IS PROVIDING A STORMWATER LEVEL OF SERVICE FOR SIGNIFICANT FLOOD EVENTS REALLY REALISTIC?

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ABSTRACT

A significant flood event is a strong trigger for infrastructure improvement works, and many Councils find themselves making political and public statements around acceptable tolerance levels for flooding, especially in the wake of a significant event. Often these flood events are extreme, and are in excess of what would ordinarily be regarded as provision of a basic stormwater utility service. The distinction between the utility provision and defence against the flooding natural hazard is often blurry. The key question that is not often considered through these statements is whether the desired outcome (for this paper a level of service) is affordable, or even attainable.

In Tauranga the stormwater budget is subject to large expenditure spikes immediately following intense rainfall events which have resulted in flooding. Following the May 2005 flood event the Council initiated a flood recovery programme which resulted in the construction of major stormwater infrastructural projects in the parts of the City affected by that event, resulting in approximately $80M being spent over a four year period, with the intention of delivering a 50 year ARI level of service (where attainable).

Continued improvements to the stormwater network are required if the Council and community want to reduce the existing flood risk within previously affected areas and those potentially at risk from flooding, if it intends to reduce the risk through infrastructure provision alone. In 2009, the then Council, received a paper from staff outlining an additional $170M would be required to improve the current situation, however no financial analysis had been undertaken to determine the accuracy of that figure, nor had any modelling been undertaken to determine the extent of the flooding issues.

The key issue is in deciding on any approach will be couched within the cost to the community of intervening or not, and whether other approaches can be put in place to support an infrastructure program. To consider a consistent approach to stormwater a level of service (LoS) provides the ability for a framework of intervention, however this is strongly influenced by funding considerations given the City’s current debt levels.

A LoS also ensures the consistent delivery of the Councils message to the community and can result in an appropriate backstop for the Council in regard to intervention and to ensure staff are appropriately provided with a policy approach to work within and funding to be provided.

To test these strategic issues above, the Council embarked on the development of a stormwater project which considered the following:

- 2D modelling and flood hazard identification;

- Development of an affordable and realistic level of service in relation to flood hazard management;
- Utilising policy/regulatory, educational and infrastructure opportunities to reduce flood risk; and
- Establishing priority areas and considering economic benefits and implications of future upgrades and other options;

The purpose of this was to seek to define an appropriate and affordable level of service coupled with other risk reduction techniques in an overall approach to flood risk management.

In this paper the above process is described. Further, this paper explores the issues surrounding the political environment of delivering stormwater improvement works and setting levels of service along with consideration of the options available to Councils to create community resilience to the current situation. The focus is a Tauranga example and is based upon the learnings that the Tauranga City Council has made to these strategic issues over the past year.

KEYWORDS

Strategic Planning, Flood Hazard Modelling, Flood Risk Reduction, Flood Risk Management, Stormwater Levels of Service

PRESENTER PROFILE

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1 INTRODUCTION

Within Tauranga, flooding of localised residential, commercial and industrial areas within parts of the City that were first developed more than 20 years ago has been an ongoing issue for many years.

Within the older established areas of the City, stormwater infrastructure provision varies and in many cases network capacity for only a 2 year or 5 year Average Recurrence Interval (ARI) event is provided. Generally in areas developed prior to the 1990's no overland flowpath, ponding network or piped network (catering for events of ARI in excess of 5 years) has been provided.

The watershed moment for investment in stormwater improvement works was in 2005 when, following a declared civil defence emergency, approximately $80M was spent to upgrade the existing stormwater network in specific locations where flooding occurred. Following implementation of the improvement works, the total operational costs increased as a result from $1-2M annually to $15M per annum.

In 2009 the budget shifted from an annual spend of $20M (2005 – 2008) to $5M, following a period of no/minor flooding resulting in damage. This drop in investment was not linked to the completion of any high level program, rather the political realities of seeking to reduce the debt burden on the ratepayer and also the fact that intense rainfalls, for a short period of time, had not occurred. At this point in time the stormwater activity budget was one quarter of the total City's debt, and additional investment in expenditure could no longer be politically justified.

However no level of service was formally set by the Council during this time, the level of service that improvement works were being designed to was a 50year ARI, providing for future increases in impervious surfaces (deemed to be the maximum probable development) and climate adjusted rainfall out to 2055. No consideration was being given to the role of regulatory change, or the need to consider these matters in any wider context to aid in flood mitigation, nor even to adequately ensure the new infrastructure was afforded a form of capacity and efficiency protection in the long term.

