Appendix B Flood Damages Assessment

REPORT

Tonkin+Taylor

Waipoua Flood Damages Assessment

Prepared for
Greater Wellington Regional Council
Prepared by
Tonkin & Taylor Ltd
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1 Purpose and objectives

Greater Wellington Regional Council (GWRC) operates a flood protection scheme for the Waipoua River to protect Masterton and provide flooding and erosion protection to adjacent rural land. This is part of GWRC's wider statutory responsibility for its river schemes in the Wairarapa, focussed on the Ruamāmanga main stem and significant tributaries. GWRC also has statutory responsibilities to investigate and manage flood risk. GWRC's chosen approach to managing its river schemes and flood risk is Floodplain Management Planning (FMP).

The Waipoua River is part of the Te Kāuru FMP. The urban reach of the Waipoua River was not included in the Te Kāuru FMP, as agreement could not be reached on management options at the time and further work was required. The work of completing the Plan for the urban reach of the Waipoua River has now been picked up by the Waipoua Project Group.

The purpose of this project is to help inform decision making on the flood risk management options for the Waipoua River, including various levels of flood protection. It is expected to be used to compare the flood benefits of different options in terms of the reduction in flood damages, in comparison with the base scenarios presented here.

This project estimates annual average damages (AAD) for flooding from the Waipoua River catchment and subsequent area of interest within the Masterton District. The scope of the project is presented in Section 3 following a discussion regarding the background information for Flood Damage Assessment in Section 2.

Summary	The purpose of this report is to present the method and results for the Waipoua flood damages assessment, and present AAD estimates for the area at risk of flooding from the Waipoua River.
Why is this important?	To understand and make better informed decisions in terms of flood risk management options for the Waipoua River. Decisions around future options for flood management will have significant cost and other impacts/benefits for the community.
Who is this for?	GWRC Knowledge Business Unit, Waipoua Project Team
Alignment	This project is part of a wider programme of work being carried out by GWRC on the flood risk of the Waipoua River, which includes other investigations and options development work.
Deliverables	Flood Damages Assessment Report, including AAD and electronic deliverables (spreadsheets and python code)
Approver(s) of deliverables	Francie Morrow
What triggers the need for an update?	Changes in statutory and/or non-statutory responsibilities Changes in objectives of stakeholders Changes in the underlying data or the direction of the overall Waipoua programme of work.

2 Background information - flood damage assessments

Defining and understanding the different types of flood damage is important for informed decision making and the implementation of effective flood risk management strategies. Having a good grasp of expected flood damage (both in dollar terms and more qualitatively) provides a sound basis for understanding the risk and choosing between flood management options. The types of flood damage can broadly be categorised as direct and indirect, tangible and intangible, and can also be evaluated in terms of economic damage or financial damages. These categories and additional discussion regarding the concept of Annualised Average Damages (AAD) are discussed in the following sub-sections.

2.1 Direct and indirect flood damage

Direct flood damage occurs through the physical contact of flood waters with human beings, properties, or any objects, leading to immediate loss or impairment. Examples include water damage to homes, infrastructure, and personal belongings. Indirect flood damage is secondary to the direct impact. It occurs as a consequence of the flood, but not as a result of water contact itself. This may include disruptions to travel, business, and public services, and can also involve more complex economic disruptions.

For example, a business that is physically unaffected by a flood may still suffer indirect damage through loss of access to raw materials or markets if the flooding disrupts transportation routes. Meanwhile, households may experience indirect damage due to loss of income if workplaces are flooded or become inaccessible.

2.2 Tangible and intangible flood damage

Tangible flood damages are those that can be directly measured in monetary terms. Repairs to buildings, replacement of lost stock, and remediation of farmland are examples of tangible damages.

Intangible damages are those that are difficult to measure in monetary terms, such as emotional distress, loss of life, and health impacts. While challenging to quantify, it is important not to ignore these damages when assessing the overall impact of floods.

2.3 Average Annual Damages

Average Annual Damage (AAD) is a useful tool for expressing flood risk, particularly for comparative purposes. It is obtained by evaluating the damage associated with each flood event across a range of likelihoods. Once the full range of frequency events are considered (i.e. frequent to extreme) the AAD represents the damage averaged out on an annual basis.

AAD is key in cost-benefit analyses (CBA), as it allows decision-makers to weigh the costs of flood mitigation against expected annual losses and compare options against each other. A crucial aspect of AAD calculation is to include, as far as practicable, all flood events that may cause damage to avoid underestimation.

It is important to note that whilst AAD calculations are a useful tool for assessing flooding impacts, there are likely to be intangible damages and other impacts of flooding that require consideration. For example, an outcome from AAD assessment can prioritise the protection of properties in higher socio-economic areas over properties in lower socio-economic areas due to the influence of property value (i.e. more investment can be justified to protect a $1M home over a $500k home). Use of AAD alone can lead to unsatisfactory outcomes.

When using AAD to determine the present value of future costs and benefits, the duration of investment and discount factor are important considerations. This helps answer questions like, “what is the total value of damage from flooding over a 30-year period?”. The discount factors apply a lower weight to future costs and benefits, reflecting the time value of money (having $100 now is worth more than receiving $100 in ten years’ time). Discounting has not been taken into consideration for this stage of the project but will need to be included when future options are being considered.

2.4 Economic and financial damages

The distinction between economic and financial damages becomes important when performing formal CBA. Economic damages reflect the depreciated values of goods at the time flooding occurs, considering that one person's loss may be another's gain, thus implying a view from the community or regional/national economy's perspective. For example, a damaged house (loss) will be repaired by a construction business (gain). It is important to clearly define the boundaries of the system when assessing economic damages (for example, considering how to treat flows of insurance claim money into a regional economy after a flood event). Properly assessing economic damages typically involves economic modelling.

Financial damages relate to the full replacement value directly incurred by individuals or entities. These are generally much easier to assess but may overestimate damage due to this implicit improvement/betterment. Deciding between these two approaches can depend on funding mechanisms for flood risk reduction projects and broader policy implications.

This flood damage assessment considers financial losses only.

3 Scope of assessment

The scope of the flood damages assessment covers direct and indirect losses and intangible losses. The in-scope items are described in Table 3.1.

Both direct and indirect losses will be assessed within the AAD. The intangible losses are described in a qualitative manner.

Table 3.1: In-scope items

Direct damage	Indirect damage	Intangible damage (not included in AAD calculations)
Building damage (residential, industrial, commercial, outbuildings)	Residential relocation costs	Risk to life
Residential contents		Non-financial impacts related to damage to essential community facilities
Vehicles		Discussion of differing vulnerability in the community and the types and scale of intangible impacts that may be relevant
Commercial/ industrial contents		General discussion and summary of expected intangible damages
Cleanup costs		
Costs of remediating areas of deposition and/or erosion on agricultural land		

Table 3.2 below describes those items that are not within the scope.

Table 3.2: Out of scope items

Direct damage	Indirect damage
Transport, 3 Waters and other utility assets	Personal or business disruption costs and/or loss of income
River management/flood protection/river monitoring assets	Business displacement/relocation
Community facilities	Emergency management costs
High potential loss sites	Economic consequences/analysis
Hazardous material facilities	Liabilities of any party
Rural damages besides buildings and deposition/erosion e.g., fencing, roading, stock losses	Assessment of any economic benefits (as opposed to costs) of flooding
Differences in losses due to longer or shorter warning time	
Undefended (banks down) losses	

3.1 Flood information

A series of different likelihood flood events have been assessed by GWRC for the Waipoua River. The flood events consider present day climate and future climate scenarios and three breach scenarios of the stopbank system. The future climate scenarios represent the 2100 timeframe and an additional two climate change scenarios for the 2050 timeframe were also received. These future climate scenarios consider the Representative Concentration Pathway (RCP) 6.0 scenario. No further information was provided alongside the breach scenario datasets. Therefore, no location or nature of breach has been taken into account in this assessment.

A further three flood scenarios were provided to test the sensitivity of the flood modelling. These datasets have been detailed below.

