XDI CROSS DEPENDENCY INITIATIVE

XDI Residential Mortgage Portfolio Report

Bank X Report

Overall Risk Profile

Property Risk Distribution

Climate Change Hazards

XDI PLATFORM

XDI Globe globe.xdi.systems Easy XDI easyxdi.com

Prepared for: Bank X	Date: July 2022

REPORT CONTENTS

The Earth could be just 10 years from heating by more than 1.5 degrees Celsius – a threshold beyond which even more serious and frequent fires, droughts, floods and cyclones are expected to wreak havoc on humanity.

IPCC 2021

IMPORTANT INFORMATION

WHAT PRODUCTS AND SERVICES IN THIS REPORT DO AND NOT DO

The Products and Services use the Climate Risk Engines operated by Climate Risk P/L that process information and return results. Generally, users select or create Representative Assets which are synthetic representations of a real or hypothetical asset which may include real estate properties, infrastructure or other physical objects. Information about this Representative Asset is processed together with other relevant information such as location, age or value. The Climate Risk Engines integrate the information sent to it with information from a large number of national and international datasets from government institutions, universities and private companies to provide a generalised model of how climate change may affect a number of physical risks to the Representative Asset, all else being equal. The physical risks covered by the analysis will be displayed where the results are presented (on a Site or in a Report). However, the Climate Risk Engines do not provide a forecast, prediction or projection based on any real or planned asset.

The analysis does not purport to 'cover the field' of all potential risks associated with climate change nor to address coincidence or correlation between such risks. For example, extremes of precipitation and flooding may be coincident with extreme wind-storms which can damage a building making it more vulnerable to damage. The Climate Risk Engines do not necessarily take into account the impact of any actual built infrastructure, modifications, adaptations or resilience-building measures (public or private) that have been, or may be, applied that reduce (or exacerbate) the relevant hazard. The representation is made in relation to the availability or coverage of insurance to a real or planned asset.

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The information presented has been generated using an expert selection of the scientific methods and computational modelling techniques available at the time of creation. However, at any time there are known limitations of which you should make yourself aware. These are constantly refined and updated and are clearly specified on the Xdi.systems and EasyXDI site

SCOPE OF MODELLING AND SCENARIOS

Science is not able to definitively predict the exact range or rate of future global warming; or the scale and rate of change of atmospheric and oceanic processes that may be hazardous, including temperatures, precipitation, wind and the rise in sea levels that result from this warming. Many variables will determine society's continuing rate of emission of 'greenhouse gases' (including political, regulatory, technological and behavioural factors), and how the Earth's natural systems respond. However, we can estimate a range of potential impacts across what mainstream science considers to be a plausible set of scenarios for future ocean and atmospheric behaviour. The scenarios used are specified in the relevant Scenarios sections of websites and reports where the Climate Risk Engines are used.

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CAVEATS AND LIMITATIONS

Excluded Hazards: The analysis only includes hazards specified – does not include hurricane/cyclone, landslip, erosion, lightening or any other hazards apart from those specifically identified.

Non-Accessible Assets: The analysis Is based on synthetic representations of owned and/or operated assets with identifiable address such as shops, offices, branches, factories. This may not include all non-physically accessible assets until and unless they have been provided/confirmed by company.

EXECUTIVE SUMMARY

PORTFOLIO REPORT OVERVIEW

Bank X presented 89,545 properties for analysis. The properties are located across Australia.

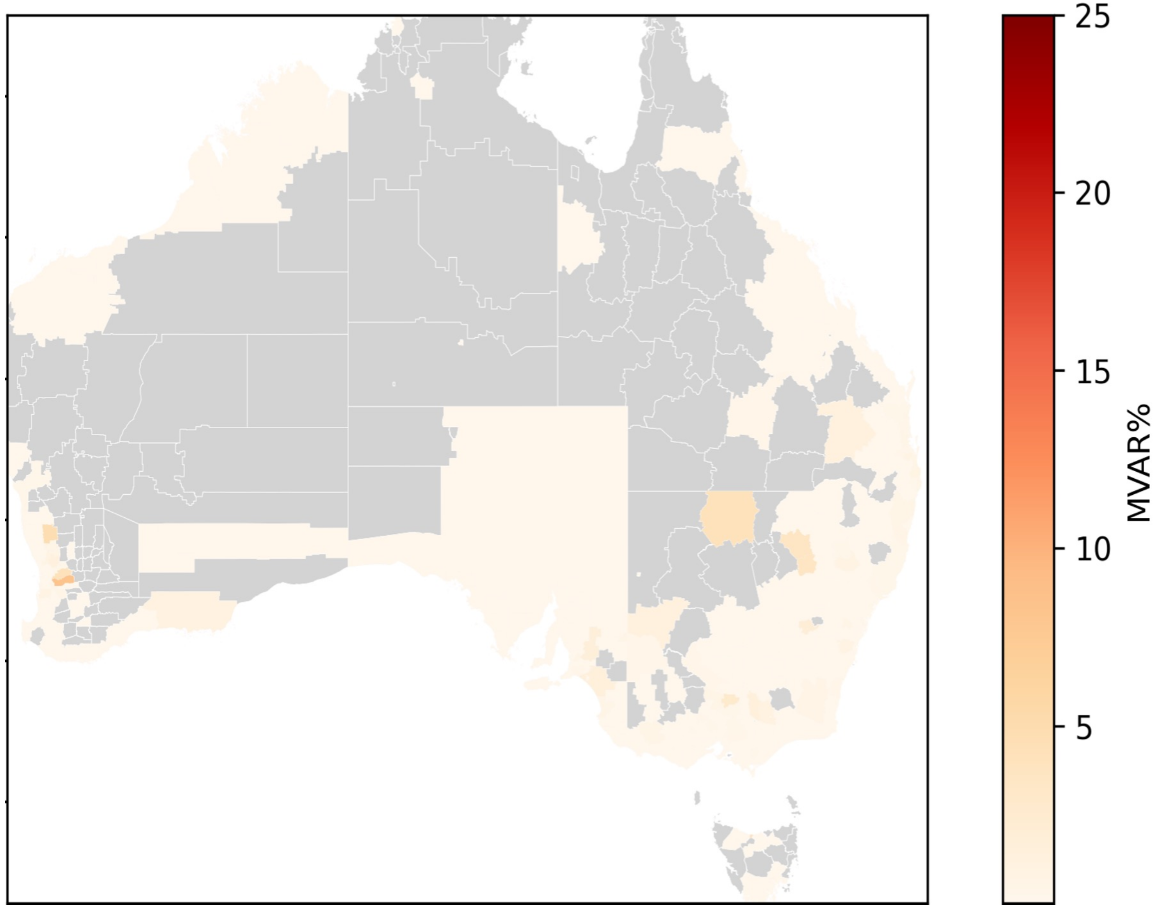
METHODS AND ASSUMPTIONS

This Residential Mortgage Portfolio Physical Risk Report has been generated using XDI's patented Climate Risk Engines. The Climate Risk Engines analyse a property's vulnerability to hazards using a representative archetype; Modern Building. A representative archetype is used to provide insights into the property's failure modes and damage thresholds.

Extreme weather and climate change drive a range of hazards which cause damage. In this report, the properties within the portfolio have been analysed against SIX extreme weather and climate change hazards; Riverine Flooding, Surface Water Flooding, Coastal Inundation, Forest Fires, Soil Subsidence and Extreme Wind events.

These hazards have then been tested using a range of climate change models under RCP8.5 (representing a warming of 3.2-5.4 degrees by 2100), RCP 4.5 (representing a warming of 2.5-3 degrees by 2100) and RCP 2.6 scenarios (representing a warming of 1.5-2˚C by 2100). Physical risks have been calculated using a combination of engineering, climate science, weather and financial data.

DISTRIBUTION OF MVAR% IN 2050



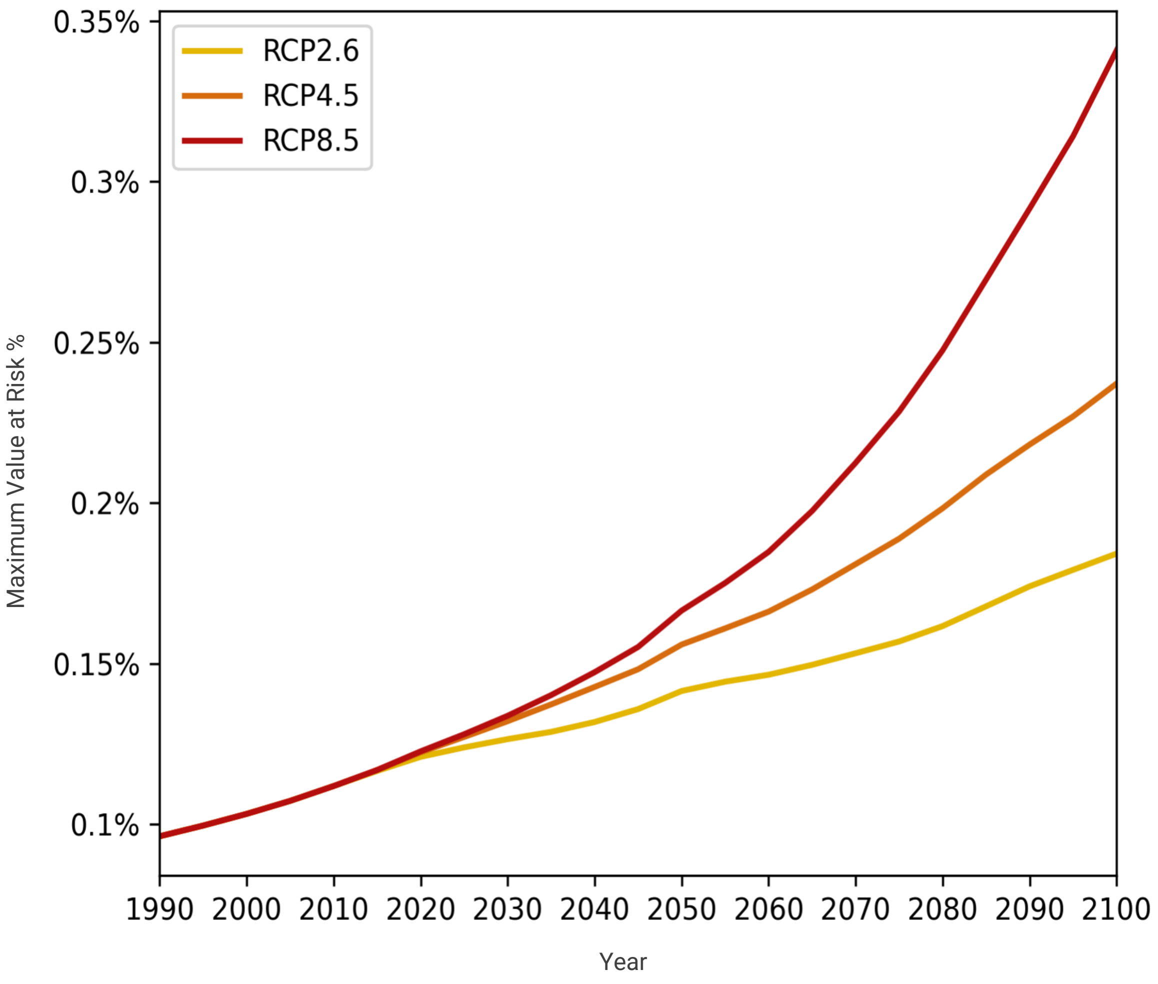
THE SIGNIFICANCE & TIMING OF THE EXTREME WEATHER AND CLIMATE RISKS FOUND

The Portfolio Maximum Value-At-Risk (MVAR) is projected to increase by **41.6%** from **0.12%** MVAR in 2020 to **0.17%** in 2050 and by **184%** from 2020 to 2100 under RCP 8.5. Over the same time period and same climate scenario, the number of High Risk Properties (greater than 1% MVAR) are projected to increase from **431** in 2020 to **590** in 2050. Assuming no change in the portfolio, this will represent approximately **2.7%** of the portfolio by 2050.

THE RELEVANT HAZARDS

The results are driven by all hazards, with **Riverine Flooding** contributing most to the overall MVAR. The hazard with the greatest change in MVAR% is **Riverine Flooding**, which from 2020 shows a **34% increase** by 2050 and a **218%** increase by 2100 (see *Hazard Breakdown, p36*).

PORTFOLIO CHANGE IN MVAR% OVER TIME



INSIGHTS

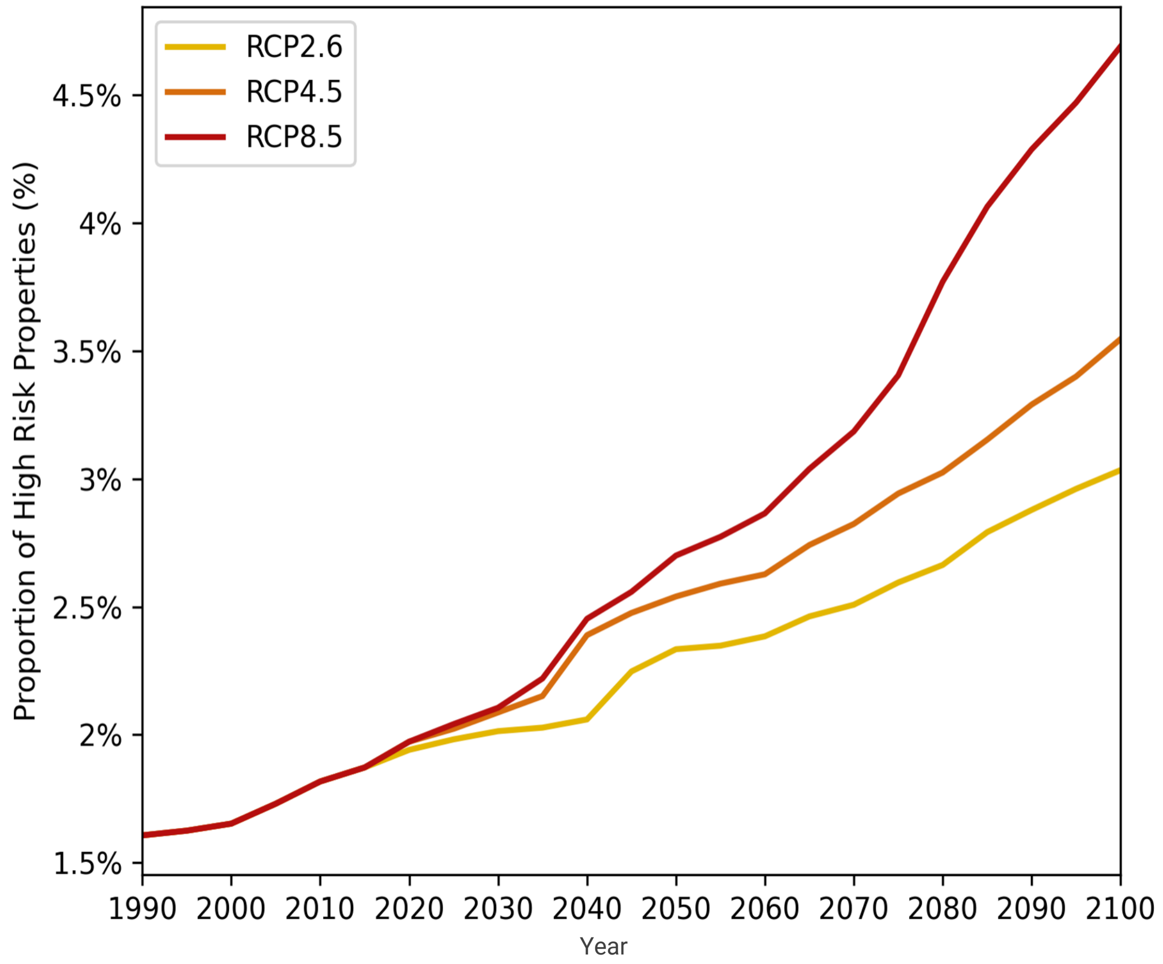
While the window of interest may only be a 30-year mortgage period to around 2050, we strongly recommend Bank X consider the 2100 data, as there is some view that climate impacts are happening much quicker than modelled.
Since some risks are anchored in long run historical data, there may be a market correction due to 'catch up' when comparing the increase from 1990 to 2020.

1. Currently the risk is non trivial. There are **2.0%** of properties which may be already classified as High Risk Properties .

2. The issue of 'serviceability' stress to customers will come from excessive insurance payments. The overall Technical Insurance Premiums is expected to increase by **35.69% by 2050** and **177.72% by 2100,** compared to 2020.

