may be affected by increased wind disruption when compared to current day, more than the other regions.

PRECIPITATION

Changes in precipitation can occur in both the intensity of rainfall (how much rain is falling within a certain period) and the frequency of rainfall (how often it is raining). A breakdown on how each were estimated, and the potential impacts are outlined for rainfall intensity and frequency below.

Precipitation Intensity

NIWA's High Intensity Rainfall Design System (HIRDS) (NIWA, 2018) gives depths and intensity for different storm durations, as well as projected changes for different RCP climate scenarios. Climate change induced changes to rainfall intensity are primarily related to changes in the atmosphere's moisture holding capacity (NIWA, 2018). The HIRDS projections are relatively constant across the entire country, varying only in the duration and exceedance probability of the event, and across RCP scenarios i.e., as warming increases, so does intensity.

The 99th percentile of daily precipitation is the top 1% of rainfall occurring over a year and therefore can be thought of as an infrequent event. It is usually rainfall intensity which contributes to flooding events. As explained above**Error! Reference source not found.**, this is projected via the NIWA HIRDS data to change somewhat evenly (on a percentage basis) across the country.

Frequency of Heavy Rain Days

A heavy rain day is defined by NIWA as a day with at least 25 mm of rainfall. The expected change in number of heavy rain days per year indicates the frequency disruptive rainfall events may occur with potential to result in flooding in the future.

SEA LEVEL RISE

Sea Level Rise (SLR) is caused by thermal expansion of the oceans and melting of ice in conjunction with vertical land movement (VLM). Several weather and climate related processes can influence coastal flooding, including an increase in mean sea level, high tides, storm-surge, wave set up, and monthly variation in mean sea level from, for example, the El Nino Southern Oscillation (see **Error! Reference source not found.**).

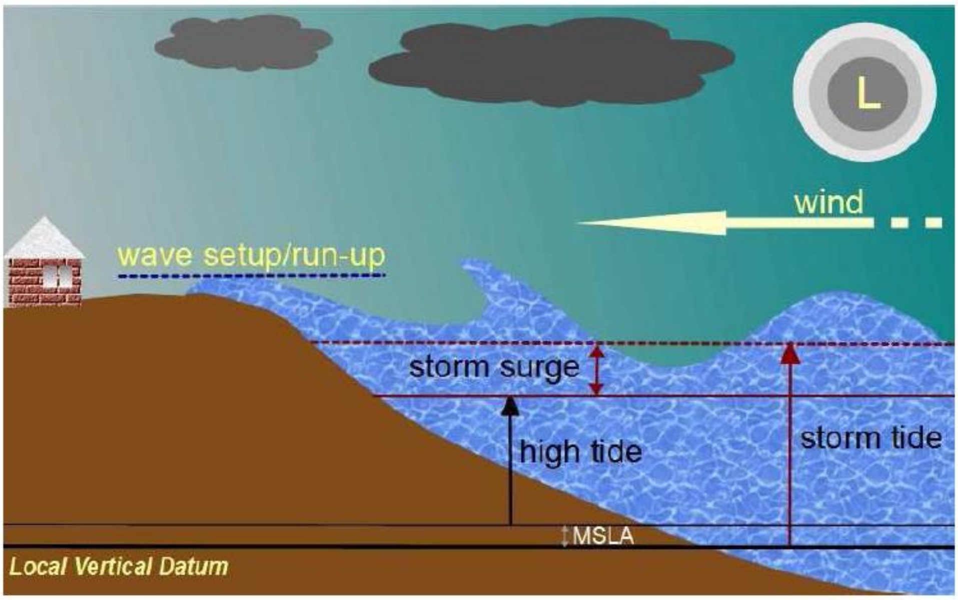


Figure 2: Schematic diagram of tidal, weather and climate components contributing to extreme sea-levels and storm-induced coastal flooding (Ministry for the Environment, 2017)

Aside from increases in mean sea level, and therefore increases in high tide levels, climate change will also impact on these other parameters. However, the impacts of these other events are also likely to be highly variable locally and regionally which makes these difficult to assess in a national screening model (Ministry for the Environment, 2017). Therefore, for the purpose of looking at how climate change might impact on tidal flooding of assets at national scale, the influence of projected SLR only was included in this assessment.