A list of the flood scenario datasets received is described below:

- 39% AEP with and without climate change;
- 20% AEP with and without climate change;
- 10% AEP with and without climate change;
- 5% AEP with and without climate change;
- 2% AEP with and without climate change;
- 2% AEP + climate change 2050;
- 1% AEP with and without climate change;
- 1% AEP + climate change 2050;
- 0.1% AEP with and without climate change;
- Breach01 – Left Bank Oxford Street (1% AEP + climate change 2100);
- Breach02 – Right Banks down – Railway Crescent and Top of Matahiwi;
- Breach03 – All Banks down;
- Sensitivity Scenario 5: increase in flow by 20% (1% and 2% AEP events); and
- Sensitivity Scenario 1: increase in Manning's 'N' by 20% (1% AEP event).

A flood damage assessment has been carried out for each of the scenarios. However, not all of these scenarios have been included in the AAD analysis. Due to the complexity associated with breach scenarios, and the substantial impact attaching a likelihood to these events can have on the AAD, they have been excluded from the AAD value. The 2050 climate change scenarios and sensitivity scenarios have also been excluded from the AAD due to a lack in range of AEP.

4 Method

The following section outlines the method used for assessing direct, indirect and intangible losses for the flood damage assessment.

Due to the inherent uncertainty that lie with many of the FDA components, each of the following sub-sections discuss the basis for making a best estimate of flood damage and an upper and lower estimate.

4.1 Direct damages assessment

To estimate direct damages, the relationship between damage and causation factors (e.g. flood depth, velocity or duration) on an asset type (e.g. building, vehicle or land) is referred to as a fragility function. For the purposes of this study, only depth-based fragility functions were utilised.

There are a range of fragility functions that represent the relationship for different elements such as buildings (residential, commercial and industrial), and vehicles. In general, there is a lack of available New Zealand focussed fragility functions. Approximately 1,000 damage samples were collected following flood events across New Zealand between 2013 and 2023 (Paulik & Wotherspoon, 2023) and we understand that a further 1,000 samples were collected across Hawkes Bay and Tairāwhiti regions following Cyclone Gabrielle in 2023. These records (~2,000) are unavailable to support this study. Our choice of fragility function is discussed in the following section where we have attempted to balance contrasting flood fragility information from overseas (e.g. United States, Europe, United Kingdom, Australia) with historic New Zealand information. The lack of access to quality flood damage records across New Zealand continues to affect the quality of Flood Damage Assessments.

4.1.1 Buildings

Residential, commercial and industrial buildings were provided by GWRC in separate geospatial layers for the area of interest within the Masterton District. The delineation of commercial, industrial and residential buildings was already established in the layers provided.

The total number of building polygons received was 2,910. These were split into two categories:

- Urban.
- Rural.

The rural buildings are those located within a "productive land" spatial layer provided by GWRC. The productive land layer represents the areas classed as productive in the Masterton area. Urban buildings are those located within the area of interest that do not sit within the "productive land" area. Of the 2,910 buildings received, 2,598 were residential (2,493 urban, 105 rural), 196 were commercial and 116 were industrial. No commercial or industrial buildings were located within the productive land layer.

Additional information was also provided that contained supplementary building information regarding wall construction, age, and valuation data. This information was not available for all buildings in the dataset.

Figure 4.1 presents the different fragility functions used for residential, commercial and industrial buildings. The information regarding wall construction and age was used to inform the fragility functions of choice. Where this additional information was not available, a default function was applied. These default functions were agreed upon due to their general alignment with the buildings in Masterton. For further detail on the specific functions assigned to each building type, refer to Appendix A.

Australian fragility curves from NCCARF (2013) are ~30% higher on average within the 0 to 0.5 m depth range (above floor level) in comparison with the NIWA (2010) fragility curves used. Flood depths within the 0.5 m above floor level are typical for flooding in Masterton. However, in this depth range, the Hazus curves give results up to ~10% lower (FEMA, 2022). This variability in the damage functions led to the adoption of a factor of -10% for the lower bound and +30% for the upper bound.

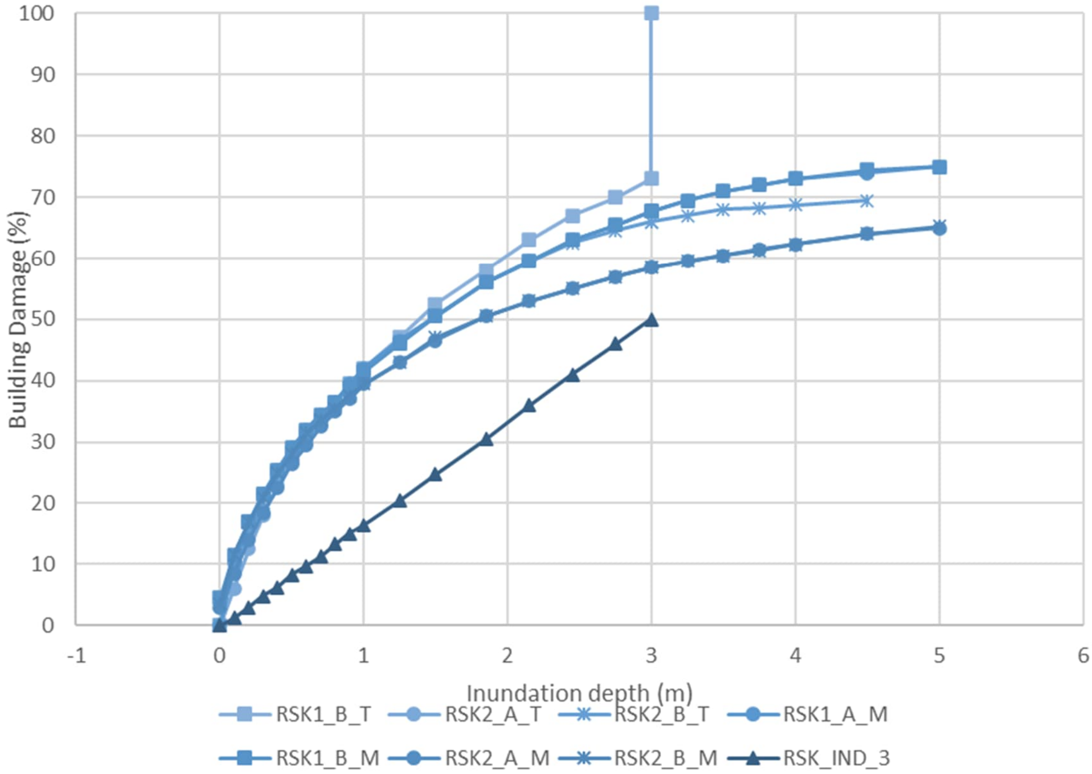

Figure 4.1: Fragility functions used in this assessment for buildings (residential, commercial and industrial) (NIWA, 2010).

Table 4.1 below presents the assumptions made for buildings in this assessment.

Table 4.1: Assumptions (buildings)

Input	Assumptions
Residential buildings	• Residential building depth damage curves from NIWA, 2010. • Where building wall construction type and age information could be joined easily in the database, this information was used to assign the appropriate fragility function. Where this information was not available, the NIWA 'timber, one storey, 1960 – 1980' fragility function was used. • No storey information exists for residential buildings, therefore it has been assumed all residential buildings are one storey. • The improvement value for each building was used in our assessment as replacement costs were not available. An improvement value could be assigned to 99% of buildings in the area of interest. Where an improvement value was not available, the capital value was used (0.6%). There were 0.4% (33) residential buildings without an improvement or capital value, therefore were assigned a default value of $191,889. • Lower bound: estimated value -10%. Upper bound: estimated value +30%.
Residential outbuildings	• Outbuildings have not been considered in this assessment, due to a lack of appropriate data to assess building damage, their likely small impact on the flood damage assessment, and the large number of buildings that are “outbuildings”. • All buildings less than 40 m^2 have been excluded from the assessment.
Commercial buildings	• It was confirmed with GWRC that most commercial buildings in Masterton would best fit the ‘masonry’ fragility function from NIWA, 2010. Therefore, this has been applied across the area of interest due to a lack of specific fragility functions available for commercial buildings. • The number of storeys for each of the commercial buildings was provided by GWRC and was used to apply the appropriate fragility function. • The improvement value for each building was used in our assessment as replacement costs were not available. An improvement value could be assigned to 92% of buildings in the area of interest. Where an improvement value was not available, the capital value was used (6%). There were 2% (3) of commercial buildings without an improvement or capital value, therefore were assigned a default value of $674,306. • Lower bound: estimated value -10%. Upper bound: estimated value +30%.
Industrial buildings	• The industrial building depth damage curves from NIWA, 2010 were used. • It was agreed that the ‘industrial, 3 m high ceiling’ fragility function was to be used, as there was no storey or ceiling height information available. • The improvement value for each building was used in our assessment as replacement costs were not available. An improvement value could be assigned to 86% of buildings in the area of interest. Where an improvement value was not available, the capital value was used (8%). There were 6% (7) industrial buildings without an improvement or capital value, therefore were assigned a default value of $280,028. • Lower bound: estimated value -10%. Upper bound: estimated value +30%.