1. The number of properties where there is 'insurance stress' (combined moderate or high risk properties) increases from **1,527 in 2020** to **2,261 in 2050**.
2. The issue of mortgage default risk is best ascribed to properties classified as High Risk (those most likely to be become uninsurable/unaffordable to insure where the Technical Insurance Premium exceeds 1% of the property replacement cost). The percentage of HRP in the portfolio has probably increased from **1.6% in 1990**, to **2.0% today**, and is projected to increase to **2.7% by 2050** and **4.7% by 2100.**

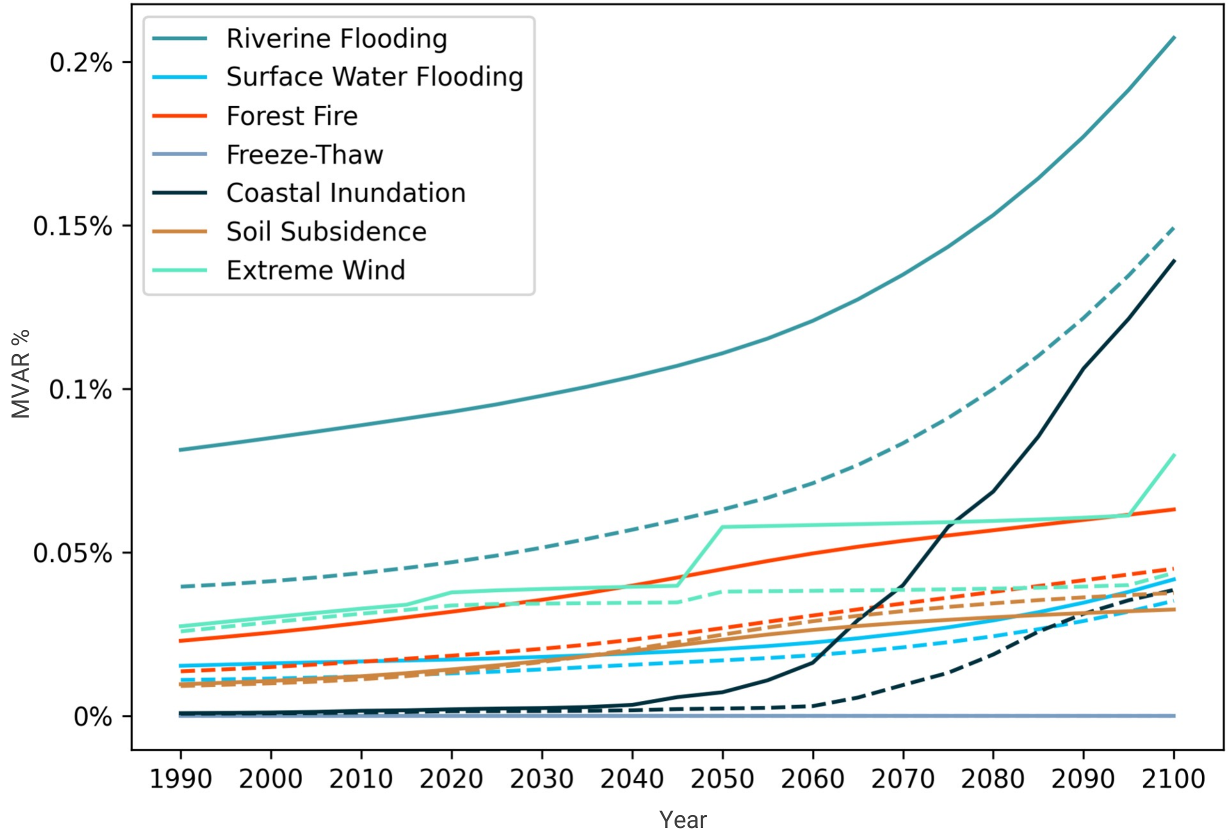
HIGH-RISK PROPERTIES OVER TIME



INSIGHTS (CONT)

5. There are wide differences in the exposure of properties, from a **26.9%** exposed to Riverine Flooding, to **99.0%** in soils vulnerable to subsidence. Going forward the biggest change is in the number of properties exposed to Coastal Inundation, from **0.43%** of the portfolio today increasing **4.5** times to **1.9%** by 2100.
6. When calibrated to the actually probability of damaging hazards occurring, the severity of damage and adjusting to a range or property resilience, the MVAR% provides a valuable insight. Riverine and Surface Water Floods dominate losses, followed by Coastal Inundation, Extreme Wind and Forest Fire.
7. Over time Surface Water Flood and Forest Fire risks increase somewhat linearly over time based on the BAU/RCP8.5 scenario, where sea level risk increases exponentially.
8. Geographically the areas of risk are quite highly clustered with the highest risk areas being Bourke, Coonamble, Gilgandra, Beverley and Moora. Going forward these will be joined by Victoria Plains and Wandering, where sea level rise will increase risks considerably.

HAZARD MAXIMUM VALUE-AT-RISK RELATIVE TO NATIONAL AVERAGE



RECOMMENDATIONS

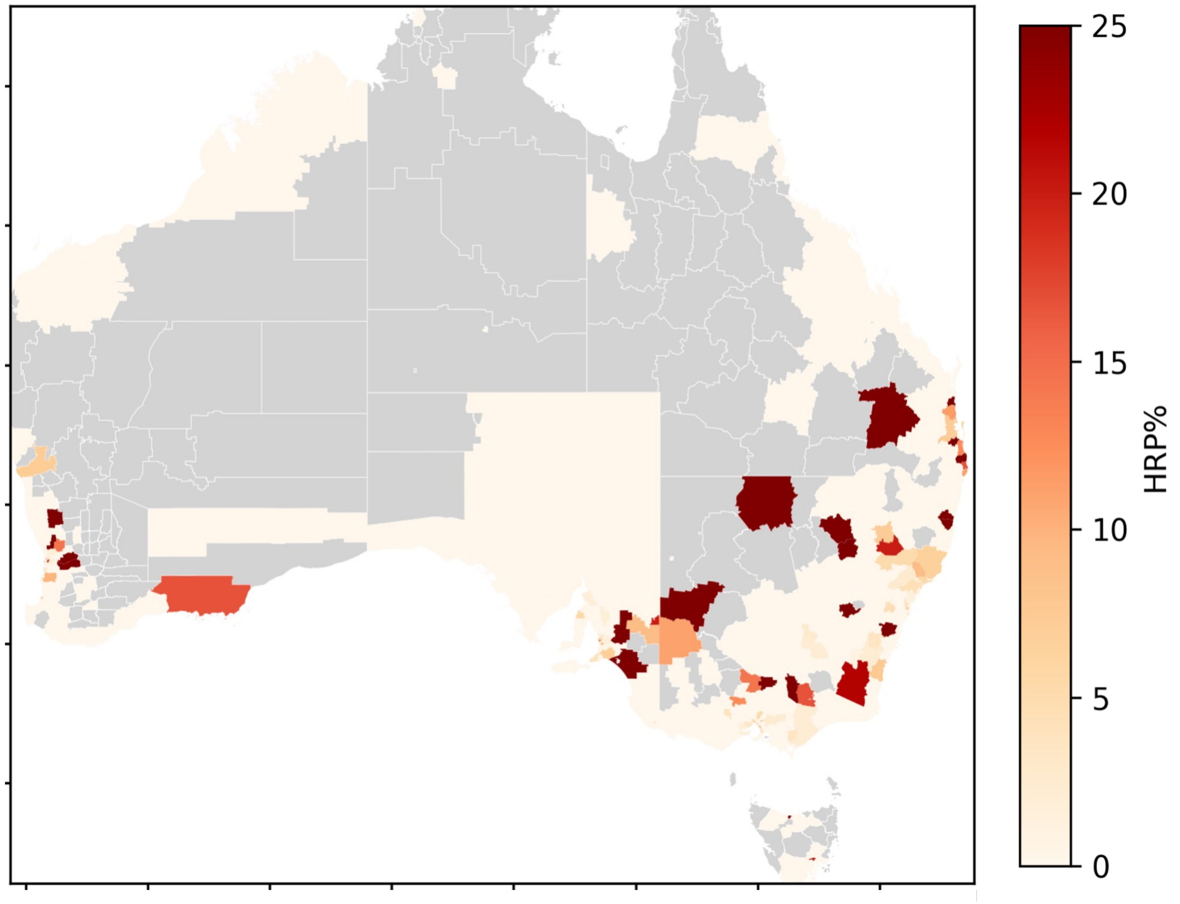
1. **Require comprehensive insurance coverage for High-Risk properties.** For the subset of confirmed high-risk properties, it is recommended that Bank X apply enhanced monitoring of borrowers' insurance coverage, particularly for relevant hazards.

1. **Prevent future risk by implementing point-of-sale screening processes.** It is recommended that Bank X adopt internal climate risk screening at the point of loan origination to avoid a higher portion of high climate risk mortgages being written in the future.

1. **Explore different vulnerability settings.** The resilience of a home greatly impacts the risk profile of a portfolio. It is prudent to test a range of outcomes using different vulnerability settings.

1. **Take advantage of growing customer interest in climate change:** Climate change is an opportunity to engage customers. XDI's partner company, [Climate Valuation](), offers affordable consumer-orientated climate risk reports that Bank X can provide to customers as part of its marketing and engagement efforts, demonstrating responsible lending practices.

DISTRIBUTION OF HIGH RISK PROPERTY % IN 2050



INTRODUCTION

RESIDENTIAL MORTGAGE PORTFOLIO REPORT

Climate change will impact the financial services sector in complex ways. Direct impacts from hazards such as flooding, coastal inundation, forest fire and wind-storms are growing in likelihood. Indirect impacts due to loss of critical infrastructure, supply chain disruption and economic impacts are equally significant. In addition, complex economic shifts because of climate change have the potential to affect the prosperity of businesses and communities.

THIS REPORT

XDI's Residential Mortgage Portfolio Report is designed to provide insights into the risks to a company's residential mortgage portfolio from extreme weather and climate change. It provides a quantitative overview of physical climate risk to inform financial and risk management decisions, based on recommendations from the emerging literature on physical climate risk reporting.

Using the multi-award winning Climate Risk Engines technology, the results are derived by computationally testing the physical vulnerability of synthetic representatives of a residential property and functional component parts against a range of extreme weather impacts such as flooding, heat, forest fire and wind. The results show the changing probability with which properties may (a) be damaged, and the possible implications on insurability and market value.

The forward looking results presented are based on the settings, scenarios and assumptions that have been selected and applied within the Climate Risk Engines. These are displayed throughout the relevant sections of this report. As such these results do not represent predictions.

This report is based on the asset, hazard and climate modelling data available at the time of the analysis. It can be updated as required if new science becomes available, data is added, or new analysis is undertaken.

GLOSSARY

TERM	DESCRIPTION
Archetype	An archetype is a representative asset class that allows the use of general or repeatable information and avoids having to uniquely specify all the characteristics of each individual asset analysed.
Failure Probability (FP)	Failure Probability is the annual probability of a climate hazard causing the asset to stop working with or without damage. This is reliant on the vulnerability of an archetype's element to a particular hazard.
High Risk Property Count (HRP#)	The total count of properties in the year specified that are 'high risk' i.e. over 1% MVAR, consistent with US Federal Emergency Management Agency (FEMA) definitions.
Medium Risk Property Count (MRP#)	The total count of properties in the year specified that are 'medium risk' i.e. between 0.2% and 1% MVAR.
Low Risk Property Count (LRP#)	The total count of properties in the year specified that are 'low risk' i.e. less than 0.2% MVAR.
Productivity Loss (PL)	Productivity loss considers the effects of different types of disruption, including periods of closure associated with different hazard events. PL% are based on Failure Probability, which includes both the annual average probabilities of event occurrence and the vulnerability of the asset and its components.
Technical Insurance Premium. (TIP)	The MVAR per asset for all hazard impacts (damage) combined. The TIP is based on the cost of damage to a property, using the replacement cost, expressed in current day dollars with no discounting or adjustments for other transaction costs.
Maximum Value-At-Risk (MVAR)	In each analysed year, an asset's overall MVAR is the potential damage costs caused by climate-related hazards, as a proportional of the total asset value.

ACRONYM	DESCRIPTION
BES	The Bank of England's discussion paper for the 2021 biennial exploratory scenario on the financial risks from climate change
CMIP	Coupled Model Inter-comparison Project
CMSI	Climate Measurement Standards Initiative
CORDEX	Coordinated Regional Downscaling Experiment
FSB	Financial Stability Board of the G20
GCM	Global Circulation Model
IPCC	Intergovernmental Panel on Climate Change
RCM	Regional Climate Model
RCP	Representative Concentration Pathway. An emission scenario as defined by the Intergovernmental Panel on Climate Change (IPCC). In this project the high global emissions (or 'business as usual') scenario known as RCP 8.5 and the low emissions scenario known as RCP 2.6 have been analysed.
RCP8.5	The default climate change scenario used in this study. Refers to a concentration of greenhouse gases that cause global warming temperature increase of between 3.2°C to 5.4°C by the end of 2100.
TCFD	Taskforce on climate-related financial disclosure

GLOSSARY - HAZARDS

TERM	DESCRIPTION
Coastal Inundation	Sea water flooding due to high tides, wind, low air pressure and waves can damage coastal land, infrastructure and buildings.
Extreme Wind	Changes in wind regimes, sea surface temperature and wind speeds. High-wind conditions that may exceed a building's design specifications.
Forest Fire	A destructive fire that spreads via trees and forest. This definition does not include grass fires. Flames and heat from burning vegetation can damage buildings and infrastructure. Increased incidence of fire weather due to confluence of days with higher temperatures, high wind speeds and drier conditions.
Riverine Flooding	Riverine (Fluvial) flooding can damage low-lying building or infrastructure assets. Changes in precipitation in a catchment that causes a river to exceed its capacity, inundating nearby areas.
Soil Subsidence	Soil contraction due to less rainfall causing subsidence damage to structures.
Surface Water Flooding	Surface Water (Pluvial) flooding can damage low-lying building or infrastructure assets. Increased frequency of extreme rainfall leading to overland flooding.

ANALYSIS SETTINGS

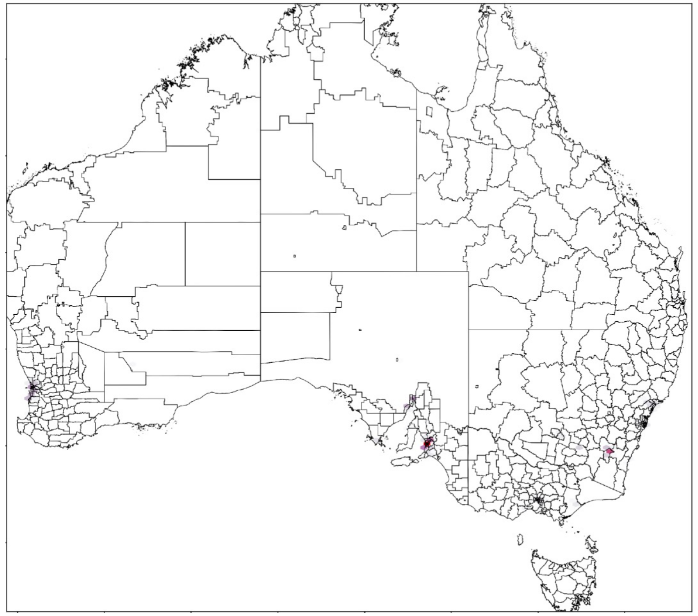
INTRODUCTION

The details of the settings used to derive the analysis for this Residential Mortgage Portfolio report for Bank X, are below.

NUMBER OF PROPERTIES MATCHED TO ADDRESS:

89,545

NAME:	Bank X
INDUSTRY:	Banking and Finance
HEAD QUARTERS:	100 Smith St, Sydney, SA
ASSET DATA PROVIDED BY:	Client-provided via Zero-Knowledge Encryption
ASSESSED COUNTRIES:	Australia
ASSET DATA VALIDATED BY COMPANY:	Yes



This map shows the locations and density of the properties identified as associated with the portfolio. The intensity of the colour represents the density of properties in that location (darker colour=higher property density).

HAZARDS ANALYSED

- ✓ COASTAL INUNDATION
- X EXTREME HEAT
- ✓ EXTREME WIND
- ✓ FOREST FIRE
- X FREEZE-THAW
- ✓ RIVERINE FLOODING
- ✓ SOIL SUBSIDENCE
- ✓ SURFACE FLOODING

MODELLED SCENARIOS & SETTINGS

DATA, SETTINGS AND SCENARIOS	THIS REPORT'S SETTINGS
Primary RCP:	RCP 8.5
Secondary RCPs:	RCP 2.6 & 4.5
Archetype used:	Modern Building
Number of Properties analysed in portfolio:	89545
Number Countries Analysed:	Australia
Sensitivity Testing Conducted:	Yes

HAZARD	REGIONAL CLIMATE MODELS
Coastal Inundation	1.5m by 2100 (midway IPCC high and NOAA high)
Extreme Wind	Multiple Cordex CMIP5 - MET/HDW
Forest Fire	Multiple Cordex CMIP5 – CRE FOREST AND URBAN
Riverine Flood	Multiple Cordex CMIP5 - JBA
Soil Subsidence	Multiple Cordex CMIP5 - NASA
Surface Water Flood	Multiple Cordex CMIP5 - JBA

Asset archetypes, with corresponding design and construction settings, are used as a stand in for the actual property to enable analysis within the Climate Risk Engines. The analysis in this report is based on the following **Modern Building** archetype. The characteristics of this archetype are detailed below.

These design and construction settings materially impact the vulnerability of the "Asset" to the hazards to which it is likely to be exposed.

ARCHETYPE CHARACTERISTIC	ARCHETYPE SETTINGS
Replacement Value	$320,000
Build Year	Year 2000
Floor Height	0.5m
Ignition Probability	Average Protection
Foundation Design	Rigid Reinforced Concrete
Wind Speed Threshold (WST)	1 in 500 years

BUILD YEAR
Build Year is used to indicate building and design standards which is used as a proxy for calculating Wind Speed threshold (WST)

IGNITION PROBABILITY
This value represents the likelihood of a fire starting on a day with the conditions required for a fire

FLOOR HEIGHT
The height of the floor above the Ground Level impacts the asset's exposure to flooding risk

FOUNDATION DESIGN
The type of piers and foundation used impacts an asset's vulnerability to movement in clay soils

REPLACEMENT VALUE
An estimation for the Replacement cost of the asset which will impact financial metrics such as TIP

DETAILED RESULTS

PORTFOLIO OVERVIEW

KEY TAKEOUT

In the current year, under the RCP8.5 scenario, **2.0%** of the portfolio is deemed to be at high-risk from physical climate change impacts. This is expected to **more than double** to **4.7%** by the year 2100, assuming no further growth in the portfolio.

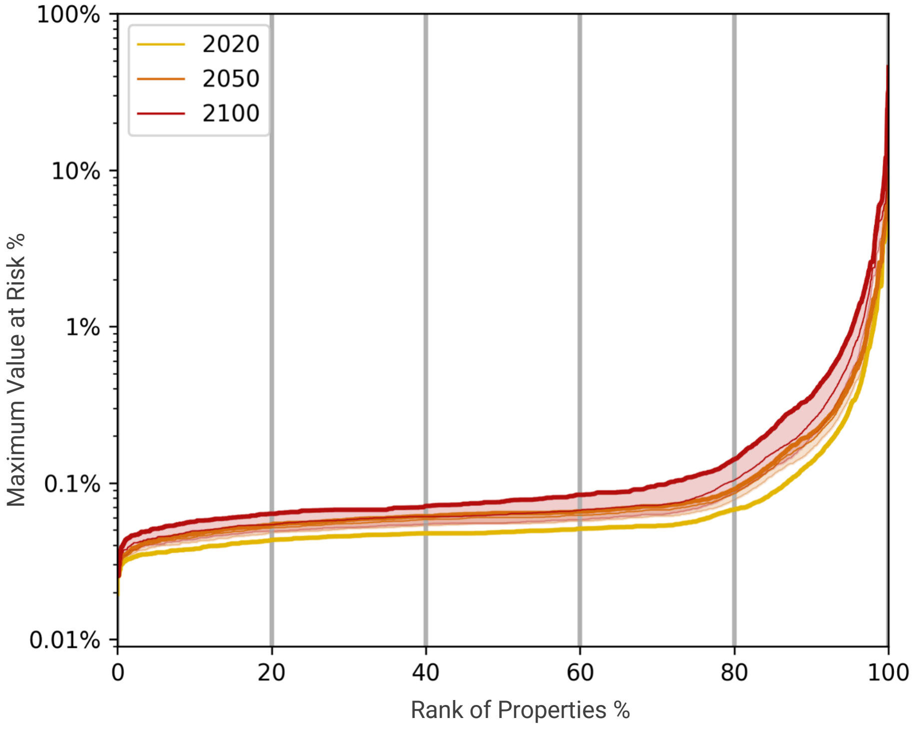
WHY IS THIS RESULT USEFUL

This distribution curve provides an overarching insight into the extent to which the portfolio is exposed to extreme weather damage and how that will evolve over time. The proportion of the portfolio which is high risk (Maximum Value-at-Risk > 1.0%) is especially important as this can lead to loss of productivity and property value.

