A FLOOD RISK MANAGEMENT FRAMEWORK FOR THE BAY OF PLENTY REGION

Mark Pennington[1]
Katalin Maltai[2]

Senior Water Resources Engineer, Tonkin & Taylor, Tauranga
Engineering Officer, Bay of Plenty Regional Council, Whakatane

ABSTRACT

A regional flood risk management framework has been developed for and by the Bay of Plenty Regional Council (BoPRC). A literature survey of current practice was conducted and the resulting framework was developed as a pathway that can be followed from a current situation where flood related assessments have a focus on hazard (only), through to a more desirable future situation where a full risk-based assessment is undertaken. There were numerous obstacles to be overcome in implementation of this changed approach, and two pilot studies were initiated to test and iteratively refine the process. The pilot studies will also test collaborative methodology of BoPRC working with Territorial Authorities and stakeholders to develop a catchment approach to flood risk management.

One of the overall goals in implementation of this framework is to achieve a position where communities are able to live with an understanding and an acceptance of the flood risks to which they are exposed. Outcomes from the risk-based assessments are used to prioritise works (both structural and non-structural) to eliminate areas of intolerable risk. Furthermore, the framework provides a basis on which to conduct future works or continuation of development in such a way that flood risk is not increased into the future.

In this paper the background to the flood risk management framework is detailed, and the framework itself (which is a living document that evolves with time) is presented. The results of the pilot studies are presented and it is hoped that the experience gained during these processes can be applied by others.

KEYWORDS

Flood Risk, framework, risk management

PRESENTER PROFILE

Mark Pennington is a Chartered Professional Engineer with 20 years of engineering experience. His main areas of expertise are in hydrological and hydraulic investigations and analyses. He currently chairs the Rivers Group, a joint technical interest group of IPENZ and WaterNZ, and is a member of the Modelling Special Interest Group Committee.

Katalin Maltai has a degree in Environmental Engineering with experience working for Territorial Authorities as well as Consultancies in both United Kingdom and New Zealand. Her main areas of expertise are in hydrological and hydraulic investigations and environmental impact studies.

1 INTRODUCTION

The purpose of the work that is summarised in this paper was to document the elements undertaken in past work and a literature survey conducted on development of a regional flood risk management strategy for Bay of Plenty Regional Council. A sub-component of this was to develop a Flood Risk Management Framework.

The framework was developed by reference to previous work and to published literature and was developed as a pathway that can be followed from the current situation through to a more desirable future situation, navigating a series of potential obstacles.

By following the flood risk management framework, these obstacles can be traversed.

2 CONTEXT

There are several principal drivers for adoption of a risk-based approach to flood assessments. One of these is a trend towards adoption of risk-based assessments to all natural hazards, of which flooding is one. There are five areas in which a risk-based approach to flood management are seen as an improvement over more traditional approaches. These are summarised in Table 1.

Table 1: Comparison of Approaches

	Traditional Approach	**Risk-based approach**
Assessments of Effects for RMA purposes	Ensure no increase in peak flood depth, velocity or discharge	Ensure no increase in risk associated with flood
Planning Decisions and considerations	Made within the framework of planning horizons	Clear and consistent approach defined, including consideration of residual risk
Cross-boundary consistency	Ensured by agreement	Adoption of consistent approach across territorial boundaries
Prioritisation of Works	Cost-benefit analysis based on property valuations	Integration of a wide range of factors in prioritisation, taking socio-economic factors into account
Design Level of Service	Driven from Building Code and from District Plans	Complete "paper trail" relating risk to level of service, with the ability to set design level of service based on risk assessment

The above table is expanded in the text that follows. These factors were principal drives in development of the Regional Flood Risk Management Framework for the Bay of Plenty.

2.1 ASSESSMENTS OF EFFECTS

It has been common and is a generally accepted approach whereby flood-related assessments are carried out largely with reference to peak flood levels and, less frequently, peak flood discharge and/or velocity. In this way acceptability of a proposed activity on flooding has been deemed acceptable if it could be demonstrated that it did not result in significant change to peak flood depth, flood velocity or peak discharge. This approach is based on the assumption that by making immaterial changes to flood depth, velocity or discharge, an activity would have immaterial effect on surrounding areas. In many cases no increases are tolerated.

Using a risk-based approach, where consequences are taken into account, it may emerge that an increase in flood depth is acceptable, as this does not result in an increase in flood risk. This is detailed in Section 5 where definition of risk is given, and by example in Section 6 in which the principles are demonstrated via a pilot study.

2.2 PLANNING DECISIONS AND CONSIDERATIONS

Frequently omitted in planning decisions is consideration of residual risk. Often decisions are made on the basis that adverse effects can be mitigated up to some pre-defined level of service, with little consideration of residual risk. A risk-based approach will allow for this to be taken into account.

2.3 CROSS BOUNDARY CONSISTENCY

Individual territorial authorities generally have their own sets of design standards. In areas where catchments straddle territorial boundaries this can lead to some inconsistency in the way that a catchment is managed. Adoption of a fully risk-based approach is one way that these differences can be accounted for in assessment and management.

2.4 PRIORITISATION OF MITIGATION WORKS

In addition to assessments of effects, prioritisation of flood mitigation works has also frequently been based on an assessment of the perceived reduction in peak flood level – and consequent reduction in flood damage – associated with specific works. This "benefit" is then compared against the cost of implementation of mitigation works and various alternatives can then be compared and ranked in terms of some form of cost-benefit analysis.