Since that time, additional flooding events have occurred resulting in damage in 2011, 2013 and 2014. Following the 2013 event the Council signaled it would further spend an additional $40M over five years to continue with its improvement program. However, as with the investment in 2005, no level of service had been set and an understanding of the funding proposed, including its implementation was not well understood nor defined. The political and community position appeared to be more of a 'we need to do something' rather than 'if we are to do something, what does that look like and where and how should we intervene'.

Ultimately the Council decided to not move forward with the $40M improvement program in favour of re-thinking its approach to flooding from intense rainfall events, the issues of "what, when, where and how" still needed to be answered. Essentially decisions to be made needed clarity on when should Council intervene, what does intervention look like and when should it be expected that the Council is not obliged (legally or otherwise) to intervene.

This process was to be wrapped up in a conversation on developing a LoS and whether such a level of service could be affordable given the limited knowledge of the problem and the potential costs that may result for undertaken further work to the network.

2 2D FLOOD MODELLING

2.1 MODEL BUILD PROCESS

The process of considering developing a level of service is not one that is easily tackled. Fortunately for Tauranga, in the same year the issue of what level of service could be put in place it had also began a significant City-wide 2D modelling program as part of the stormwater project. To be delivered over three years, and modelling the known 'at risk' catchments first (based upon known historical flooding problems), Council was able to understand the potential issues that it was likely to need to grapple with.

The flood modelling program made use of the Danish Hydrological Institute's (DHI) Mike Software. The program established was to procure four key consultancies to build the City's models with oversight of the model builds being provided by DHI itself, on behalf of the Council. The 2D models took into account (amongst varying other matters):

- Design rainfall events, of varying ARI;
- A temporal rainfall profile;
- The full Tauranga stormwater network;
- The Council's digital terrain model, based on LiDAR (DTM).
- Calculations of proportions of existing impervious surfaces and existing development extents.

The models are validated against prior known events, and also verified on the ground by in house Council staff. The program enabled the extent of the city-wide problem to be understood, quantified (on a per property basis) and clearly described. Note that in some areas, a potential flood hazard has been identified where there are no recent observations of flooding (due to there not having been recent significant rainfall in these areas).

Figure 1: Flood Map (Depth) 100 year Existing Development– Pillans/Bureta Modelled Catchment provides an example of the 2D Model output:

Figure 1: Flood Map (Depth) 100 year Existing Development – Pillans/Bureta Modelled Catchment.

The 100 year ARI event was selected as the preferred modelling scenario as:

- Under the Building Act 2004 what is required to be considered is the level of all naturally occurring surface water resulting from rainfall on the site or water flowing onto the site that has a 2% AEP (50 year event) on the day the building consent is lodged which takes into account the existing development in the catchment and the current stormwater network;
- In a situation where a building site was subject to flooding, while a 50 year event is appropriate for code compliance under E1.3.2, a 100 year event is appropriate when considering the application of section 71 and 72 of the Building Act 2004 (Refer Department of Building and Housing Determination 2010/82);
- In terms of predicted effects of climate change on rainfall intensity and sea level, neither the Building Code nor the Building Act 2004 give any specific guidance. What is required to be considered under the Building Act is the effect of surface water on the day the building consent is lodged/granted not the consideration of future predicted effects;
- Predicted levels of flooding on a property based upon a possible future impervious surface scenario may not constitute accurate information and therefore it is questionable whether this information can be relied upon to meet the tests under the Local Government Official Meetings and Information Act 1987.