OBSERVATION

In the current year 2022, **2.0%** of the portfolio is deemed to be at High Risk from physical climate change impacts. This represents **1766** properties that may suffer damages greater than or equal to 1.0% of the replacement cost of the property. This is expected to increase to **2418** portfolio properties in the year 2050 and **4201** portfolio properties in the year 2100.

AVERAGE MVAR% DISTRIBUTION



This graph shows the distribution of Maximum Value-at-Risk across the portfolio under the RCP8.5 scenario. The vertical axis is Maximum Value-at-Risk % and the horizontal axis is the percentile of the Bank X's properties in that MVAR band.

CHANGE IN MAXIMUM VALUE-AT-RISK % OVER TIME

KEY TAKEOUT

The company's average annual Maximum Value-At-Risk % increases by **41.6%** from **0.12%** MVAR in 2020 to **0.17%** in 2050 under RCP 8.5 Scenario. This increases by **184%** to **0.34%** from 2020 to 2100. This is driven by increased risks from a range of hazards.

WHY IS THIS RESULT USEFUL

This graph helps identify the extent to which climate change is contributing to property risk across the portfolio under three different RCP scenarios and how that risk is expected to change over time without adaptation or intervention. The shape of the curve reflects different levels of climate forcing of the hazard.

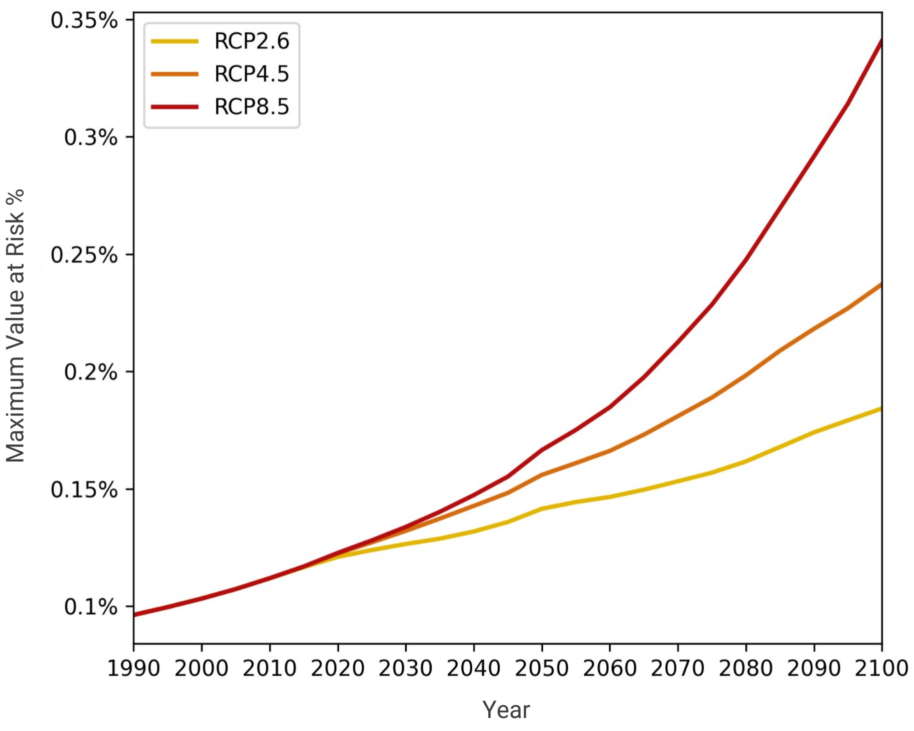
OBSERVATION

The average Maximum Value-At-Risk % for the residential mortgage portfolio increases by **41.6%** from 2020 to 2050 and **240%** from 1990 to 2100. Under lower emission pathways the increase is curbed but still rises as some hazards have long term inertia.

CHANGE IN MVAR OVER TIME

Year	1990	2020	2030	2050	2080	2100
Avg MVAR%	0.10%	0.12%	0.13%	0.17%	0.25%	0.34%

This table shows the average MVAR% for the entire portfolio under the RCP 8.5 scenario.



This graph illustrates the changes in the Maximum Value-at-Risk% over the period analysed, for all three scenarios RCP 2.6, 4.5 and 8.5.

THE NUMBER OF LOW, MODERATE & HIGH RISK PROPERTIES

KEY TAKEOUT

Under the RCP8.5 scenario, the number of High Risk Properties (HRP#) in the residential mortgage portfolio rises exponentially. Approximately **460** of the the portfolio's owned and leased property portfolio will be categorised as high risk from physical climate change impacts by 2030. This **more than doubles** to **1,025** by the year 2100. These represent the properties most at risk of unaffordable or unavailable insurance, as well as productivity loss and business disruption.

WHY IS THIS RESULT USEFUL

It is useful for companies to identify the number of properties in their portfolio that are classified as low, moderate and high risk and how this is likely to change over time. When applied to financial exposure, these figures may indicate the level of credit risk to the portfolio now and in the future, as well as the timelines for the financial impacts expected.

OBSERVATION

Based on the **89,545** properties analysed, using an interpretation of the US Government's FEMA index used for insurance, the residential mortgage portfolio risk under RCP8.5 scenario, is:

- High Risk: **1766** properties in 2020, to **2418** in 2050.
- Moderate Risk: **4492** properties in 2020, to **6848** in 2050.
- Low Risk: **83287** properties in 2020, to **77664** in 2050.

COUNT OF LRP, MRP, HRP

Year	LRP#	MRP#	HRP#
1990	84623	3483	1438
2020	83287	4492	1766
2030	82603	5057	1885
2050	77664	6848	2418
2080	77664	8504	3377
2100	75246	10098	4201

This table shows the number of properties in the portfolio that are classified as low, moderate and high risk at each time interval under the RCP8.5 scenario (using a modern building archetype).

THE PERCENTAGE OF LOW, MODERATE & HIGH RISK PROPERTIES

KEY TAKEOUT

The majority of the the portfolio can be considered **Low** Risk today, but by 2050, **7.6%** will be at **Moderate** Risk (MVAR > 0.2%) and a further **2.7%** of the properties will be deemed to be at **High** Risk from physical climate change impacts (MVAR > 1.0%).

WHY IS THIS RESULT USEFUL

It is useful for companies to identify the portion of their portfolio that is classified as low, moderate and high risk and how this is likely to change over time. These figures may indicate the level of risk to the portfolio now and in the future, as well as the timelines for the portfolio's deterioration (assuming no mitigation measures).

OBSERVATION

Based on the **89,545** properties analysed, using an interpretation of the US Government's FEMA index used for insurance, the residential mortgage portfolio risk under RCP8.5 scenario, is:

- High Risk: **2.0%** in 2020, to **2.7%** by 2050
- Moderate Risk: **5.0%** in 2020, to **7.6%** by 2050
- Low Risk: **93.0%** in 2020, to **89.7%** by 2050

PERCENT OF LRP, MRP, HRP

Year	LRP	MRP	HRP
1990	94.5%	3.9%	1.6%
2020	93.0%	5.0%	2.0%
2030	92.2%	5.6%	2.1%
2050	89.7%	7.6%	2.7%
2080	86.7%	9.5%	3.8%
2100	84.0%	11.3%	4.7%

This table shows the % of the portfolio that is classified as low, moderate and high risk at each given time interval under the RCP8.5 scenario (using a modern building archetype).

CHANGE IN PERCENTAGE OF HIGH RISK PROPERTIES OVER TIME

KEY TAKEOUT

Under the RCP8.5 scenario, the number of High Risk Properties (HRP) in the residential mortgage portfolio rises **steadily** to **2.7%** by 2050. The proportion of high risk properties does not differ significantly between the current year and 2050. Under RCP 4.5 and RCP 2.6 HRP are **2.5%** and **2.3%** in 2050, respectively.

WHY IS THIS RESULT USEFUL

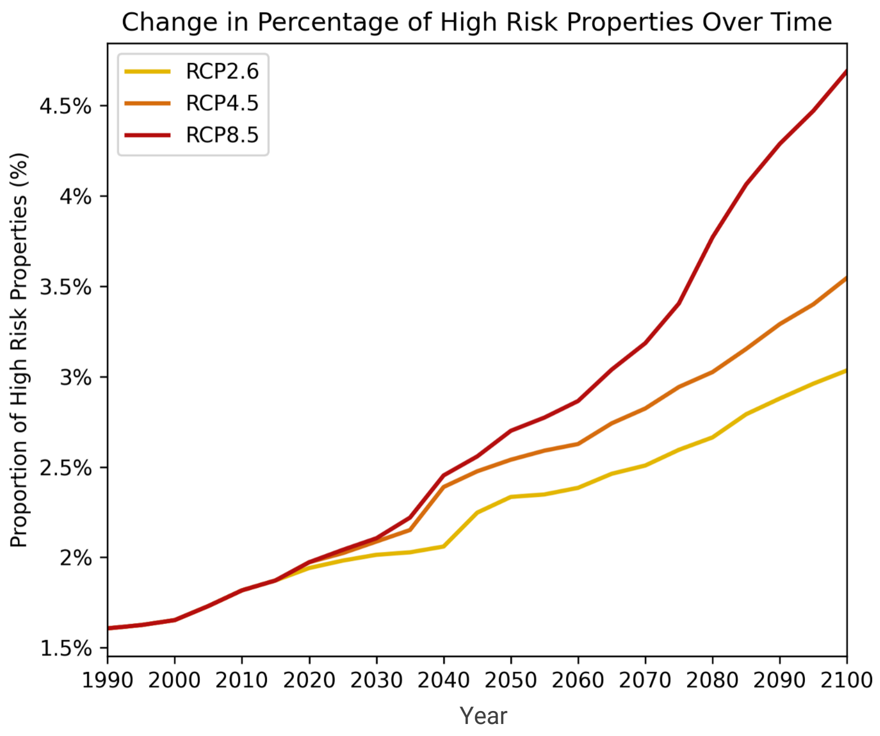
It is useful for companies to identify the portions of their portfolio that are classified as low, moderate and high risk and how they are likely to change over time. These figures may indicate the level of risk to the portfolio now and in the future, as well as the timelines for the portfolio's deterioration under different climate scenarios. The proportion of the portfolio which is High Risk is particularly important, impacting default and present credit risk to the company.

OBSERVATION

For the residential mortgage portfolio under RCP8.5 scenario, **2.0%** of the portfolio's properties are currently deemed high risk and increasing by **35%** to **2.7%** by 2050. HRP under RCP 4.5 and RCP 2.6 track slightly lower than RCP 8.5 until 2060, where the proportion of HRP increases significantly more under RCP 8.5.

It is quite common that there is not a uniform change, as different hazards impact different properties at different time periods. For the portfolio, the point of divergence begins around 2070 as **Riverine Flood** risks become more prevalent.

CHANGE IN % HRP OVER TIME



This graph illustrates the changes in the percentage of high risk properties over the period analysed, for all three scenarios RCP 2.6, 4.5 and 8.5.

CHANGE IN PERCENTAGE OF MODERATE RISK PROPERTIES OVER TIME

KEY TAKEOUT

Under the RCP8.5 scenario, **5.6%** of the portfolio will be categorised as Moderate risk from physical climate change impacts by 2030. This will increase from 2030 to 2050 by **36%** to **7.6%** as more properties move from the low risk category.

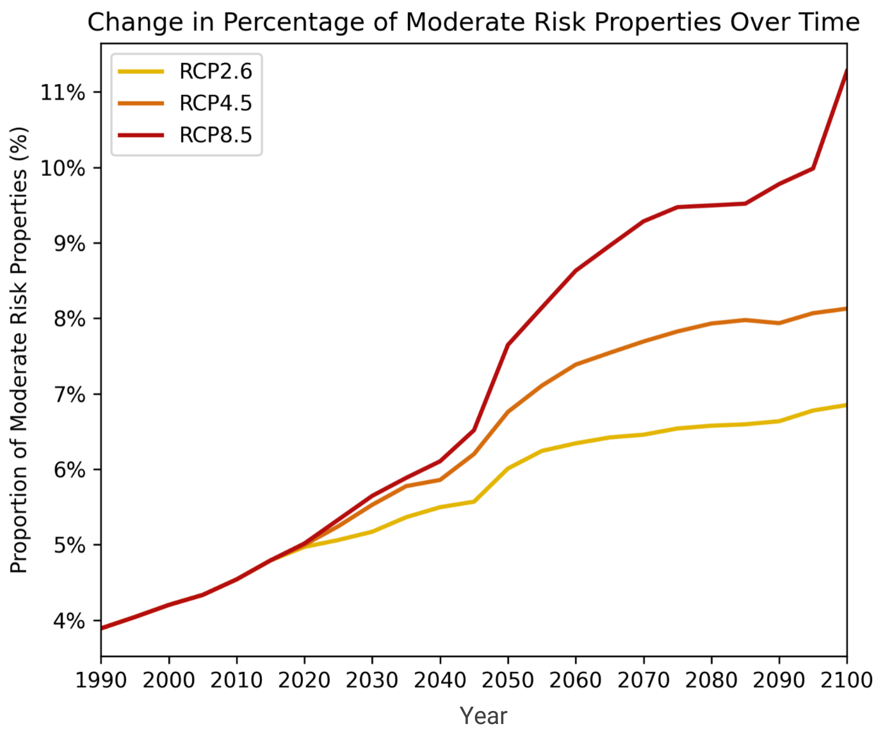
WHY IS THIS RESULT USEFUL

It is useful for companies to identify the portions of their portfolio that are classified as low, moderate and high risk and how they are likely to change over time. These figures may indicate the level of risk to the portfolio now and in the future, as well as the timelines for the portfolio's deterioration. The properties that are classified as moderate risk may still be insurable but at a higher cost.

OBSERVATION

Under the RCP8.5 scenario, **5.0%** of the residential mortgage portfolio is deemed moderate risk today, rising to **5.6%** by 2030, **7.6%** by 2050 and to **11.3%** by 2100.

CHANGE IN % MRP OVER TIME



This graph illustrates the changes in the percentage of moderate risk properties over the period analysed, for all three scenarios RCP 2.6, 4.5 and 8.5.

PORTFOLIO TECHNICAL INSURANCE PREMIUM (TIP) OVERVIEW

KEY TAKEOUT

Based on an assigned replacement cost for each property, the average Technical Insurance Premium (TIP) for extreme weather across the residential mortgage portfolio is currently around **$385** per property. Note that this has increased significantly from 1990 levels, which is the data upon which the market still prices many insurance premiums today. By the end of the century, TIP due to climate change and extreme weather risk are expected to increase to an average TIP of **$522** by 2050 and **$1,069** by 2100.

WHY IS THIS RESULT USEFUL

This result may help the mortgage holders infer the sorts of insurance costs to be expected, and in turn, how these costs may impact the serviceability of any loans outstanding on the properties.

OBSERVATION

Under the RCP8.5 scenario, the residential mortgage portfolio has a current Average TIP of $385, rising to an average TIP of **$420** in 2030, **$522** in 2050 and to **$1,069** in 2100.

(See *Archetype Settings* for Replacement Cost).

CHANGE IN TIP OVER TIME

Year	Average TIP	Total TIP
1990	$302	$27,015,108
2020	$385	$34,439,790
2030	$420	$37,570,680
2050	$522	$46,694,988
2080	$777	$69,505,758
2100	$1,069	$95,626,326

This table shows the change in average Technical Insurance Premium per property, as well as the total Technical Insurance Premium expected across the entire portfolio.

CHANGE IN TOTAL TECHNICAL INSURANCE PREMIUM (TIP) UNDER DIFFERENT SCENARIOS

KEY TAKEOUT

This graph shows the change in Total Technical Insurance Premium (TTIP) over time, thereby helping the mortgage holder infer the sorts of insurance costs to be expected, and in turn, how these costs may impact the profitability of business operations and serviceability of any loans outstanding on the properties.
The TTIP increase from now until 2050 is $3,002,766. Under RCP 4.5, the TTIP increase from now to 2050 is $2,297,073 and under RCP 2.6 the TTIP for the same time period is $1,404,262.

WHY IS THIS RESULT USEFUL

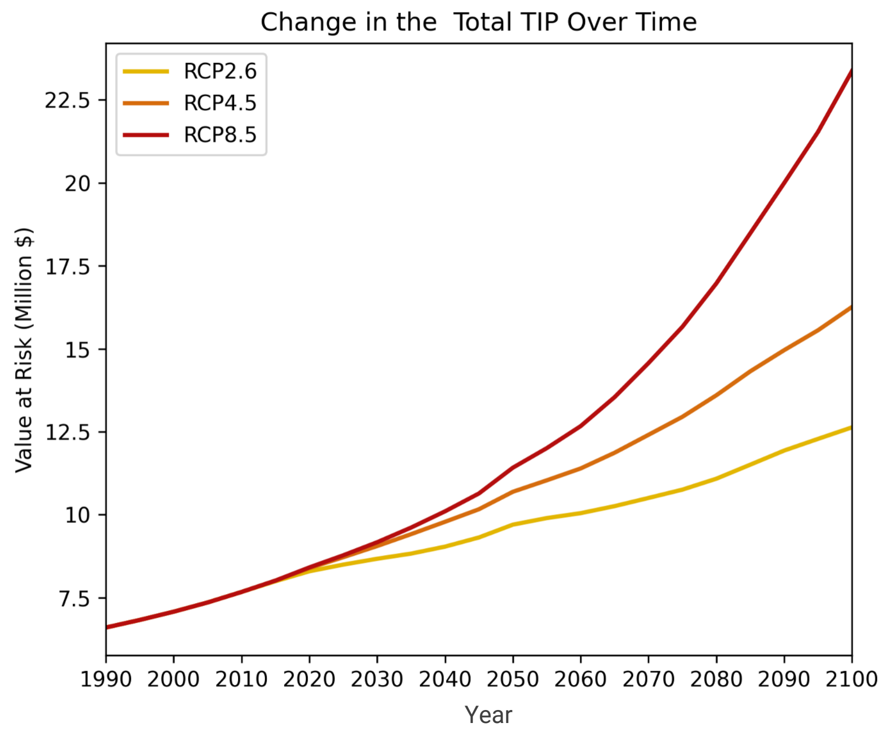
The Technical Insurance Premium (TIP) is defined as the Annual Average Loss (AAL) per property for all hazard impacts. For each property, TIP is calculated based on the probability of a hazard exceeding the damage threshold of an property component and the consequential damage costs to each component. Total TIP (TTIP) is the sum of all property TIPs within the portfolio.

