New Zealand's Next Top Model: integrating tsunami modelling into land use planning

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In April 2011 a guideline will be released on how tsunami inundation modelling can be integrated in land use planning. Drafted with participation from Council staff at Gisborne, Environment Waikato, Thames-Coromandel, and Bay of Plenty (and associated territorial authorities), the guideline is based on two key questions:

1. How can tsunami modelling be incorporated into land use planning?
2. What information do planners need from modellers to improve planning and policy for tsunami?

While the guideline is not a statutory document, it is intended to assist in guiding and informing regional policy statements, district plans, growth management plans etc. It achieves this by providing: an overview of tsunami basics; roles and responsibilities for tsunami risk; presenting a decision tree for incorporating tsunami risk into land use planning; outlining levels of tsunami modelling, how to incorporate uncertainty into planning maps; summarising planning approaches available to manage tsunami risk; presenting a risk-based approach to land use planning; and the role of pre-event recovery planning.

This paper will briefly provide an overview of selected key elements of the report, namely the decision tree for including tsunami modelling into land use planning; tsunami modelling levels on which land use planning options are based; how to map uncertainty into tsunami hazard zones; and options for incorporating tsunami risks into land use planning. The guideline will be freely available in April 2011.

1. A decision tree for including tsunami into land use planning

Figure 1 presents a decision tree for including tsunami risk into land use planning, and forms the basis for the guideline. The purpose of this figure is to lead the decision maker through a process of modelling, risk assessment, review of data quality and inclusion into LIM's, emergency management, and land use planning. Each step is outlined in the guideline, including how to quantify and qualify levels of risk. A key element of Figure 1 are four levels of tsunami modelling (1-4), which are recognised for establishing tsunami evacuation zone boundaries. These are outlined below.

2. Tsunami modelling levels

Level 1 is a simple 'bathtub' model in which inundation is determined based on a maximum wave height, projected inland from the coast to some cut-off elevation. This approach provides the crudest and simplest method of mapping evacuation zones, and not recommended for land use planning purposes. Level 1 modelling can provide enough information to gain political support to undertaking higher level modelling.

Level 2 uses a measure of rule-based wave height attenuation inland from the coast. GIS can be utilised for applying the attenuation rule. This approach derives a more realistic output than a simple 'bathtub' model but is still a rough estimation which cannot account for physical variations in wave behaviour. The rule is applied to probabilistic wave heights derived separately. This rule does not account for all scenarios and improvements are expected to come with time. Rules developed for mapping may take a precautionary approach that is more likely to overstate the area at risk than understate it. Local knowledge must also be applied to support the process. Level 2 is recommended for inclusion into LIMs and civil defence emergency management planning, but not for land use planning.