2.2 OVERLAND FLOWPATH AND WATERSHED MAPPING

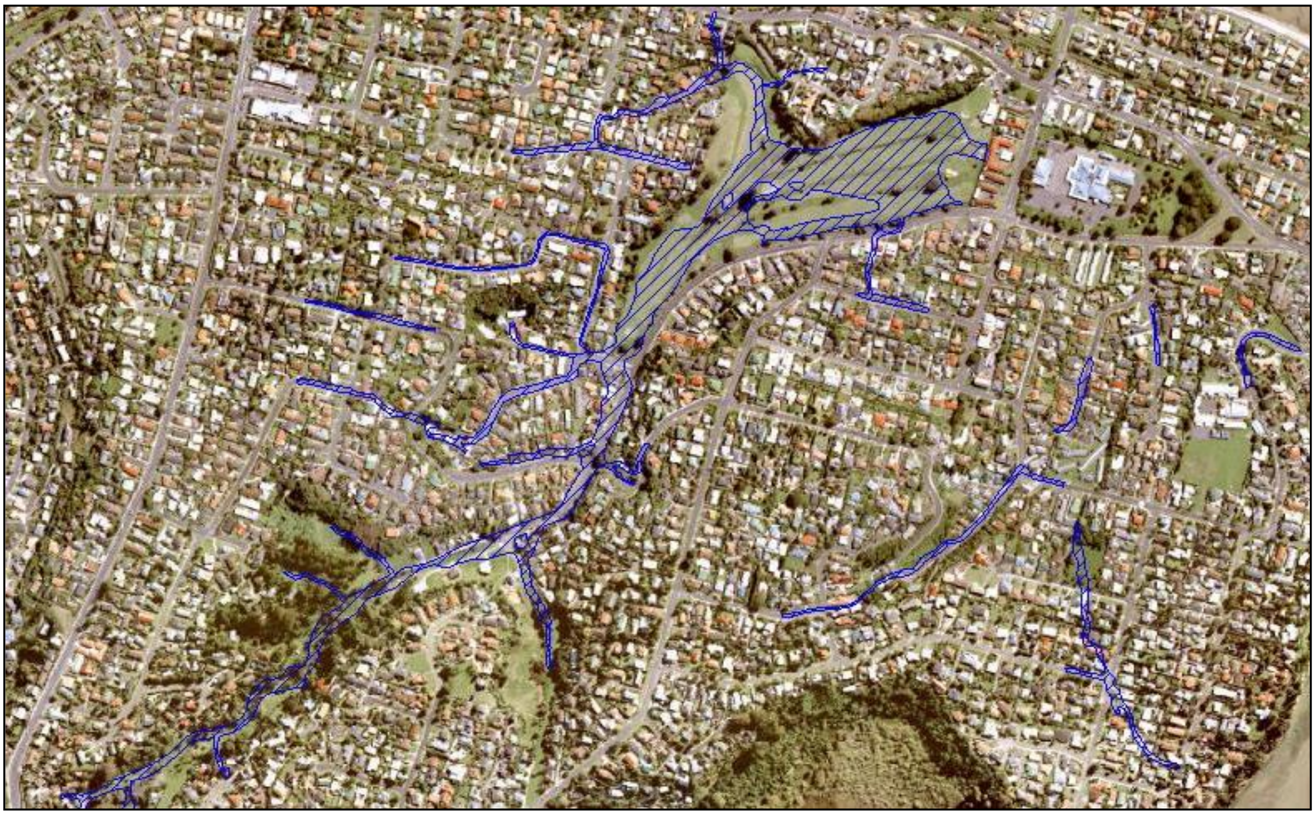
As well as modelling for flood extent and depth, Council also models the velocity and flow direction of flood water. This provides important information about where flood waters flow in response to a heavy rainfall event.

Existing overland flowpaths throughout the City are progressively being mapped as Council undertakes its wider Flood Hazard Mapping project.

The methodology to map overland flowpaths was established using data derived from the DTM and the Velocity-Depth Product (VxD) so that a continuous flowpath could be determined.

An example of the output is shown below. This tool enables the Council to map the overland flow paths, flow direction and then begin to engage with landowners on appropriate flood risk reduction methodologies to aid in the improvement of flows. Into the future it is anticipated that these locations will be freed from development and restrictions put in place to ensure no new structures or earthworks inhibit or amend the natural flow of the stormwater.

Figure 2: Example of Overland Flowpath Map.



2.3 HIGH/LOW HAZARD ZONE MAPPING – DEPTH TIMES VELOCITY

To aid in the mapping of the overland flowpaths and to determine the hazardous areas of the City, the Council also used the 2D models to map high/low hazard zones.

It did this through the use of the same Depth times Velocity (DxV) calculations as it had to determine the main overland flowpaths. The determination on what was a high hazard zone and what was a low hazard zone was derived from the prior research undertaken by the Australian Rainfall and Runoff Revision Projects -Project 10, Appropriate Safety Criteria for People – Stage 1 Report (April 2010).

This research comes from work undertaken over the last four decades through a number of laboratory-based experimental studies to define the limits of stability within differing flow regimes.

