A REALITY CHECK ON FLOOD RISK

Barry Carter , Nick Brown , Neil Blazey. Auckland Council, Auckland , New Zealand.

ABSTRACT

Traditional approaches to flood risk assessments involve modelling catchment systems to determine predicted flood plains and using these to assess flood risks for property and infrastructure. While this is a necessary first step in determining flood risk it is far from adequate.

This paper considers the wide ranging physical dynamics that come into play during actual flood events. A set of factors and processes to determine more realistic flood risks is put forward. The refining of modelling techniques in recent years has misled stormwater practitioners into a false sense of confidence in predicting outcomes of flood events. This paper provides a reality check on what actually happens during extreme flood events and advocates for more consideration of potential blockage, obstructions, changes to waterways during flood events and impacts on water level associated with velocity and momentum.

Consideration of these factors may lead to improved prediction of flood hazards, more effective flood mitigation measures and better preparedness for emergency management and response.

KEYWORDS

Flood risk assessment, hazards, blockage, residual risk, consequences

PRESENTER PROFILE

Barry Carter is a Team Leader within the Stormwater Catchment Planning Team of Auckland Council. For the past 7 years Barry has been leading the development of catchment plans for the North Shore area. With a background in Civil Engineering Barry has over 20 years experience within Local Authorities and 15 years experience in the private sector.

1 INTRODUCTION

In observing what actually happens in extreme flood events it is frequently apparent that the factors related to risk to life and property are not adequately considered in the assessments traditionally carried out by stormwater planners.

This paper discusses a range of observed flood events and the factors that frequently come into play that have significant effect on the severity of flood risk and consequences.

These observations are then related to common practice for assessment of flood risk and the underlying assumptions normally made in carrying out this work.

Common practice is to predict flood plains and to do little else to assess flood risk. This paper emphasises the distinction between assessing flood plains and assessing flood risk.

A set of factors and processes for determining more realistic flood risks is put forward for consideration.

The objective of this paper is to raise awareness and promote a more realistic assessment of flood risk in order to enable more effective flood mitigation measures and better preparedness for emergency management and response.

2 WHEN FLOODS GO BAD

Over recent years there have been many images from within New Zealand and around the world of extreme flood events. The following is a sample to provide some context and direction for this paper.

2.1 TAURANGA, NEW ZEALAND 18 MAY 2005

- 310mm of rainfall over 36 hours
- 315 Houses evacuated
- Landslides undermined houses at top of slopes, debris damaged houses at toe of slopes.
- $11M infrastructure reinstatement costs plus $65M stormwater improvement works required.

Photograph 1: Landslide at Otumoetai, Tauranga May 2005

2.2 MATATA, NEW ZEALAND 18 MAY 2005

- 308 mm of rainfall over 20 hours, 94mm in peak hour

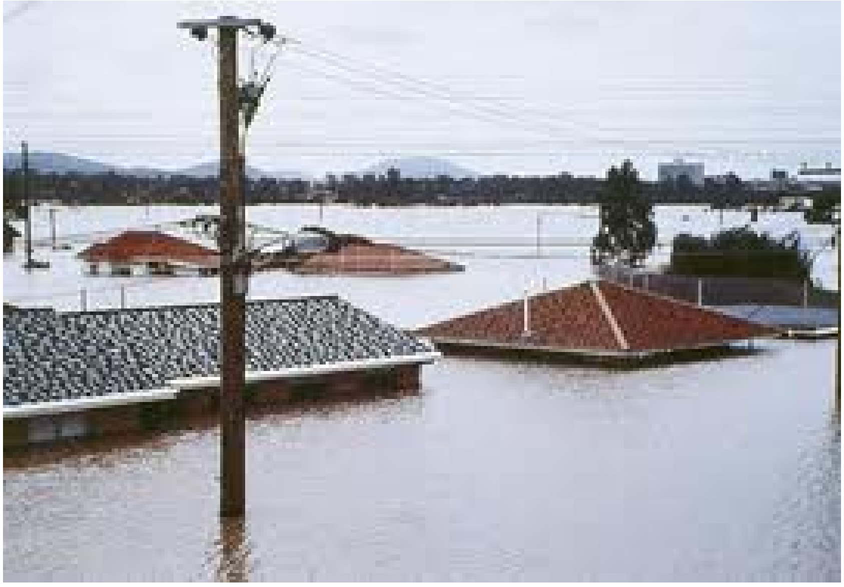
- 538 people evacuated
- 27 homes destroyed
- 87 homes damaged
- 700,000 m3 of debris (including boulders up to 7m wide)
- $30M insurance claims in the Bay of Plenty area from this event