OBSERVATION

This result shows the different costs associated with different climate scenarios, putting into perspective the savings still possible with more stringent measures to curb climate change.

Under the RCP8.5 scenario, the residential mortgage portfolio has an expected changed in TTIP from roughly $27,015,108 currently, to $46,694,988 in 2050 and more than doubling to $ 95,626,326 by 2100.
The TTIP figures are significantly lower under different climate scenarios, particularly from 2040 onwards.

CHANGE IN TTIP OVER TIME



This graph shows the change Total Technical Insurance Premium expected across the entire portfolio under PCR 8.5, 4.5 & 2.6.

SPATIAL RISK MAPPING

KEY TAKEOUT

This physical distribution of total properties can be compared to maps of the distribution of various risk indicators (later in this report) to help visualise the difference between locations where risk is dominated by property density and those dominated by hazard exposure.

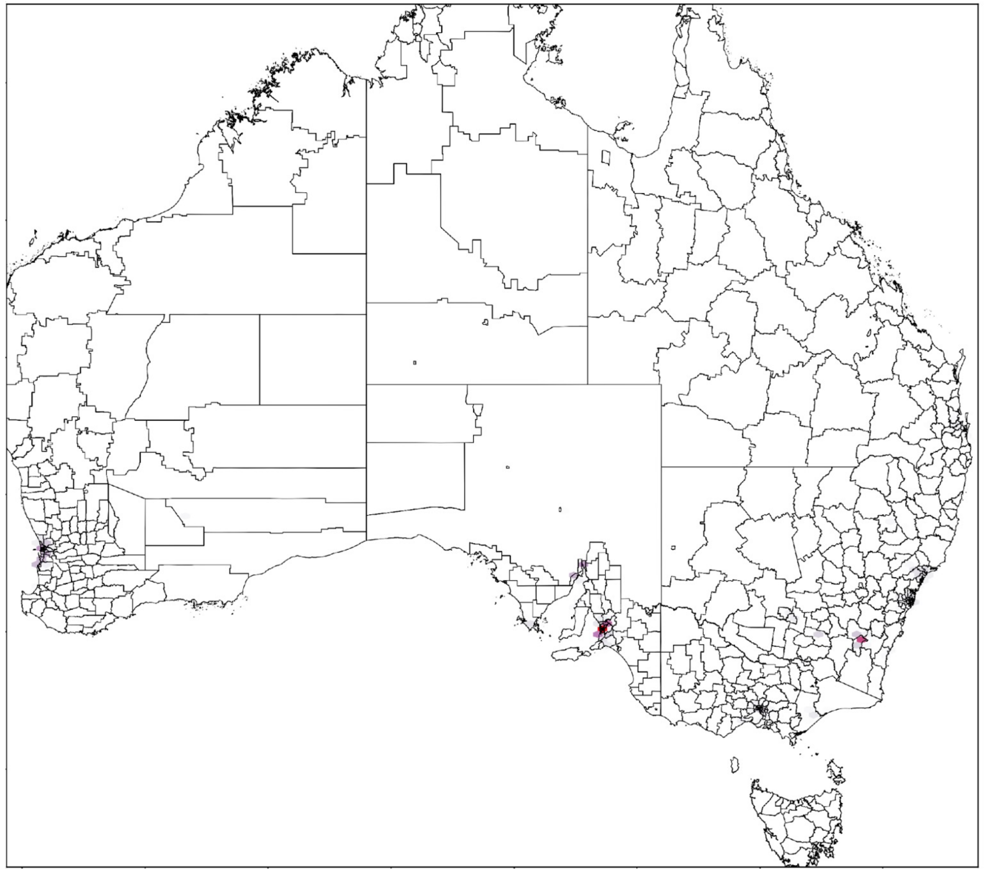
WHY IS THIS RESULT USEFUL

This map plots a total of 89,545 properties identified within the portfolio.

OBSERVATION

The residential mortgage portfolio of owned and leased properties consists of 89,545 identifiable properties.

SPATIAL DISTRIBUTION OF PROPERTIES



This map shows the locations and density of the properties identified as associated with the portfolio. The intensity of the colour represents the density of properties in that location (darker colour=higher property density).

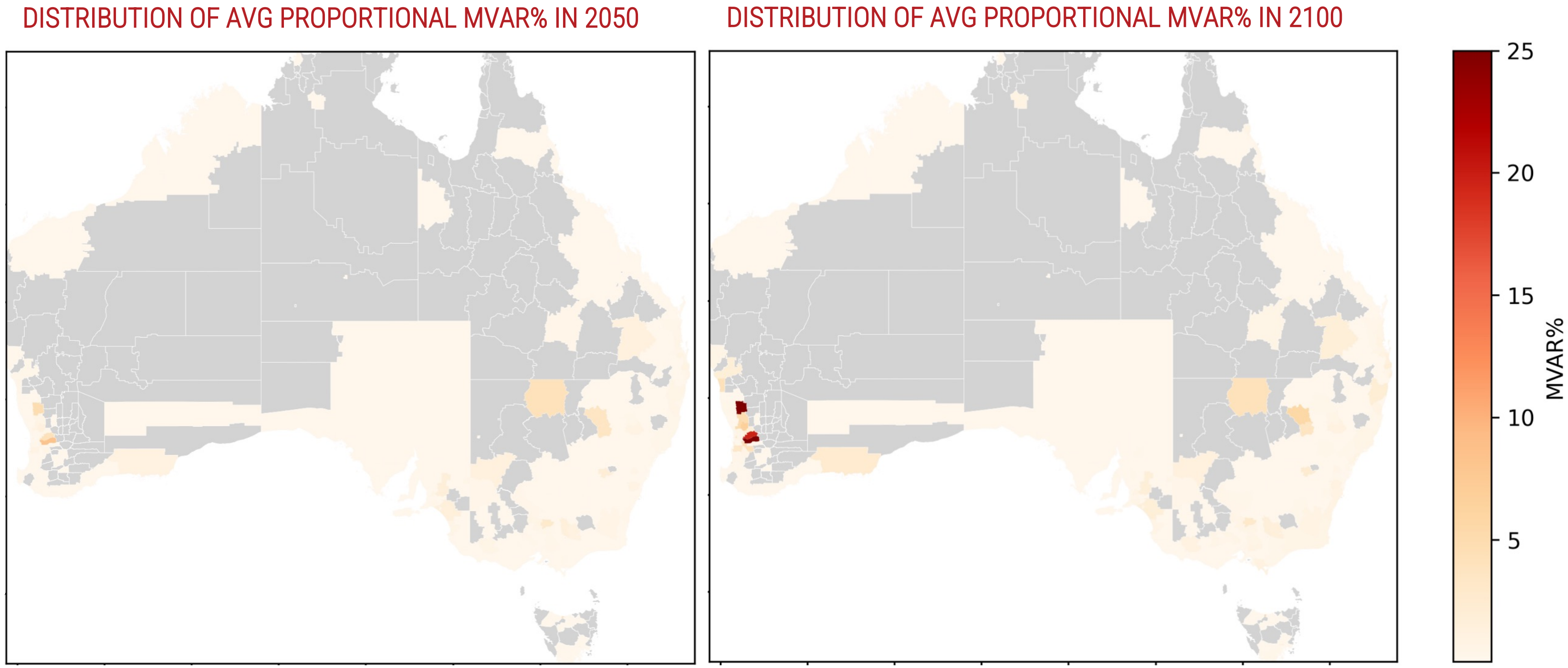
GEOGRAPHICAL DISTRIBUTION OF MAXIMUM VALUE AT RISK (MVAR%)

KEY TAKEOUT

These maps of Maximum Value-at-Risk (MVAR%) intensity for the years 2050 and 2100 show a trend in the increase of average physical risk over time in all areas. These maps demonstrate that climate risk distribution is not necessarily proportionate to the number of properties in that area.

WHY IS THIS RESULT USEFUL

These maps show the locations and density of the company's average Maximum Value-At-Risk (MVAR%) across several time periods. It focuses attention on where risks of damage are highest and avoids property value bias, and may therefore be a useful indication of the regions where the mortgage owner needs to focus risk management attention.



CHANGE IN AVERAGE VALUE AT RISK (MVAR%) SINCE 1990

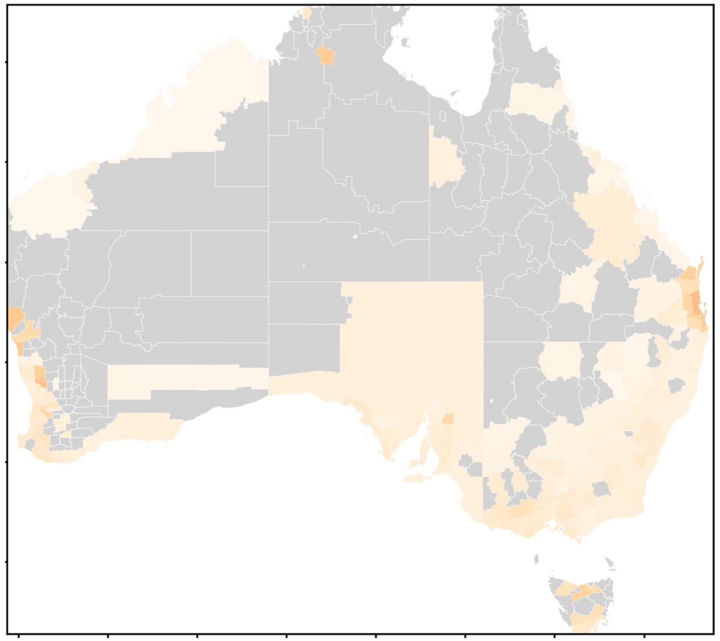
KEY TAKEOUT

The greatest increase in physical risk to the the residential mortgage portfolio is seen to be geographically spread, with a high proportion of locations notably closer to the coast. The majority of regions will see more than **0.15%** increase in Maximum Value-at-Risk over the century.

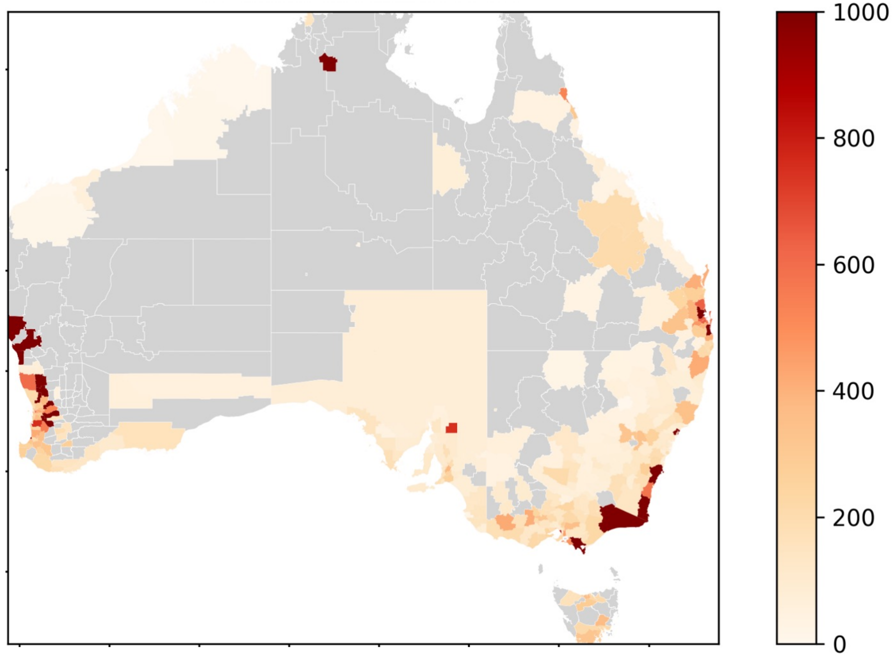
WHY IS THIS RESULT USEFUL

These maps show change in average Maximum Value-at-Risk% from a baseline of 1990, focusing attention on areas of high MVAR% concentration. The results may be a useful indication of abnormally high climate change impacts in different regions.

DISTRIBUTION OF RELATIVE CHANGE MVAR% IN 2050



DISTRIBUTION OF RELATIVE CHANGE MVAR% IN 2100



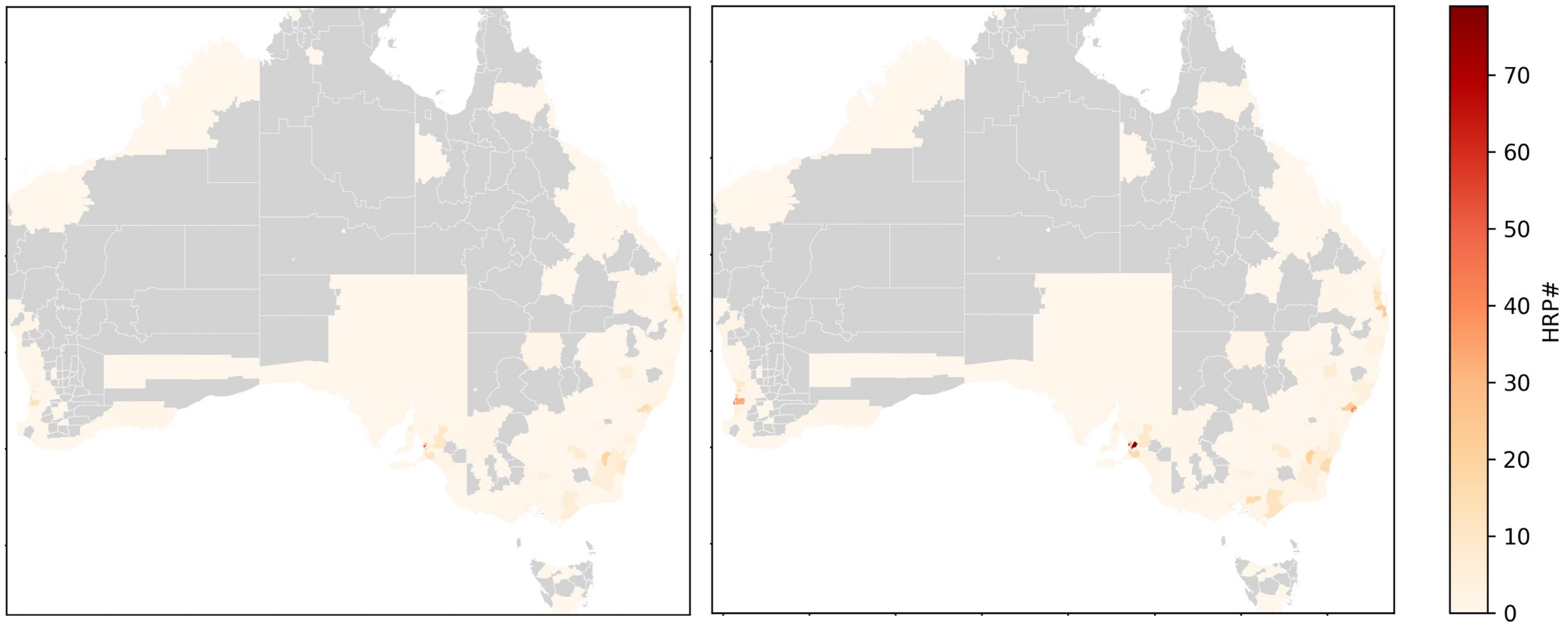
KEY TAKEOUT

These maps show the locations and density of the portfolio's High Risk Properties (HRP#) in years 2050 and 2100 for all properties within its owned and leased property portfolio.

WHY IS THIS RESULT USEFUL

These maps focus attention on high risk concentration areas. These maps could be used as a proxy, indicating regions where high levels of default and credit risk may be expected.

DISTRIBUTION OF HRP# IN 2050 | DISTRIBUTION OF HRP# IN 2100



GEOGRAPHICAL DISTRIBUTION OF HIGH-RISK PROPERTIES (HRP%)

KEY TAKEOUT

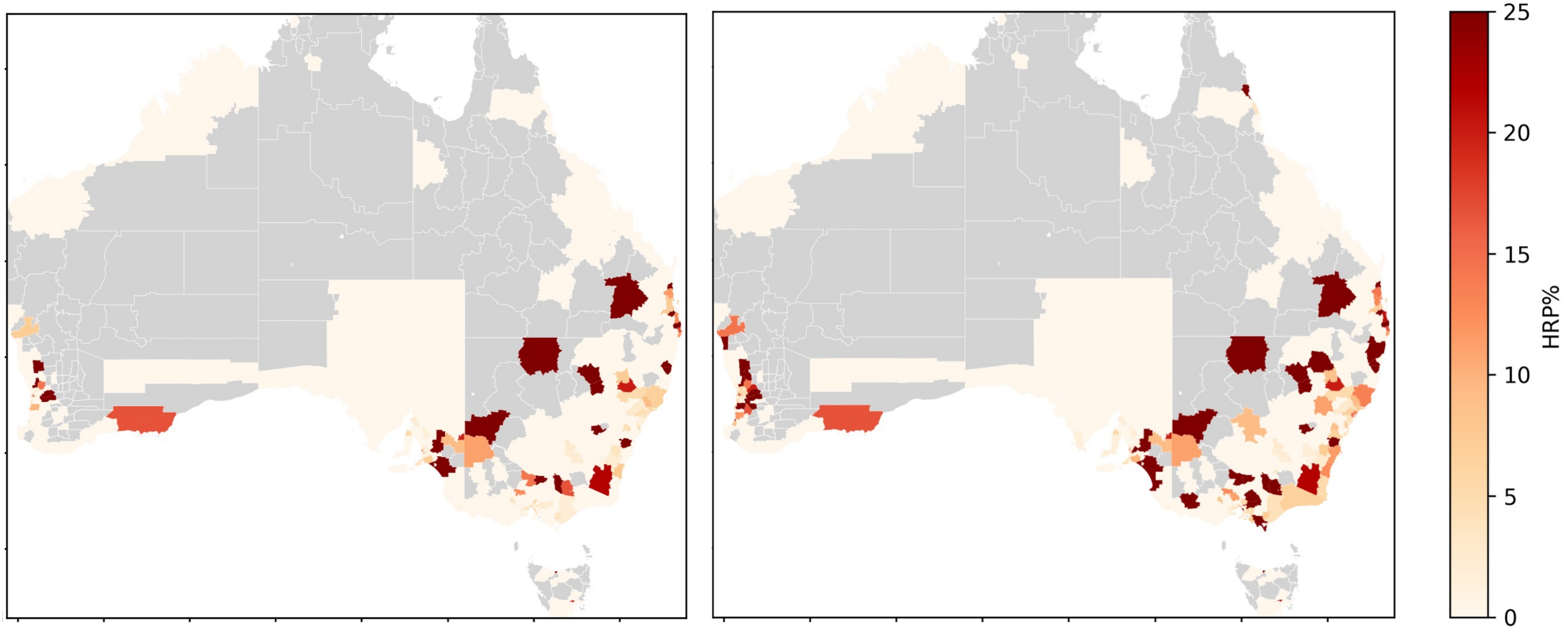
The modelling suggests that a large number of areas will have a significant increase in the proportion of high-risk properties with majority of change concentrated around low lying coastal and inland regions with exposure to flooding. This could have potential negative effects on the local economy leading to these areas becoming undesirable for buyers and insurers.