4.1.2 Vehicles

No vehicle data was available for each of the individual properties across the area of interest. Therefore, it has been assumed that every residential house has 1.7 cars, and that all cars are parked at home during the flood event. This is based on the average number of cars per household from the 2018 Census data for Masterton. No consideration of commercial/industrial car parks has been included in this assessment.

The NIWA 2016 vehicle damage function was used to assess damage to vehicles during flood events (Figure 4.2) (NIWA, 2016). Further assumptions are described in Table 4.2.

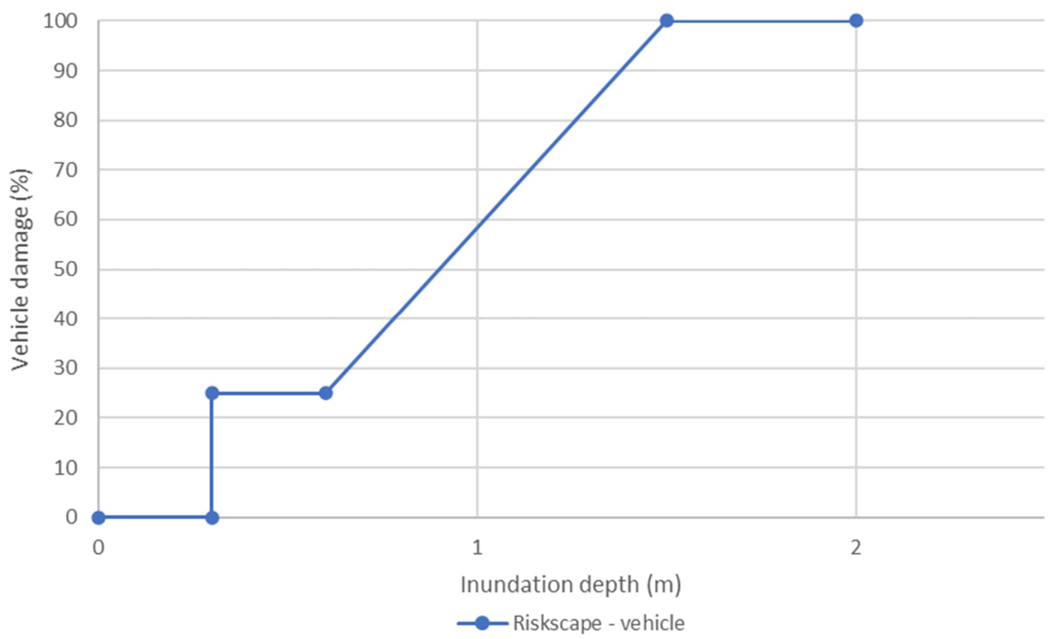

Figure 4.2: Fragility functions used in this assessment for vehicles (NIWA, 2016).

Table 4.2: Assumptions (vehicles)

Input	Assumptions
Vehicles	• Damage ratio is presented based on NIWA, 2016 depth-damage curve. • That every household has 1.7 vehicles (based on average census data), and these are associated with every flooded residential building in the area of interest (i.e. the cars are all parked at houses). • That every flooded household has a ‘large’ car as it is the average type across the available fragility functions. • An upper and lower bound in terms of car value has been applied. It has been assumed that the lower bound is $8,000, and the upper bound is $16,000. We do not have supporting evidence to justify these valuations and should be treated as a high-level estimate to support the flood damage assessment only. Where more comprehensive car valuation information is available, then this could be incorporated into future assessments.

4.1.3 Contents

Supporting information to value contents/stock/plant was not available for any of the building types included in this assessment. To allow for inclusion in the AAD, a process was followed to establish an appropriate upper and lower contents value per building. The following process was completed:

- 21 residential buildings across the Masterton area were sampled.
- The Sum Insured CIRCA Net Contents Calculator was used to understand approximate contents values across the 21 buildings.
- Of the 21 buildings sampled, 12 were located within the area of interest and included an improvement value.
- Analysis was completed to understand the contents value as a percentage of improvement value for these 12 properties. This ranged from 40%-70% across these properties.
- Upper and lower bounds for residential contents values across the study area were then derived:
  - 40% of improvement value – lower bound; and
  - 70% of improvement value – upper bound.

To establish contents costs for commercial and industrial buildings, the approach taken in both the Hazus and European Union papers was applied for buildings where the contents value is unknown (Joint Research Centre, 2017). This gave an upper and lower bound of:

- 100% of improvement value – lower bound; and
- 150% of improvement value – upper bound.

Literature highlights similarities and differences between contents damage for commercial, industrial and residential buildings. In particular, the amount of cabling and electronic equipment in an office or retail store is typically higher than a residential property. Despite there being rationale to increase the percentage damage to 5% as soon as flood depths exceed floor level residential contents damage curves have been applied for all building uses. Some of the uncertainty is accounted for by using an upper and lower bound fragility curve. The following functions were used to establish contents damage for residential, commercial and industrial buildings (Figure 4.3):

- Hazus 2022 (residential contents – first floor); and
- NIWA 2010 (residential contents).

Figure 4.3 below outlines that there is crossover between the two functions at shallower flood depths. As a result, the lowest resulting value was used for the lower bound estimate, and the highest for the upper bound estimate. This was combined with the lower and upper bound improvement values described above.

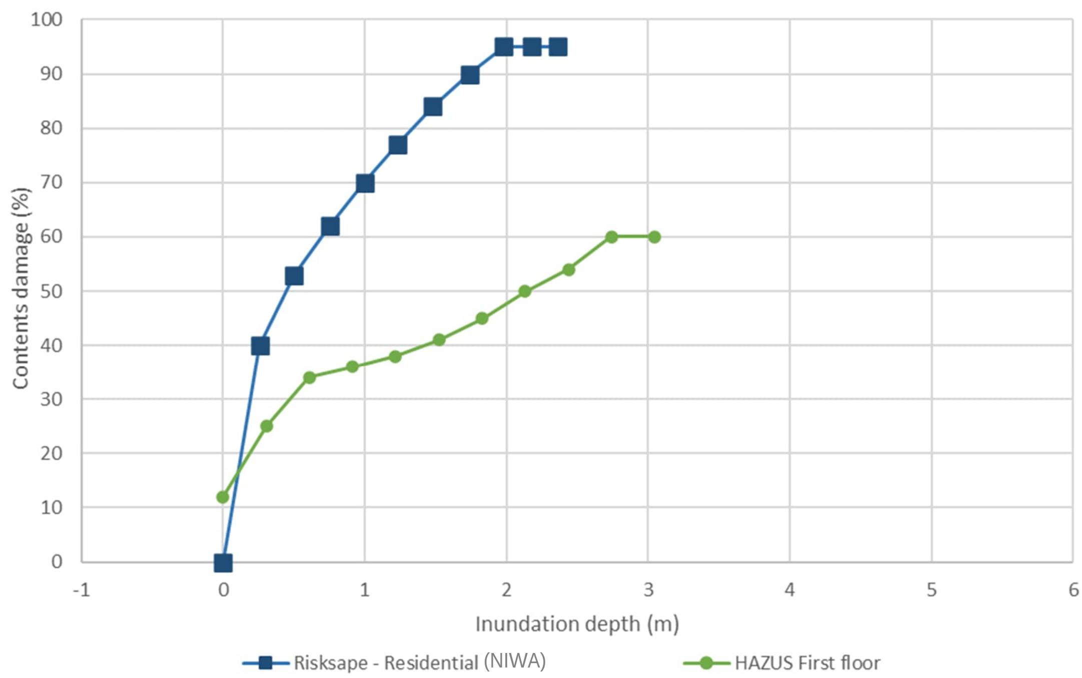

Figure 4.3: Contents fragility functions used in the assessment.

Further assumptions are described in Table 4.3.