By following this approach, given that benefits in implementation of works are assessed against property value, it frequently emerges that the greatest cost-benefit ratio is obtained for works undertaken in areas with higher property values. This is because the costs of implementation are not driven by property value (e.g. the cost of laying a pipe is not related to rateable value).

If following a risk-based approach to prioritisation of works, these effects can be negated.

2.5 DESIGN LEVEL OF SERVICE

The question frequently arises as to what the design level of service in flood protection should be provided by authorities. Clearly the higher the level of service, the higher the cost for implementation, and a balance is required. Many authorities reference the Building Code for a design level of service, and it is difficult to justify a higher level.

A risk-based approach to flood management is one way in which a design level of service can be selected. The level of service of frequency of event to be used in design and assessment can be inked to overall flood risk, providing a clear paper-trail on which decision making was based.

3 LEGISLATIVE FRAMEWORK

In New Zealand the legislative acts of most relevance to flood risk management are:

- Resource Management Act 1991
- Soil Conservation and Rivers Control Act 1941
- Local Government Act 2002
- Building Act 2004
- Civil Defence and Emergency Management Act 2002.

The Resource Management Act 1991 (RMA) gives Regional Councils the function of controlling land use for the purpose of (amongst other things) the avoidance or mitigation of natural hazards. Territorial Authorities (TA) serve a complementary function in the control of any actual or potential effects of the use, development or protection of land, including for the purpose of the avoidance or mitigation of natural hazards. Flood risk management responsibility can therefore be viewed as being administered through joint regional/TA's. The Resource Management Reform 2013 is proposed to include comprehensive management if natural hazards in planning and consenting.

The Soil Conservation and Rivers Control Act 1941 (SCRC Act) gives the Bay of Plenty Regional Council (BoPRC) the task of minimising and/or preventing damage from floods and erosion. This Act enables BoPRC to achieve its function (typically related to implementation of physical works) but does not require BoPRC to exercise these powers.

No current legislation confers on the Regional Council or on TA's the exclusive power or responsibility for management of flood risk, whether through works or services. There is confusion in some parts of New Zealand about jurisdiction over drainage and flood management, due in part to a lack of legislative clarity. There are a number of mechanisms in the RMA to require information sharing and ensure a consultative approach between regional councils and TA's, but there is evidence that this is not always effective, and on occasion decisions by the Environment Court have been required.

In some places, councils have entered into agreements or memoranda of understanding or have transferred functions under the RMA and Local Government Act to ensure that there is clarity around the management of watercourses and flooding.

In general development in flood-prone areas is controlled, but is still occurring. In some cases the policy framework adopted by councils has not provided these councils with the tools required to address the effects of an activity on managing flood risk successfully.

Flooding is one of a number of hazards that must be taken into account by councils and developers. Flood hazard is generally regarded as having less severe consequences when compared against those from other natural hazards (such as tsunami, earthquake). However the total damage and cost associated with frequent, but less severe, flood events requires consideration when the comparison is made with a single catastrophic event of lower probability. The failure to manage cumulative effects can result in greater long-term costs.

4 FLOOD RISK MANAGEMENT FRAMEWORK

Based on the results of a literature survey on the topic, a flood risk management framework was developed for the Bay of Plenty region. This comprises four phases, with a number of elements within each phase. The framework is laid out as a sequential series of tasks, but it is emphasised that many of these can be run in parallel.

4.1 PHASE 1: SETTING THE SCENE

This phase is in preparation and understanding the catchment(s) being the subject of the flood risk assessment.

Identify target catchment: Catchment identification at the outset is necessary to ensure that a catchment-wide focus is adopted. Establishment of catchment boundaries and which various planning level underlays and land uses are covered will provide a foundation for the assessment. There may also be other non-flood considerations that dictate catchment definitions such as receiving environments affected by sediment and water quality. It may be preferable to align with catchment definitions for those purposes that are used elsewhere in Council so that integrated planning can occur. Also included is consideration of key catchment parameters that have influence on flood risk. These include physical parameters (such as vegetation cover, slopes and soil types) and socio-economic factors (which affect flood vulnerability). Both current and likely future scenarios require consideration.

Engage key stakeholders: Getting key stakeholder engagement at a very early stage in the process will greatly assist in ownership and success of any flood risk management strategy. Key stakeholders clearly include Territorial Authorities and the Regional Council, but also include commercial, community and private individuals and interest groups.

4.2 PHASE 2: UNDERTAKING THE ASSESSMENT

Assess current situation: As part of the assessment process, establishment of the baseline situation is important before mitigation measures can be progressed. This assessment should include damage records from recent flood events and results from any hydrological or hydraulic analyses that have been completed. Understanding where current pressures exist in terms of flood risk management is required, and can include the following:

- Current known flood prone areas and levels of service
- Known erosion areas
- Existing flood schemes and levels of service
- Design lives of infrastructure assets.

Assess flood hazard for target event: Once an understanding of the existing catchment performance is gained then an assessment of the hazard in response to the required level of service can be undertaken. This essentially involves establishment of the technical parameters that can be changed to alleviate flood hazard for events of various probabilities of occurrence. For example, areas prone to different categories of flood hazard (by reference to an agreed hazard definition) can be established for various flood events.

Establish flood risk management principles: The principles to be applied to flood risk management need to be defined on a catchment-by-catchment basis. These principles include safety, understanding of river and catchment processes, climate change, life-supporting capacity, planning ahead, options, responsibility and decision-making.

Assess flood vulnerability: A flood vulnerability assessment is comprised using inundation area maps, an understanding of the nature of flooding, the land use and asset database and socio-economic factors including flood resilience and susceptibility to damage. This is shown diagrammatically in Figure 1.

