APPENDIX 18

NIWA RISKCAPE ASSESSMENT

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Joseph Camuso
Northland Regional Council
36 Water Street
Whangārei 0110

Dear Joseph

NIWA has estimated building and population exposure and impacts in the Kaitaia-Awanui area from a 100-year annual recurrence interval (ARI) fluvial flood event before and after a proposed flood scheme upgrade. This letter describes a property level dataset for building exposure, loss and safety.

Data files supplied to Northland Regional Council

NIWA has supplied the following files to Northland Regional Council (NRC):

- A .zip file containing tabular (.csv) and spatial (.shp) files representing building level fluvial flood hazard exposure and impact information. This file includes:
  - Kaitaia-Awanui Flood Scheme Results.xlsx
    - Aggregated information for 'Building Exposure', 'Building Loss', 'Threat to Safety' and ' Resident Displacement'.
  - Pre_Design_Building_Exposure (.csv and .shp) and Post_Design_Building_Exposure (.csv and .shp):
    - Building level information identifying the modelled 'Exposure_State', 'Flood_Depth_Above_Floor_Level' (output.), asset attributes (asset.) and hazard intensity (hazard.) information.
  - Pre_Design_Building_Loss (.csv and .shp) and Post_Design_Building_ Loss (.csv and .shp):
    - Building level information identifying the modelled:
      - direct impacts:'Building_Repair_Cost', 'Content_Replacement_Cost', 'Plant_Replacement_Cost', 'Stock_Replacement_Cost', 'Cleanup_Cost', 'Displacement_Cost' (output.),
      - indirect impacts: 'Resident_Displacement_Days', 'Residents_Displaced', and
      - asset attributes (asset.) and hazard intensity (hazard.) information.
  - Pre_Design_Building_Safety (.csv and .shp) and Post_Design_Building_Safety (.csv and .shp):
    - Building level information identifying the modelled 'Safety_Threat_Level', 'Residents_At_Risk' (output.), asset attributes (asset.) and hazard intensity (hazard.) information.

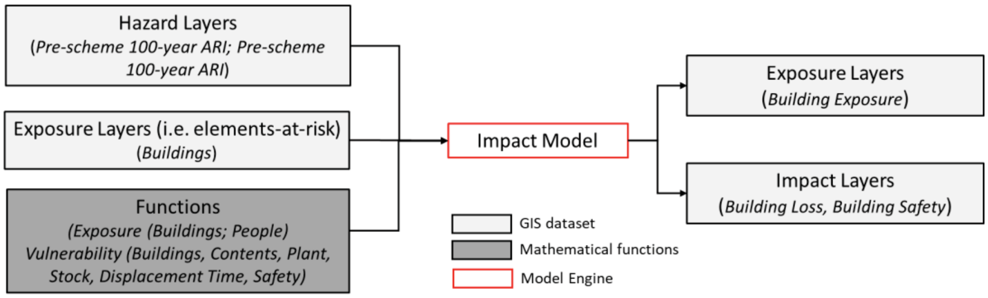
- A .zip file containing RiskScape flood exposure impact model configuration files including fluvial flood hazard layers, asset layers and vulnerability functions.

Methods

Building level datasets were created using the "RiskScape" multi-hazard risk model framework (Schmidt et al. 2011; Paulik et al. 2020). RiskScape software was configured to identify *elements-at-risk* (i.e. buildings and people) within the modelled 100-year ARI floodplain, then apply both *exposure* and *vulnerability* functions to quantify the impacts from their exposure to flood hazards. The process to model and report

301 Evans Bay Parade, Hataitai, Wellington 6021 | Phone +64 4 386 0300
Private Bag 14901, Kilbirnie, Wellington 6241

building and population exposure and impacts from fluvial flooding in the Kaitaia-Awanui area is conceptually presented in Figure 1.



Hazard Layers

Fluvial flood hazard layers representing modelled 100-year ARI fluvial flood events for pre- and post- flood scheme upgrade scenarios were provided to NIWA by NRC.

Flood Depth Above Ground (m) was extracted by RiskScape for building locations from modelled flood inundation grids and is reported in building level exposure and impact layer tables where field headings starting with 'hazard.'

Exposure Layers

A Kaitaia-Awanui area building polygon layer was created for the modelled pre-flood scheme upgrade 100-year ARI floodplain.