Table 4.3: Assumptions (contents)

Input	Assumptions
Residential, commercial and industrial contents damage	• Both the NIWA 2010 and Hazus 2022 functions have been used to assess the contents damage for residential, commercial and industrial buildings. Due to the crossover between functions, the lowest resulting value was used for the lower bound estimate, and the highest for the upper bound estimate (Figure 4.3). • Contents value has been assumed for all buildings, as this information was not available. This is based on 100% of building value (lower bound) and 150% of building value (upper bound). • The NIWA contents fragility function assumes that when a building has a flood depth of 1.5 m or greater above floor level, that contents damage is 95% of the direct building damage (as shown in Figure 4.3). • The delineation between commercial, industrial and residential buildings was pre-determined in the layers provided by GWRC.

4.1.4 Cleanup costs

There is likely to be considerable cleanup costs associated with flood events. The extent and cost of cleanup will depend on the size of the event, and the type of buildings damaged. There are a few different approaches that can be undertaken to estimate cleanup costs:

- Time and materials (labour costs plus number of machines for number of days); and
- Price per square metre / price per building.

For the purposes of this assessment, the "price per square metre/ price per building" approach has been taken. The UK Department of Environment, Climate Change and Water (DECCW) residential stage-damage curves make allowance for residential cleanup costs at approximately $4,800 per building at 2007 prices (DECCW, 2007). We have increased this cost to reflect 2024 prices. When calculating this with the Reserve Bank inflation calculator, the price of this in 2024 terms is $7,500 (General CPI), and $11,000 (Housing). These have formed our upper and lower bound for residential buildings. Any building where flood depth is above floor level, has been applied with the same cleanup cost.

The floor areas of commercial and industrial buildings across the area of interest are more commonly larger than residential buildings. For this reason, the upper and lower bound values used above were multiplied by 2.5 to represent the cleanup costs associated with commercial and industrial buildings.

Note that infrastructure cleanup costs have not been considered in this flood damages assessment. Table 4.4 presents the assumptions for cleanup costs.

Table 4.4: Assumptions (cleanup costs)

Input	Assumptions
Clean up costs	• The DECCW, 2007 residential stage-damage curves were used to estimate a cleanup cost per building. When indexing it to 2024 prices, it was established that the lower bound was $7,500 (Stats NZ General CPI index), and the upper bound was $11,000 (Stats NZ Housing index). • Due to commercial and industrial building being larger than residential buildings, the values above were multiplied by 2.5, as the average commercial and industrial building was approximately 2.5 times the average residential building.

4.1.5 Rural damage approach

A 'productive land' geospatial layer was provided by GWRC. This layer distinguishes the different land use types across the area of interest, with a total of 21 different types. For further detail on the land use types available, refer to Appendix B.

The approach adopted for assessing productive land damage from flooding utilises the previous work done by GWRC in 2014, which estimated depth-damage values in terms of dollars per hectare. This is understood to have taken both production losses and direct damage into account, so is a mix of direct and indirect damage. GWRC's 2014 assessment relies in large part on a 2004 report by AgFirst for Bay of Plenty Regional Council for the Whakatāne floodplain, which gave depth-damage curves for three land uses. GWRC extrapolated these results to seven land types present in the study area. These depth-damage relationships are shown in Table 4.5, below.

The damage values have been indexed from 2014 to 2023 dollars.

The values from 2014 were indexed to Q3 2023 (the last quarter for which data was available) through consideration of three indices published by Stats NZ:

- Farm Expenses Price Index;
- Capital Goods Price Index; and
- Producers Price Index.

These gave results in the range of 29 % to 52% increases since 2014; therefore, a value of 40% was adopted.

The functions used in 2014 covered 78% of the rural land being assessed for this project. The remaining 22% includes ‘unspecified’ and ‘not farmed’ land types, so while our assessment covers less than 100% and more than 78% of the productive rural land, we cannot be sure exactly how much without further investigation.

Due to a number of significant assumptions made above in adopting, indexing and applying the 2014 GWRC depth-damage values, these results should be considered high-level and interim only. To increase confidence, GWRC may wish to consider carrying out a similar study to the 2004 Whakatāne analysis in order to establish up-to-date depth-damage relationships for the land uses present in the study area. An upper and lower bound of +/- 30% from the estimated value was adopted.

Table 4.5: Rural damage ($/hectare)

Depth (m)	Beef	Dairy	Deer	Grazing	Lifestyle	Sheep	Sheep and Beef
0	0	0	0	0	0	0	0
0.5	361	1159	361	361	682	361	361
1	578	2117	578	578	1077	578	578
1.5	1449	5299	1449	1449	2699	1449	1449
2	1747	6269	1747	1747	3112	1747	1747
2.5	2106	6875	2106	2106	3972	2106	2106

Note: These have been derived from the GWRC 2014 report, that references a 2004 report by AgFirst for Bay of Plenty Regional Council. This report looked at different land use types in the Whakatāne floodplain.

Rural buildings have been identified as those located within the productive land layer. These have been assessed the same way as all other residential buildings (refer to Section 4.1.1). They are separated out within the AAD calculations of Section 5.

4.2 Indirect damages assessment

Indirect damages relate to a resulting impact not attributed to direct contact with the flood water. For this assessment, only relocation costs for residential building occupants have been considered as the indirect damage for inclusion in the AAD.

The costs associated with displacement relate to the duration of displacement and the rental costs. There are additional relocation costs which were not considered.

It has been assumed that all flood damaged residential building occupants will be displaced for a temporary period of time. The NIWA 2010 function for relocation has been applied (Figure 4.4) (NIWA, 2010). Other assumptions made are documented in Table 4.6.

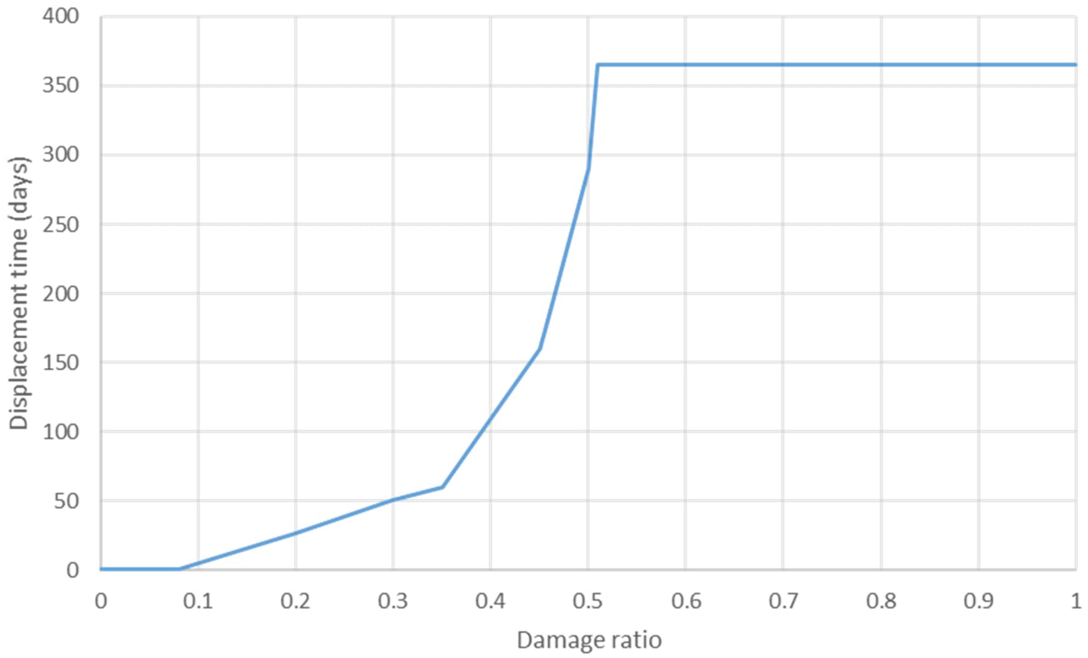

Figure 4.4: Damage function for estimating the duration of displacement

Table 4.6: Assumptions (indirect damages)

Input	Assumptions
Residential relocation expenses	• Weekly rent costs have been assumed from Infometrics (Infometrics, 2024). For the lower bound: residential buildings are assumed to have a weekly rent of $469 (regardless of size). For the upper bound a weekly rent of $529. • Duration of displacement is based on damage-to-loss function from NIWA, 2010. This assumes that all flood damaged residential building occupants will be displaced for a temporary period of time.