Prepare flood risk maps: Flood risk maps can be prepared by combining a flood vulnerability map, a hazard probability map and cost-damage functions. This process will result in an assessment of flood risk in the target area, and will form the basis of decisions on any further actions or assessments. It can also be used for comparative assessments.

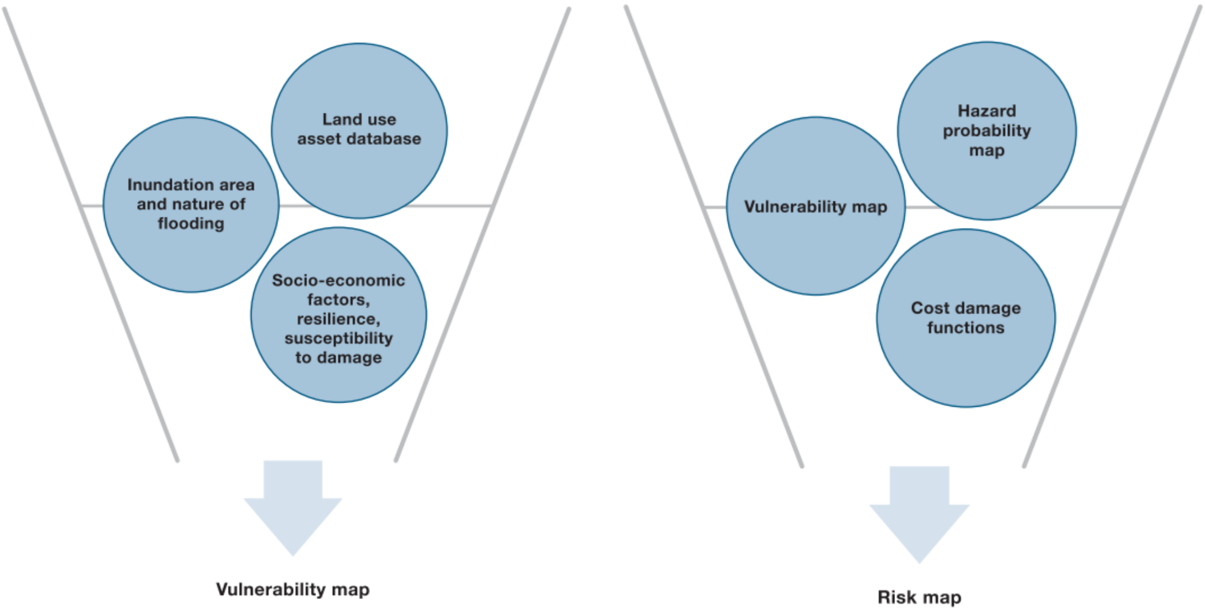

Figure 1: Vulnerability and Risk Map Elements

4.3 PHASE 3: IMPLEMENTATION

The implementation phase sets out the ways by which the strategy that has been developed will be rolled out to communities.

Establish management measures: Management measures are established by reference to the Flood Risk Management Framework. In this the critical elements for the subject catchment are identified, and these may differ from catchment to catchment.

Devise action plan: Knowing management measures to be adopted and areas exposed to unacceptable degrees of flood risk, action plans to address the flood risk can be developed. An action plan will need to cross reference the adopted Flood Risk Management Framework, in particular the underlying philosophy that has been adopted.

Assign responsibilities: Responsibilities for each flood risk management assessment need to be assigned, particularly if actions are required.

4.4 PHASE 4: REVIEW

This is possibly one of the more crucial elements to a flood risk management assessment process, in that it is almost inevitable that things will change with time that will affect the process to be adopted. With implementation of any plan there should be allowance made for review and update and regular intervals. With all review and updates the entire flood risk management process should be followed.

A full flood risk management framework diagram, across the above four phases, is shown in Appendix A.

5 DEFINITIONS

The term "flood risk" requires definition in this paper. Frequently the term "risk" is interchanged with "probability" in an erroneous way. In this document, "flood risk" is defined as the combination of probability of a flood occurring with the consequences of such a flood being experienced. A classic definition of risk is as the product of probability and consequences.

Risk = Probability x Consequences

This can be expanded to be

Risk = Hazard x Exposure x Vulnerability

To reduce risk there are three clear options – reduce the hazard, reduce the assets exposed to the hazard, or reduce the vulnerability.

The way in which each of the parameters within the above equation are assessed is often not clear nor consistent. There is a lot of ongoing investigation into these, both nationally and internationally. Of importance in application of the framework is adoption of a consistent approach to enable valid comparisons to be made. An attempt at this was made in a pilot study, outlined below.

6 PILOT STUDY

To demonstrate the process, a pilot study was undertaken. Initially it was suggested that this pilot study extend across all of a flood-prone urban area, but this was soon found to be cumbersome for the purpose of demonstration of the process, and the target area was simplified to a single flood-prone camping ground. Within this camping ground there are several different types of 'land use' that could be used as proxies for an actual settled area, and a significant stream flows through the middle of the campground.

Questions on overall management of the stream have been raised, with competition for space between campground activities and flood carrying capacity of the stream is an ongoing issue.

Land uses are shown in Figure 2, and comprise the following:

- Facility Buildings: high-value buildings with fit-out.
- Permanent Units: high-value.
- Non-Permanent Units: lower value than permanent, but potentially vulnerable.
- Tent Sites: Low vulnerability as tents can be moved in advance of a flood.
- Roadways: Very low vulnerability.