SLR data was sourced from the NZ SeaRise platform (NZ SeaRise, 2022). The NZ SeaRise platform gives SLR and vertical land movement (VLM) for every two kilometres of New Zealand's coastline. The SLR projections are based on the updated IPCC Sixth Assessment Report (AR6) Shared Socioeconomic Pathways (SSP) SSP1-2.6; SSP2-4.5 and SSP5-8.5 being analogous to the RCP2.6, RCP4.5 and RCP8.5 scenarios. For the purposes of this assessment, the 2040 SSP5-8.5 scenario only (with VLM) was selected due to projected SLR for the individual scenarios not diverging significantly until after 2040, and not being substantively different from present day in 2025 and 2030. All SLR data values used are median (p50) values.

This p50 (i.e., median) SLR range is recommended for SLR assessments by the Ministry for the Environment NZ SeaRise Guidance 2022. There is also vertical land movement to consider, which may increase/decrease this amount of SLR – and provides the 'relative' change in SLR. SLR data was considered in conjunction with tidal flooding data which is discussed below.

NATIONAL FLOOD DATA

National Flood Data was sourced from CoreLogic who have a license to provide national flood datasets for fluvial, pluvial, and tidal flooding from Ambiental – a Royal Haskoning DHV company. At the current time, this is the only available source of national flood modelling data. These datasets use the New Zealand FloodMap v1.1 model and Land Information New Zealand (LINZ) data to present flood depths for different annual exceedance probabilities across the country. The data includes pluvial (flash/surface water flooding from rainfall), fluvial (river) and tidal flooding (sea/estuary/coast). The model output is current flood depths for seven modelled return periods from 1 in 20 to 1 in 10,000 annual exceedance probabilities (AEPs), based off NIWA datasets which use real historical data from the national climate database CliDB (NIWA, 2018). However, the modelling available for this assessment was present day only and did not give projected changes with climate change. Therefore, the data was used to indicate where there is potential for flooding to exist, giving an indication of where tidal and rainfall induced flooding may be exacerbated by climate change.

GEOSPATIAL ANALYSIS

Data was processed using Esri's ArcGIS software, to provide a spatial understanding of climate change risk. The data for climate impact drivers was extracted to provide site-specific results for each of the parameters to determine projected impacts of climate change at each asset location. From this analysis associated risk (or indication of exposure changes) of each climate impact driver was identified and interpreted. This will inform the entity's mandatory reporting.

An interactive online geospatial web viewer was developed which visually showcases the data and allows the entity to navigate between locations to look up the relevant exposure risks associated with each climate impact driver at each asset.

DISCUSSION ON FLOOD ANALYSIS

The existing methodology and national screening tool are limited by the data presently available and incorporation of climate projections. The limitations to the data and methodology with specific relation to flooding are discussed below with reference to future options, improvements and datasets which may strengthen this type of analysis.

LIMITATIONS

FUTURE TIDAL FLOODING ESTIMATION

CoreLogic data used in this case study did not incorporate climate change projections. SLR was assessed by combining the NZ SeaRise data available publicly, with the CoreLogic tidal flooding datasets. Only the RCP8.5 (SSP5-8.5) + VLM 2040 scenario was assessed due to the lack of divergence between the scenarios over this relatively short timeframe. The number of sites included in the assessment was condensed by selecting sites which currently face exposure from a 1 in 1,000 AEP tidal flooding event when assessed using CoreLogic data. Projected SLR taken from the nearest NZ SeaRise data point was added to this (essentially increasing or decreasing (with VLM) the mean sea level line in Figure 2) to determine which Z asset locations may be most vulnerable to SLR.

It is acknowledged that there are many factors which influence SLR and tidal flooding and that this additive approach of SLR to existing tidal flood depths is a simplified approach to approximate future tidal flooding with a high level of uncertainty. For each Z asset exposed to the 1 in 1000 AEP tidal flood event, the p50 SLR data for 2040 was extracted and added to the flood depth value. It is noted that there is a high level of uncertainty in these values and that the p83 (83rd percentile) is also recommended in some instances in the interim guidance on use of new SLR projections (Ministry for the Environment, 2022). For sites potentially exposed to SLR, the difference between the p50 to p83 values can be significant, meaning approximations give an indication of magnitude but are likely to vary from the reported values.