Photograph 2: Debris flows at Matata May 2005

2.3 QUEENSLAND, AUSTRALIA JANUARY 2011

- A series of widespread storms over more than 2 weeks from the end of December 2010 until mid January 2011.
- Between 600-1000mm of rain in most Brisbane catchments
- 600mm of rainfall recorded in parts of the Stanley River catchment between 9 January and 13 January 2011.
- 33 people killed.
- 70 towns and 200,000 people affected
- A$10 Billion cost to Australian economy
- A$1.5 Billion flood damage insurance claims
- 90,000 km of roads damaged

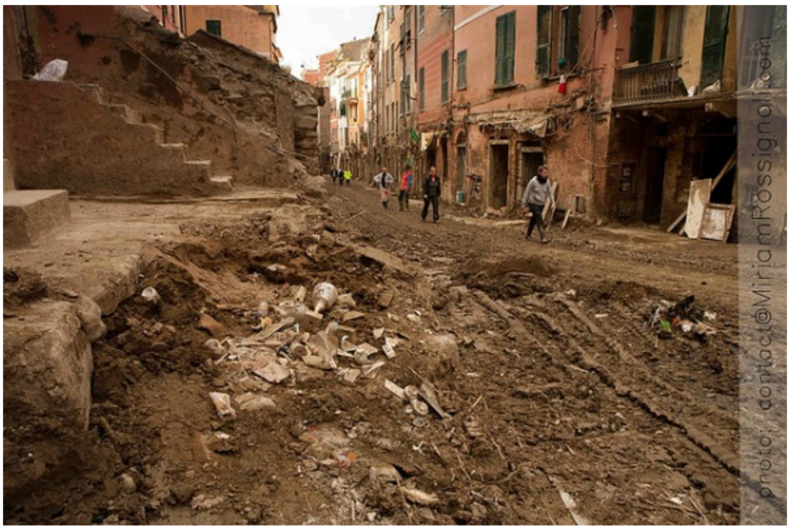
Photograph 3: Widespread flooding Brisbane January 2011



2.4 VERNAZZA, ITALY, 25 OCTOBER 2011

- 500mm of rain in 4 hours
- 1,500,000 m3 of mud, trees and debris flowed through the valley with debris in the main street up to 4m high
- 300 landslides over an area of 12square kilometres
- 3 people killed
- Town evacuated by sea and all services destroyed
- €108M estimated damage to Vernazza
- Several nearby villages suffer similar damage

Photograph 4: Flood debris Vernazza October 2011



.

3 CONSEQUENCES OF FLOOD EVENTS

The examples of extreme flood events outlined in 2 above provide a range of common consequences. These can be summarized as follows:

- Loss of life and severe injuries. (Between 1990 and 2000 the average yearly loss of life on a worldwide basis as a result of flood events was over 9000.)
- Health impacts from water borne disease and stress
- Damage to buildings and contents ($46M of claims related to flooding in New Zealand during 2011)
- Damage to infrastructure (Including roads, bridges, culverts and services)
- Significant land slips
- Major debris movement

Collectively these consequences have significant social, financial, economic and environmental impacts on the communities and regions affected.

4 CURRENT PRACTICE-ASSESSMENT OF FLOOD RISK AND ASSUMPTIONS

4.1 THE MODELLING PROCESS

Common practice in assessing flood risk is to develop models to predict flood flows and flood extents for a catchment. The process in summary involves:

- Capturing and validating data related to rainfall and runoff and metrics for the stormwater system and terrain.
- Building a digital terrain model.
- Applying a set of rainfall depth, duration and frequency profiles to a catchment
- Determining runoff characteristics based on topography, geology, permeability, land use and vegetation cover.
- Determining and accounting for system features including overland flowpaths, piped network, storage, culverts, bridges, inlets to systems, streams and tidal influences.
- Accounting for the areal extent to which the design rainfall will apply.
- Developing scenarios related to current and future states for the catchment including predicted land use and imperviousness and the impacts of predicted climate change.
- Building a hydraulic model
- Validating, testing and documenting the model
- Running the model to produce predicted flood flows, staging and flood levels for various storm profiles and durations.
- Mapping of flood plain extents for selected scenarios.

Flood extent maps are the primary tool used to predict flood risk to existing or proposed development. Models can be used to assess the impacts and sensitivities of altering any of the model inputs or assumptions. In this way system performance improvements can be assessed and the scope and nature of land development and improvement works can be optimized.

4.2 MODELLING ACCURACY

In recent years there have been significant developments in improving the accuracy of data used in modelling work. These improvements include:

- Use of LiDAR surveying to improve the accuracy of digital terrain modelling.
- Use of GIS tools to analyse existing and predicted land use, surface types and permeability
- More reliable and longer rainfall and flow gauging records.