WHY IS THIS RESULT USEFUL

These maps show the areas which have the highest proportion of high risk properties as a percentage of all of the properties in that area. The high risk properties are those at most risk of under insurance, devaluation and serviceability stress. These maps could be used as a proxy for regions where high levels of default and credit risk may be expected.

DISTRIBUTION OF HRP% IN 2050

DISTRIBUTION OF HRP% IN 2100



HAZARD BREAKDOWN

KEY TAKEOUT

Hazards such as **Coastal Inundation** are only relevant to a very small percentage of the portfolio properties, whereas most properties have some amount of **Extreme Wind** or **Soil Subsidence** exposure at some point. This is commonly seen across all national addresses and does not indicate the severity of the risk to the bank.

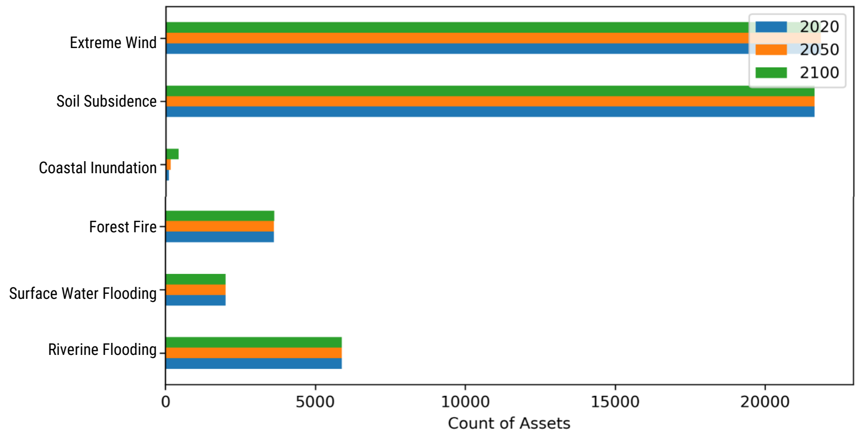
WHY IS THIS RESULT USEFUL

This table provides an insight into the portfolio's underlying hazard exposure which is a useful reference point when considering overall risk results. It helps explain why hazards like soil subsidence can often contribute significantly to average MVAR%, as such hazards typically affect a large number of properties without necessarily contributing to a significant total MVAR%.

OBSERVATION

Before calculating vulnerabilities and risk levels, the Climate Risk Engines address (a) spatial context-related exposure, such as proximity to forests or presence of moveable soils, and (b) the degree of that exposure, such as the amount of canopy cover or concentration of clay in the soil. In this table the percentage of properties exposed to each hazard are shown – even if damage risks from those hazards are small.

COUNT OF PROPERTIES EXPOSED IN 2050



The graph shows the total count and of properties exposed in 2050 to each of the hazards analysed.

PERCENTAGE AND COUNT EXPOSED IN 2050

Hazard	Properties Exposed in 2050 (%)	Properties Exposed in 2050 (#)
Coastal Inundation	0.75	672
Extreme Wind	100	89,545
Forest Fire	16.6	14864
Riverine Flooding	26.9	24088
Soil Subsidence	99.0	88650
Surface Water Flooding	9.2	8238

The table shows the total count and percentage of properties exposed in 2050 to each of the hazards analysed.

KEY TAKEOUT

For **Riverine Flooding, Surface Water Flooding, Coastal Inundation, Forest Fire and Extreme Wind**, the portfolio rates higher than the national average for MVAR%. **Soil Subsidence** tracks slightly lower than the national average.

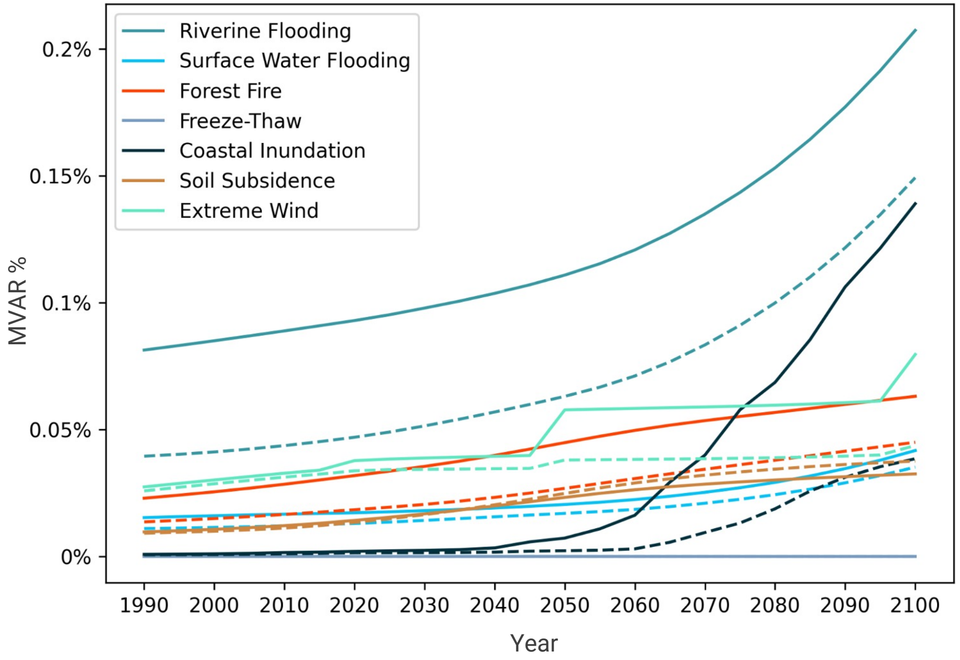
WHY IS THIS RESULT USEFUL

This graph provides an insight into the portfolio's underlying hazard exposure which is a useful reference point when considering overall risk results. The portfolio results can be compared to the national average MVAR%, providing insight into the relative vulnerability of the portfolio.

OBSERVATION

Riverine Flooding and **Coastal Inundation** MVAR% values are significantly higher than the national average, and all hazards except **Soil Subsidence** are above the national average.

HAZARD MAXIMUM VALUE-AT-RISK RELATIVE TO NATIONAL AVERAGE



This graph show the change in MVAR% per hazard for the portfolio (solid line) versus the national average (dotted line).

HAZARD CONTRIBUTION TO TOTAL MVAR%

KEY TAKEOUT

Riverine Flooding and **Extreme Wind** are the highest contributors to Maximum Value-at-Risk% in each year of the four years shown. While Coastal Inundation affects a small volume of properties, those that are affected have very high associated damage.

WHY IS THIS RESULT USEFUL

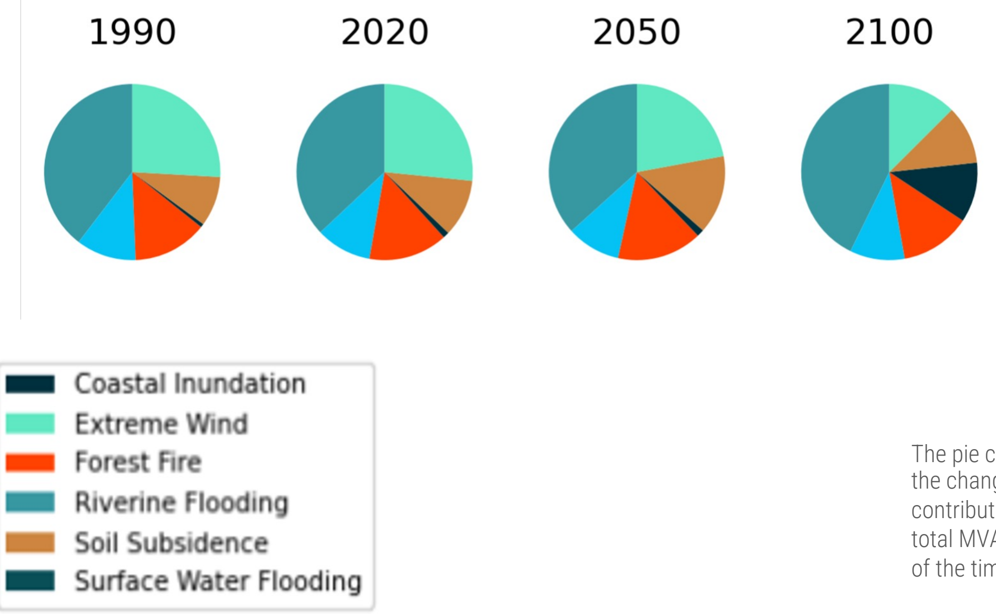
These pie charts show the portion of the total Maximum Value-at-Risk% (100%) represented by each hazard in each of the four chosen years. They identify which hazards contribute most to the portfolio's climate-related financial risk, regardless of the number of properties impacted.

OBSERVATION

The largest contributor to the overall risk in 2050 is **Riverine Flooding**, followed by **Extreme Wind. Riverine Flooding** remains the highest contributor over the century while **Extreme Wind** becomes relatives less risk as other hazards increase over time period.

See the individual Hazard breakdowns for more detailed results.

HAZARD CONTRIBUTION TO MVAR% OVER TIME



The pie charts show the changing hazard contribution to the total MVAR% in each of the time steps.

KEY TAKEOUT

Under RCP8.5 scenario, the portfolio's average Maximum Value-At-Risk from Coastal Inundation is expected to increase by around **0.002%** between 2020 and 2050. The impacts of this hazard can be seen to increase sharply to **0.039%** by 2100, **25 times** the 2020 value.

WHY IS THIS RESULT USEFUL

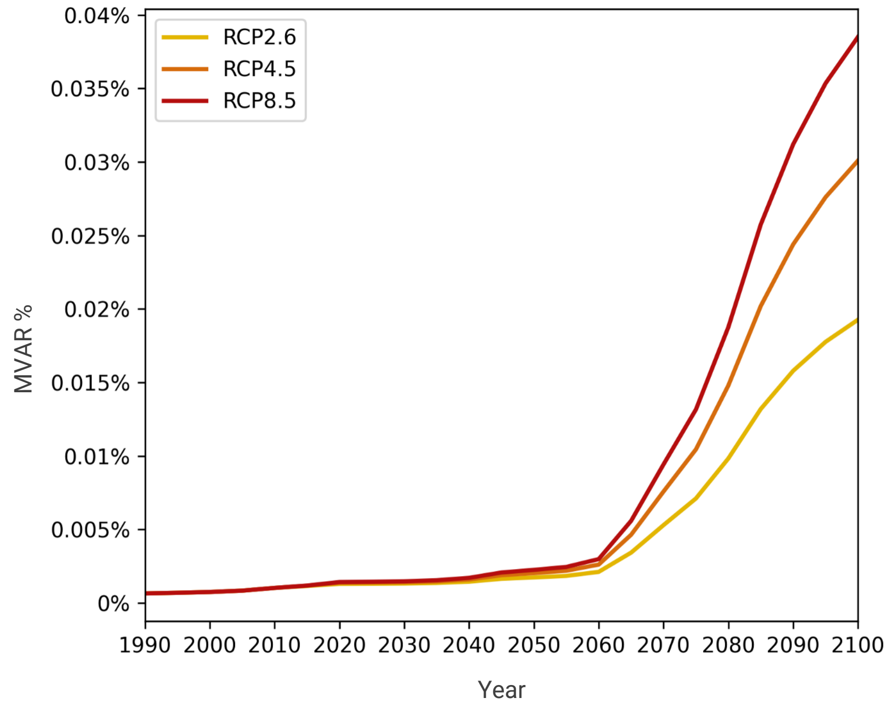
For each emissions scenario, this graph shows the average Coastal Inundation MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the coastal inundation hazard.

OBSERVATION

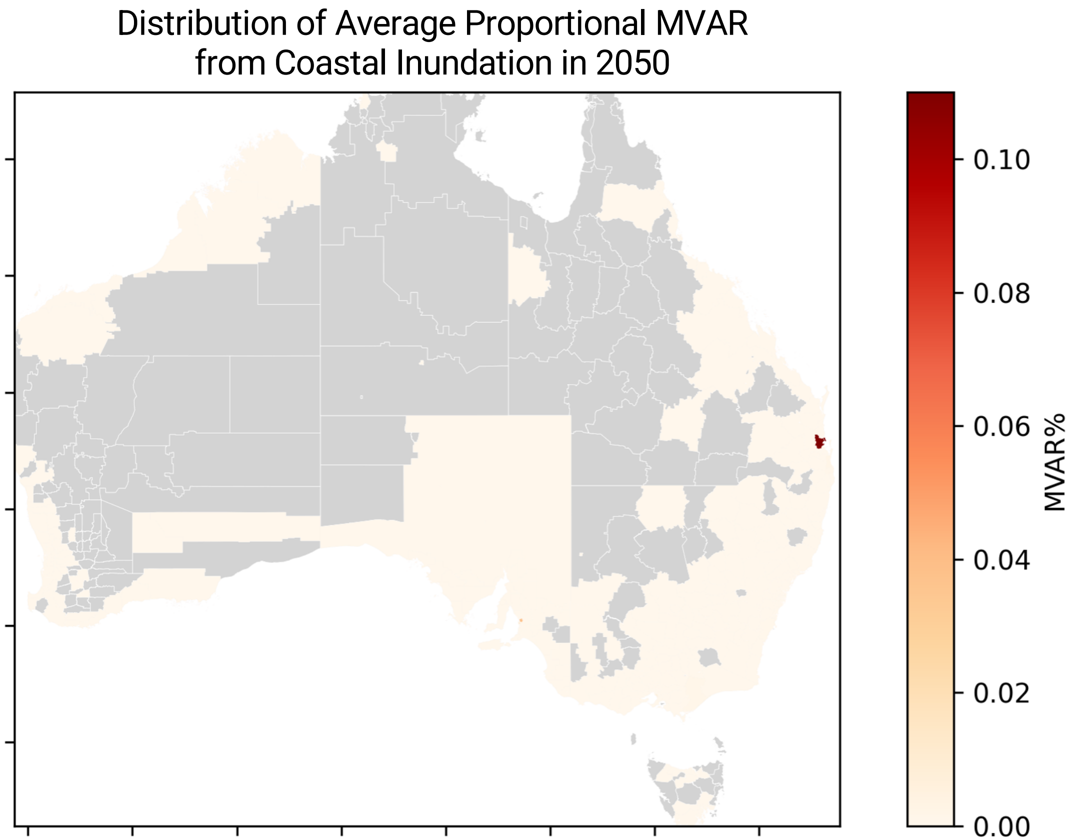
Coastal Inundation increases slowly until 2060, where it increases sharply until the end of the reporting period.

Note that sea levels will continue to rise for some time, even after global greenhouse gas concentrations have been stabilised, thus damage from coastal inundation is evident in the portfolio regardless of which RCP is selected.

MVAR% COASTAL INUNDATION OVER TIME



This graph shows the change in the MVAR% from Coastal Inundation over time under RCP 8.5, 4.5 and 2.6.


Distribution of Average Proportional MVAR
from Coastal Inundation in 2050
0.10
0.08
0.06
0.04
0.02
0.00
MVAR%

EXTREME WIND – CHANGE IN MVAR%

KEY TAKEOUT

Overall the projected MVAR% and the subsequent risks have increased with climate change and continue to rise of the century. Extreme Wind MVAR increases from **0.03%** in 2020 by **27%** to **0.38%** by 2050. Beyond the current modelling, there is a risk that rising Pacific and Indian ocean temperatures could cause cyclones to reach further south in future, exceeding the design standard of buildings in southern parts of the globe.

WHY IS THIS RESULT USEFUL

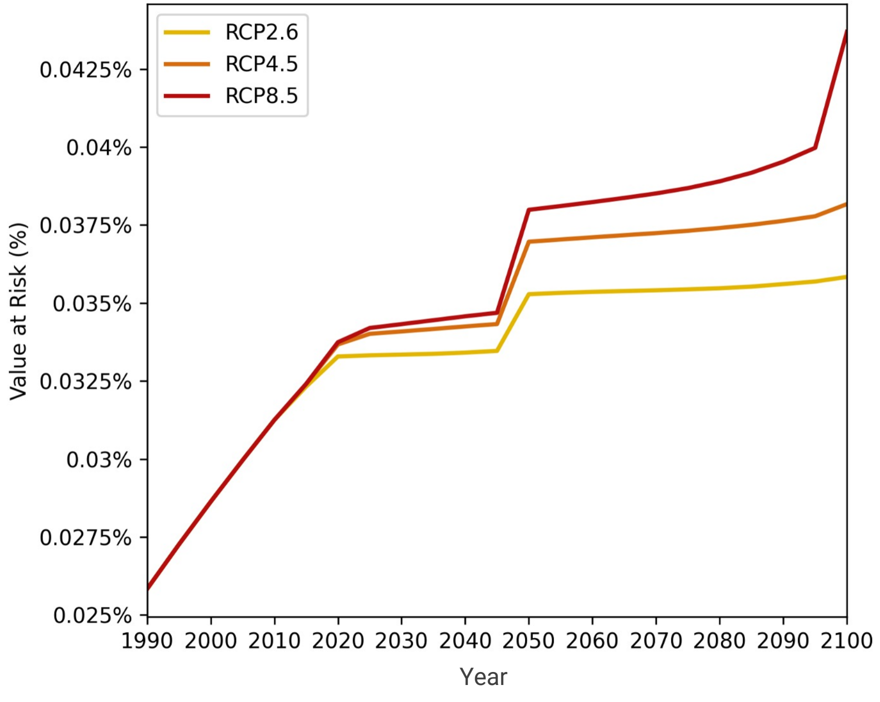
For each emissions scenario, this graph shows the average Extreme Wind MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the extreme wind hazard.