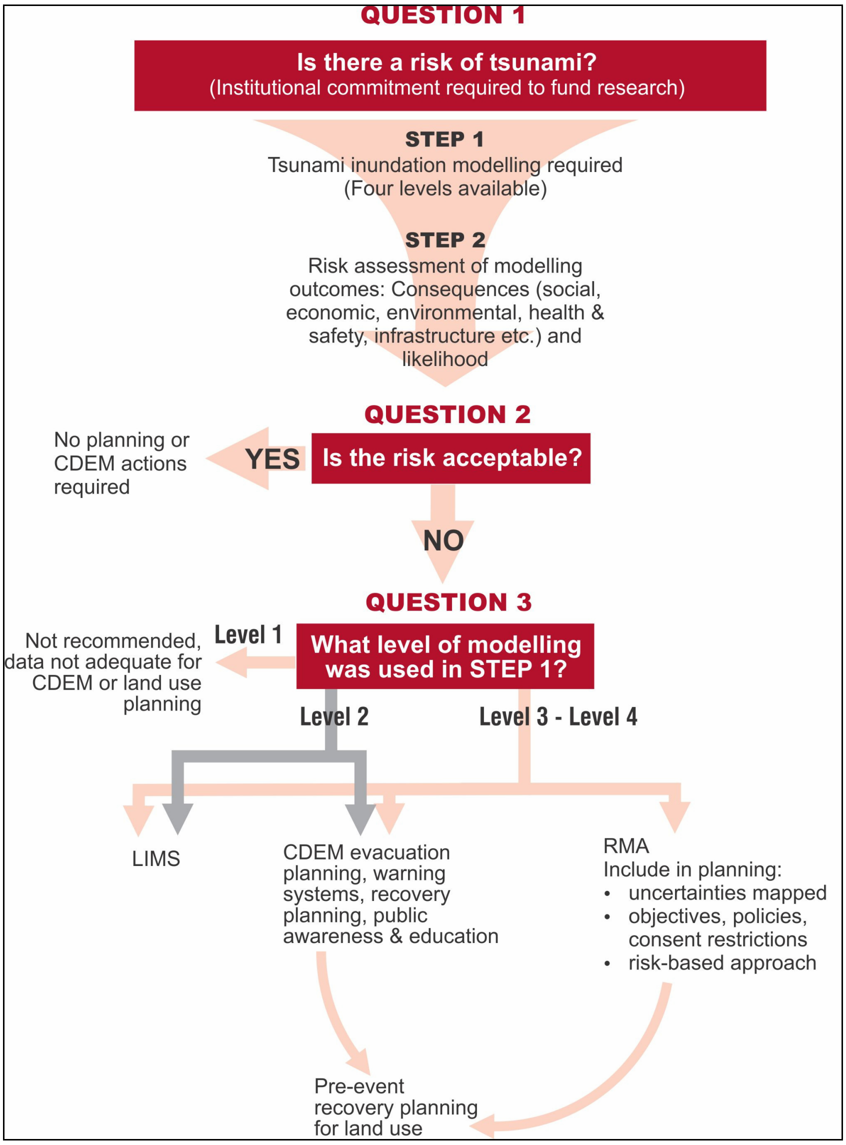

Figure 1: Decision tree for including tsunami risk in land use planning.

Level 3 is a computer-derived simulation model that theoretically allows for complexities that a simpler 'rule' cannot, such as varied surface roughness from different land uses, and water turning corners and travelling laterally to the coast on its inundation path. The model is applied to probabilistic wave heights derived separately. Such modelling is expensive and the quality of output is dependent on the science behind the hazard model. Level 3 is of a quality recommendable for land use planning.

Level 4 is the most complete approach, based on an envelope around all inundations from multiple (likely many) well-tested computer models covering all credible scenarios. Development to this level of sophistication will require a comprehensive scientific understanding of all possible tsunami sources (distant, regional and local), wave propagation and inundation behaviours, across a range of magnitudes. Level 4 is recommended for land use planning.

As discussed, modelling undertaken at Levels 3 or 4 is considered robust enough to include in land use planning. The following sections provide an overview of planning options, firstly with an outline of how uncertainty can be mapped for tsunami.

3. Mapping uncertainty for land use planning

For other natural hazards i.e. active faults and landslides, uncertainty is already included in planning maps. Examples of mapping uncertainty include using a 'well defined', 'constrained' and 'distributed' mapping of active faults (Kerr et al., 2003); and landslide 'core' and 'fringe' areas (Saunders & Glassey, 2007). For example, in Nelson the Tahunanui Slope Risk Area, commonly known as the Tahunanui Slump, is defined on the Planning Maps within the Nelson Resource Management Plan. It consists of a core area where the hazard is known, surrounded by a fringe area where the edge of the active slump has not been able to be accurately defined (Nelson City Council). Rules stipulate that new residential units within the core are non-complying; within the fringe area (i.e. area of residual risk) they are discretionary (Rule REr.77.3).

For tsunami, a similar approach could be taken, as shown in Figures 2 and 3. Figure 2 presents a cross section of modelled probabilistic tsunami wave heights at the coast, and associated levels of (un)certainties. The middle hashed zone is the boundary between the lower and upper levels of a chosen level of confidence. Figure 3 presents a birds-eye view of how Figure 2 can be mapped. Confidence levels are expressed as percentages. On a graph or a map they define a confidence interval either side of an average value. In Figures 2 and 3 this average value lies in the middle of the hashed 'Uncertain tsunami inundation' zone. Details on how these confidence levels have been derived are outlined in the guideline.