Development of modelling software and techniques has also enabled refined accuracy of models and outputs. These developments include:

- Quickly evolving development of 2D modelling software
- Rapid Flood Hazard Assessments prior to detailed modelling and data collection
- Move to 64 bit multicore processing to reduce model run times

The improvements in data accuracy are unquestionably valuable. The development of modelling software and techniques also has valuable potential. However, the application of the modelling tools and techniques requires considerable skill and expertise.

Recent experience within Auckland Council has shown that there is a wide variation in quality and reliability of models developed in the Auckland region in the last few years. Common problems encountered include:

- Not validating the physical dimensions and characteristics of networks.
- Assumptions underlying models not being appropriate and/or not being tested for sensitivity
- Application of modelling techniques not being appropriate and leading to gross errors
- Models not being reviewed
- Hand verification of results not being undertaken

The key message is that robust processes and highly skilled, well trained modellers are needed to ensure hydraulic models are fit for purpose and reasonably reflect the likely flood extents within the bounds of the assumptions and scenarios being modelled.

There is significant inherent risk in relying on models that have not been adequately developed and checked. The capability of the software and techniques can easily lead to over confidence in the accuracy of the deliverables.

4.3 MODELLING ASSUMPTIONS AND LIMITATIONS

If it is assumed that a completed model is reliable within the bounds of its assumptions and limitations the next aspect to explore in terms of flood risk assessment is the adequacy of typical modelling assumptions and limitations.

Commonly models are set up on the assumption that stormwater will be delivered to piped systems or watercourses without restriction or with limited restriction. During major storm events this assumption is invariably invalid at some or many locations within the catchment. The usual faults are:

- The inlets to systems, individually and collectively do not have the capacity to take the modelled flows even if they remain unobstructed.

- Inlets and watercourses are blocked partially or totally by storm debris including vegetation, trees, sediment and boulders, vehicles, minor buildings and household furniture.

- Assuming all pipes are maintained and operable - no roots or obstructions in any part of the network.

Another common assumption is that the watercourses will remain intact through the storm. During major storm events this assumption is often invalid because landslips and erosion occurs and debris is carried through watercourses. This results in the cross sections of the water courses changing as erosion and deposition occurs. Higher than predicted flood levels may occur at some locations which in turn may lead to flood flows being diverted to flowpaths other than those predicted. The erosive power of debris filled flows may also exacerbate erosion, resulting in the development of new flowpaths and a very different flood situation to that predicted.

The assumption that storm flows have the viscosity of water is also frequently invalid and in extreme cases such as the 2005 Matata storm would lead to significant under-prediction of flood levels.

4.4 HAZARD ASSESSMENT

Putting aside the limitations and concerns expressed above, common practice is to develop flood hazard maps from models to indicate the extent and predicted flood levels resulting from modelled storm events. The risk associated with the limitations of modelling and the underlying assumptions is usually accounted for by applying a blanket freeboard or sensitivity allowance to the flood level, typically 0.5m.

Flood hazard maps are then used to assess risk to existing and proposed development. Options to alter, improve or optimize the performance of systems can then be modelled and assessed.

More recently hazards to public safety associated with depth and velocity are being considered and progress is being made towards development of maps to reflect these hazards.

5 IMPROVING FLOOD HAZARD ASSESSMENT AND MANAGING RISK.

Extreme flood events may or may not exceed an estimated 1% annual exceedance probability event. The challenge is to consider and manage the residual risk for rare events and to mitigate the consequences where this is reasonably practicable.

Having identified the concerns and limitations of current practice related to flood hazard assessment the following discussion puts forward a set of factors and processes for determining more realistic flood risks associated with major storm events and managing risk.

- Ensure the critical assets are identified and represented correctly in models. Often the connectivity and/or dimensions of critical assets are not verified in models and headlosses at these critical structures are poorly understood.

- Have programmes to assess the condition and maintain, improve or renew critical assets. Asset failure during storm events and consequential damage can often be prevented or minimized by having robust proactive asset management programmes.

- Identify and ground truth the nature, capacity and risk of blockage of inlets to systems. In major events the risk of blockage is high and can be very unpredictable. Reliance on inlet capacity is risky. Manage residual risk by building in redundancies such as secondary weir inlets at critical locations. Examples of items blocking inlets include: trees, vegetation, mattresses, hail, garden sheds, cars, containers, signs, blocked trash racks and erosion debris.

- Identify and assess depressions in the catchment. These are areas of particular hazard because depressions can fill, sometimes to several metres depth, if drainage systems block. Run scenarios to account for total blockage, consider fail safe overland flow path exits from depression areas. Do not apply flood risk assessment to these areas simply in terms of freeboard above predicted modelled flood levels. Consider potential flood levels and hazard areas by taking total system blockage and fail safe levels into account.