A national building asset database created by NIWA and GNS Science was spatially joined to Land Information New Zealand (LINZ) 'NZ Building Outline'[1] polygons. The LINZ dataset provides a more accurate representation of building locations and geometries. National database attributes including 'Construction Frame', Floor Height, Storeys and Year (of construction) were joined to polygons. Square meter (m^2) building area values for 'Replacement Cost', 'Content Value' were updated to $NZD 2019 based on QV Costbuilder Guidelines (Quotable Value, 2020), using the criteria applied by Lin et al. (2016). 'Plant Value' and 'Stock Value' respectively were derived from $NZD 2013 industry group 'plant, machinery and equipment' (Statistics New Zealand, 2016a) and 'wholesale stock' values respectively (Statistics New Zealand, 2016b). Additionally, meshblock averaged residential building population rates were estimated from the 2013 usually-resident population (Paulik et al. 2020). Finally, the 'Suburb' of building location was joined from the New Zealand Fire Service 'localities' database.

All asset attributes are reported in building level exposure and impact layer tables with field headings starting with 'asset.'.

Functions

RiskScape applied a suite of exposure and vulnerability functions to create building level exposure and impact layers from modelled 100-year ARI fluvial flood events for pre- and post- flood scheme upgrade scenarios.

Exposure functions were applied to identify and report 'Building Exposure' as:

[1] https://data.linz.govt.nz/layer/101290-nz-building-outlines/

- ‘Building Exposure State’ (i.e. Exposed, Not Exposed):
  - Function: *Flood Depth > 0 = Exposed* or *Flood Depth = 0 = Not Exposed*.
- ‘Flood Depth Above Floor Level’ (i.e. Above Floor Level, Below Floor Level).
  - Function: *Flood Depth – Floor Height > 0 = Above Floor Level* or *Flood Depth – Floor Height <= 0 = Below Floor Level*.

Vulnerability functions were applied to identify and report ‘Building Loss’ as:

- ‘Building Repair Cost’.
  - Building damage ratios (cost-to-repair/cost-to-replace) were estimated for building typologies using ‘depth-damage’ curves developed by Reese and Ramsay (2010). Curves are applied where flood inundation depth exceeds floor level, with the resulting damage ratio multiplied by ‘Replacement Cost’ to estimate ‘Building Repair Cost’.
- ‘Content Replacement Cost’.
  - Content damage ratios were estimated for building typologies using ‘depth-damage’ curves developed by Reese and Ramsay (2010). Curves are applied where flood inundation depth exceeds floor level, with the resulting damage ratio multiplied by ‘Content Value’ to estimate ‘Content Replacement Cost’.
- ‘Plant Replacement Cost’.
  - Plant (i.e. plant, machinery and equipment) damage ratios were estimated for non-residential building typologies using discrete ‘depth-damage’ values developed by Kriebich (2010). Mean damage ratios are applied where flood inundation depth exceeds floor level, with the resulting damage ratio multiplied by ‘Plant Value’ to estimate ‘Plant Replacement Cost’.
- ‘Stock Replacement Cost’.
  - Stock (i.e. saleable items) damage ratios were estimated for non-residential building typologies using discrete ‘depth-damage’ values developed by Kriebich (2010). Mean damage ratios are applied where flood inundation depth exceeds floor level, with the resulting damage ratio multiplied by ‘Stock Value’ to estimate ‘Stock Replacement Cost’.
- ‘Clean-up Cost’.
  - Building clean-up cost ($NZD 2019) were estimated using a damage-to-loss function informed from building damage ratios. In the absence of an empirical New Zealand dataset clean-up cost estimates are adapted from UK buildings presented in the UK Multi-Coloured Flood Hazard Manual (Penning-Rowsell et al. 2013). Clean-up costs are estimated for buildings <200m^2 and >200m^2. UK clean-up cost rates were translated into linear functions that represent greater clean-up costs ($NZD 2019) in response building damage becomes more severe. Maximum clean-up costs of $13,450 (<200m^2) and $23,075 (>200m^2) are reached when building damage ratios exceed 0.7 (i.e. 70% of building replacement value).
- ‘Displacement Cost’.
  - Displacement costs were only estimated for residential buildings using a ‘damage-to-loss’ function informed from resident displacement time (Paulik, 2016). Mean expected temporary accommodation cost (NZD 2019) is estimated from the duration of time residents are displaced from their dwellings.
- ‘Resident Displacement Days’.
  - Resident displacement days were only estimated for residential buildings using a ‘damage-to-loss’ function informed from building damage ratios. A linear function is applied to estimate the mean expected time duration of time residents are displaced from their dwellings (Paulik, 2016).