OBSERVATION

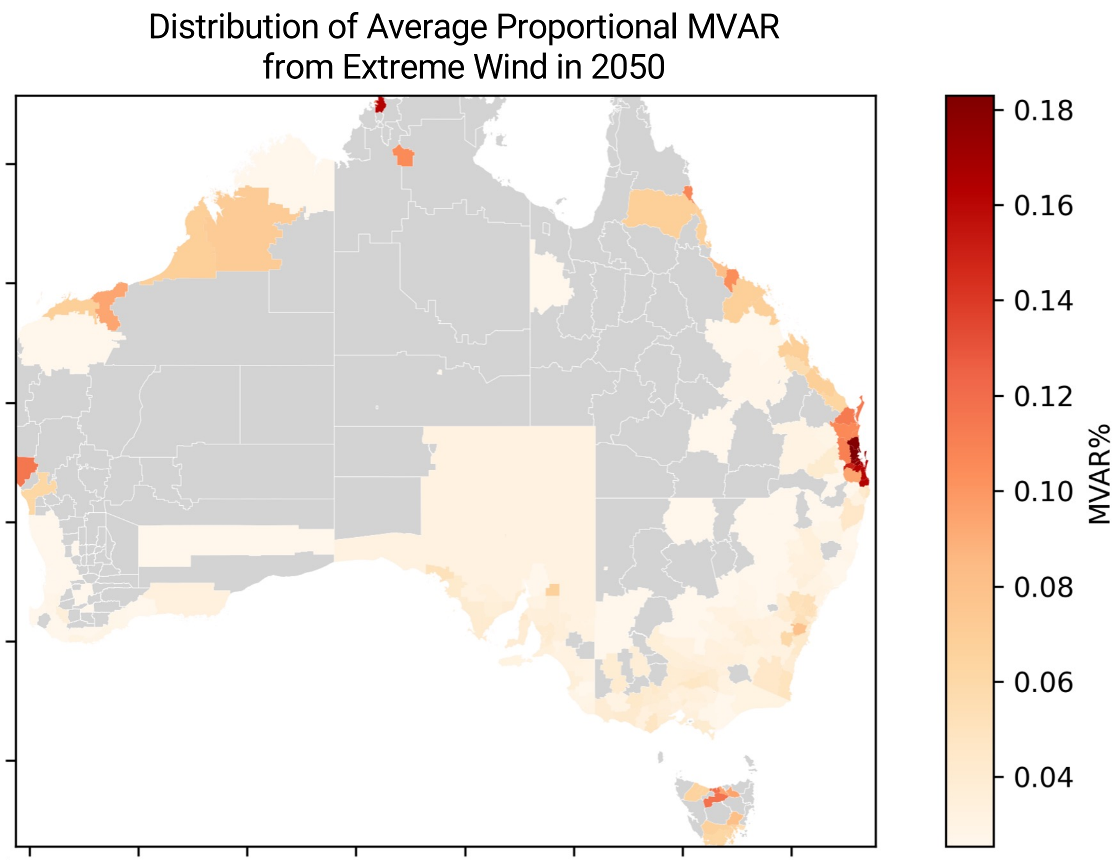
Extreme Wind risks to the portfolio from the climate models start low but increase steadily.

Most climate models have limitations with regard to wind; they do not yet model small convective storms.

MVAR% EXTREME WIND OVER TIME



This graph shows the change in the MVAR% from Extreme Wind over time under RCP 8.5, 4.5 and 2.6.


Distribution of Average Proportional MVAR
from Extreme Wind in 2050
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
MVAR%

KEY TAKEOUT

Forest Fire risk is driven by the confluence of low humidity, temperatures and high winds. Forest Fire MVAR increases **45.7%** from **0.018%** in 2020 **to 0.027%** in 2050 and by **144%** to **0.045%** by 2100. These are conditions are projected to increase exponentially under RCP 8.5 scenario, and be significantly contained under a the RCP 2.6 emission scenario.

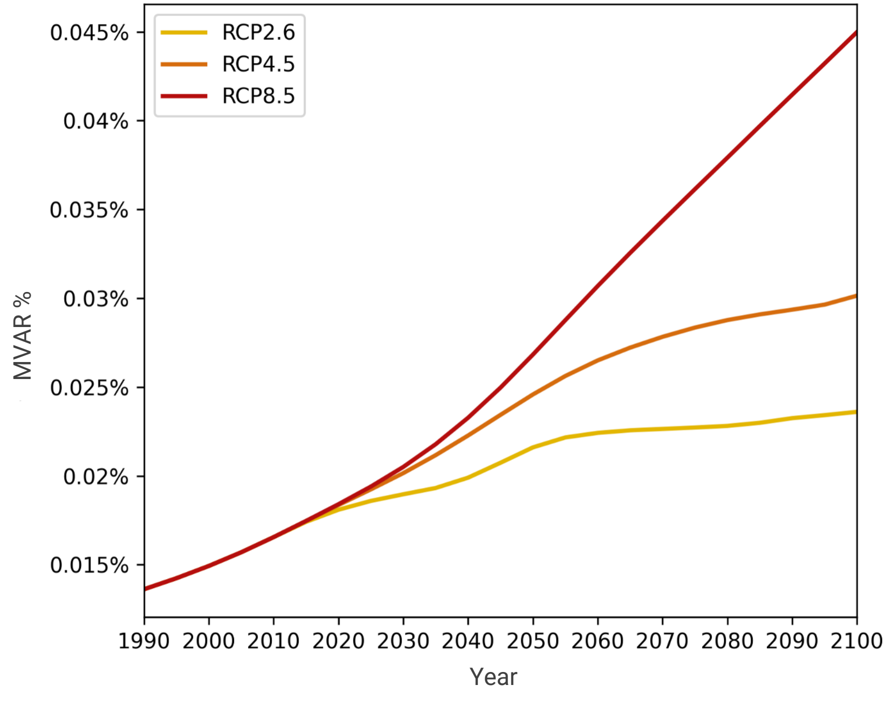
WHY IS THIS RESULT USEFUL

For each emissions scenario, this graph shows the average Forest Fire MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the forest fire hazard.

OBSERVATION

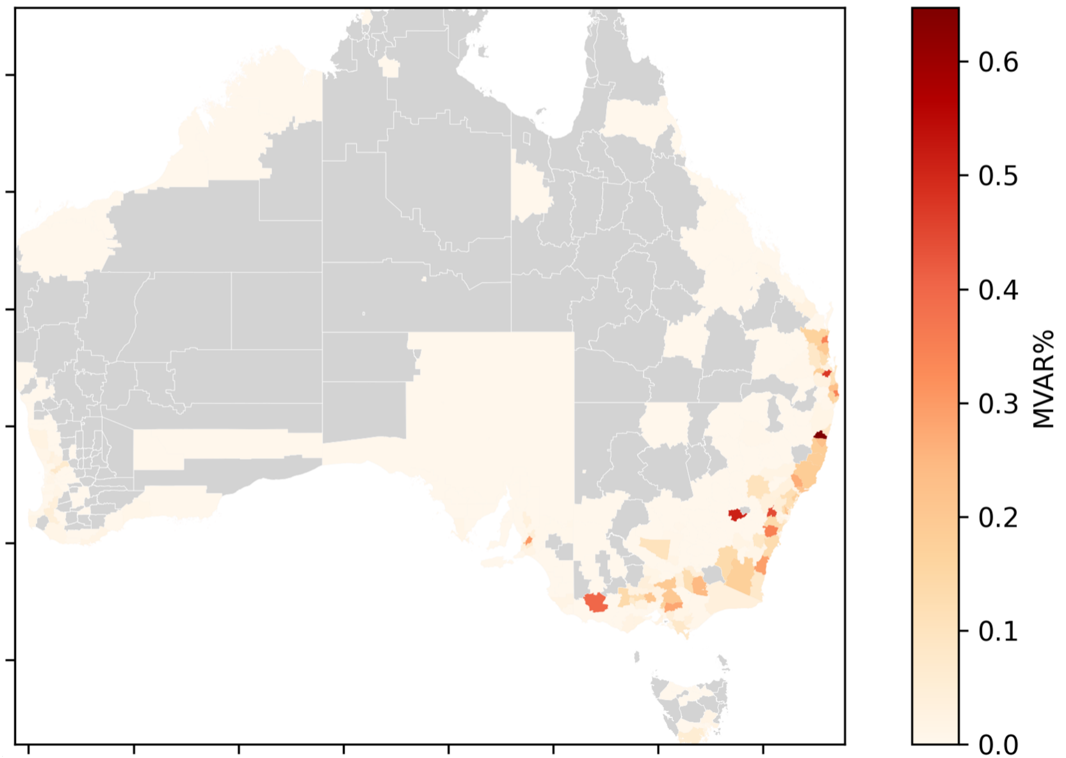
Forest Fire risk is driven by the confluence of low humidity, temperatures and high winds. There has already been a small increase from **0.014%** MVAR in 1990 to **0.018%** in 2020. This is projected to **almost double** to **0.027%** in 2050.

MVAR% FOREST FIRE OVER TIME



This graph shows the change in the MVAR% from Forest Fire over time under RCP 8.5, 4.5 and 2.6.

Distribution of Average Proportional
MVAR from Forest Fire in 2050



RIVERINE FLOODING – CHANGE IN MVAR%

KEY TAKEOUT

The portfolio's aggregate Maximum Value-at-Risk from Riverine Flooding under RCP8.5, shows significant growth, with a **34% increase** from 2020 to 2050 and a **218%** increase from 2020 to 2100. Lower emission pathways lower or curb the long term growth in flood risks.

WHY IS THIS RESULT USEFUL

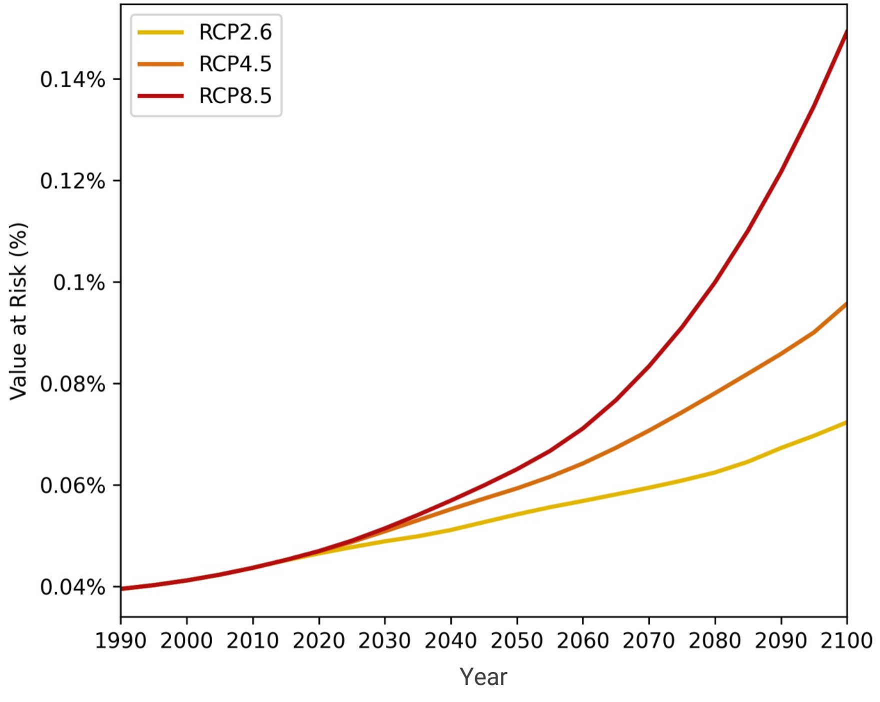
For each emissions scenario, this graph shows the average Riverine Flooding MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the riverine flooding hazard.

OBSERVATION

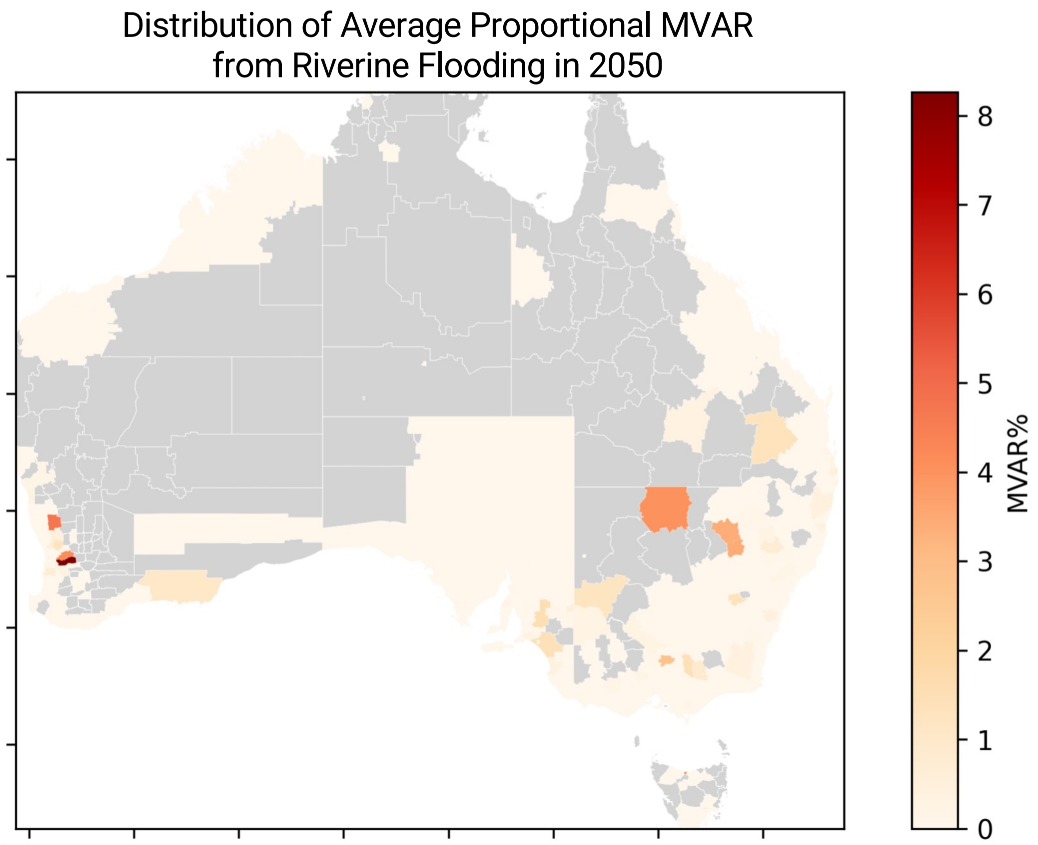
The portfolio's aggregate Maximum Value-at-Risk from Riverine Flooding under the RCP8.5 scenario, shows significant growth from 20202 leading to a **34% increase** by 2050 and a **218%** increase by 2100. There has already been a small increase from **0.04%** MVAR% in 1990 to **0.05%** in 2020.

Note that 40 years of change in risk probability between 1990 and 2030 appear to be unavoidable.

MVAR% RIVERINE FLOODING OVER TIME



This graph shows the change in the MVAR% from Riverine Flooding over time under RCP 8.5, 4.5 and 2.6.


Distribution of Average Proportional MVAR
from Riverine Flooding in 2050
8
7
6
5
4
3
2
1
0
MVAR%

KEY TAKEOUT

The modelling suggests Soil Subsidence Maximum Value-at-Risk in the residential mortgage portfolio has already increased due to an increased probability of droughts and this is projected to continue to increase over the century. Soil Subsidence MVAR increases by **85%** from **0.013%** in 2020 to **0.025%** in 2050 and **181%** to **0.037%** by 2100. These risks are generally non-catastrophic for an individual property, but can be widespread. Majority of insurers do not currently offer coverage for damage due to soil subsidence.

WHY IS THIS RESULT USEFUL

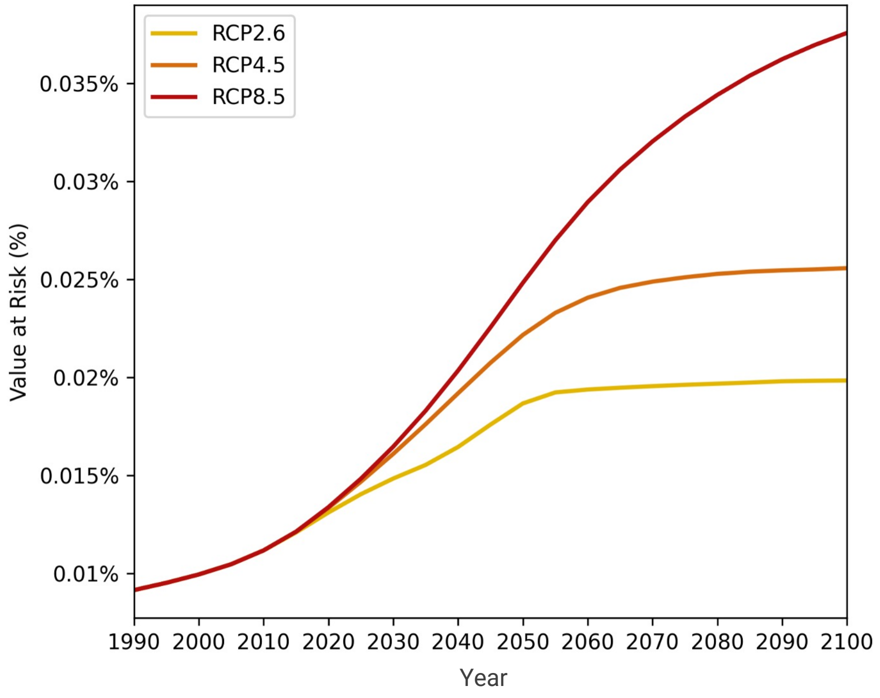
For each emissions scenario, this graph shows the average soil subsidence MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the soil subsidence hazard.