- Identify and ground truth significant overland flowpaths. Commonly a high percentage of habitable floor flooding particularly in small catchments occurs as a result of obstructions to overland flowpaths. A focus on assessing these overland flowpaths and determining risk and potential improvements can go a long way towards managing flood risk and damage.

- Consider the potential for landslips and erosion in a catchment. This involves study of stability of soils and slopes in the upper or steep sections of catchments and stability of streams. It is important to understand the geomorphology and history of sensitive catchments. In catchments where these risks are significant consider flood risk scenarios associated with potential erosion and deposition. If nothing else, apply considered engineering judgement in determining additional allowance for flood risk and undertake assessment of mitigation measures. Risk assessment should consider the higher probability of system blockage and the likely consequences of deposition of debris. Measures to keep development clear of likely flow paths and removal of existing development from high risk areas should be considered.

- Take into account flow velocity and energy head.

    - Flood levels on the outside of fast flowing river bends will be significantly higher than the centre of river flood levels determined by conventional modelling (1D modelling or 1D, 2D coupled modelling is not typically able to calculate super elevation). In such areas where there is current or potential development this assessment of risk and the associated modelling should be undertaken.

- Buildings and structures in the path of fast flows will experience flood levels considerably higher than the unobstructed flood levels predicted from conventional modelling. These changes will be associated with the loss of energy as the water meets the obstruction and from turbulence and pressure waves. It is important to identify where such concerns may occur and to take into account the energy grade line and the additional risk that may apply in these locations. Mitigation works involved in such areas may include altering flowpaths, raising floors, providing resilience such as flood shutters to doorways, or removing/relocating buildings.

Photograph 5: Impact of fast flows

- Develop flood hazard maps identifying potential areas of high velocities during storm events. Much of the loss of life and serious harm associated with storm events arises from people being in or entering fast flowing water.

- Communication of information between stormwater planners, stormwater operational staff, emergency management teams, residents and business owners is an essential process in ensuring that flood risks are understood and managed and that consequences in major storm events are mitigated.

- Understanding and accounting for flood hazard risks by the development community including regulators is an essential component in managing flood risk associated with future development.

6 CONCLUSIONS

Current processes and methods of flood risk assessment are commonly limited and as a result frequently under-estimate the consequences arising from major storm events. In observing actual storm events landslides, debris flows and impacts of high velocity usually have major significance.

The challenge is to consider and manage the residual risk for rare events and to mitigate the consequences where reasonably practicable.

The development of processes to assess overland flowpaths, the potential for landslips and erosion and accounting for the impacts of high velocity flows as part of the assessment of flood hazards for a catchment will lead to more robust hazard assessment.

Proactive asset management programmes to monitor and mitigate flood risks associated with stormwater systems can contribute significantly to management of flood risk.

Provision of appropriate rules in District Plans can go a long way towards limiting development and risk in flood prone areas.

Effective communication between stormwater planners, stormwater operational staff, the development community, regulators, emergency management teams, residents and business owners is an essential part of managing flood risk and the consequences of major storm events.

ACKNOWLEDGEMENTS

The authors acknowledge the many teams within Auckland Council working to achieve more effective flood risk assessment and flood mitigation.

Views expressed in this paper are those of the authors and do not necessarily represent policy or position of the Auckland Council.

REFERENCES

Flood blog New Zealand

http://magik-floods.blogspot.co.nz/

Humanitarian Early Warning Service (developed by the World Food Programme)

http://www.hewsweb.org/floods/

Institute of Geological and Nuclear Sciences Ltd-The 18 May 2005 Debris-flow Disaster at Matata

http://www.geonet.org.nz/content/download/7527/44031/file/report8.pdf

Ir. S.N. Jonkman Rijkswaterstaat, Dienst Weg- en Waterbouwkunde Loss of life caused by floods: an overview of mortality statistics for worldwide floods

http://www.tudelft.nl/live/binaries/a4751543-3c3e-4787-b3c2-ae34f717f351/doc/citatie161.pdf

Save Vernazza ONLUS (An Italian non-profit organization)

http://savevernazza.com/vernazza-disaster-fact-sheet/

The Insurance Council of New Zealand-The Cost of Disaster Events

http://www.icnz.org.nz/current/weather/

Whakatane District Council-Matata five years on

http://www.whakatane.govt.nz/News/News-Archive/Matata-five-years-on/

Wikipedia 2010-2011 Queensland Floods

http://en.wikipedia.org/wiki/2010%E2%80%932011_Queensland_floods