4.3 Intangible damages assessment

Intangible damages are those that either cannot or have not been expressed in an economic value, particularly within the scope of a Flood Damage Assessment. They include aspects such as human health and safety (including mental health), community vulnerability and loss of livelihood. Importantly, GWRC have requested that human life is reported as an intangible, as opposed to assigning a value to human life.

To assess the intangible damage of risk to life, the Australian Rainfall and Runoff (ARR) classification has been used (Figure 4.5) (Australian Government, 2019). Those hazard zones within H3-H6 have been included in our assessment due to the consequences associated with the criteria. For example, from H3 and above it is deemed unsafe for all vehicles and pedestrians, with H6 being unconditionally dangerous.

Table 4.7 describes how each of the intangible elements within scope have been assessed in this assessment.

Table 4.7: Intangible damage approach

Input	Approach
Risk to life	• The number of houses and length of road located within hazard zones H3-H6 (refer to Figure 4.5) have been presented. These different metrics can be compared for different mitigation options just like AAD can be. • As agreed with GWRC these metrics have not been converted to the number of people at risk.
Non-financial impacts related to damage to essential community facilities	• Qualitatively described in Section 5.5.2
Discussion of differing vulnerability in the community and the types- and scale of intangible impacts that may be relevant	• Qualitatively described in Section 5.5.2 • Key features in the area of interest can be found on Figure 5.2. Note these key features have been identified by the Waipoua Group as key features across the area of interest. Only those features that could be found on Google Maps were included on the map.
General discussion and summary of expected intangible damages	• Qualitatively described in Section 5.5.2.

Hazard Classification	Description (and defined limits)
H1	Relatively benign flow conditions. No vulnerability constraints. (D < 0.3 m, V < 2.0 m/s, or V x D < 0.3)
H2	Unsafe for small vehicles. (D < 0.5 m, V < 2.0 m/s, or V x D < 0.6)
H3	Unsafe for all vehicles, children and the elderly. (D < 1.2 m, V < 2.0 m/s, or V x D < 0.6)
H4	Unsafe for all pedestrians and vehicles. (D < 2.0 m, V < 2.0 m/s, or V x D < 1.0)
H5	Unsafe for all pedestrians and vehicles. Buildings require special engineering design and construction. (D < 4.0 m, V < 4.0 m/s, or V x D < 4.0)
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. (D > 4.0 m, V > 4.0 m/s, or V x D > 4.0)

Figure 4.5: Australian Rainfall and Runoff (ARR) hazard classification

4.4 AAD calculation

Calculating AAD essentially integrates the area under a curve of damage (per AEP event) plotted against the AEP. Put another way, it sums up the damage for all events from a small (frequent) to a large (rare) flood and multiplies this by its probability of occurring in a particular year, to give the damage expected each year on average from floods of all sizes.

$$\sum_{n=1}^{x} interval \times \frac{(damage\; n\,) + (damage\; n+1\,)}{2}$$

5 Results

The following section presents the results of the flood damage assessment for each of the scenarios presented in Section 3.1. Some of these scenarios are then used to inform the AAD assessment results.

5.1 Total flood damages

Table 5.1 presents the flood damages results for each of the flooding scenarios assessed. It is presented as a range, to reflect the uncertainty in the assessment. The following inputs have been considered in this assessment:

- Damage to buildings (residential, commercial and industrial);
- Vehicles;
- Contents;
- Cleanup costs;
- Relocation costs; and
- Rural damage.

Table 5.1: Flood damages results

Flood scenario	Lower bound	Upper bound
Present day		
39.35% AEP	$12,806	$23,782
20% AEP	$46,492	$89,380
10% AEP	$88,320	$169,580
5% AEP	$716,384	$1,415,082
2% AEP	$4,855,645	$9,916,691
1% AEP	$8,185,853	$16,726,505
0.1% AEP	$27,210,111	$54,022,251
Climate change (2100)		
39.35% AEP	$32,886	$67,813
20% AEP	$77,238	$151,391
10% AEP	$545,672	$1,060,555
5% AEP	$3,608,687	$7,219,087
2% AEP	$10,545,792	$21,295,860
1% AEP	$21,482,681	$42,367,328
0.1% AEP	$92,208,153	$175,794,418
Climate change (2050)		
2% AEP	$5,669,417	$11,602,280
1% AEP	$11,693,157	$23,298,813
Breach scenarios (1% AEP 2100 climate change)		
Breach 01	$19,574,191	$38,624,767
Breach 02	$25,036,272	$48,555,250
Breach 03	$20,892,058	$41,165,896

Note: only the “present day” and “Climate change (2100) results are used in the AAD assessment.

5.2 AAD

The results of the AAD have been split into two, to communicate both the "present day" (Table 5.2) and "2100 climate change" flood scenarios (Table 5.3). These tables present those inputs assessed in this scope of work only. For further detailed AAD tables, refer to Appendix C.

Table 5.2: AAD Summary (present day)

Input	Best estimate for building damage	Lower bound	Upper bound
Residential buildings damage	$70,613	$63,552	$91,797
Residential building contents damage		$32,885	$104,885
Vehicles		$9,521	$19,041
Industrial building damage	$4,758	$4,282	$5,710
Industrial building contents damage		$30,755	$93,645
Commercial building damage	$52,256	$47,030	$67,933
Commercial building contents damage		$72,954	$189,869
Productive land		$16,482	$28,211
Rural housing	$4,817	$4,335	$6,262
Rural housing contents		$2,594	$8,720
Rural vehicles		$585	$1,170
Relocation expenses		$7,454	$8,328
Cleanup costs		$75,444	$110,652
AAD	$132,444	$367,874	$736,223

Table 5.3: AAD Summary (2100 climate change events)

Input	Best estimate for building damage	Lower bound	Upper bound
Residential buildings damage	$257,513	$231,762	$334,767
Residential building contents damage		$125,278	$360,983
Vehicles		$32,187	$64,374
Industrial building damage	$15,148	$13,633	$19,692
Industrial building contents damage		$89,254	$241,942
Commercial building damage	$159,621	$143,659	$207,507
Commercial building contents damage		$210,181	$536,852
Productive land		$27,775	$51,583
Rural housing	$19,789	$17,810	$25,726
Rural housing contents		$9,585	$31,466
Rural vehicles		$1,495	$2,990
Relocation expenses		$20,569	$22,982
Cleanup costs		$198,748	$291,497
AAD	$452,071	$1,121,936	$2,192,361

The AAD estimates range between approximately $367,800 and $736,200 for the present day, increasing to between $1.1 million and $2.2 million as a result of climate change out to 2100. The AAD values does not include intangible damages.

Table 5.4 presents the approximate contribution from each of the items to the AAD. The table considers both existing and future climate scenarios.

Table 5.4: AAD distribution

Input	Proportion of AAD
Residential buildings damage	13-18%
Residential building contents damage	8-14%
Vehicles	3%
Industrial building damage	~1%
Industrial building contents damage	7-11%
Commercial building damage	9-13%
Commercial building contents damage	19-26%
Productive land	4-7%
Rural housing	1-2%
Rural housing contents	1-2%
Rural vehicles	<1%
Relocation expenses	1-2%
Cleanup costs	15-21%

The results highlight that despite the significant increases in damage as a result of climate change, the relative contribution from each of the assessed items remain similar (less than 5% variability up or down). Commercial contents costs contribute the highest proportion to the AAD (19-26%), followed by cleanup costs (14%-21%), and residential building damage (12%-20%). This reflects the generally shallow nature of the flooding in the scenarios assessed, and the fact that the commercial area of Masterton is disproportionately affected.

Urban damage accounts for 93% of the AAD for the non-climate change scenarios, and 95% when considering the climate change scenarios. Anecdotally, we understand that the dominance of urban damage is consistent with previous flood damage trends observed out in the Wellington region.

5.3 Sensitivity analysis

Table 5.1 presents the flood damages results for the three additional flood sensitivity scenarios. It is presented as a range, to reflect the uncertainty in the assessment. The following inputs have been considered in this assessment:

- Damage to buildings (residential, commercial and industrial);
- Vehicles;
- Contents;
- Cleanup costs;
- Relocation costs; and
- Rural damage.