- 'Residents Displaced'.
    - Residents displaced from dwelling is reported from the meshblock averaged 2013 usually-resident population attributed to buildings where displacement days exceed 0.

Vulnerability functions were also applied to identify and report 'Building Safety' as:

- 'Safety Threat Level'.
    - The safety of people can be compromised when exposed to flows which exceed their ability to remain standing and/or traverse flood waters. Ordinal levels (Low, Medium, Significant, Extreme) were identified based on flood depths that could threaten an adult's ability to safely stand in flood waters (Cox et al. 2010).
- 'Residents at Risk'.
    - Residents at risk were only estimated for residential buildings. The meshblock averaged usually-resident population is reported for the corresponding building location 'Safety Threat Level'.

Key Limitations

The following are key limitations with the exposure layers and functions applied:

- Exposure Layers:
    - Building attributes are mostly derived from a national dataset, which includes modelled values for structural and non-structural attributes such as 'construction frame', 'floor height' and 'Year' (of construction). While care was taken in joining attributes LINZ building outlines, time availability limited attribute quality and assurance to desktop visual checking of attributes using satellite imagery.
    - Monetary values for building, contents, plant and stock were derived from industry construction cost guidelines and national level statistics.
    - Meshblock averaged residential building occupancy rates are attributed to residential buildings. Actual occupancy rates will be highly variable at building level. Meshblock population data for 2013 was applied due to issues cited with completeness of the 2018 Census dataset.
- Functions
    - Identifying flood inundation depths above and below floor level is dependant of accurate floor height information. Similar, vulnerability functions estimating direct economic loss to building, content, plant and stock begin to estimate monetary loss once flood depths rise above floor level. Functions for estimating residents displaced, resident displacement days, disruption cost and clean-up cost are dependent on building damage estimates and in turn, accurate floor heights.
    - RiskScape 2.0 software extracts a single flood inundation depth value at the building outline polygon centroid. This value may not represent a maximum depth and can lead to an underestimation of damage and loss. A beta software function is currently in development for statistical sampling of grids intersecting with asset features.
    - Building 'depth-damage' curves developed by Reese and Ramsay (2010) are based on expert judgement and representative of a limited range of building typologies, mostly residential buildings with timber construction frames. It is likely curves representative of residential building typologies are applied to non-residential buildings.
    - Functions developed by Cox et al. (2010) to estimate human stability in flood flows are based on the depth-velocity product. Only flood inundation depths were represented in the modelled flood scenarios.

Results

The following tables present estimate building and population exposure and impacts in the Kaitaia-Awanui area from a 100-year annual recurrence interval (ARI) fluvial flood event both before and after a proposed flood scheme upgrade.

Building Exposure

Scenario	Buildings Exposed	Below Floor Level	Above Floor Level
Pre-Scheme	1,066	680	386
Post-Scheme	486	248	238

Building Loss

Scenario	Building Repair Cost	Content Replace-ment Cost	Plant Replacement Cost	Stock Replacement Cost	Clean-up Cost	Displace-ment Cost	Total
Pre-Scheme	15,393,984	3,718,415	1,985,041	906,639	2,520,139	1,360,509	25,884,727
Post-Scheme	4,673,339	1,242,033	1,431,650	477,383	1,389,559	380,678	9,594,642

Scenario	Residents Exposed	Resident Displacement Days	Residents Displaced
Pre-Scheme	1,227	6,709	260
Post-Scheme	390	2,054	93

Building Safety

Scenario	Buildings Exposed	Low	Medium	Significant	Extreme
Pre-Scheme	1,066	869	66	70	61
Post-Scheme	486	381	50	35	20

Scenario	People Exposed	Low	Medium	Significant	Extreme
Pre-Scheme	1227	997	64	87	79
Post-Scheme	390	326	24	28	12

Yours sincerely

Ryan Paulik
Senior Risk Specialist

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