This screening model approach supplies an indicator but has significant limitations. Site-specific sea-level rise assessment will typically be required to increase the accuracy of analysis, given that SLR flood risk is not additive but exponential. This occurs because the combined effects of storm surge and tidal influences (which are both location specific) mean that even small increases in SLR will result in a given threshold being reached or exceeded much more frequently. Detailed site information like elevation was not readily available for this assessment and would be needed for subsequent further detailed assessments focusing on SLR or flood risk exposure.

FUTURE PLUVIAL AND FLUVIAL FLOODING ESTIMATION

Pluvial flooding is caused by surface flooding from rainfall whereas fluvial flooding is river-related flooding from rivers overtopping or bursting their banks and flooding surrounding land. The likelihood of both types of flooding occurring is increased with heavy rainfall events. The pluvial data obtained by CoreLogic was based on flood modelling a few hours after a 3-hour storm event. This allows time for surface rainfall to, for example, run off or be absorbed by the land, enter the stormwater network, or be evaporated. Hydrological advice was that the fluvial flood layer should be used preferentially, with the pluvial value only used if a fluvial value was not available for that asset location. This is because the short retention time of the pluvial data suggests it is for smaller catchments which would not be covered by fluvial modelling.

Again, the assessment was limited to present day asset exposure to flood events due to climate projections not yet being available within the CoreLogic dataset. Interpolation of the HIRDS RCP modelled dataset suggests three-hour storm duration rainfall will increase in depth across the country by around 7% - 10% by 2040 (RCP2.6 – RCP8.5). Hydrological river (fluvial) modelling has shown a -40% to +40% change in river flows across the country with climate change (NIWA, 2018). Due to this large range and variability between individual rivers, it was not possible to estimate at a high level for a national screening assessment how asset exposure to fluvial flooding might change with climate change. As the fluvial flooding was used preferentially over the pluvial, it is also not possible to fully assess how climate change might change the risk of river related flooding.

In most cases it is likely flooding will be exacerbated with climate change, particularly on floodplains located close to the coast, where the effects of sea level rise will reduce the effective head of the river system. Therefore, assets already located in areas of flooding could likely face a higher level of exposure in the future. Therefore, the approach used here is to assess potential site exposure to flood events as a baseline for considering future potential climate change impacts. Future availability of flood data with climate projections will improve this approach and better estimate future exposure.

DATA ACCURACY

One key limitation of the data is by working on a national scale the resolution of data is more coarse. This is more apparent in the NIWA datasets which also do not cover some coastal areas of NZ. When combining the SLR with CoreLogic rasters, SLR was every 2 km along the coast, whilst CoreLogic was 5 m x 5 m (urban) and 8 m x 8 m (rural) resolution. The limited access to accurate elevation data is also a major limitation. The national elevation data is an 8 m digital elevation model derived from 20 m contours which provides a low level of accuracy when reporting values on an individual site basis.

ALTERNATIVE METHODOLOGIES

There are many data sources available to estimate SLR and tidal, pluvial and fluvial flooding in New Zealand, some other sources of data which were considered, have been released, or are anticipated to be released, since this initial assessment approach was developed include:

- At the time of writing, CoreLogic are in the process of incorporating three different potential emissions pathways (low, medium or high emissions) for probabilistic projections to predict future flood impacts at three time periods (or 'epochs') – early (2030s), mid (2050s) and late (2080s) 21st century. These will include 1 in 20, 1 in 100, 1 in 500 AEPs. This will allow more appropriate estimation of future pluvial and fluvial flooding with increase rainfall intensity as well as tidal flooding with incorporated sea level rise predictions than this initial screening assessment methodology.