Table 5.5: Flood sensitivity

Flood scenario	Lower bound	Upper bound
Sensitivity Scenario 1: increase in Manning's 'n' by 20%	$48,578,422	$93,960,331
Sensitivity Scenario 5: increase in flow by 20% (1% AEP)	$86,774,233	$165,959,678
Sensitivity Scenario 5: increase in flow by 20% (2% AEP)	$36,014,440	$69,734,269

5.4 Waipoua river levels versus total damage

Stage-damage curves can be used to illustrate the relationship between increasing water level ('stage') at a known location and changes in damages. The railway bridge was agreed with GWRC as the location for plotting a stage-damage curve[1]. The curve plotted below in Figure 5.1 was based on a table of river stage for each flood event provided by LandRiverSea consulting on behalf of GWRC (breach scenario results not included).

The bed level, based on the Te Kaura FMP Audit Report is approximately 118 mRL, so the flood depths in Figure 5.1 represent flood depths of around 4 m to 6 m (LandRiverSea, 2019).

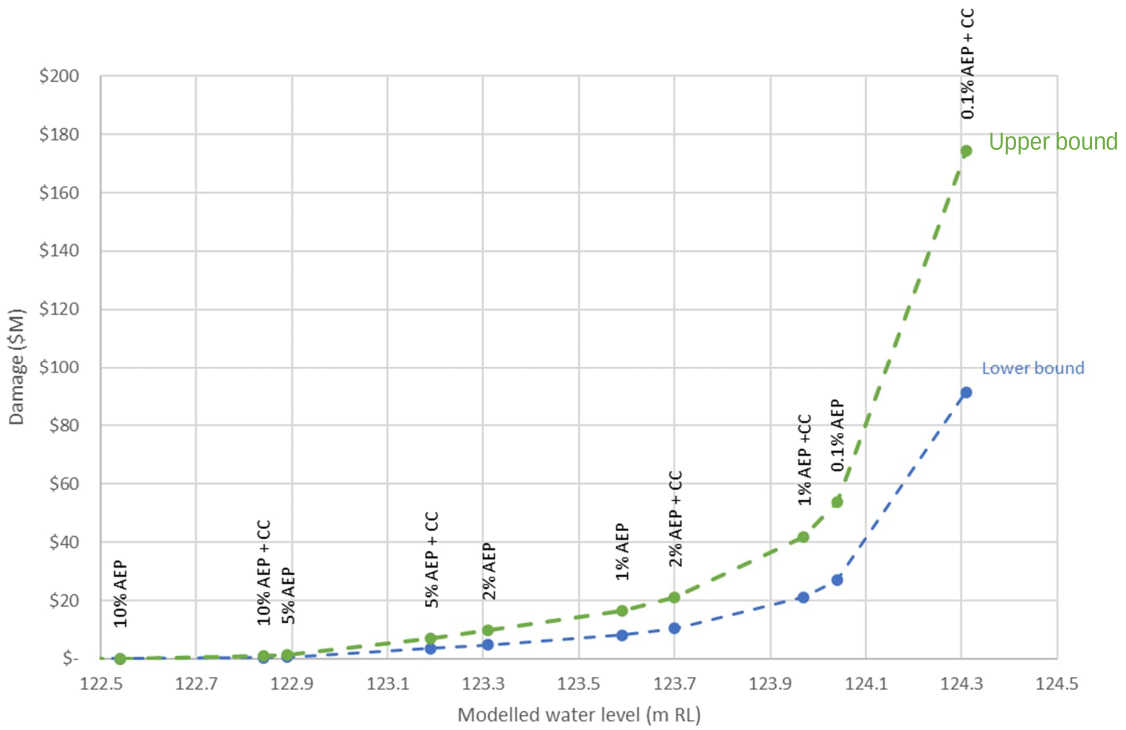

Figure 5.1 Stage-damage curves at the railway bridge

5.5 Intangible damage

Intangible damage includes risk to physical human health, psychological impacts and social / community impacts.

5.5.1 Loss of life / risk to life

The count of buildings and length of road within the H3-H6 ARR classifications (refer Section 4.3). have been measured for each of the flood scenarios assessed (excluding breach scenarios).

[1] The 'stage" location does not represent flood levels throughout the area of damage.

Table 5.6 and Table 5.7 present the results of risk to life assessment on the basis of the number buildings and road lengths exposed, respectively.

Table 5.6: Number of buildings within the H3-H6 hazard classification

Flood scenario	H3 (count)	H4 (count)	H5 (count)	H6 (count)
39% AEP	0	0	0	0
20% AEP	0	0	0	0
10% AEP	0	0	0	0
5% AEP	7	0	0	0
2% AEP	6	5	0	0
1% AEP	7	7	0	0
0.1% AEP	27	8	0	0
39% AEP (climate change)	0	0	0	0
20% AEP (climate change)	0	0	0	0
10% AEP (climate change)	6	0	0	0
5% AEP (climate change)	5	4	0	0
2% AEP (climate change- 2050)	5	6	0	0
2% AEP (climate change- 2100)	13	7	0	0
1% AEP (climate change- 2050)	16	7	0	0
1% AEP (climate change- 2100)	25	7	0	0
0.1% AEP (climate change)	82	10	5	0

Table 5.7: Length of road (m) within the H3-H6 hazard classification

Flood scenario	H3 (m)	H4 (m)	H5 (m)	H6 (m)
39% AEP	4	0	0	0
20% AEP	7	0	0	0
10% AEP	14	0	0	0
5% AEP	41	0	0	0
2% AEP	341	60	0	0
1% AEP	490	288	2	0
0.1% AEP	715	666	94	0
39% AEP (climate change)	7	0	0	0
20% AEP (climate change)	9	0	0	0
10% AEP (climate change)	31	0	0	0
5% AEP (climate change)	202	2	0	0
2% AEP (climate change- 2050)	408	121	0	0
2% AEP (climate change- 2100)	573	348	0	0
1% AEP (climate change- 2050)	704	370	0	0
1% AEP (climate change- 2100)	1130	735	42	0
0.1% AEP (climate change)	2292	1741	486	0

5.5.2 Other intangibles

People and businesses may become displaced due to buildings damaged from flood water (indirect relocation expenses included in the Total Flood Damage estimate (Section 5.1). This is disruptive to lives and creates uncertainty leading to mental health and wellbeing impacts. These may include but are not limited to:

- Grief of losing personal belongings, homes, pets, gardens, or businesses.
- Financial anxiety because of inadequate insurance cover, inability to afford or find temporary and long-term housing, and loss of income (GW, n.d.).
- Overall stress and anxiety of re-establishing lives.

Alongside the loss of homes and becoming displaced, flood events can cause a loss of community cohesion. This is due to community separation that can occur as a result of relocation (temporarily or permanently). Community facilities and hubs may also be damaged in flood events, resulting in temporary or permanent closure (Figure 5.2). Both of these impacts can affect people's local support networks and increase feelings of isolation and loneliness during a time of need. Local events and festivals may also be cancelled which can impact the social morale of the community (Flood Awareness, 2024). This may impact tourism and deprive businesses in the surrounding areas of income.

Flood events can also cause people to lose their livelihoods. Those working in the agricultural sector are often some of the worst impacted by flood events due to the large presence of productive land in floodplains. Those with commercially based livelihoods can also be impacted from flood events. Shops and other buildings can be damaged from flood water, which may result in temporary or permanent closure of businesses. The loss of livelihood can impact mental health through financial anxiety. Financial anxiety can be amplified by uncertainty about the future.

Another critical mental health impact that flood victims experience is post-traumatic stress disorders (PTSD). This occurs if people have experienced or witnessed a traumatic event, such as a flood event. PTSD causes severe anxiety, where certain triggers can initiate memories, intense emotions, and physical reactions. The following demographics are at higher risk to developing PTSD after a natural disaster than others (Golitaleb, et al., 2022 & Zenker, et al., 2024):

- Females.
- People of lower socioeconomic status.
- People who have lost their house/ is displaced.
- Individual or loved one gets seriously injured.
- People who are unsupported and feel lonely.
- Education level.
- Symptoms of previous mental illnesses.

