24 May 2022

Mr John Hutchings,
HenleyHutchings Ltd,
Lambton Key,
Wellington.

Dear John

RE: Report of Findings – Westport Flood Damage Mitigation Costs Assessment

Please find enclosed a Technical Summary detailing the results and findings of the Westport Flood Damage Mitigation Costs Assessment which NIWA was engaged to deliver.

Please do not hesitate to contact me via email (Shaun.Williams@niwa.co.nz) or phone (+64-3-3437880), should you have any queries associated with the enclosed information.

Yours sincerely

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Direct Damage Analysis for Scenario Flooding in Westport

Technical Summary Report

Prepared for HenleyHutchings Ltd

May 2022

Prepared by: Alec Wild, Ryan Paulik, Shaun Williams

Contents

1 Overview

NIWA was engaged by HenleyHutchings Ltd on behalf of the West Coast Regional Council (WCRC) to undertake services pertaining to the delivery of a flood damage analysis for the Westport Flood Damage Mitigation Costs Assessment.

NIWA has modelled flood hazard exposure and direct losses in NZD$ (based on values for the year 2022), for buildings, roads and railways in Westport, with model outputs/results files supplied to HenleyHutchings. These include:

1. A .zip file containing tabular and spatial files (.csv, .xlsx, .shp) representing building, road and rail flood hazard exposure and impact (direct damage and loss) information, which includes:
   - Buildings
     - Exposure: Total (count); Use (count); Total by inundation depth (count); Use by inundation depth (count).
     - Loss: Total Repair Cost (NZD$); Repair Cost by Use (NZD$).
   - Roads
     - Exposure: Total (length); Type (length); Total by inundation depth (length); Use by inundation depth (length).
     - Loss: Total Repair Cost (NZD$); Repair Cost by Type (NZD$).
   - Rail
     - Exposure: Total (length); Type (length); Total by inundation depth (length).
     - Loss: Total Repair Cost (NZD$).

This technical summary report outlines the methods and data used in the analysis as well as results, interpretations of the findings and analysis limitations.

2 Methods

Direct damage in terms of monetary loss (NZ$) for Westport buildings, roads and rails exposed to flooding from the Buller River under different mitigation scenarios were modelled using the RiskScape multi-hazard risk analysis framework (Paulik et al. 2022). The modelling framework combines 'hazard' with 'exposure' information along with pre-defined 'vulnerability' relationships describing the physical damage response of exposed elements to flood 'hazard depth' intensity, to estimate monetary losses in this study.

A deterministic model was developed in RiskScape to identify the exposure of elements-at-risk (i.e., buildings, roads and rails), within the modelled Buller River floodplain, and apply vulnerability functions to quantify the direct damage in monetary losses for the hazard scenarios assessed.

2.1 Hazard Layers

The flood hazard layers used in the analysis were produced by Land River Sea Ltd (LRS). These hazard layers represent 29 Buller River flood hazard scenarios under different mitigation options. Flood hazard layers for each scenario represent flood extent and flow depth (D) on a 5 m grid supplied as Geotiffs (.tif). The modelled Representative Concentration Pathways (RCP) for the ARI 100-year scenarios account for the expected climate for an RCP*x* scenario for the decade from 2090 to 2100 for river flows, and 2120 for sea level.

An additional layer representing the 15–18 July 2021 Westport Flood Event water surface was produced by NIWA from a spatial interpolation (1 m grid) of approx. 240 geodetic measurements of flood extent and 'D' collected during surveys carried out by WCRC, NIWA, and Chris J Coll Surveying Ltd.

Detailed descriptions of the flood hazard models, layers and mitigation are available from LRS. The scenarios were applied to estimate monetary losses 'as-was' provided to NIWA, and include (Table 1):

Table 1: Flood hazard model scenarios analyzed in this study.