Within this work, two sets of safety criteria were developed based on analysis of data collected during laboratory and field investigations. Hazard regimes as a function of limiting flow values for infants, children and adults are presented in *Figure 3: Flow hazard regimes for infants, children and adults.*

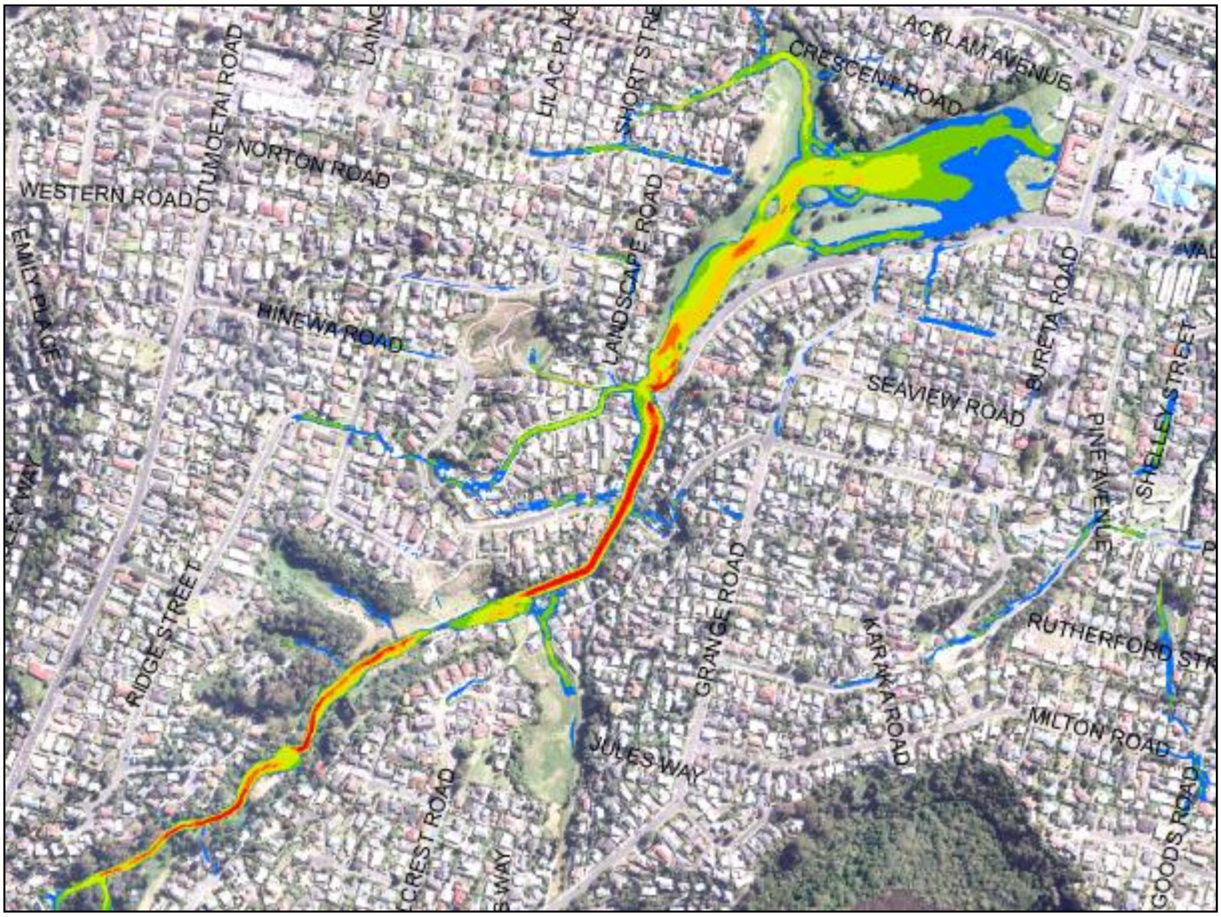
Figure 3: Flow hazard regimes for infants, children and adults - Australian Rainfall and Runoff Revision Projects -Project 10, Appropriate Safety Criteria for People – Stage 1 Report (April 2010).

DV (m^2s^{-1})	Infants, small children (H.M ≤ 25) and frail/older persons	Children (H.M = 25 to 50)	Adults (H.M > 50)
0	Safe	Safe	Safe
0 – 0.4	Extreme Hazard; Dangerous to all	Low Hazard[1]	Low Hazard[1]
0.4 – 0.6		Significant Hazard; Dangerous to most	
0.6 – 0.8		Extreme Hazard; Dangerous to all	Moderate Hazard; Dangerous to some[2]
0.8 – 1.2			Significant Hazard; Dangerous to most[3]
> 1.2			Extreme Hazard; Dangerous to all

The research identifies the thresholds that individuals (based upon height and mass) can withstand until their safety is compromised.