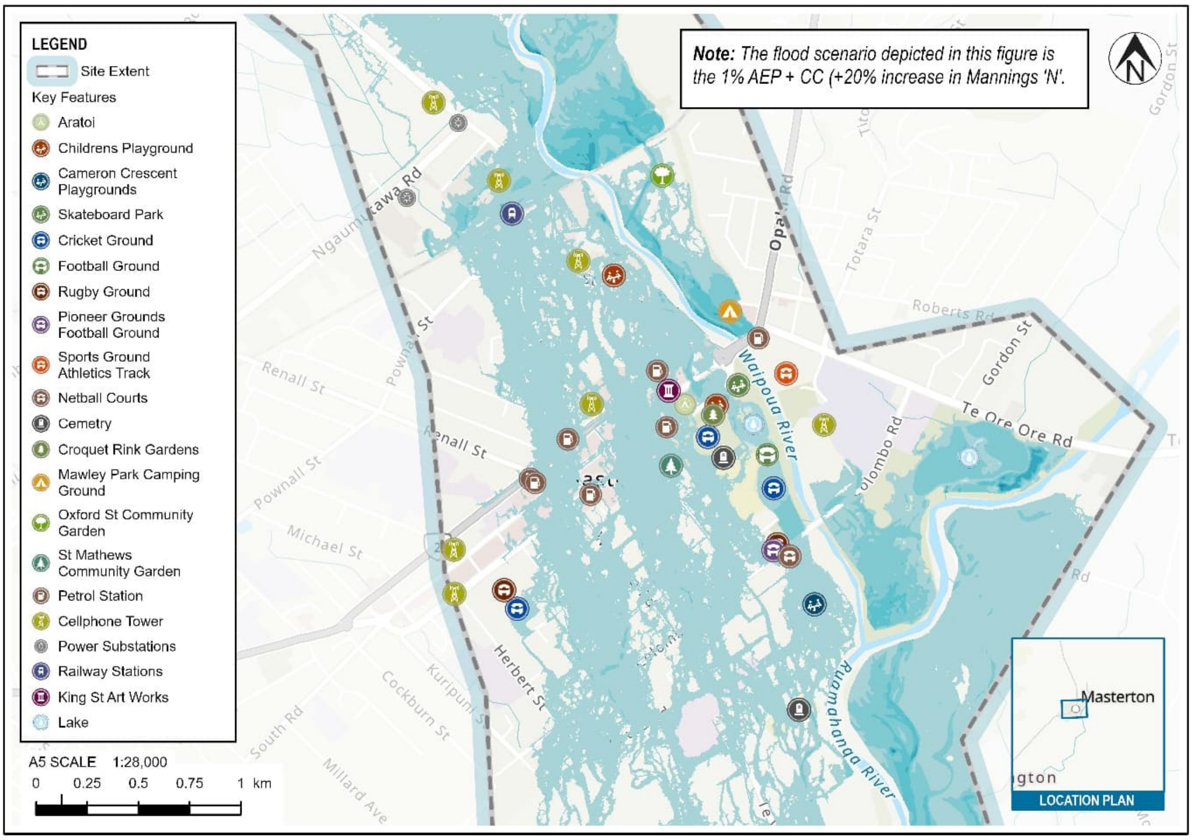

Figure 5.2: Key features identified across the area of interest overlaid on the 1% AEP + CC (+20% increase in Mannings 'n' scenario. These were identified by the Waipoua Group and were included if the feature could be located using GoogleMaps.

6 Conclusions

The purpose of this project is to help inform decision making on the flood risk management options for the Waipoua River, based on an assessment of flood damage and an annual average damages (AAD) assessment. These outputs help GWRC compare the costs and benefits of flood management interventions with the baseline scenarios presented in this report.

The flood damage assessment covers direct losses, indirect losses and intangible losses. The items included and excluded from the assessment are provided in Section 3. Of particular note are the large number of indirect damages which are excluded (e.g. business disruption costs) and that risk to life is not monetised in the damage assessments or AAD.

This flood damages assessment of the Waipoua River and AAD analysis has indicated that a much greater contribution of flood damages arise from the urban area of Masterton than the rural area. The urban damages are most attributed to commercial contents, cleanup costs and residential building damage.

The AAD associated with present day events ranges from $367,800 to $736,200. This increases by roughly 200% to $1.1 million - $2.2 million when considering climate change to 2100.

Building exposure and road length exposure to hazardous flood flows has been assessed as a proxy for a risk to life assessment in agreement with GWRC. The results show that up to 82 buildings are exposed to potentially damaging flood hazard, and that up to 2km of road length is exposed flood characteristics that is unsafe for all vehicles (0.1% AEP).

The damage associated with three breach scenarios was assessed, although not included in the AAD assessment. The results identified that the damage associated with dam breaches is broadly similar to the future (2100) 1% AEP climate change induced flood damages. The choice of breach scenario typically affects the damage by between $5M (lower bound) and $10M (upper bound) with 'Breach 02' scenario causing the greatest damage.

7 Applicability

This report has been prepared for the exclusive use of our client Greater Wellington Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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Appendix A Fragility functions

- Fragility functions used for buildings

Appendix A Table 1: Fragility functions used for buildings

Building type	Wall construction	Age	Storey	Fragility function applied
Residential building	Weatherboard	1960 - 1980	Not available (default: one storey)	RSK1_B_T Timber, one storey, 1960-1980
		Pre 1960 and post 1980		RSK1_A_T Timber, one storey, pre 1960 & post 1980
	Other materials	1960 - 1980		RSK1_B_M Masonry, one storey, 1960-1980
		Pre 1960 and post 1980		RSK1_A_M Masonry, one storey, pre 1960 & post 1980
	No material information	No age information		RSK1_B_T Timber, one storey, 1960-1980
Commercial buildings	Weatherboard	1960 - 1980	1	RSK1_B_T Timber, one storey, 1960-1980
			>2	RSK2_B_T Timber, two storey, age class 2
		Pre 1960 and post 1980	1	RSK1_A_T Timber, one storey, pre 1960 & post 1980
			>2	RSK2_A_T Timber, two storey, age class 1
	Other materials	1960 - 1980	1	RSK1_B_M Masonry, one storey, 1960-1980
			>2	RSK2_B_M Masonry, two storey, 1960-1980
		Pre 1960 and post 1980	1	RSK1_A_M Masonry, one storey, pre 1960 & post 1980
			>2	RSK2_A_M Masonry, two storey, pre 1960 & post 1980
	No material information	No age information	1	RSK1_B_M Masonry, one storey, 1960-1980
			>2	RSK2_B_M Masonry, two storey, 1960-1980
Industrial buildings	N/A	N/A	N/A	RSK_IND_3 Industrial, 3 m ceiling height

Appendix B Land use types

- Land use type - acronyms

Appendix B Table 1: Land use type - acronyms

Acronym	Land use type
ALA	Description not supplied
ARA	Arable cropping or seed
BEF	Beef
DAI	Dairy
DEE	Deer
FOR	Forestry
FRU	Fruit
GOA	Goat
GRA	Grazing
HOR	Horses
LIF	Lifestyle
NAT	Native bush
NEW	Not confirmed
NOF	Not farmed
NUR	Plant nursery
OPL	Other planted types
OTH	Other
SHP	Sheep
SNB	Sheep and beef
UNS	Unspecified
VIT	Viticulture

Appendix C AAD results

- AAD results (non-climate change scenarios)
- AAD results (climate change scenarios)

Annual Average Damage Assessment (AAD) Summary for "Waipoua River" (Present Day Climate)

Tonkin+Taylor

Models assessed
- 39% AEP no climate change
- 20% AEP no climate change
- 10% AEP no climate change
- 5% AEP no climate change
- 2% AEP no climate change
- 1% AEP no climate change
- 0.1% AEP no climate change