- NIWA Extreme coastal flood maps for Aotearoa New Zealand (released May 2023) (Paulik, et al., 2023). This data provides a modelled representation of New Zealand's 1% annual exceedance probability (AEP) extreme sea level flooding under current climatic sea conditions; plus relative sea level rise up to 2 m above present-day mean sea level. The Aotearoa-New Zealand 1% AEP extreme sea level flooding map dataset comprises 21 coastal flooding scenarios representing relative sea-level rise ranging from 0 to 2m in 10cm (0.1m) increments. NIWA and GNS Science are partners in NZ SeaRise, which is hosted at Victoria University of Wellington and therefore it is assumed that data from these projects should be consistent and able to be used in conjunction with one another, however further research prior to use is recommended.
- The NIWA "Mā te haumaru ō ngā puna wai ō Rākaihautū ka ora mō ake tonu" program aims to develop a flood database containing consistent flood hazard maps for a range of Annual Exceedance Probabilities (AEP) covering every catchment in the country. This will provide a consistent approach for flood data across NZ and include climate projections. As part of this work NIWA aims to explore how cascading events (multiple large flooding events or combinations of flooding with other exacerbating factors) can affect tolerance to flooding, especially under climate change (NIWA, 2023). This data is likely to be highly applicable to this type of assessment and improve climate risk methodologies when released.
- Regional and district council modeling for locations – a range of local councils and regional authorities have undertaken modelling in specific locations for sea level rise and flooding in specific regions. These models are expected to model flooding in smaller catchments more accurately and capture local variations in better granularity than a macroscale model which is applied at national level. These models are not available across all of New Zealand and there are therefore gaps where a national model such as CoreLogic is still required. Local-scale models are built up with varying assumptions and approaches and applying these models at a national level may result in inconsistencies in comparison to a national scale model with uniform assumptions. These models are however most appropriate for further characterization of risk and impacts when undertaking further site-specific analysis.

It is likely that a number of other flood estimation datasets and tools will emerge from different entities in addition to the above-mentioned data. The applicability to this type of assessment will need to be established prior to incorporating any data into a climate impact methodology. It is possible these datasets may also function well for the next stages of assessment focusing on high-risk sites screened by the initial assessment and investigating vulnerability.

There are a number of other global SLR estimation tools and data available which could have been considered for this type of assessment. However, at the time of application, given the purpose of this methodology the NZ SeaRise Programme was considered the most robust source of New Zealand specific data with consideration of other relevant parameters such as predicted vertical land movement.

The pluvial and fluvial flooding along with tidal flooding data from CoreLogic allowed for indication of areas which are susceptible to flooding in present day and may be exacerbated by climate change, noting limitations in the data applied in the screening methodology and future improvements which will be applied.

APPLICATION

A case study was undertaken to demonstrate the use of these datasets applying the above methodology to provide a visual risk assessment for Z's portfolio of assets. Due to the similarity in the projected climate change data across the RCP scenarios until around 2040, the findings of the assessment presented RCP8.5 for simplicity.

This assessment was undertaken to increase Z's knowledge of climate related risks to assets as part of the transition to mandated climate reporting under the recently released Aotearoa New Zealand Climate Standards (2022). PDP worked alongside PwC who undertook a quantitative financial assessment of Z retail sites based on historical precipitation and wind conditions and future climate change projections.