Scenario Suite	Digital Layers (*Source*)	Description
July 2021 Flood event	July_2021_Flood (*NIWA, 2021*)	Benchmark inundation model for the July 2021 Flood
Base scenarios with no mitigation intervention	Base_ARI20 (*LRS, 2022*)	Historic Climate, 20-year ARI event
	Base_ARI50 (*LRS, 2022*)	Historic Climate, 50-year ARI event
	Base_ARI100 (*LRS, 2022*)	Historic Climate, 100-year ARI event
	Base_ARI100_RCP6 (*LRS, 2022*)	Future Climate, 100-year ARI event (RCP6 2100)
	Base_ARI100_RCP8.5 (*LRS, 2022*)	Future Climate, 100-year ARI event (RCP8.5 2100)
Option 1 mitigation scenarios	Op1_ARI20 (*LRS, 2022*)	Historic Climate, 20-year ARI event
	Op1_ARI50 (*LRS, 2022*)	Historic Climate, 50-year ARI event
	Op1_ARI100_RingBank *(LRS, 2022)*	Historic Climate, 100-year ARI event

Scenario Suite	Digital Layers (*Source*)	Description
	Op1_ARI100_RCP6 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100)
	Op1_ARI100_RCP8.5 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP8.5 2100)
	Op1_ARI100_RCP8.5_Overdesign *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP8.5 2100) flows with protection up to the RCP6 level of protection
Option 2 mitigation scenarios	Op2_ARI20 *(LRS, 2022)*	Historic Climate, 20-year ARI event
	Op2_ARI50 *(LRS, 2022)*	Historic Climate, 50-year ARI event
	Op2_ARI100 *(LRS, 2022)*	Historic Climate, 100-year ARI event
	Op2_ARI100_RCP6 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100)
	Op2_ARI100_RCP8.5 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP8.5 2100)
	Op2_ARI100_RCP8.5_Overdesign *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP8.5 2100) with protection up to the RCP6 level of protection)
Option A mitigation scenarios	OpA_ARI20 *(LRS, 2022)*	Historic Climate, 20-year ARI event
	OpA_ARI50 *(LRS, 2022)*	Historic Climate, 50-year ARI event
	OpA_ARI100 *(LRS, 2022)*	Historic Climate, 100-year ARI event
	OpA_ARI100_RCP6 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100) assuming full protection to this level of standard
	OpA_ARI100_RCP6_Overdesign *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road
	OpA_ARI100_RCP8.5_Overdesign *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP8.5 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road
Option B mitigation scenarios	OpB_ARI20 *(LRS, 2022)*	Historic Climate, 20-year ARI event
	OpB_ARI50 *(LRS, 2022)*	Historic Climate, 50-year ARI event
	OpB_ARI100 *(LRS, 2022)*	Historic Climate, 100-year ARI event
	OpB_ARI100_RCP6 *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100) assuming full protection to this level of standard

Scenario Suite	Digital Layers (*Source*)	Description
	OpB_ARI100_RCP6_Overdesign *(LRS, 2022)*	Future Climate, 100-year ARI event (RCP6 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road

2.2 Exposure Layers

2.2.1 Buildings

A spatial dataset of building objects and their characteristics was created for the study area. Building objects are represented from Land Information New Zealand (LINZ) 'NZ Building Outline' polygons.

Building characteristics are summarised in Table 2 and were primarily determined from the district valuation roll and desktop mapping methods.

Onsite measurement of building floor heights was not in the scope of this study. Therefore, floor heights for several building classes are assumed based on use, storeys and age: 0.4 m (Residential; 1 Storey; Age < 1950), 0.5 m (Residential; 1 Storey; Age 1950 < 1990), 0.2 m (all other building uses). Indicative flood heights were informed from observations of residential buildings damaged in five previous New Zealand flood events between 2010–2020 (Paulik et al. 2021).

Total building replacement values ($NZD) were estimated using Quotable Value (QV) Costbuilder to determine unit area (m^2) replacement value rates based on building use and size (storeys; area).

Table 2: Summary of contextual information for building characteristics used in this study.

Primary Attribute	Secondary Attribute	Metric / Value	Description
Age	-	Integer	Estimated year of building construction from district valuation roll
Floor Height	-	Floating	Modelled first finished floor level height above ground level (m)
Area	-	Integer	Area of building roof outline (m^2)
Storeys	-	Integer	Number of complete building floor levels (>0)
Replacement Value	-	Integer	Total building replacement values ($NZD 2022) from Quotable Value (QV) Costbuilder

Primary Attribute	Secondary Attribute	Metric / Value	Description
Use Category	Residential; Commercial; Supermarket Industrial; Critical Infrastructure; Territorial Authority; School; Community; Recreation; Religious; Health; Agriculture; Auxiliary	Text	Observed or estimated primary building use from district valuation roll
Wall Cladding	Aluminium; Brick; Concrete Block; Fibre Cement; Glass; Malthoid/Fab; Mixed Material; Plastic; Roughcast; Sheet Metal; Steel/G-Iron; Stone	Text	Observed or estimated primary building wall cladding from district valuation roll

2.2.2 Roads and Railways

Roads and railways were extracted from the Waka Kotahi One Network Road Classification (ONRC) dataset (as of February 2022).