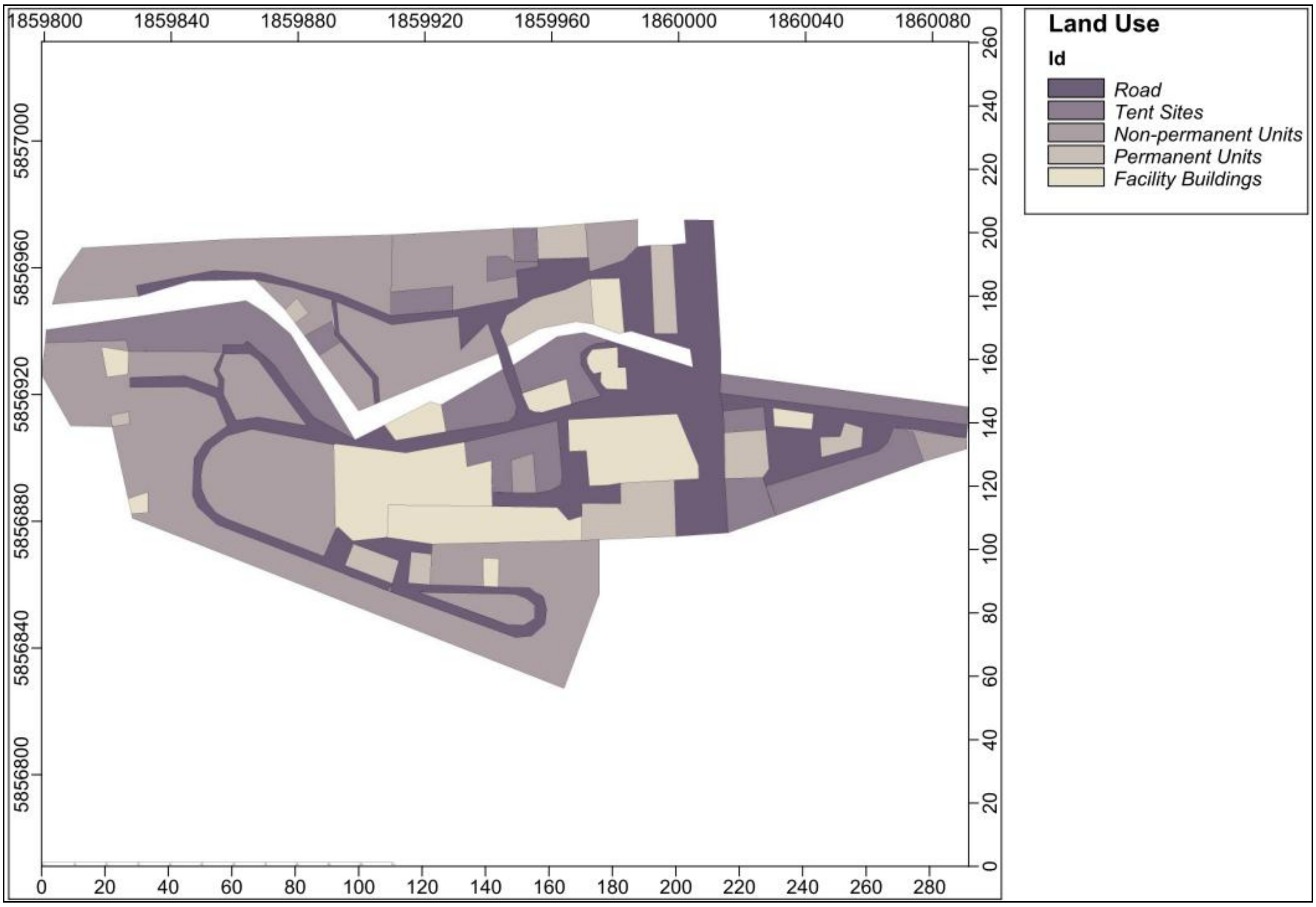

Figure 2: Land Use Map

The full Flood Risk Management Framework could easily be rolled out to this camping ground, as there is a single owner. For the purpose of example, it fitted well.

Following the framework, the target catchment was identified and the single stakeholder was consulted. Phase 1 was complete. Phase 2 involved undertaking the assessment, and this hinged off a detailed 1D-2D modelling assessment. Phase 2 also involved some detailed assessment of hazard, exposure, vulnerability and, ultimately, risk. While this is not intended as a template to be followed for other flood risk assessments, it is demonstrative of a process that could be followed.

As identified, flood hazard was initially assessed. This was based on the Average Recurrence Interval of each event that causes flooding, and was combined with predicted flood depth and velocity. A resulting flood hazard map is shown in Figure 3.

In this figure the areas subject to flood hazard are shown, in this case for an event of 100-year ARI. Results were all gridded to a 3mx3m square grid.