Utilising the models, the risk to a person's safety can be quantified through geospatial analysis. As an example, the following type of map can be produced to aid in assessment of risk to people's safety on both private property and within public land.

Figure 4: Example of Depth-Velocity Map – Pillans/Bureta Modelled Catchment.



2.1 HOW HAVE THE OUTPUTS BEEN UTILISED?

These outputs spurned the conversation of what to do going forward and how best to consider intervention.

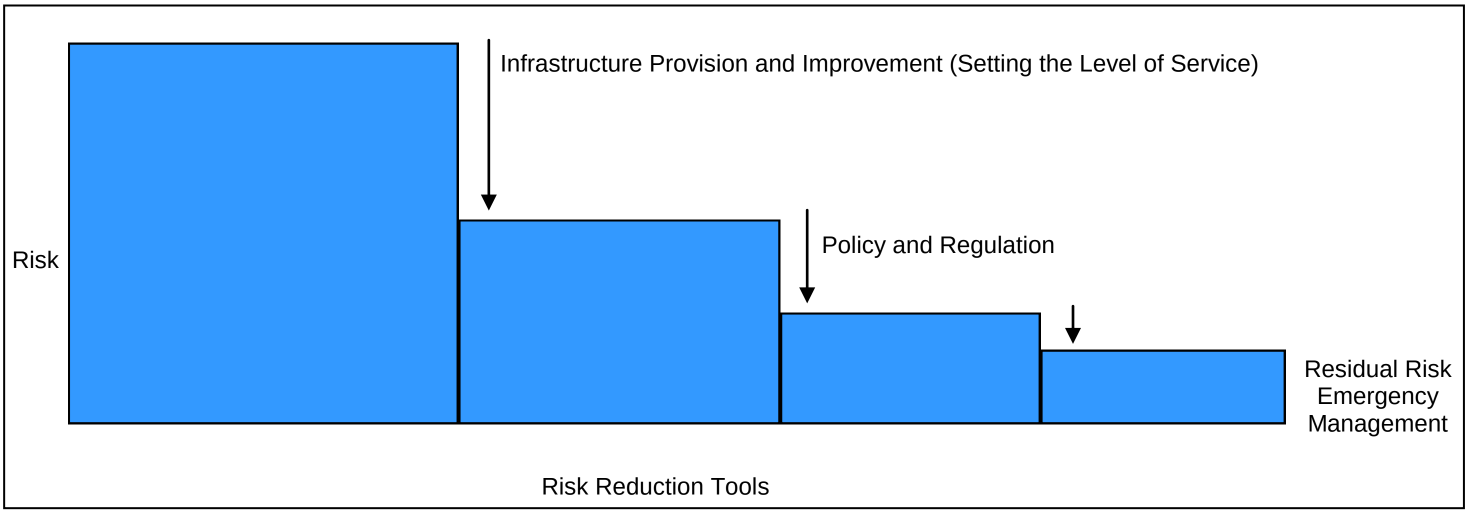
This was because at the time of submitting this paper the outputs of 8 modelled catchments (of a total of 19) showed that 35% of the City's properties were likely to be affected by flooding in some form in a 100 year ARI event, and 29% of all building stock was likely to be affected in some way by flood waters. This could be by predicted flood extents just coming into contact with a building footprint; however further analysis was required to determine whether or not any material damage would result.

To consider these issues the process landed on two key questions:

- What are the acceptable, tolerable and intolerable levels of risk in regards to a person's safety in flood events ranging from the annual to 1% AEP;
- What are the acceptable, tolerable and intolerable levels of risk in regards to building damage in flood events ranging from the annual to 1% AEP.

Using the 2D models, the Council was in a position to be able to test the risk parameters and engage on a conversation of individual risk appetite. However infrastructure delivery was still seen as the key means to reduce the modelled flood risk, a conversation about personal and community risk also paved the way to consider the other options not considered within Tauranga to aid in risk reduction (such as regulation, education and residual risk). The approach put forward is best identified *Figure 2: Risk Reduction Tools*.

Figure 5: Risk Reduction Tools.



These concepts were all used to initiate debate on what is in fact an appropriate LoS in respect of stormwater improvement works and how was the Council then going to intervene.