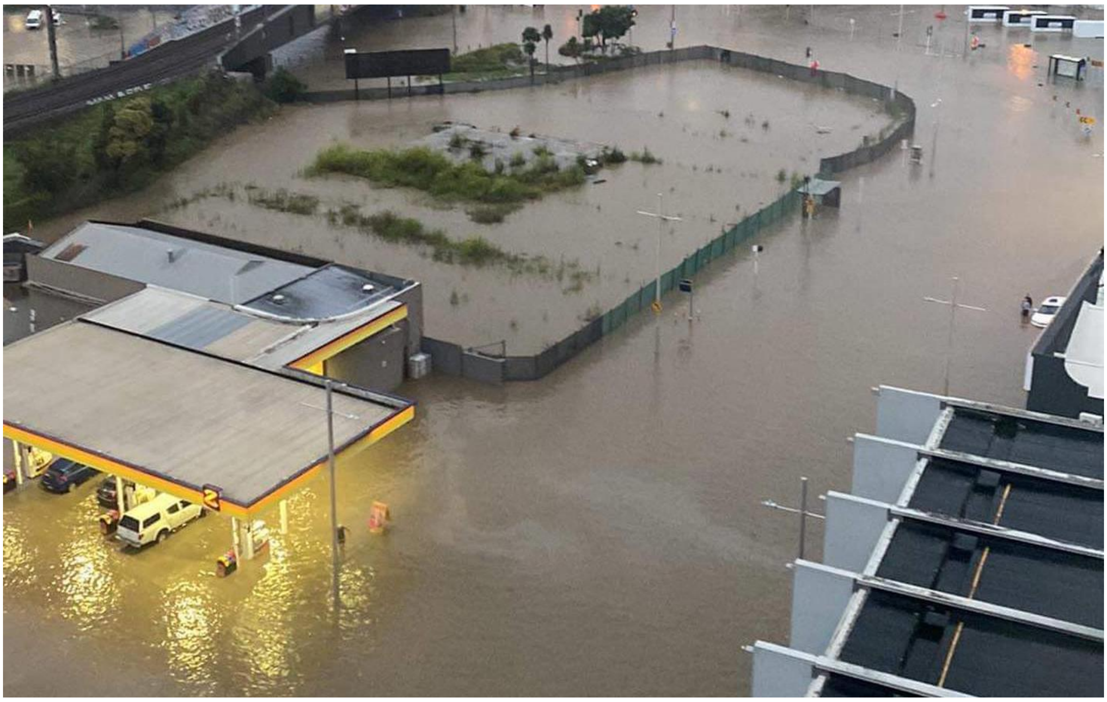
Results identified Z assets which may be at risk of exposure to sea level rise, pluvial/fluvial flood, increased precipitation intensity, drought or other risks. Estimated increases in risk exposure for each site were extracted for each asset location and reported using an interactive geospatial viewer. This information has allowed Z to further investigate asset vulnerability at 'higher' risk asset locations for the identified increased climate impact risks.

The assessment of likely physical impacts, alongside inputs from PwC financial analysis of review of maintenance and insurance claims identified the highest climate change risks to Z assets from the selected climate impact drivers. The following summarises how these climate impact drivers pose a risk to Z assets:

- <u>Sea Level Rise:</u> may impact on integrity of aboveground and underground infrastructure and storage systems; increase likelihood of damage from tidal and/or sunny day flooding; may increase exposure to demurrage charges due to changes in tidal range and increased storm frequency and intensity.
- <u>Rainfall:</u> flooding caused by increased rainfall frequency or intensity (potentially exacerbated by sea level rise) may affect the integrity of aboveground and underground infrastructure and storage systems; increased rainfall may increase demurrage charges and equipment maintenance; decreased rainfall may limit water supply; changes in rainfall – both wetter and drier – may impact on clay bunding stability.
- <u>Drought:</u> Increased frequency of drought may result in water supply restrictions, impacting on car wash facilities and operational water use.
- <u>Wind:</u> high winds may affect shipping loading/unloading times and can damage equipment. Wind can also pose risks to tanks, retail sites and signage.

In addition to sourcing climate change data, the assessment comprised: workshopping the climate data with Z, PwC, and PDP to understand context and implications; and providing outputs which included a technical report, tabulated climate data and an interactive geospatial viewer to help Z understand their asset risks. Vulnerability of assets to climate impact drivers was not assessed by PDP, but was to a limited extent by PwC, who used historical financial information to estimate how maintenance costs, in response to climate events, might increase in the future.

Z can expect climate related risk associated with precipitation, wind, drought, flooding, and sea level rise to increase across most of its sites with time and depending on the extent of global emissions reductions. In particular, flooding related to sea level rise and precipitation has the potential to significantly impact on assets and their operation, though localised studies are required to determine to what extent. Indeed, some of the sites identified as high risk in this analysis, were affected by the recent climate events which caused significant business disruption (Photograph 1).



Photograph 1: Flooding in Auckland looking from Beach Rd at the bottom of Parnell towards the Auckland Domain. Photo / Tom McCondach (Howie, 28 January 2023)

The Z assets at highest risk of exposure to pluvial, fluvial and tidal flooding were identified and presented to Z for consideration in their future planning for asset resilience and climate change adaptation. An example of regions with the most assets potentially exposed to pluvial, fluvial and tidal flooding under a 1 in 200 AEP scenario are demonstrated in Figure 3.