Road and railway objects were represented as polylines and cut into 5 m segments (1 m segment for the July 2021 Flood event), for spatial sampling of flood inundation 'depth' intensities.

The Asset Value (AV in $NZ) for roads and railways were obtained from Mr Julian Williams (Economics Consultant and Researcher), which include:

- Road AV$: $50 mil per km.
- Rail AV$: $26 mil per km.

2.3 Vulnerability Functions

Vulnerability functions determine the exposure and impacts of elements-at-risk (i.e., buildings, roads, rails), from flood inundation based on attributes that influence their susceptibility to damage or loss.

For **buildings,** damage curves from Reese and Ramsey (2010) were applied to Westport buildings based on use, storeys, wall cladding and floor height. These curves produce a building damage ratio representing 'cost-to-repair'/'cost-to-replace' that is multiplied by the buildings replacement value to estimate the monetary loss from physical damage.

For **roads** we applied the 'Low flow' mapping curves (C1, C3, C5 in Figure 1), to the ONRC dataset which draw on relationships developed by Van Ginkel et al. (2021). Roads were split into 5 m segments to align with each flood ARI model resolution (1 m segments for the July 2021 Flood layer) (Table 3). A damage ratio was then produced for each segment with a given ONRC class and corresponding exposure depth, and the ratio multiplied by $50,000 (i.e., per metre cost consistent with the values specified in Section 2.2.2) and segment length (in metres). Outputs were then aggregated to the parent road ID.

For **rails** the damage curve developed by Kok et al. (2005) was used in the analysis (Figure 2). A similar approach was used to estimate the exposure costs for rails as was done for roads.

Exposure or repair costs estimated from vulnerability functions are presented as descriptive statistics (e.g., count, sum, $value).

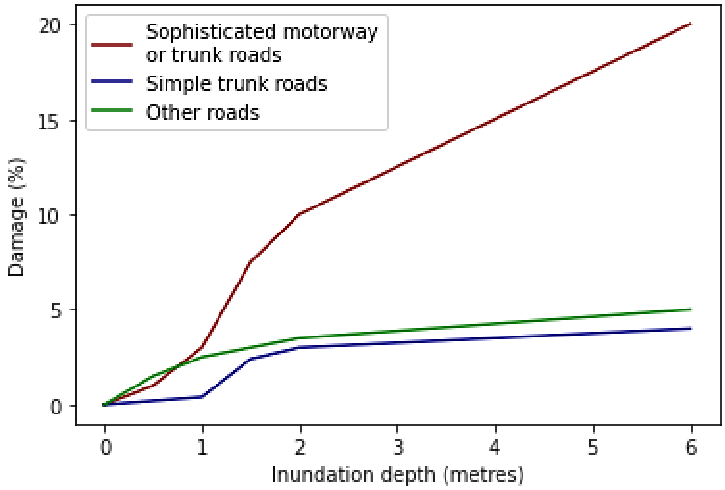

Figure 1: Flood depth-damage relationships for roads used to define vulnerability functions in this study (adapted from Van Ginkel et al. 2021).

Table 3: Corresponding vulnerability curves of Van Ginkel et al. (2021) with ONRC Road Classes in this study.