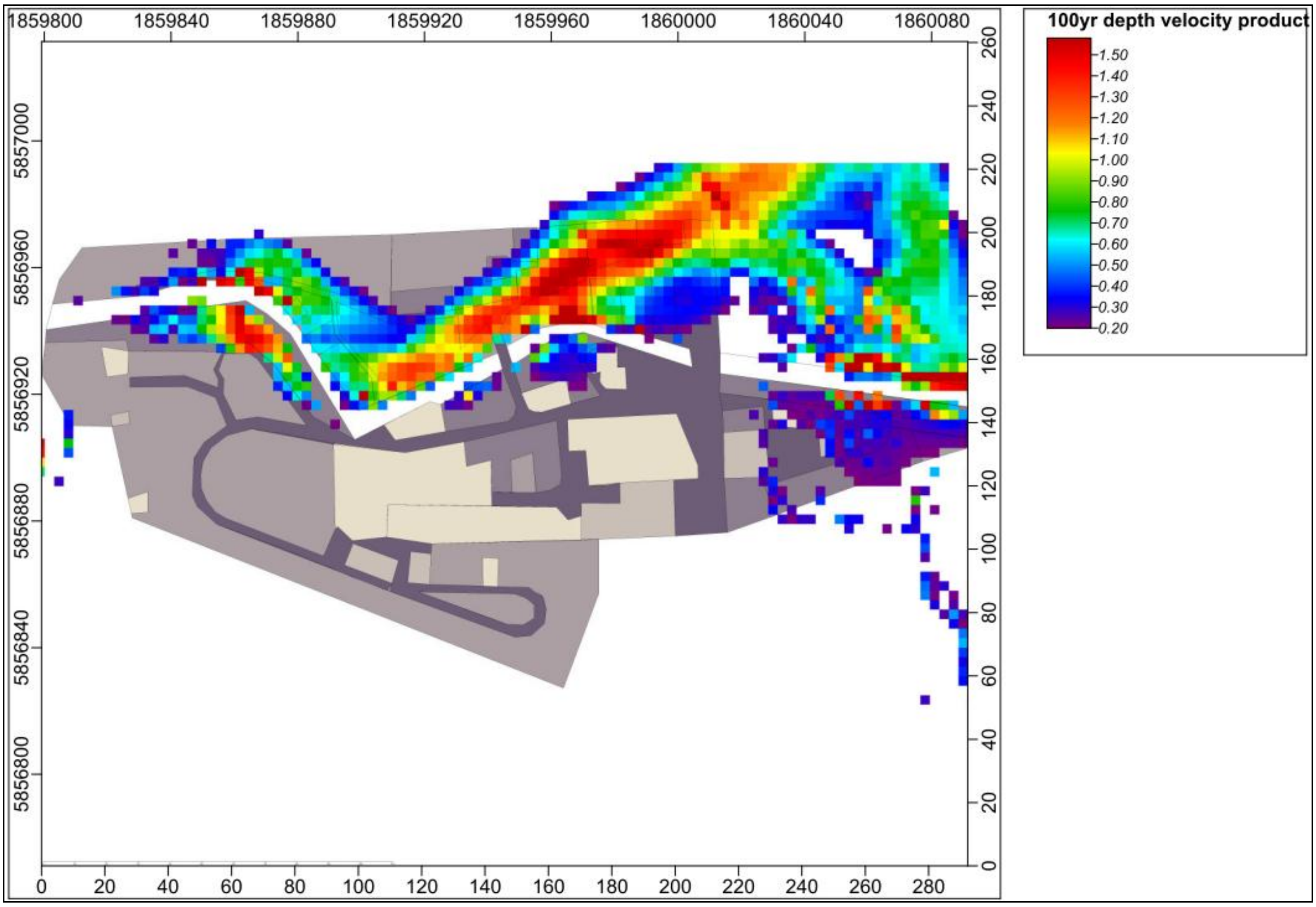

Figure 3: Flood Hazard Map

Exposure was determined by 'land use' in the camping ground, combined with a binary multiplier that ensured a zero value applied to areas not prone to flooding in this particular event. This means that there is no flood risk in areas where there is no flooding.

Different weightings can be given to each of the component parameters, and in this pilot study example all parameters were equally weighted. This is unlikely to be realistic, but is done here to demonstrate the process rather than present actual results.

Exposure was then gridded onto the same grid as that for hazard, with the resulting plot shown in Figure 4. The units in the "exposure scale" are not defined here, although this scale is kept constant across successive iterations to enable comparisons to be made. Sensitivity testing of the weightings of parameters would lead to a good understanding of how outcomes can be directed by certain of the parameters included.