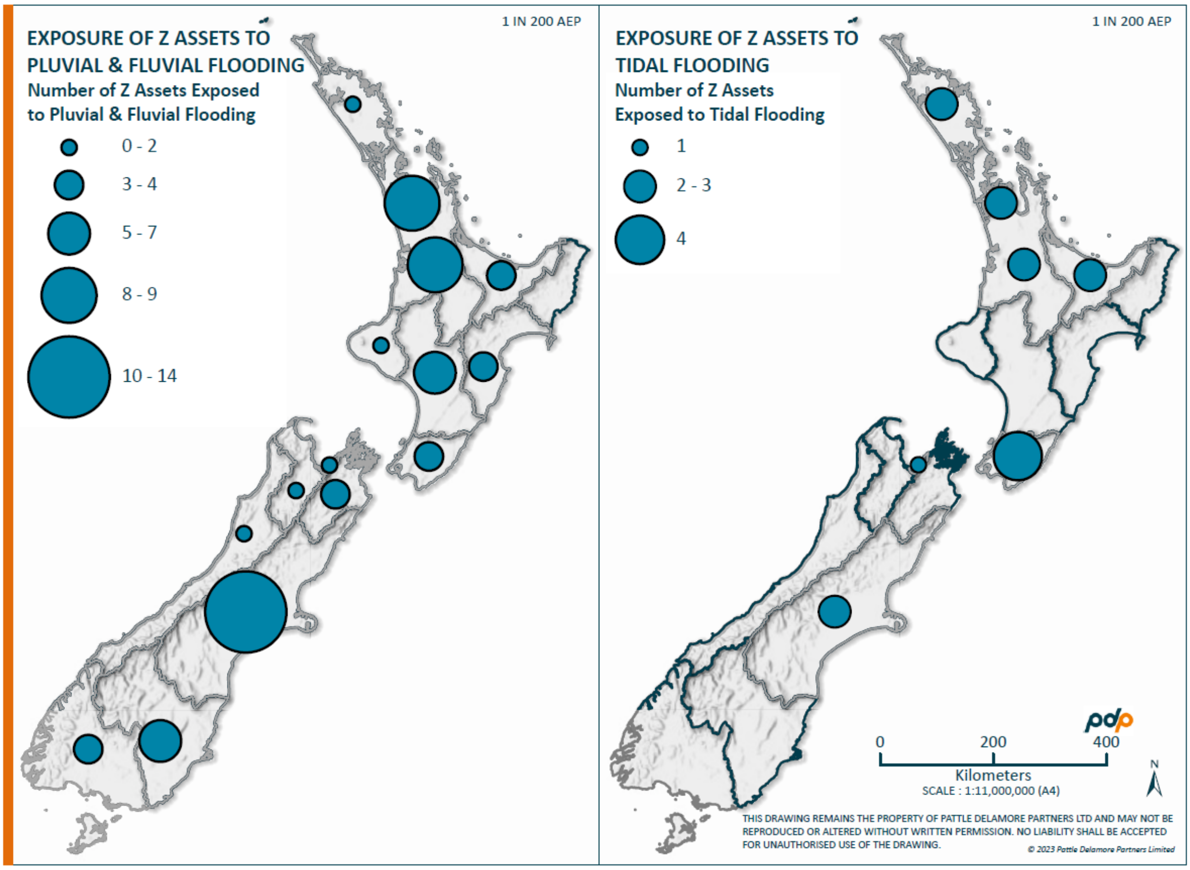


Figure 3: Exposure of Z assets to pluvial, fluvial and tidal flooding for a 1 in 200 AEP

The outcome of this screening level assessment will be published, based on materiality, by Z for their climate related disclosures in 2024.

CONCLUSIONS

By leveraging various existing datasets and climate related models as they become available, large entities can better understand and manage their climate-related risks and provide transparent and consistent information to stakeholders about their efforts to address these risks. The methodology developed to initially assist entities with this component of climate disclosure reporting has delivered a purpose-built and informative assessment given the limitations of available data. However, it is noted that data is constantly improving and therefore future methodologies are expected to evolve significantly to incorporate this information and ensure a robust, well-informed risk and impact assessment is undertaken.