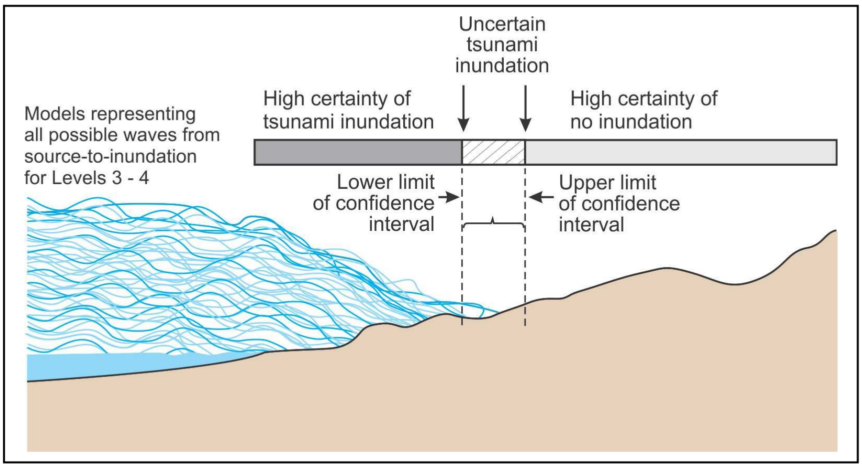

Figure 2: Cross section of modelled probabilistic tsunami wave heights at the coast, and associated levels of (un)certainties (to a chosen level of confidence – i.e. a confidence interval).

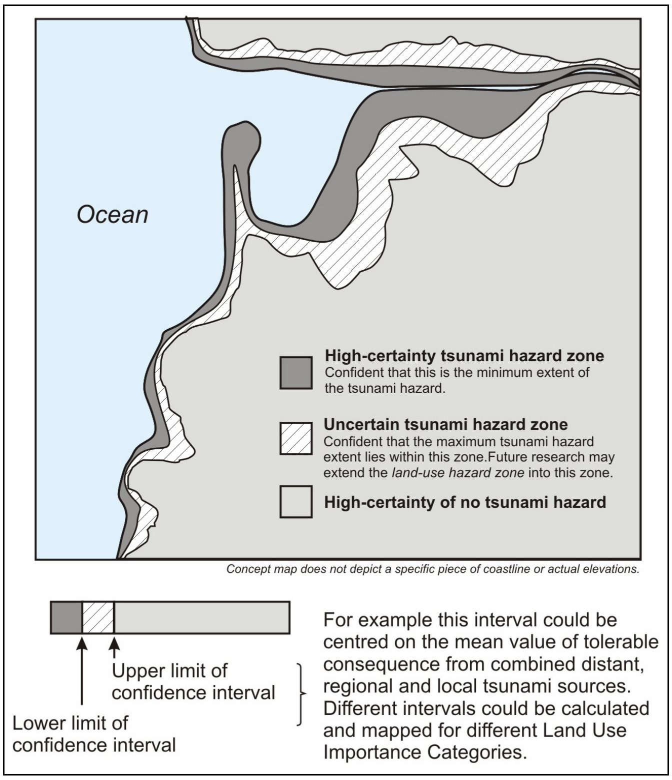

Figure 3: Birds-eye view of the tsunami inundation shown in Figure 2.

Once tsunami inundation zones can be mapped, then planning options can be considered for managing the risk. These options are outlined in the following section.

4. Options for land use planning

While there is limited guidance available for planning options for tsunami, in 2001 the National Tsunami Hazard Mitigation Program in the U.S. produced a guideline which outlines seven planning principles (National Tsunami Hazard Mitigation Program, 2001). These principles are provided below and shown in Figure 4:

1. Know your community's tsunami risk: hazard, vulnerability and exposure;
2. Avoid new development in tsunami run-up areas to minimize future tsunami losses;
3. Locate and configure new development that occurs in tsunami run-up areas to minimise future tsunami losses;
4. Design and construct new buildings to minimise tsunami damage;
5. Protect existing development from tsunami losses through redevelopment, retrofit, and land reuse plans and projects;
6. Take special precautions in locating and designing infrastructure and critical facilities to minimise tsunami damage; and
7. Plan for evacuation.