Curve	Corresponding ONRC Class
“Sophisticated” accessory roads	"National Strategic", "National", "High Volume", "Regional", "Arterial"
“Simple” roads	"Primary Collector", "Secondary Collector", "Low Volume"
“Other” roads	"Access"

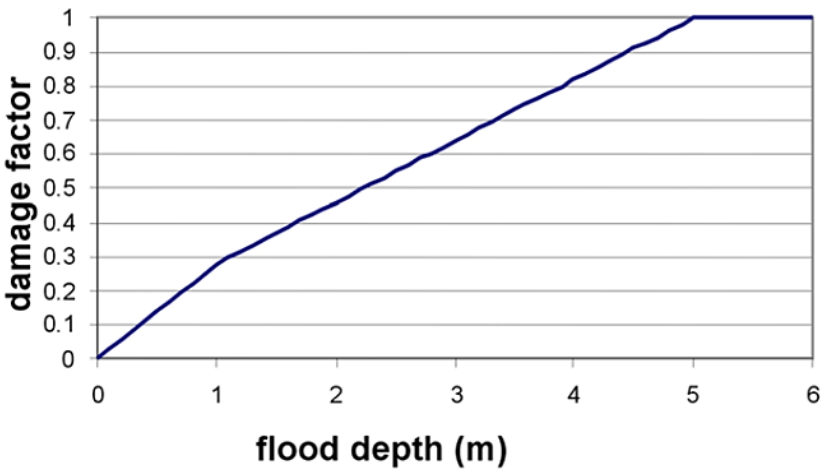

Figure 2: Flood depth-damage relationships for railways used to define vulnerability functions in this study (from Kok et al. 2005).

3 Results

3.1 Aggregated Losses to Different Flood Hazard Scenarios

Monetary losses ($NZD 2022) for buildings, roads and railways exposed to Buller River flood hazard scenarios included in this study are summarized in Table 4.

Tabular (.xlsx and .csv) and geospatial (.shp) digital output files containing information on buildings, roads and railways exposure and monetary loss for each scenario is provided in the .zip file accompanying this document.

Table 4: Summary of aggregated monetary losses for exposure elements assessed in each scenario flood.

Model Scenario	Buildings: Sum of Building $Loss ($NZ)	Roads: Sum of Exposure Costs ($NZ)	Rails: Sum of Exposure Costs ($NZ)	Scenario Total ($NZ)	Description of Flood Hazard Model Scenario
July 2021 Flood	$ 36,327,145	$ 23,301,479	$ 53,031,704	**$ 112,660,328**	Benchmark inundation model for the July 2021 Flood
Base_ARI20	$ 11,516,949	$ 12,564,883	$ 25,696,776	**$ 49,778,608**	Historic Climate, 20-year ARI event
Base_ARI50	$ 40,884,034	$ 23,266,328	$ 41,592,534	**$ 105,742,897**	Historic Climate, 50-year ARI event
Base_ARI100	$ 152,394,892	$ 40,179,542	$ 71,899,719	**$ 264,474,154**	Historic Climate, 100-year ARI event
Base_ARI100_RCP6	$ 404,927,949	$ 77,426,220	$ 113,254,863	**$ 595,609,033**	Future Climate, 100-year ARI event (RCP6 2100)
Base_ARI100_RCP8.5	$ 479,436,822	$ 89,429,597	$ 131,162,934	**$ 700,029,354**	Future Climate, 100-year ARI event (RCP8.5 2100)
Op1_ARI20	$ 1,856,651	$ 9,433,005	$ 23,650,812	**$ 34,940,468**	Historic Climate, 20-year ARI event
Op1_ARI50	$ 3,613,392	$ 12,261,835	$ 35,982,244	**$ 51,857,471**	Historic Climate, 50-year ARI event
Op1_ARI100_RingBank	$ 5,368,801	$ 14,722,349	$ 46,105,234	**$ 66,196,384**	Historic Climate, 100-year ARI event
Op1_ARI100_RCP6	$ 10,725,438	$ 23,608,580	$ 66,877,189	**$ 101,211,206**	Future Climate, 100-year ARI event (RCP6 2100)
Op1_ARI100_RCP8.5	$ 23,692,348	$ 27,443,515	$ 78,505,313	**$ 129,641,176**	Future Climate, 100-year ARI event (RCP8.5 2100)
Op1_ARI100_RCP8.5_Overdesign	$ 421,674,431	$ 81,468,888	$ 126,559,544	**$ 629,702,863**	Future Climate, 100-year ARI event (RCP8.5 2100) flows with protection up to the RCP6 level of protection
Op2_ARI20	$ 2,525,599	$ 9,768,976	$ 23,511,413	**$ 35,805,988**	Historic Climate, 20-year ARI event
Op2_ARI50	$ 5,835,939	$ 13,050,923	$ 35,408,533	**$ 54,295,395**	Historic Climate, 50-year ARI event
Op2_ARI100	$ 8,572,956	$ 15,618,279	$ 44,781,335	**$ 68,972,570**	Historic Climate, 100-year ARI event
Op2_ARI100_RCP6	$ 15,909,719	$ 24,791,622	$ 63,910,345	**$ 104,611,687**	Future Climate, 100-year ARI event (RCP6 2100)
Op2_ARI100_RCP8.5	$ 18,675,285	$ 27,581,928	$ 73,744,856	**$ 120,002,069**	Future Climate, 100-year ARI event (RCP8.5 2100)
Op2_ARI100_RCP8.5_Overdesign	$ 400,300,110	$ 78,996,799	$ 122,167,579	**$ 601,464,488**	Future Climate, 100-year ARI event (RCP8.5 2100) with protection up to the RCP6 level of protection)
OpA_ARI20	$ 1,995,693	$ 9,186,842	$ 23,475,747	**$ 34,658,283**	Historic Climate, 20-year ARI event
OpA_ARI50	$ 4,499,499	$ 12,105,123	$ 35,334,533	**$ 51,939,155**	Historic Climate, 50-year ARI event
OpA_ARI100	$ 6,510,332	$ 14,680,696	$ 45,644,525	**$ 66,835,553**	Historic Climate, 100-year ARI event
OpA_ARI100_RCP6	$ 12,184,885	$ 22,919,294	$ 64,793,796	**$ 99,897,975**	Future Climate, 100-year ARI event (RCP6 2100) assuming full protection to this level of standard