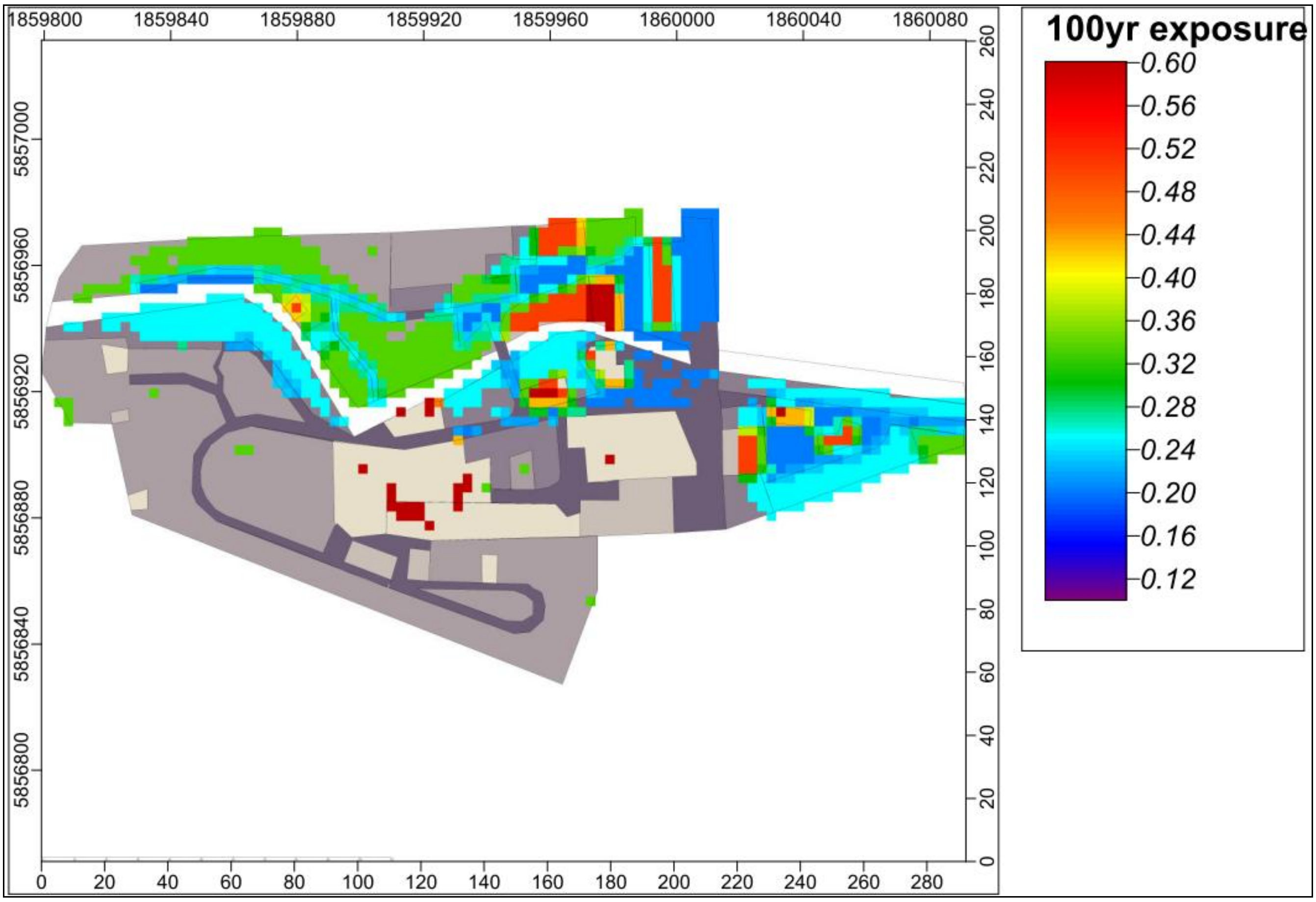

Figure 4: Flood Exposure Map

In this figure it can be seen that flood exposure is greater than zero only where there are assets in need of protection (i.e. only within the camping ground for the pilot study), and only where flood depth exceeds zero.

Vulnerability was assessed in two parts. Firstly, depth-damage was calculated based on some arbitrarily derived depth-damage curves (it is suggested that these be defined explicitly in any actual roll-out). A different curve was applied to each land use, and results were calculated on a square metre basis. This resulted in a gridded map of total damage, for each flood event examined.

Secondly, a socio-economic weighting was applied that was based on the camping ground 'land use'. A weighting of 3 for permanent units, 2 for facility buildings and 1 for all other 'land uses' was applied. In reality determination of appropriate socio-economic weightings is probably the most challenging aspect of this process, but it is suggested that results can be checked for sensitivity in this and possible conclusions can be drawn from this alone.

The result of the above was a gridded vulnerability map, for the 100-year ARI flood event. This is shown in Figure 5, with the components of the vulnerability map being those identified in Figure 1. As with other maps produced, the unit on the scale is not defined, and is based on selected weightings of component parameters.