To do this a risk based approach was taken. The risk based approach adopted the consideration of likelihood and consequences and recognised that through modelling the risks could be quantified, graphed and assessment undertaken.

3 UTILISING RISK AS AN ASSESSMENT TOOL

The benefit of taking a risk based approach to the management of this issue is that Council can look to maximise the contribution it makes to its community (if it so chose to invest) to reduce risk and assess this risk reduction against the benefits potentially gained.

Risk assessments are a useful tool to aid in considering the setting of a LoS. This is because through risk based assessments we can begin to initiate the conversation of where the greatest risk is, and therefore the greatest need.

To do this, the Council adopted three risk categories towards managing the risk from flooding from intense rainfall events, being intolerable, tolerable and acceptable.

- **Intolerable**

  Risk exceeding the upper limit of the tolerable range: The risk is unacceptable and cannot be justified and risk reduction is essential whatever the cost. Anything that is determined to be intolerable should result in action being undertaken by the Council to alleviate the risk, whether that be through infrastructure upgrades, land purchase or other risk reduction mechanisms.

- **Tolerable**

  Risk within the tolerable range: The risk should be reduced to be as low as reasonably practicable. The methods to do this will need to be determined by the Council, and will involve:

  - Education;
  - Regulation;
  - Infrastructure/Land Purchase

  The key question here is what is the Council's position to when it will no longer provide a minimum infrastructure service and therefore utilise its other tools of regulation, education or determine that any residual flooding above the LoS is the realm of emergency management?

- **Acceptable**

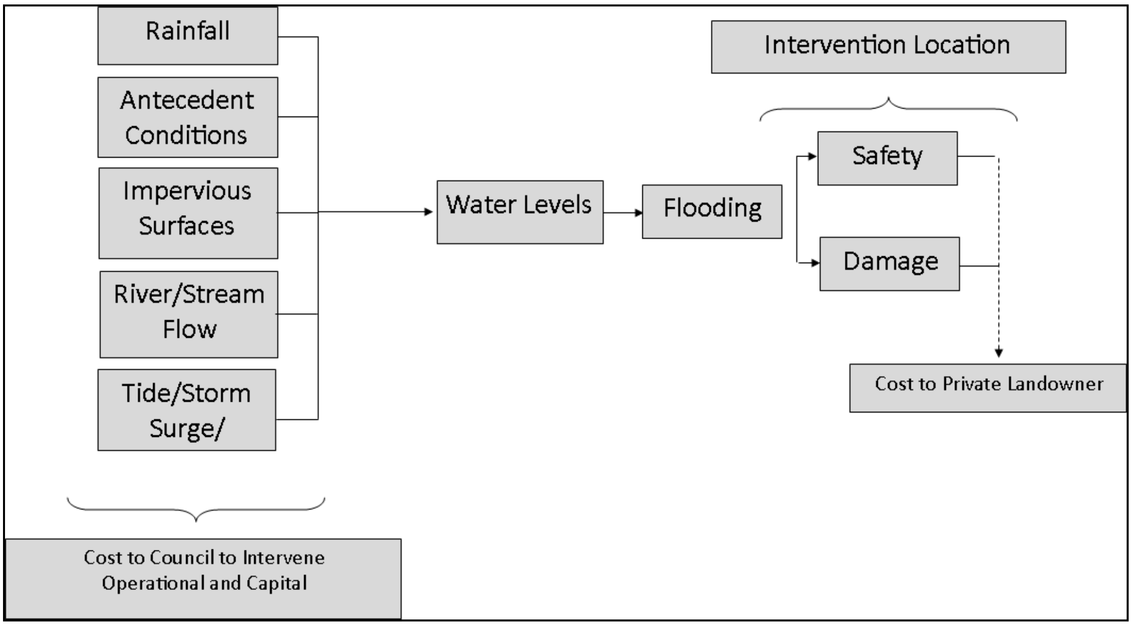
  Risk less than the lower limit of the tolerable range. The risk is broadly acceptable and the cost of further reducing risk is grossly disproportionate to the benefits gained. In this category it is recognised that while the risk is acceptable, there will always be a residual or future risk of flooding. When the risk is acceptable it is considered that education is still required to inform landowners of the risk that they live with (i.e. in an intense rainfall event all local roads will be closed as this infrastructure asset is designed to flood, rather than private property, therefore during and following the event landowners will not be able to get to or leave their properties).