OpA_ARI100_RCP6_Overdesign	$ 211,983,537	$ 48,247,583	$ 73,502,279	**$ 333,733,398**	Future Climate, 100-year ARI event (RCP6 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road
OpA_ARI100_RCP8.5_Overdesign	$ 271,721,157	$ 99,522,725	$ 62,701,880	**$ 433,945,762**	Future Climate, 100-year ARI event (RCP8.5 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road
OpB_ARI20	$ 1,980,507	$ 23,465,844	$ 9,690,324	**$ 35,136,674**	Historic Climate, 20-year ARI event
OpB_ARI50	$ 4,758,534	$ 35,358,853	$ 13,501,653	**$ 53,619,040**	Historic Climate, 50-year ARI event
OpB_ARI100	$ 7,413,325	$ 47,382,643	$ 16,804,478	**$ 71,600,446**	Historic Climate, 100-year ARI event
OpB_ARI100_RCP6	$ 15,490,025	$ 66,665,094	$ 26,956,520	**$ 109,111,640**	Future Climate, 100-year ARI event (RCP6 2100) assuming full protection to this level of standard
OpB_ARI100_RCP6_Overdesign	$ 214,229,501	$ 75,130,532	$ 51,598,508	**$ 340,958,541**	Future Climate, 100-year ARI event (RCP6 2100) assuming only 100-year (historic climate) level of service for the Orowaiti banks downstream from Stephens Road

3.2 Analysis Limitations

The RiskScape results presented in this study are subject to uncertainties associated with the input datasets used. Key limitations of the results presented in this report are outlined below:

1. Hazard layers:

   - The July 2021 Flood hazard layer was used 'as-is' in this analysis and has not been compared/validated against the rapid building impacts assessment data (i.e., yellow, orange, red damage stickered buildings) collected after the event. Nevertheless, for the purposes in this assignment it is taken to represent the closest available approximation of flow depth and flooding extent for the July 2021 event.

   - The 2D flood modelled scenarios used in the analysis, like all 2D flood models, are subject to inherent uncertainties associated with the baseline topography, climate and hydrometeorological data as well as underpinning model equations and assumptions.

2. Exposure layers:

   - The replacement values (NZ$) for the building objects were estimated using QV Costbuilder and are representative of 2022 values.

   - The asset value (NZ$) for roads and rails were used 'as-was' provided by Mr Julian Williams.

   - Generic first finished floor level heights above ground level (m) are assumed for several building classes and were not measured onsite.

3. Vulnerability functions and output results:

   - The building damage losses presented in the results reflect direct damage to buildings and do not consider contents and other capital asset damage / losses on the property that might be claimable via insurance.

   - The values presented for buildings are representative of 2022 $NZD values as calculated using QV Costbuilder, and do not consider future changes in estimated building values.