Several limitations were inherent in this assessment methodology due to, among other factors, national data accessibility, this being a national level climate data assessment covering the full extent of an entities assets across the country. This means the assessment can provide an indication of where climate related risks may eventuate but should not be used for, for example, strategic decision making or infrastructure design. For that, further detailed assessment is required using local and site level information to determine risks to assets which incorporate the vulnerability of the asset in question and its resilience to respond to climate related risk, including cascading risk. In addition, the implications of climate change across multiple sites and supply chains need to be better understood. It is often those impacts that can result in extended business disruption and the most significant cost implications.

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NOMENCLATURE

Term	Description
10 Day Dry Spell Days (no. of days)	A period of ten or more days where daily rainfall is less than 1 mm. The total number of days which fall within a 10-day dry spell over the year are summed together, regardless of the length of a dry spell.
83rd Percentile (p83)	P83 refers the 83rd percentile, specifically applied in Sea Level Rise projections.
99 Percentile Precipitation (mm)	A daily rainfall depth in mm which is higher than 99% of all other rain days in the same year i.e., is a wetter day than all but 1% of rain days.
99 Percentile Wind (m/s)	The daily mean wind speed in m/s on the day which is windier that 99% of all other days in the same year.
Annual 99 Percentile Daily Wind (m/s)	The mean daily wind speed which is 99% higher than all other than all other days.
Extreme Heatwave Days >30C (days)	A period where the maximum temperature is more than 30°C for at least three days is termed a heatwave. The total number of days that fall within a heatwave are summed together, regardless of the length of the heatwave.
Extreme Hot Days >30C (days)	Number of days where the maximum temperature is over 30°C .
Heavy Rain Days > 25mm (days)	Number of days in a year with more than 25 mm of rainfall.
HIRDS (1 in 100 or 1 in 50 year; 24 hr and 60min time periods) (mm)	HIRDS is NIWA’s High Intensity Rainfall Design System and gives projections for intensity of extreme weather events over a certain amount of time and for a particular storm event. HIRDS is generally used for determining extreme rainfall volumes for designing storm water systems and other engineering designs.
Maximum 5 Day Rainfall (mm)	The maximum rainfall occurring in a five-day period over a year.
Maximum 1 Day Rainfall (mm)	The maximum rainfall for any one day in a year.
Median (p50)	The median is the value that's exactly in the middle of a dataset when it is ordered. It's a measure of central tendency that separates the lowest 50% from the highest 50% of values. P50 refers the 50th percentile.
PED (Potential Evapotranspiration	An indicator of drought. The PED gives the difference between how much water could be potentially lost to

Deficit) accumulation (mm)	the atmosphere in evapotranspiration verse the amount that is available. PED provides a "robust measure of drought intensity and duration" (NIWA, 2022). Days when water demand is not met, and pasture growth is reduced are days with a PED deficit. In New Zealand, an increase in PED of 30 mm or more corresponds to around an extra week of reduced grass growth. The PED accumulation is the sum of PED over a year.
Rainfall Total (mm)	The total rainfall over one year in mm.
Representative Concentration Pathway (RCP)	Scenarios predicting how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities.
Sea Level Rise (SLR)	An increase in the level of the world's oceans due to the effects of global warming.
Snow Days (days)	Number of days a year where the mean temperature is below freezing point (i.e. days which have a mean temperature of 0˚C or less and on which there is rain).
Shared Socioeconomic Pathways (SSPs)	Are scenarios of projected socioeconomic global changes up to 2100.
Temp. Max (˚C)	The annual mean maximum temperature.
Temp. Min (˚C)	The annual mean minimum temperature.
Vertical Land Movement (VLM)	Is a generic term for all processes that impact the elevation at a given locations (tectonic movements, subsidence, ground water extraction), causing land to move up or down. This is typically a slow process with magnitudes commonly between -10 (sinking) and +10 (rising) mm/year.
Windy Days (days)	The number of days a year where the mean wind speed is more than 10 m/s or 36 km/h.