Essentially the LoS can be summarised into 'what frequency and of what nature of event' the Council is willing to provide a service to reduce the risk of flooding from intense rainfall events.

As part of answering this, the Council also needed to decide what it is not going to provide for and therefore what risk it is going to accept be managed through regulatory change, education or be considered as residual risk and therefore managed through operational management or emergency management processes.

The development of a LoS needs to consider a range of required factors, as outlined in *Figure 6: Input factors to determine a level of service*, and whether they should be provided for, or excluded.

Figure 6: Input factors to determine what is required to be considered in developing a level of service.



All of the factors in the figure above contribute in some form to flooding that results in a risk to safety or risk of damage.

There is a direct relationship between:

- The level of intervention provided for in each of the above factors;
- The overall LoS delivered in regard to flood protection, and
- The associated cost to the Council and ultimately the community.

All the above factors have been simulated in Council's 2D models and the risk has been assessed using geospatial assessment and other risk based assessment approaches.

The assessment work undertaken to support the development of a LoS covers the following:

- Risk Assessments (total building damage);
- Risk to a person's life; and
- Cost comparison of providing for different LoS.

The key input in the development of the LoS is the design rainfall depth as this is the key critical factor that triggers flooding and therefore damage and risk. All other factors are ancillary to the effects of damage occurring.

3.1 DETERMINING THE RISKS

To determine the risk of building damage within each modelled catchment, the software package called 'Riskscape' (developed by both the National Institute of Water and Atmospheric Research Ltd and the institute of Geological and Nuclear Sciences) was used. Riskscape converts hazard exposure information into likely consequences, such as damages and replacement costs through depth & velocity/damage curves.

The damage calculations created through 'Riskscape', are extrapolated out as an estimated damage state for the entire City that is likely to be affected by flooding at some point into the future. This extrapolation was based on catchments within which a detailed analysis was conducted.

This approach enables appropriate judgment decisions to be made about what the actual risk is to the specific factor being assessed based upon the assumptions made within the model. The following factors were assessed:

- Risk – Total Buildings Damaged

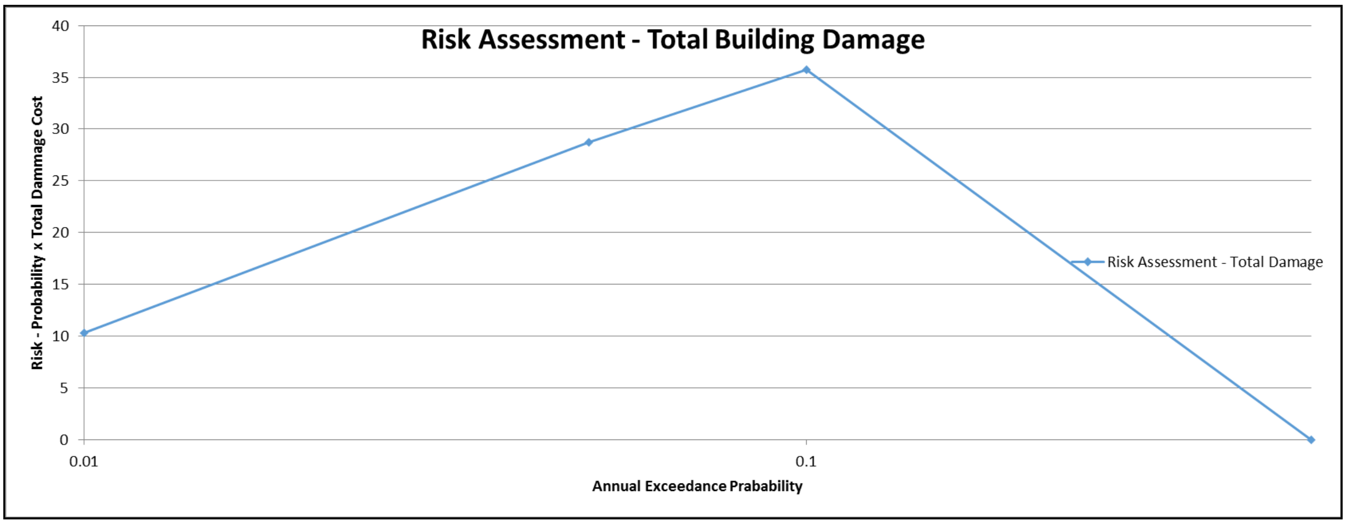
  (a) Insignificant
  (b) Light - Non-structural damage, or minor non-structural damage
  (c) Moderate - Reparable structural damage
  (d) Severe - Irreparable structural damage
  (e) Critical - Structural integrity fails.