OBSERVATION

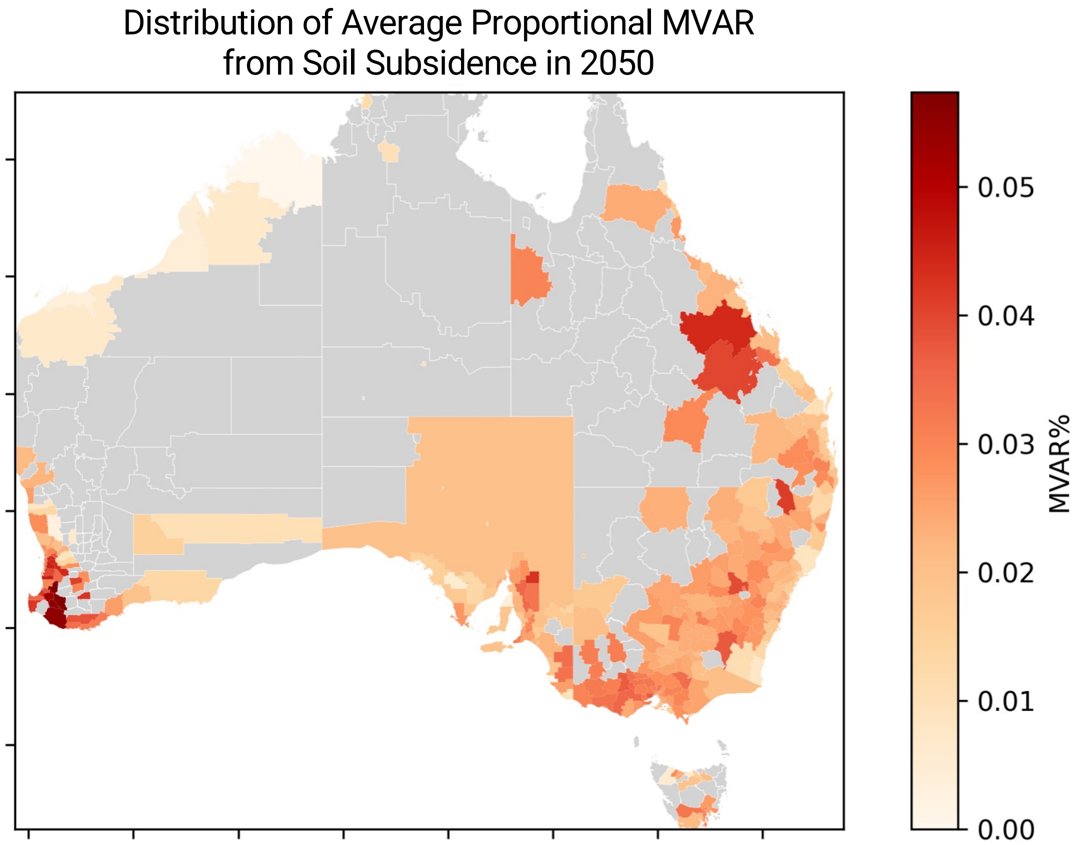
Under RCP8.5, the modelling suggests the portfolio's aggregate Maximum Value-at-Risk from Soil Subsidence has already increased from 1990 to 2020 due to increased probability of droughts.
There has already been a small increase from **0.010%** MVAR% in 1990 to **0.013%** in 2020. This is projected to almost **double** to **0.025%** in 2050 and **triple** to **0.038%** in 2100.

These risks are generally non-catastrophic for an individual property, but can be widespread.

MVAR% SOIL SUBSIDENCE OVER TIME



This graph shows the change in the MVAR% from Soil Subsidence over time under RCP 8.5, 4.5 and 2.6.


Distribution of Average Proportional MVAR
from Soil Subsidence in 2050
0.05
0.04
0.03
0.02
0.01
0.00
MVAR%

SURFACE WATER FLOODING – CHANGE IN MVAR%

KEY TAKEOUT

The portfolio's aggregate Maximum Value-at-Risk from Surface Water Flooding under RCP8.5 increases from **0.013%** in 2020 by **31%** to **0.017%** in 2050 and by **171%** to **0.035%** in 2100. Surface Water Flooding is significantly higher under RCP 8.5 for the second half of the century to 2100.

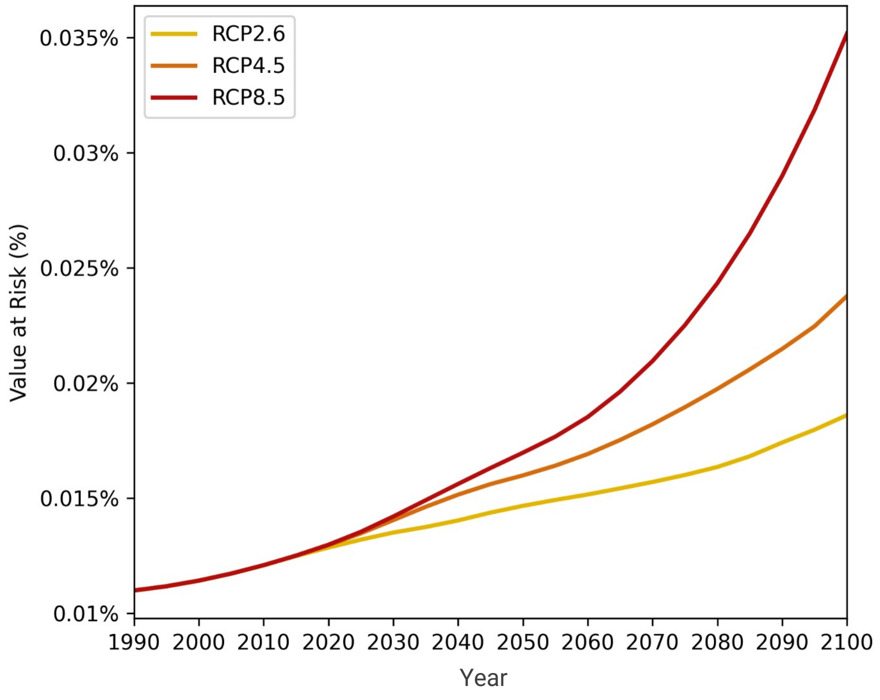
WHY IS THIS RESULT USEFUL

For each emissions scenario, this graph shows the average Surface Water Flooding MVAR% over the course of the century. This is useful in determining the severity of the financial risk present to the portfolio from the Surface Water Flooding hazard.

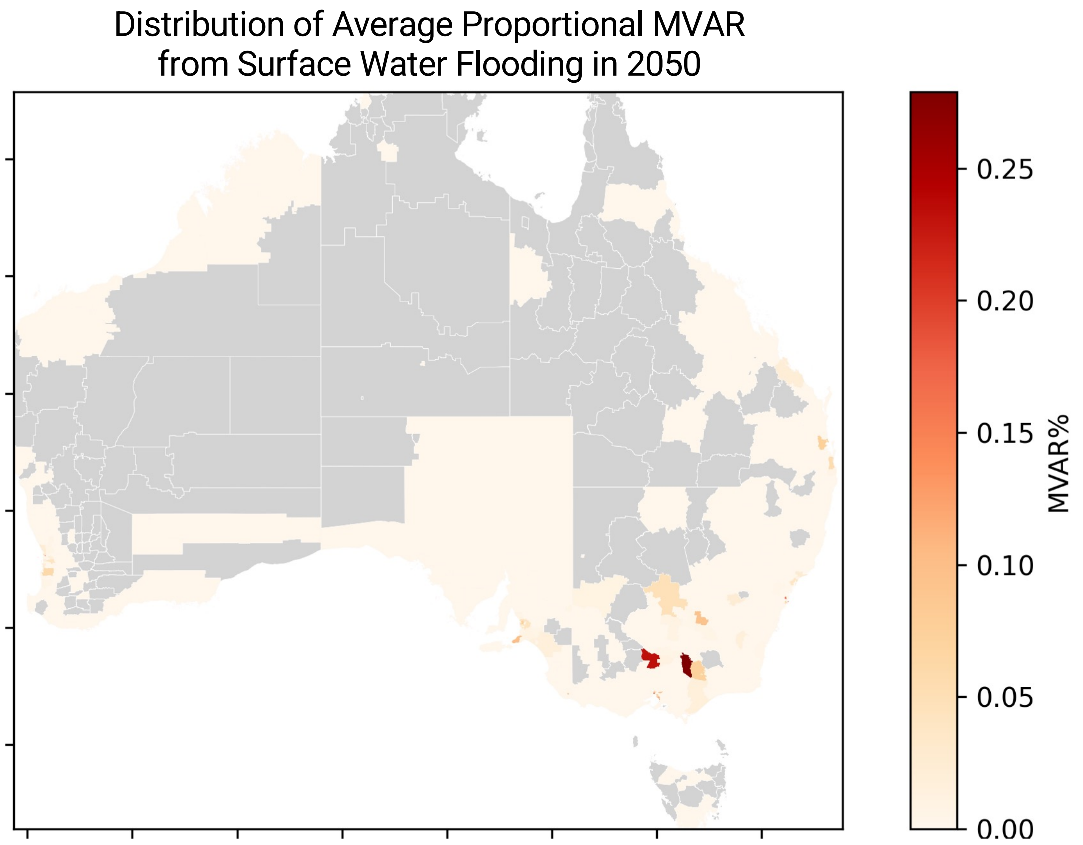
OBSERVATION

The portfolio's aggregate Maximum Value-at-Risk from Surface Water Flooding under RCP8.5 increases from **0.013%** in 2020 by **31%** to **0.017%** in 2050 and by **171%** to **0.035%** in 2100.
T

MVAR% SURFACE WATER FLOODING OVER TIME



This graph shows the change in the MVAR% from Surface Water Flooding over time under RCP 8.5, 4.5 and 2.6.


Distribution of Average Proportional MVAR
from Surface Water Flooding in 2050
0.25
0.20
0.15
0.10
0.05
0.00
MVAR%

APPENDIX

METHODS USED FOR ANALYSIS

These results have been generated using purpose-built software running on an array of high- speed servers provided by Climate Risk Pty Ltd. The Climate Risk Engines assess climate impacts by placing an archetype at each address analysed. Using the design specifications and materials typical of a recent building, the Climate Risk Engines compute the threshold at which its various key components would fail if exposed to hazards such as flooding, subsidence and forest fires.

Using this information, the annual probability of damage caused by such events is calculated by gathering a range of data on forests, soils, floods, elevations, tides, and waves, then coupling this with long term data from local meteorological stations. Finally, the future probabilities of damage are calculated by extracting the changes in the statistical distribution of key parameters such as heat, precipitation, wind and humidity from global climate change models.

THE CLIMATE RISK ENGINES

The Climate Risk Engines are purpose built to compute hypothetical future risks to a modelled asset (synthesised with engineering data) that is designed to represent property and infrastructure. The system enables each such asset to be stress-tested against a wide range of extreme weather and extreme sea events typical of its location. A range of future-looking scenarios can be applied that are consistent with different greenhouse gas emission scenarios, atmospheric sensitivity and response, adaptation pathways, building standards and planning regimes.

The Climate Risk Engines combine engineering analysis with statistical analysis of historical weather and climate projections, and probabilistic methods for financial analysis of risk and value. It's important to note that these results apply to a synthetic 'Representative Asset' under a range of future scenarios. The results cannot therefore be taken as representations of the actual future risks to, or value of, a real or planned property or infrastructure asset.

RISK ENVELOPE APPROACH

This analysis uses an IPCC greenhouse gas emission scenario that follows business-as-usual (RCP8.5), with climate modelling from CSIRO, UNSW, UQ, IPCC and NOAA used to indicate the impacts on weather parameters and sea levels (a full list of agencies accessed for data is provided in the appendix).

Models come from a short list of those that are known to perform well across a multitude of countries. Specific models are selected to 'stress test' each hazard - thus a model which tends to predict a drier future is used to consider drought, and a model which predicts a wetter future is used to test flood risk. This selection process avoids masking risks or diluting impacts through averaging an ensemble of models, however results should be interpreted as a stress- test, not a mean projection.

A REPRESENTATIVE ASSET

Initially the system creates a synthetic representation of an asset that is based on nominal industry archetypes, but may include some customisation by the user. This 'Representative Asset' could be selected and tailored to mimic a real asset at the same location – such as a house, road or phone tower – or be created as an entirely hypothetical asset being placed in that location.

INCLUDED HAZARDS

This analysis covers riverine flooding, surface water flooding, coastal inundation, forest fires, wind gusts and subsidence of clay soils. It does not cover other hazards such as coastal erosion, extreme heat, grass fires, freeze-thaw, land slip or hail.

MATHEMATICAL ANALYSIS

The extreme weather and climate risks to an asset will depend on its exposure and vulnerability to each hazard, as well as the current and future severity and frequency of the hazard that may alter with climate change. How each of these are handled by the Climate Risk Engines is discussed below.

HAZARD EXPOSURE

To understand if the Representative Asset is exposed to a hazard or not, contextual information about each location is gathered by the Climate Risk Engines. This may include information about the soils, tree cover, topology, elevation, flood plains, local tides or waves. Contextual information may even extend to current or historical national design standards for buildings or infrastructure.

Data is gathered on these contextual features from national and international sources selected on the basis of scientific methods used, accuracy, spatial resolution, completeness and the standing of the institution that has generated the information. The organisations from which data have been used are set out in the appendix of this document.

VULNERABILITY ANALYSIS; DAMAGE AND FAILURE THRESHOLDS

Each asset is tested for its ability to withstand the hazards to which it is likely to be exposed each year. The system tests both failure thresholds and damage thresholds.

A damage threshold is breached when an asset is affected by a hazard such that it is broken or excessively weakened. Examples might be flood waters damaging an electrical control system, or a wind storm blowing the roof off a house.

A failure threshold is breached when an element of the asset prevents the asset from performing is function. For example, when the roof is blown off in a storm it is both damaged and it fails to protect its occupants from the weather. However, it is possible to have failure without damage, for example an electrical control system that exceeds its operating temperature in a heat wave may stop the asset working, but there will be no damage (when the temperature drops it will start working again).

WEATHER DATE

To establish the precise probability that a hazard will exceed the coping threshold of an asset or element, information about the driving weather indicators may be needed, for example the likelihood of flooding is linked to the likelihood of extreme precipitation.

The Climate Risk Engines have access to 100,000 national weather stations around the world. Internal algorithms are used to select which stations to use when testing an asset based on proximity, data quality, duration and completeness. In some cases, the Climate Risk Engines may use a combination of data from more than one station or gridded data sets made by national meteorological centres.

CLIMATE CHANGE MODELING

Changes in the composition of the atmosphere due to greenhouse gas emissions will change how the atmosphere and oceans behave. Therefore, the historical weather station statistics need to be adjusted to allow for climate change.

The Climate Risk Engines have access to a large number of data sets from the Coupled Model Inter-comparison Project (CMIP) in which participant organisations model the atmosphere under various Representative Concentration Scenarios (RCP). At a whole of atmosphere scale the General Circulation Models (GCMs) have a resolution down to about 100km3.

With downscaling, Regional Climate Models (RCMs) include local topology and land surface information to provide weather parameters at higher spatial resolutions - between 5km3 and 50km3.

In the XDI Platform, users can select the GCM/RCM they wish to apply to the analysis of the Representative Asset. In this Physical Risk Report, the Climate Risk Engines select by default the most appropriate climate modelling to use based on: the models available in the region; the ‘skill’ of the model in capturing typical weather behaviour in a certain region; the range of parameters included or reported; the spatial resolution; and how the results of the model fit within the ensemble of other models for the region. The CORDEX set of projections has been used for all assets analysed in this project.

APPENDIX 2 - LOCATING XDI ANALYSIS IN TCFD LEADING PRACTICE

SUMMARY TABLE: XDI DELIVERY OF TCFD REPORTING RECOMMENDED PRACTICE

ELEMENTS OF PHYSICAL RISK ASSESSMENT	GUIDANCE AND RECOMMENDATIONS	WHAT XDI DELIVERS
HAZARDS	Storms, extreme rainfall, extreme heat, heatwave, flood, drought and wildfire, variability in precipitation and temperature, water stress, sea- level rise, land degradation (IIGCC 2020a). Heat stress, extreme rainfall, drought, cyclones, rising sea levels, wildfire and other industry-relevant and/or locally specific climate hazards across the corporate value chain (EBRD 2018).	XDI modelling incorporates eight climate hazards: coastal inundation (sea level rise), riverine flooding and pluvial flooding (extreme rainfall), extreme heat, wind (storms), soil contraction (effect of drought), freeze/thaw (effect of temperature) and forest fire.
TIMEFRAMES	Short and medium term: 2020-2040 (IIGCC 2020a, EBRD 2018). For this time frame, the EBRD recommends probabilistic risk analysis. Longer term: 2040-2100 (IIGCC 2020a, EBRD 2018). For this time frame, the EBRD recommends scenario-based analysis. The BOE's biennial exploratory scenario will model 2020-2050 but for the "no policy action" scenario, physical impacts in 2050 will represent expected physical impacts in 2080 (BOE 2019b).	The analysis is probabilistic from 2020 to 2100 for multiple climate scenarios ranging from "no policy action" (RCP8.5) through to "extreme policy action" (RCP2.6). Results can be presented in different decadal time steps (e.g. 2030, 2050 and 2100) depending on client requirements.
SCALE	Location (country or city) of key supplier facilities and critical business facilities with evaluation of their importance (EBRD 2018). Asset-level data and assessment with attention to downscaling limitations of models (IIGCC 2020a, CISL 2019).	XDI works at address and site level, data is aggregated from suburbs to national as required. Regional Climate Models (RCMs) include local topology and land surface information to provide spatial resolutions to between 5 and 50km square resolution. Further hazard layer context includes local weather data, elevation data, vegetation maps and wind zones with resolutions between 5 and 250 metres.
SCENARIOS	Most guidance for physical risk assessment recommend use of 2°C and 4°C pathways (CISL 2019, IIGCC 2020a). Consistent with IIGCC recommendation, the TCFD 2019 Status report indicates that RCPs 2.6 and RCP8.5 are commonly being used as best and worst case 2°C scenario and 4°C scenarios respectively.	XDI can model comparative effects of RCP2.6 and RCP8.5 and can also include RCP4.5 as a moderate mitigation pathway (which still results in average warming over 2°C).
DIRECT AND INDIRECT PHYSICAL CLIMATE IMPACTS	Direct and first-order: damage and loss of real assets, disruption to value chains, supply chain costs, lost hours of staff (IIGCC 2020a, EBRD 2018). Indirect and second-order: Insurance costs, energy costs, regulatory change, legal liabilities, market changes, borrowing costs, social license (IIGCC 2020a, EBRD 2018).	Direct and first-order: damage and loss of real assets, lost hours of staff, customer impact. Indirect and second-order: insurance premiums.