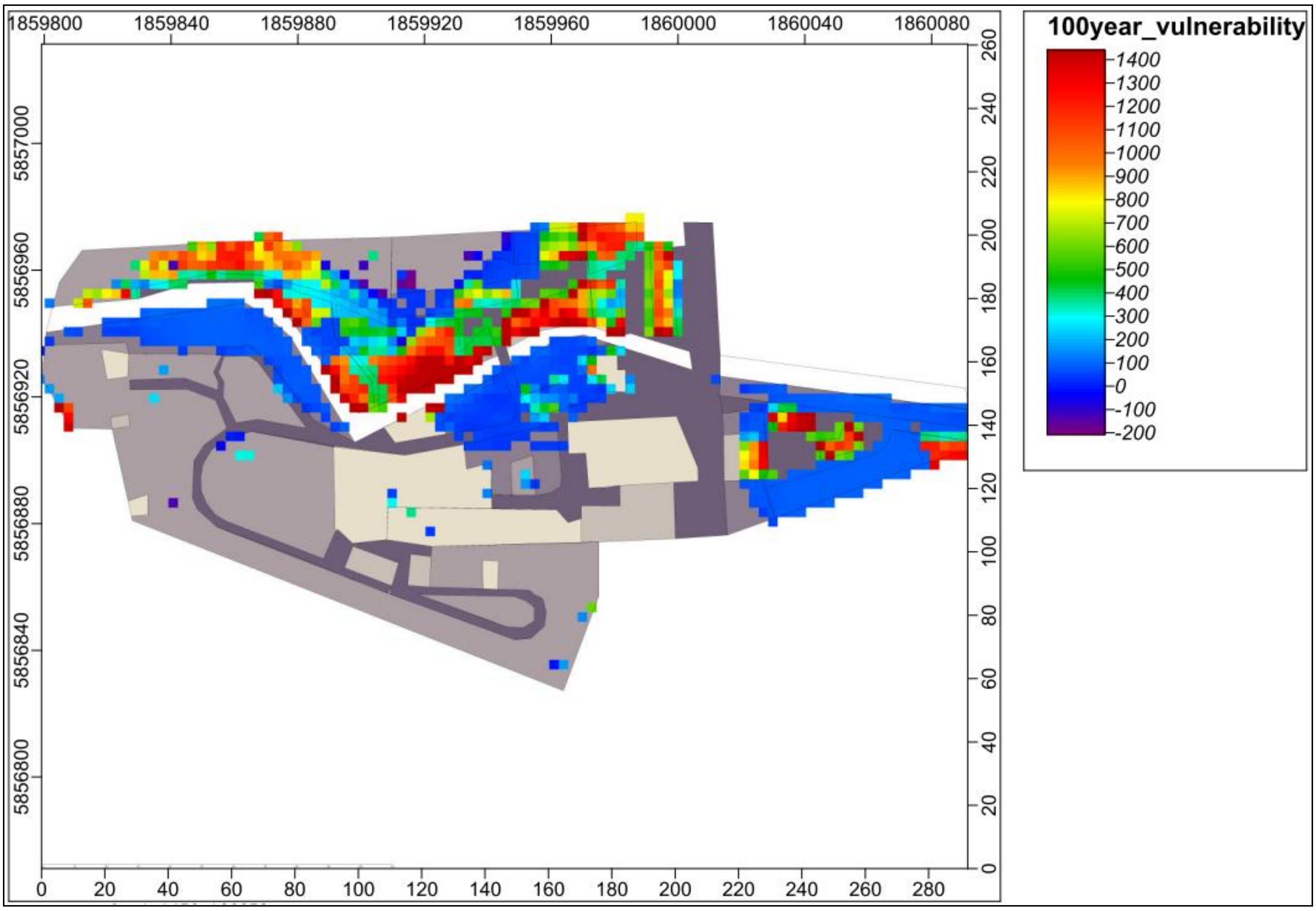

Figure 5: Flood Vulnerability Map

A final step in preparation of the 100-year ARI flood risk map is combination of the hazard (Figure 3), exposure (Figure 4) and vulnerability (Figure 5) maps, to result in the risk map shown in Figure 6.

From this the areas of highest flood risk, in response to the 100-year ARI flood event, can be easily identified.

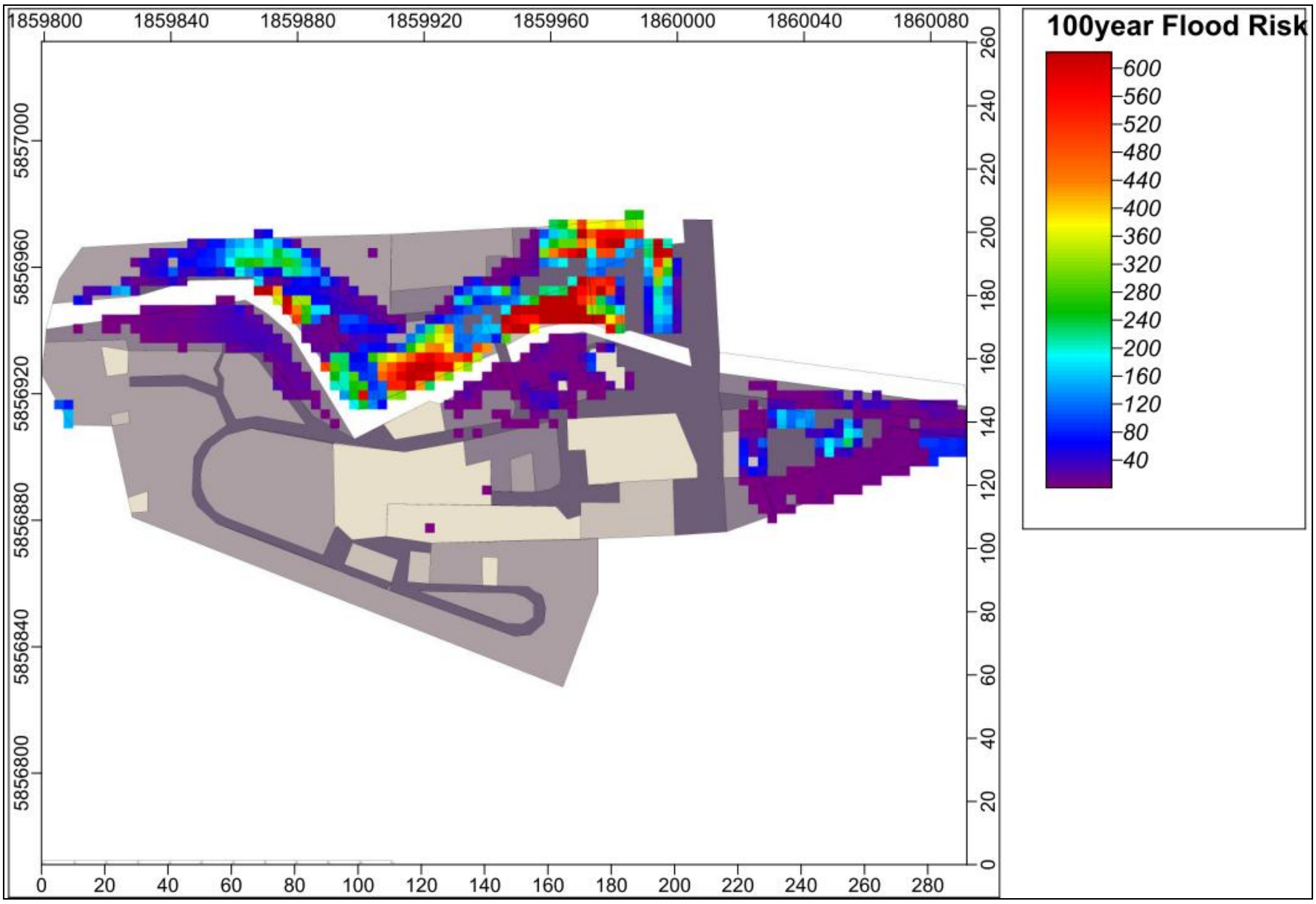

Figure 6: Flood Risk Map

7 MANAGEMENT OF FLOOD RISK

Having defined a method for preparation of a flood risk map, a consistent set of such maps can be developed. Each of these will be developed for a specific set of circumstances relating to flood event selected and land use adopted.