			Included in FDA?	Description	Building direct damage - higher confidence	Lower bound	Upper bound
Direct physical damage	Residential buildings damage		✓	2,598 residential buildings, of which 2,493 are located within the urban area. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$70,613	$63,552	$91,797
	Residential out buildings		☒	Not considered in the assessment, due to lack of appropriate data	☒	☒	☒
	Residential building contents damage		✓	Blanket contents cost applied across all residential buildings. Value includes only urban Lower bound: 40% of improvement value (HAZUS function) Upper bound: 70% of improvement value (Riskscape function)	☒	$32,885	$104,885
	Vehicles		✓	Each residential property was assumed to have 1.7 cars. Upper bound cost of car: $16,000 Lower bound cost of car: $8,000 Value includes both urban and rural.	☒	$9,521	$19,041
	Industrial building damage		✓	116 industrial buildings, of which all are located in the urban area. No range has been applied as there is no basis within literature. Industrial buildings represent a smaller portion of the overall damage, therefore one value has been established.	$4,758	$4,282	$5,710
	Industrial building contents damage		✓	Blanket contents cost applied across all residential buildings. Lower bound: 100% of improvement value (HAZUS function) Upper bound: 150% of improvement value (Riskscape function)	☒	$30,755	$93,645
	Commercial building damage		✓	196 residential buildings, of which all are located within the urban area. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$52,256	$47,030	$67,933
	Commercial building contents damage		✓	Blanket contents cost applied across all residential buildings. Lower bound: 100% of improvement value (HAZUS function) Upper bound: 150% of improvement value (Riskscape function)	☒	$72,954	$189,869
	Transport network	Roads	☒	Not considered	☒	☒	☒
		Rail	☒	Not considered	☒	☒	☒
		Ports, harbours and ferry's	☒	Not considered	☒	☒	☒
	Utility network	Water	☒	Not considered	☒	☒	☒
		Wastewater	☒	Not considered	☒	☒	☒
		Natural Gas	☒	Not considered	☒	☒	☒
		Communications	☒	Not considered	☒	☒	☒
		Electric	☒	Not considered	☒	☒	☒
		Stormwater	☒	Not considered	☒	☒	☒
		Oil	☒	Not considered	☒	☒	☒
	Productive land		✓	22 different farm types were considered within the area of interest. $/hectare were available for 78% of the area of interest. Upper bound: + 30% of damage calculated Lower bound: -30% of damage calculated	☒	$16,482	$28,211
	Rural housing		✓	105 residential buildings are located within the rural area. These have been assessed the same way as the urban residential buildings. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$4,817	$4,335	$6,262
	Rural housing contents		✓	This has been assessed the same as urban residential buildings.	☒	$2,594	$8,720
	Rural vehicles		✓	This has been assessed the same as urban residential vehicles.	☒	$585	$1,170
	Other		☒	Nothing else considered	☒	☒	☒
Economic	Duration of displacement		☒	Duration of displacement has been considered in the AAD under 'relocation expenses'. The number of days displaced was derived using the Riskscape 2016 fragility function.	☒	☒	☒
	Relocation expenses		✓	Relocation expenses consider the duration of displacement and weekly rent prices for residential buildings in the area of interest. Upper bound rental costs: $524 Lower bound rental costs: $469 Value includes both urban and rural	☒	$7,454	$8,328
	Cleanup costs		✓	A cost per property was used for all building types. Commercial and industrial buildings were increased by x2.5 due to the average area being approximately x2.5 more than the average residential.	☒	$75,444	$110,652
	Disruption costs		☒	Disruption costs have not been included for businesses. Disruption costs have been captured for residential, through relocation expenses above.	☒	☒	☒
	Emergency costs		☒	Not considered	☒	☒	☒
	Other		☒	Not considered	☒	☒	☒
	Indirect economic		☒	Loss of business production, loss of sales, and unemployment excluded.	☒	☒	☒
Intangible Damage	Risk to life		☒	Risk to life is not included within the AAD. However, is represented by number of buildings and km of road within H4-H6 zones.	☒	☒	☒
	Socio-economic factor		☒	Not considered	☒	☒	☒
Other	Warning time		☒	The effects of warning time were not considered or applied in the catchment because warning time is likely to be too short (<1 hour).	☒	☒	☒
	Benefits of flooding		☒	No allowance for 'benefits of flooding' have been considered in this assessment.	☒	☒	☒
	Experience		☒	No allowance for experience has been considered in this assessment.	☒	☒	☒
	Other		☒	Not considered	☒	☒	☒
				Total Average Annual Damage (AAD)	$132,444	$367,874	$736,223

Annual Average Damage Assessment (AAD) Summary for "Waipoua River"
Climate Change (2100)

Tonkin+Taylor

Models assessed
- 39% AEP climate change
- 20% AEP climate change
- 10% AEP climate change
- 5% AEP climate change
- 2% AEP climate change
- 1% AEP climate change
- 0.1% AEP climate change

			Included in FDA?	Description	Building direct	Lower bound	Upper bound
Direct physical damage	Residential buildings damage		✓	2,598 residential buildings, of which 2,493 are located within the urban area. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$257,513	$231,762	$334,767
	Residential out buildings		☒	Not considered in the assessment, due to lack of appropriate data	☒	☒	☒
	Residential building contents damage		✓	Blanket contents cost applied across all residential buildings. Value includes only urban Lower bound: 40% of improvement value (HAZUS function) Upper bound: 70% of improvement value (Riskscape function)	☒	$125,278	$360,983
	Vehicles		✓	Each residential property was assumed to have 1.7 cars. Upper bound cost of car: $16,000 Lower bound cost of car: $8,000 Value includes both urban and rural.	☒	$32,187	$64,374
	Industrial building damage		✓	116 industrial buildings, of which all are located in the urban area. No range has been applied as there is no basis within literature. Industrial buildings represent a smaller portion of the overall damage, therefore one value has been established.	$15,148	$13,633	$19,692
	Industrial building contents damage		✓	Blanket contents cost applied across all residential buildings. Lower bound: 100% of improvement value (HAZUS function) Upper bound: 150% of improvement value (Riskscape function)	☒	$89,254	$241,942
	Commercial building damage		✓	196 residential buildings, of which all are located within the urban area. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$159,621	$143,659	$207,507
	Commercial building contents damage		✓	Blanket contents cost applied across all residential buildings. Lower bound: 100% of improvement value (HAZUS function) Upper bound: 150% of improvement value (Riskscape function)	☒	$210,181	$536,852
	Transport network	Roads	☒	Not considered	☒	☒	☒
		Rail	☒	Not considered	☒	☒	☒
		Ports, harbours and ferry's	☒	Not considered	☒	☒	☒
	Utility network	Water	☒	Not considered	☒	☒	☒
		Wastewater	☒	Not considered	☒	☒	☒
		Natural Gas	☒	Not considered	☒	☒	☒
		Communications	☒	Not considered	☒	☒	☒
		Electric	☒	Not considered	☒	☒	☒
		Stormwater	☒	Not considered	☒	☒	☒
		Oil	☒	Not considered	☒	☒	☒
	Productive land		✓	22 different farm types were considered within the area of interest. $/hectare were available for 78% of the area of interest. Upper bound: + 30% of damage calculated Lower bound: -30% of damage calculated	☒	$27,775	$51,583
	Rural housing		✓	105 residential buildings are located within the rural area. These have been assessed the same way as the urban residential buildings. Upper bound cost: + 30% of direct damage Lower bound cost: -10% of direct damage	$19,789	$17,810	$25,726
	Rural housing contents		✓	This has been assessed the same as urban residential buildings.	☒	$9,585	$31,466
	Rural vehicles		✓	This has been assessed the same as urban residential vehicles.	☒	$1,495	$2,990
	Other		☒	Nothing else considered	☒	☒	☒
Economic	Duration of displacement		☒	Duration of displacement has been considered in the AAD under 'relocation expenses'. The number of days displaced was derived using the Riskscape 2016 fragility function.	☒	☒	☒
	Relocation expenses		✓	Relocation expenses consider the duration of displacement and weekly rent prices for residential buildings in the area of interest. Upper bound rental costs: $524 Lower bound rental costs: $469 Value includes both urban and rural	☒	$20,569	$22,982
	Cleanup costs		✓	A cost per property was used for all building types. Commercial and industrial buildings were increased by x2.5 due to the average area being approximately x2.5 more than the average residential.	☒	$198,748	$291,497
	Disruption costs		☒	Disruption costs have not been included for businesses. Disruption costs have been captured for residential, through relocation expenses above.	☒	☒	☒
	Emergency costs		☒	Not considered	☒	☒	☒
	Other		☒	Not considered	☒	☒	☒
	Indirect economic		☒	Loss of business production, loss of sales, and unemployment excluded.	☒	☒	☒
Intangible Damage	Risk to life		☒	Risk to life is not included within the AAD. However, is represented by number of buildings and km of road within H4-H6 zones.	☒	☒	☒
	Socio-economic factor		☒	Not considered	☒	☒	☒
Other	Warning time		☒	The effects of warning time were not considered or applied in the catchment because warning time is likely to be too short (<1 hour).	☒	☒	☒
	Benefits of flooding		☒	No allowance for 'benefits of flooding' have been considered in this assessment.	☒	☒	☒
	Experience		☒	No allowance for experience has been considered in this assessment.	☒	☒	☒
	Other		☒	Not considered	☒	☒	☒
				Total Average Annual Damage (AAD)	$452,071	$1,121,936	$2,192,361