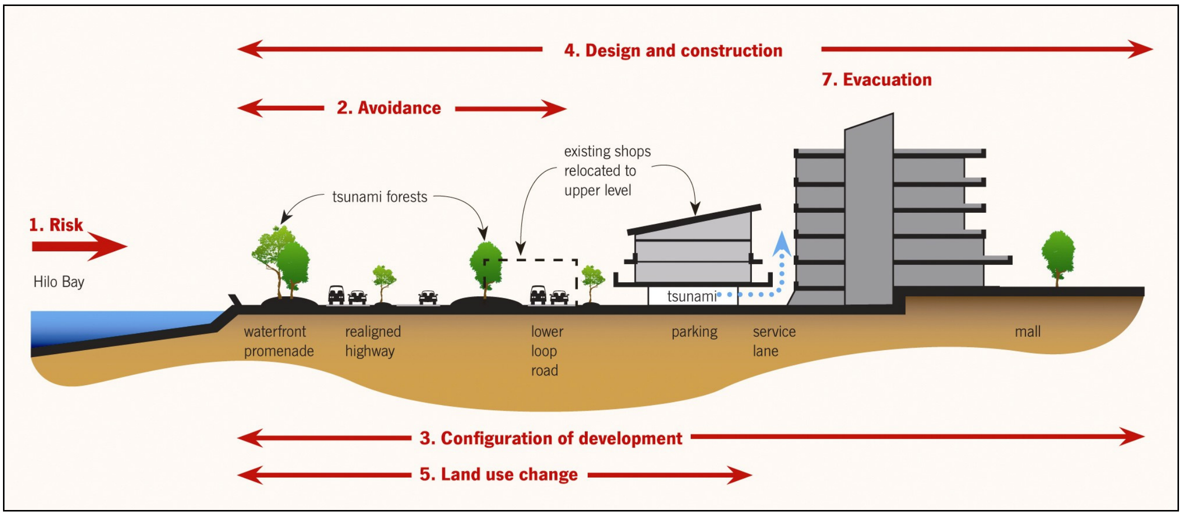

Figure 4: Seven principles for planning and designing for tsunami hazards in Hilo, Hawaii (adapted from National Tsunami Hazard Mitigation Program, 2001, p27).

Taking into account the above principles and the risk-based, precautionary and participatory planning methods, the following regulatory and non-regulatory approaches incorporate tsunami risk into land use planning.

5. Regulatory and non-regulatory approaches to planning for tsunami

Regulatory approaches for the high certainty and uncertain tsunami zones include, but are not limited to, the following (in no particular order):

- Know your tsunami risk (e.g. identification of at risk areas), and include tsunami as a coastal hazard if appropriate (see Figure 4);
- Consistent risk reduction objectives and policies between CDEM Group Plans, RPSs and district/city plans;
  - Avoid new development in at-risk areas e.g. via setbacks. May be impractical at some locations;
  - Avoid locating critical facilities (e.g. public utilities, medical facilities, facilities with post-disaster functions, emergency services, large dams, hazardous facilities) within tsunami hazard zone;
  - Mitigation i.e. community response plans, integration with emergency management preparedness and building design (e.g. for vertical evacuation). May not address life safety concerns for local-source events;
  - Limit infill development so as not to increase the risk to people and property.
- Planners, emergency management officers and transportation planners/engineers work together to ensure the integrity of tsunami evacuation routes are retained i.e. future proofed via high road of importance ranking;
- Ensure tsunami inundation modelling at levels 2-4 are included in LIMs, with an explanation of what the different zones mean and actions required;

- Take a risk-based approach to policy and consents i.e. more restrictive consent activity status with increasing risk;
- Encourage low-density development to reduce the number of people and property at risk;
- Within high-density developments, encourage medium- to high-rise buildings to allow for vertical evacuation (also reduces number of people at risk and limits impacts on buildings);
- Include the assessment of tsunami risk within the Assessment of Environment Effects;
- As condition of consent require an evacuation plan/community response plan to be drafted and accepted by Council, with an annual audited evacuation exercise (refer to Environment Court case Kaihikatea Estate ENV-2006-AKL-001021 where this approach has been used for flooding). NOTE: if a community response/evacuation plan constitutes risk treatment, is the proposal sustainable?
- Combine hazard zones i.e. coastal erosion setbacks with tsunami inundation plus allowance for climate change (sea level rise, increased erosion etc);
- Incorporate design standards for buildings in tsunami inundation zones, particularly for those that could be used for vertical evacuation (future research area).

Non-regulatory approaches for the high certainty and uncertain tsunami zones include, but are not limited to, the following (in no particular order):

- Restore or enhance natural defences, such as dune systems, mangroves, wetlands, and coastal vegetation;
- With participation from the community, develop a strategy for relocating at-risk land uses;
- Pre-plan for land use recovery (e.g. change) post-tsunami event (see Becker, Saunders, Hopkins, Wright, & Kerr, 2008);
- Ensure tsunami hazard zones are incorporated into any structure plans, master plans, development plans, etc., with evacuation routes future-proofed and accessible;
- Communicate risk to owners and visitors via information boards.

6. Summary

This paper has briefly outlined the key elements of a guideline on integrating tsunami inundation modelling into land use planning. Whether tsunami modelling can be used for land use planning purposes depends on what level of modelling has been undertaken, with higher levels of modelling providing the best results for inclusion into land use planning. Further details are provided in the guidelines, which are due for release in April 2011. For further information on the guideline, or to download a copy, please contact the author.

7. Acknowledgments

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8. References

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