7.1 THRESHOLD APPROACH

A threshold for tolerance of flood risk can then be defined. This may be an absolute value, and the flood risk map can be interrogated for areas where this tolerance is exceeded. Mitigation works can then be aimed at reduction of risk over these areas to result in a flood risk map where this tolerance is not exceeded. Changing land use will result in changes to the flood risk map. This approach can be applied iteratively until all areas where risk exceeds a defined 'tolerable' level can be removed.

7.2 TOTAL RISK PROFILE APPROACH

Alternatively total flood risk for this scenario (flood event and land use, socio-economic situation) can be assessed by integration of all individual grid cell risk values into a histogram, such as that shown in Figure 7. These histograms can then be used to compare one scenario against another. This gives a measure of the "total risk" for the particular scenario mapped.

7.3 SELECTION OF LEVEL OF SERVICE

Finally, if this process is repeated for a number of flood event probabilities, total flood risk can then be plotted on a graph of risk versus probability to determine the event (i.e. probability) that results in the greatest flood risk. This may be used in setting level of service.

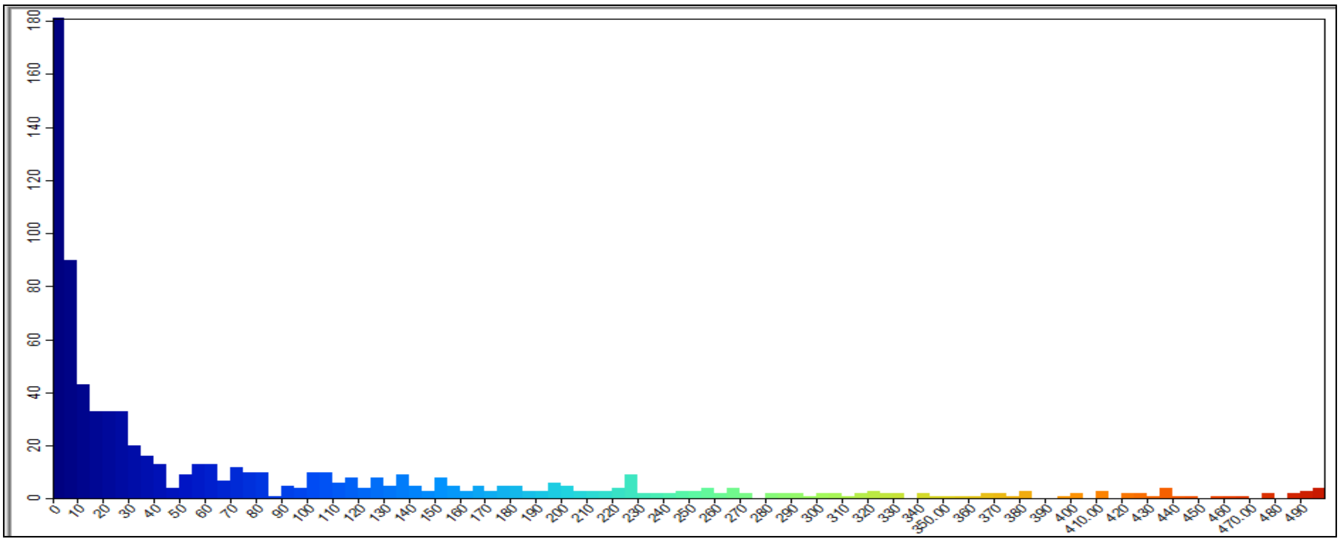

Figure 7: Flood Risk Histogram

8 CONCLUSIONS

Work continues to progress with the implementation of this risk-based framework within catchments in the Bay of Plenty region. While the framework and assessment methods are under development, some useful outcomes have been achieved in some of the pilot study catchments.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Bay of Plenty Regional Council for commissioning this project and for continuous input into it. Specifically David Boothway and Mark James have had significant input. We also wish to acknowledge Western Bay of Plenty District Council in permission for use of detailed modelling results in the pilot study.

Futhermore, we recognise the contributions to the risk management framework made by Tauranga City Council and Western Bay of Plenty District Council staff.

REFERENCES

Allan AJN, Harley GA, Hooker M, Christensen KJ and Wesney HPJ (2013), *Upper Wairarapa Floodplain Management Plan*, WaterNZ South Pacific Stormwater Conference 2013.

Environment Agency (2008), *The Humber Flood Risk Management Strategy*, Summary Document March 2008.

Ministry for the Environment (2008), *Meeting the Challenges of Future Flooding in New Zealand*.

Otago Regional Council and Clutha District Council (2012), *Milton 2060: Flood Risk Management Strategy for Milton and Tokomairiro Plain*.

Otago Regional Council and Queenstown Lakes District Council (2006), *Learning to Live with Flooding: A Flood Risk Management Strategy for the Communities of Lakes Wakatipu and Wanaka*.

The World Bank (2012), *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*, ISBN 978-0-8213-9477-9.

Waikato Regional Council (2009), *River Flood Risk Management Strategy 2009*, ISSN 1174-7234, Environment Waikato Policy Series 2009/20.

9 APPENDIX A: FLOOD RISK MANAGEMENT FRAMEWORK