APPENDIX 2 - LOCATING XDI ANALYSIS IN TCFD LEADING PRACTICE

SUMMARY TABLE: XDI DELIVERY OF TCFD REPORTING RECOMMENDED PRACTICE

ELEMENTS OF PHYSICAL RISK ASSESSMENT	GUIDANCE AND RECOMMENDATIONS	WHAT XDI DELIVERS
METRICS AND OUTPUTS	Data: Most guidance recommended climate data overlaid with business data, within a socio-economic and regulatory context. Recent and historic impacts: EBRD recommends firms estimate current costs of extreme weather events, including days of business interruptions and associated costs, costs of repairs or upgrades, fixed-asset impairment, supply chain disruptions and lost revenues. Average Annual Loss (CISL 2019, BOE 2019b, EBRD 2018). Number of sites and business lines exposed to relevant climate impacts (EBRD 2019). Maximum Value-at-risk (EDRB 2018). Identification of critical thresholds (IIGCC 2020a).	Climate data overlaid with business asset data. Possible outputs include: • Average Annual Loss. • Total Technical Insurance Premium (TTIP), (total annual cost of damage assuming all hazards are insured) • Percentage of Maximum Value-at-risk (MVAR%), (TTIP as a percentage of the replacement cost of the property). • Number of High-Risk Properties (HRP#), (property assets where the MVAR is greater than 1%). • Percentage of High-Risk Properties (HRP%), (HRP# expressed as a percentage of all properties in the LGA). • Failure Probability. • Productivity Loss.
ADAPTATION MEASURES	Inclusion of asset-level and broader adaptation options in model (CISL 2019, BOE 2019b, IIGCC 2020a) including planned improvements, retrofits, relocations, or other changes to facilities.	In some projects, analysis of available adaptation measures at the address and locality scale and how they change risk profile. Evaluation of net risk exposure after adaptation applied.
STRATEGY, POLICY AND ADVOCACY	Supply-chain risk management strategy incl. engagement with suppliers on strategy (EBRD 2018). Engagement with local or national governments and local stakeholders on local climate resilience (EBRD 2018).	In some projects, cross dependency analysis identifies shared risk with upstream infrastructure including road access, water and power supply.

REFERENCES

Task force on Climate-related Financial Disclosure: The 2017 Final Report from the Task Force for Climate-related Financial Disclosure (TCFD 2017)

European Bank for Reconstruction and Development (EBRD): Advancing TCFD guidance on physical climate risks and opportunities (EBRD 2018)

Cambridge Institute for Sustainability Leadership (CISL): Physical risk framework Understanding the impacts of climate change on real estate lending and investment portfolios. (CISL 2019).

TCFS 2019 Status Report 2019: (TCFD 2019).

Institutional Investor Group on Climate Change (IIGCC): Understanding physical climate risks and opportunities – a guide for investors (IIGCC 2020)

Bank of England (BOE): Discussion paper for the 2021 Biennial Exploratory Scenario (BES) on the financial risks from climate change. (BOE 2019b).

Risk analysis of any type has inherent uncertainties. This is compounded in climate related risk analysis, as risk calculations combine information from many different sources, many of which change over time. Each of these sources of information contain uncertainties of some kind, and only a few of these types of uncertainties are reasonably quantifiable. Key sources of uncertainty in the XDI analysis methodology include:

Climate projections: This includes quantifiable uncertainty in historical weather observations and in model behaviour in response to driving variables (including emissions scenarios), as well as unquantifiable uncertainty around model structure, and likelihood of socio-political trajectories associated with proposed emissions scenarios.

Geospatial context data: This includes uncertainties in observed and modelled data representing various physical quantities that affect an asset's exposure to various climate-related hazards.

Asset vulnerability data: Every asset is different, and asset-specific data (e.g. material and design information) usually only captures some aspects of that variance. Much information about an asset that might heavily impact its vulnerability (e.g. how often the gutters of a house in a fire zone are cleaned), is not practically available or estimable.

Impact model structure: Models that can estimate the damage, system failure, and financial and human impacts to an asset in the event of a climate event need substantial data (e.g. historical impact data) to adequately constrain their design. This data is often only sparsely available.

In this analysis, uncertainty is captured and addressed in two key ways:

Firstly, each asset is analysed using the IPCC's RCP8.5 scenario, which presents the most high-risk possible future for which projections are available. Developed by International Institute for Applied Systems Analysis (IIASA) Austria, RCP 8.5 refers to a concentration of greenhouse gases that cause global warming temperature increase of between 3.2°C to 5.4°C by the end of 2100. RCP 8.5 represents the closest approximation to current business-as-usual socio-political outcomes, based on measured climate changes over the last few decades.

There are many modelling institutions around the world that have separately modelled the outcomes of an RCP8.5 concentration pathway. The Climate Risk Engines are programmed to select the climate model that represents the strongest driver for each hazard, for a given region of the globe. These projections are then adjusted to indicate the effects of lower emission pathways, according to calculated difference between using global projections for temperature for RCP8.5, RCP4.5, and RCP2.6. This enables a comparison with different socio-political scenarios.

Secondly, a representative sample of assets has been analysed using two different sets of assumptions about vulnerability, which help explore the uncertainty due to lack of asset-specific information. The MVAR for both the high and low resilience assets is calculated, and the higher and lower boundaries of possible risk distribution are determined.

The position of the 'Modern Building' archetype used in this study is then located within the distribution to determine the appropriate range of uncertainty to apply to the results. While this sensitivity analysis includes the likely range of forward-looking resilience, it is not a dynamic projection that accounts for changes to building standards and possible vulnerability over time. In order to account for uncertainty, sensitivity testing has been executed across a sample of random assets within the portfolio, using both high and low resilience archetypes. The results from this sensitivity testing place the 'Modern Building' archetype (on which the body of the analysis was conducted) within the lower quartile of the risk distribution. By applying the results from this sensitivity test, its likely that the actual portfolio risk could be up to 30% higher than quoted results.

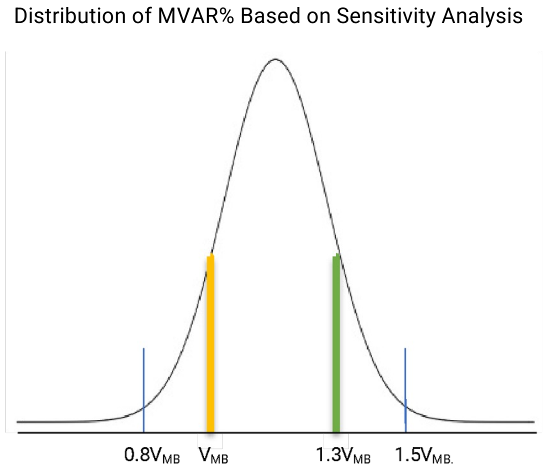
A sensitivity analysis suggests that the range of Maximum Value-at-Risk for the Portfolio sits between 22% and 30% either side of the median. The 'Modern Building' archetype used in this study is at the higher resilience end for flood, coastal inundation and wind–storms, but with no special provisions for subsidence or forest fire. Thus a high resilience asset would have approximately 22% lower Maximum Value-at-Risk than the 'Modern Building' archetype upon which this study was conducted. Similarly a low resilience asset would result in a MVAR% approximately 50% higher than the 'Modern Building' archetype. A high confidence can be given to the MVAR% range between the reference data contained within this report and a MVAR% of 30% higher. This range should be assumed to apply to all other risk matrix provided throughout the report.

HOW IS THIS RESULT CALCULATED?

A sample set of high and low resilience assets are analysed individually. The average MVAR for both is calculated, including median and difference. The position of the 'Modern Building' archetype is estimated within the distribution and a proposed uncertainty range around the reference archetype data is identified.

CAVEATS & ASSUMPTIONS

The mix of building designs and standards will change over time, and while this sensitivity analysis includes the likely range of forward looking resilience, it is not a dynamic projection changing in vulnerability over time. Assuming a normal distribution of MVAR, the sensitivity analysis provides the results for the higher and lower resilience archetypes (blue lines). The actual position of the whole portfolio is likely to lie between the "Modern Building' archetype (red line) and up to 30% higher (green line).



Schematic distribution of Maximum Value-at-Risk (MVAR%) for the sensitivity analysis using the 'Modern Building' archetype (V_{MB}) as the reference.

COASTAL INUNDATION

OVERVIEW

Flooding caused by sea-water is referred to as Coastal Inundation. It can be caused by high tides in combination with elevated water levels driven by winds, low air pressure, waves and the dynamics at the sea-land interface. Over the course of the century, climate change is projected to result in elevated sea levels, which will increase the frequency and severity of coastal inundation events.

ASSET DATA

The vulnerability of an asset to coastal inundation is based on the elements present at the property, the relative elevations of each exposed element and the behaviour of the materials used in that element when exposed to water. Most critical is the elevation of the Civil element (e.g. floor heights), as empirical data shows a sharp increase in loss once water breaches the normal floor level. XDI can adjust elevations for individual assets (to override that of the archetype), or for sensitivity testing and adaptation planning.

CONTEXTUAL DATA

Coastal inundation levels are referenced relative to the national height datum taken from a range of international digital elevation models. In more populated areas, where airborne light detection and ranging (LIDAR) surveys have been conducted, these models typically have a 5X5 m horizontal resolution, and a height resolution of a few centimetres. In less populated areas, where the source of geospatial data is commonly satellite imagery, the resolution may be 30x30m, with uncertainty of at least 0.5 m.

BASELINE HAZARD DATA

Seal level data is based on an array of national tidal gauges located around the world. These tide gauges provide a spectral probability distribution of tide levels, including during extreme sea events, based on empirical measurements.

CLIMATE CHANGE PROJECTIONS

Currently the average global sea level is rising by 3.2 mm per year (NASA, 2017). The IPCC has established a series of sea level rise projections for different emissions pathways (Church et al 2013) for the scenarios known as RCP 8.5, RCP 6.0, RCP 4.5 and RCP 2.6. These provide the Climate Risk Engines with a nominal ‘likely’ range of 0.28 m to 0.98 m of sea level rise by 2100 (including 95% confidence bounds). The system includes two projections from a United States National Oceanic and Atmospheric Administration (NOAA) report (Sweet et al 2017) outlining (less likely but still possible) 'High' (2 m) and 'Extreme' (2.5 m) 2100 average global sea level rise scenarios. XDI’s analysis also includes an intermediate projection (Haigh et al 2014) and a 1.1 m by 2100 projection to match the Australian Government’s research into coastal impacts (Department of Environment 2009).

EXTREME WIND

OVERVIEW

Air travelling at high speeds, even in short gusts, can cause direct damage to buildings and infrastructure assets. High winds can also cause indirect disruption when trees drop limbs onto power lines or debris puts life and property at risk. General increases in the amount of moisture in the air caused by warming can change convective forces in storms and the severity of down draughts.

XDI does not currently analyse risks associated with cyclones and convective storms, due to:

- unavailability of the very high-resolution modelling outputs required
- difficulty in making clear statements about changes in cyclone frequency, duration or intensity, as for a individual given location a cyclone is actually quite a rare event.

ASSET DATA

The wind speed design threshold for each asset is assumed to follow national building code for the year of build or re-build. Increased design resilience may be applied for dwellings that have been built beyond code requirements to specific wind speed thresholds or return frequencies. Reduced resilience may be applied based on empirical wind performance data.

CONTEXTUAL DATA

No context data layers are used for the extreme wind hazard

BASELINE HAZARD DATA

Bias correction for wind damage is disabled by default, as wind data is only very sparsely available at the required record length and quality. This does not however pose a problem, as the Climate Risk Engines use asset-level probabilistic wind tolerance thresholds (such as 1:500 year), and calculates the physical wind speed threshold from this probabilistic threshold over the baseline period. This means that a bias in the wind data will not affect the results, as we are only looking at the trend in risk relative to the baseline, and the wind tolerance design threshold as specified by the relevant building code.

CLIMATE CHANGE PROJECTIONS

Climate projections are used to establish baseline wind gust speed for threshold return frequencies and then used to project how this speed changes over time. The main climate variable used is the 2-10 second wind gust speed or the 1-5 minute maximum wind speed, depending on how the relevant projection was produced.

FOREST FIRE

OVERVIEW

Forest fires can destroy buildings and infrastructure through direct flame or intense radiant heat. Assets considered to be at risk are those under or surrounded by trees, or close enough to trees to be affected by intense thermal radiation should the forest catch on fire. Grass fires are also a potential risk but are not covered by XDI's analysis.

ASSET DATA

The exposure of the elements of an asset (e.g. roof, walls, floor) to a forest-fire are defined within each asset archetype.

CONTEXTUAL DATA

Context layers used for the forest fire hazard are as follows:

- Global Land Analysis and Discovery's per pixel estimates of circa 2010 maximum tree canopy cover percentages (at growing season peak period), derived from cloud-free annual growing season composite Landsat 7 ETM+ data
- An economic activity intensity layer, used to moderate fire weather projections based on the assumption that more urbanised areas face lower overall fire risks as they have better fire prevention and suppression capabilities.
- An empirical ignition probability model, which is based on analysis of insurance loss data.

BASELINE HAZARD DATA

The driving parameters of forest fire are temperature, humidity, wind speeds and forest-fire prone land. The Hot-Dry-Windy index (HDW) is a new index of fire-weather based on maximum wind speed and vapour pressure deficit (VPD, the difference between the absolute humidity and the water vapour saturation point for a given temperature). The forest fire hazard layers in the Climate Risk Engines use forest canopy cover from satellite data in conjunction with algorithms to account for proximity and surrounded-ness for a specific location. The baseline annual probability of ignition draws upon empirical data on annual average forest fire extents, as well as on typical natural and human caused ignition rates.

CLIMATE CHANGE PROJECTIONS

Gridded projections for future epochs, based on GCM/RCMs from CORDEX are used to project the changes to the key inputs for the HDW index.

RIVERINE FLOODING

OVERVIEW

XDI computes fluvial flooding - also known as riverine flooding as opposed to sea water or surface level flooding.

ASSET DATA

The vulnerability of an asset to flooding is based on the elements present in each archetype, the relative elevations of each exposed element, and the assumed behaviour of the materials used in that element when exposed to water. Most critical is the elevation of the Civil element (e.g. floor heights), as empirical data shows a sharp increase in loss once water breaches the normal flood level (Bundaberg Regional Council 2014). XDI can adjust elevations for individual assets (to override that of the archetype), or for sensitivity testing and adaptation planning.

CONTEXTUAL DATA

Flood maps used in the Climate Risk Engine analysis contain water depths and flood extents for each of a number of flood events characterised by Return Periods (RPs - such as 1 in 100, 1 in 20 and 1 in 50). The Climate Risk Engines use flood data from multiple sources, including various commercial providers, as well as regionally specific flood data. In general these datasets contain information on water depths for 4-8 different RPs. The Climate Risk engines interpolate between these layers to estimate the return probability for a flood that would breach the asset floor height (and in some cases specific element heights). This return period is then used as a threshold for the climate projection risk estimates.

BASELINE HAZARD DATA

To consider changes to the probability of flooding due to climate change, projected changes to precipitation must be examined. For historical data, annual maximum 24-hour precipitation weather station data for the 30 years pre-2000 is used. Only data sets with at least 20 years of data are considered to have sufficient statistical depth. Regionalisation, which is the process of combining distant data sets to create longer time series for a given location, is not applied.

CLIMATE CHANGE PROJECTIONS

Climate change impacts on precipitation and flooding are computed through the locally downscaled modelling of future precipitation changes (using CORDEX GCMs/RCMs). A commonly used approximation for calculating increased flood risk is the application of a 5% increase in precipitation intensity for each degree rise in global mean temperature (Ball et al 2016). This factor can be applied to modelled or measured Intensity-Frequency (IF) curves for any given location.

SURFACE WATER FLOODING

OVERVIEW

XDI computes pluvial flooding - also known as surface water flooding as opposed to sea water or riverine flooding.

ASSET DATA

The vulnerability of an asset to flooding is based on the elements present in each archetype, the relative elevations of each exposed element, and the assumed behaviour of the materials used in that element when exposed to water. Most critical is the elevation of the Civil element (e.g. floor heights), as empirical data shows a sharp increase in loss once water breaches the normal flood level (Bundaberg Regional Council 2014). XDI can adjust elevations for individual assets (to override that of the archetype), or for sensitivity testing and adaptation planning.

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Flood maps used in the Climate Risk Engine analysis contain water depths and flood extents for each of a number of flood events characterised by Return Periods (RPs - such as 1 in 100, 1 in 20 and 1 in 50). The Climate Risk Engines use flood data from multiple sources, including various commercial providers, as well as regionally specific flood data. In general these datasets contain information on water depths for 4-8 different RPs. The Climate Risk engines interpolate between these layers to estimate the return probability for a flood that would breach the asset floor height (and in some cases specific element heights). This return period is then used as a threshold for the climate projection risk estimates.

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SOIL SUBSIDENCE

OVERVIEW

Low soil moisture within reactive clay soils is a trigger for major soil movement and cracking, as the process of lower level suction leads to clay soils drawing moisture away from the surface soils during drought. Shrinking and subsequent swelling can lead to extensive asset damage if the asset's foundations move. Buildings on light strip footings or unstiffened slabs are particularly vulnerable to soil movement.

ASSET DATA

The vulnerability of assets to severe soil movement is associated with the design of foundations, and less so with the type of materials used. Foundations can be designed to cope with soil movements and such designs are captured at the archetype level. For foundations vulnerable to soil movement, an empirical probability of damage is assigned to the civil elements.

CONTEXTUAL DATA

Assets are initially checked to test for the types of soils upon which they are located, and thereby the level of exposure to soil movement. XDI's analysis uses soil clay percentage (at 30 cm depth) data, derived from the International Soil Reference and Information Centre's Soil Grids global digital soil mapping system.

BASELINE HAZARD DATA

For the soil movement due to drought hazard, XDI assumes 'drought' to equate to 'serious rainfall deficiency', defined as the circumstance in which annual total rainfall is in the lowest decile (that is lowest 10%) of records for the local region (Bureau of Meteorology 2012). The probability of droughts occurring at an asset's location is based on interrogation of data from the nearest historical weather stations and rain gauges. The annual precipitation data is extracted, and the rainfall consistent with the lowest 10% of annual precipitation is analysed. This provides a base probability for drought conditions that may lead to soil movement.

CLIMATE CHANGE PROJECTIONS

Soil movement in reactive soil types is correlated with the amount of moisture within the soil. Most changes in soil moisture content are caused by seasonal climate variations and precipitation volumes. Downscaled data for 'drought' is drawn from the GCMs and RCMs. Generally, XDI selects the drier GCMs/RCMs which also have the highest spatial resolution.

Bank X Report