4 Discussion and Interpretation

The July 2021 flood scenario:

- Provides a benchmark proxy to help contextualize the modelled scenarios and potential modelled-to-observed impact scaling. For example, the estimated direct building damage losses for the event was approx. $36 mil in this analysis, compared with approx. $88 mil in buildings and contents insurance claims (based on ICNZ 2022 as of May 2022).
- That is, it appears the reported losses are approx. 2–3 times greater than the modelled losses for the July 2021 event, which could imply that the modelled building losses presented for each ARI scenario in this study could be up to 2–3 times lower than the actual costs which might be incurred/observed (based on $values for the year 2022).
- However, this observation is preliminary and further investigation is required to elucidate any apparent modelled-to-observed loss patterns for the July 2021 event in this study. Furthermore, the reported or 'observed' losses (based on ICNZ 2022) likely include financial losses of contents within the building as well as in other structures on the property (e.g., sheds), and potentially extend to other buildings outside of Westport which were not modelled in this study.

Changes in direct losses for the modelled mitigation/intervention scenarios based on the results in this study include:

- ARI20 scenarios
  - **For buildings only: Option 1** mitigation scenario (i.e., 'Op1_ARI20' in Table 4), appears to produce the greatest reduction in losses relative to the base ARI20 scenario. That is, a reduction of approx. NZ$10 mil (84% reduction) is observed.
  - **For total aggregated losses (buildings, roads and rails): Option A** (i.e., 'OpA_ARI20' in Table 4), appears to produce the greatest reduction in losses relative to the base ARI20 scenario. That is, a reduction of approx. NZ$15 mil (30% reduction) is observed.
- ARI50 scenarios
  - **For buildings only: Option 1** mitigation scenario (i.e., 'Op1_ARI50' in Table 4), appears to produce the greatest reduction in losses relative to the base ARI50 scenario. That is, a reduction of approx. NZ$38 mil (91% reduction) is observed.
  - **For total aggregated losses (buildings, roads and rails): Option 1** (i.e., 'Op1_ARI50' in Table 4), appears to produce the greatest reduction in losses relative to the base ARI50 scenario. That is, a reduction of approx. NZ$54 mil (51% reduction) is observed.
- ARI100 (Historic) scenarios
  - **For buildings only: Option 1** mitigation scenario (i.e., 'Op1_ARI100_Ringbank' in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100 scenario. That is, a reduction of approx. NZ$147 mil (96% reduction) is observed.

  - **For total aggregated losses (buildings, roads and rails): Option 1** (i.e., ‘Op1_ARI100_Ringbank’ in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100 scenario. That is, a reduction of approx. NZ$20 mil (75% reduction) is observed.

- ARI100 RCP6 scenarios

  - **For buildings only: Option 1** mitigation scenario (i.e., ‘Op1_ARI100_RCP6’ in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100_RCP6 scenario. That is, a reduction of approx. NZ$147 mil (96% reduction) is observed.

  - **For total aggregated losses (buildings, roads and rails): Option A** mitigation scenario (i.e., ‘OpA_ARI100_RCP6’ in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100_RCP6 scenario. That is, a reduction of approx. NZ$496 mil (83% reduction) is observed.

- ARI100 RCP8.5 scenarios

  - **For buildings only: Option 2** mitigation scenario (i.e., ‘Op2_ARI100_RCP8.5’ in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100_RCP8.5 scenario. That is, a reduction of approx. NZ$461 mil (96% reduction) is observed.

  - **For total aggregated losses (buildings, roads and rails): Option 2** mitigation scenario (i.e., ‘Op2_ARI100_RCP8.5’ in Table 4), appears to produce the greatest reduction in losses relative to the base ARI100_RCP8.5 scenario. That is, a reduction of approx. NZ$580 mil (83% reduction) is observed.

- Technical Advisory Group (TAG) recommended Option A:

  - Under an ARI100 RCP6 flooding scenario approx. $405 mil of building damages are estimated to occur.

  - If the TAG recommended embankment configuration (Option A) is applied to this ARI100 RCP6 scenario, then building damages would be reduced to approx. $12 mil.

  - Therefore, the TAG embankment configuration will give rise to a saving of approx. $393 mil of recovery costs for buildings compared to the cost impact if those embankments had not been there.

5 References

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