Using this information the likely damage to buildings within a modelled catchment can be calculated using both information within Riskscape and the Council's own datasets.

The below figures and tables are a culmination of risk assessments for all modelled catchments, in terms of total damage (to buildings) noting all graphs are shown with a log scale on the horizontal axis.

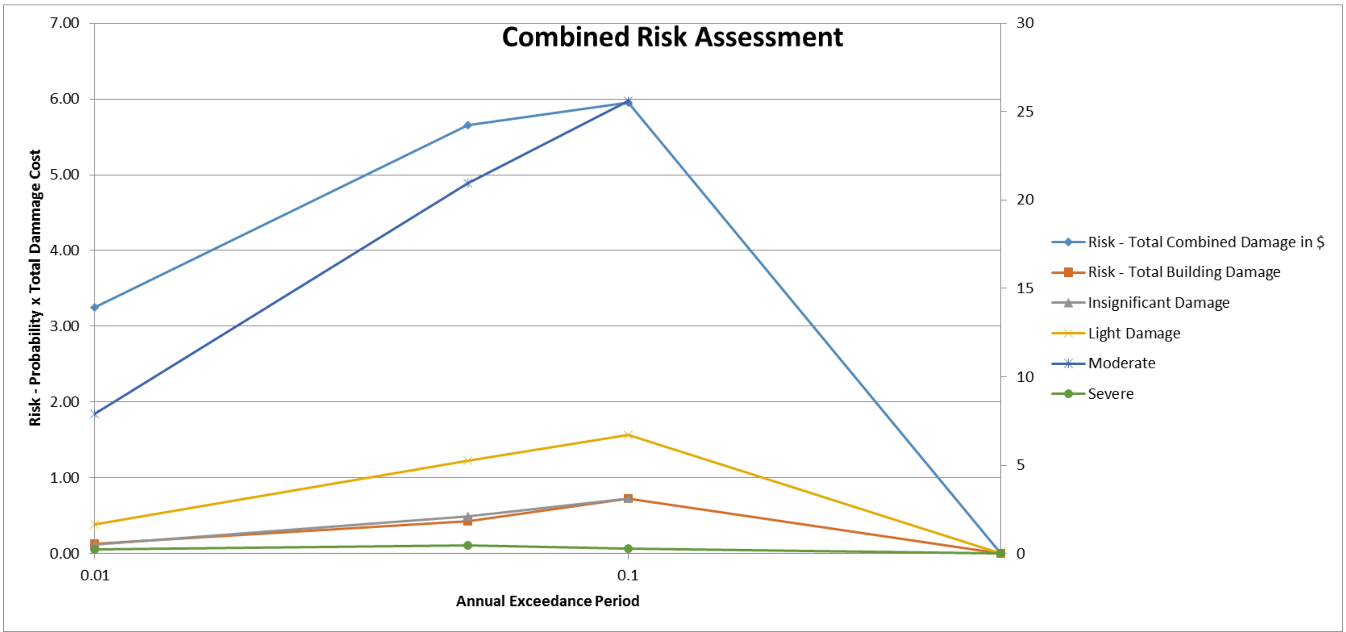
Figure 7: Risk Assessment –All 2D Modelled Catchment – Total Damage identifies the modelled risk (total building damamge) within all modelled catchments, as asssed against a 100year, 20year and 10year ARI event.

Figure 7: Risk Assessment –All 2D Modelled Catchment – Total Damage.



Combining this risk assessment, against total building damage ($), along with an assessment of damage within a range of damage categories, and showing it in in one graph aids in determining where the greatest risk is within the modelled catchments, and ultimately where Council could look to invest in stormwater improvement works. This has been done below, where the result is shown if it were to focus its program on risk considerations alone, without considering the financial consequences of intervening.

Figure 8: Risk Assessment - All 2D Modelled Catchment – Total Building Damage (all Buildings)



The above risk assessments identify that through assessing the 10year, 20year and 100 year ARI's that the greatest risk across the City (based upon current modelled areas) in terms of both building damage and total damage cost) sits at the 10year ARI.

This finding fits with similar findings from other areas where the greatest risk is associated with events that are expected to occur relatively frequently, and that as event frequency is reduced with event severity, the resulting risk decreases. There appears to be a weighting of asset vulnerability towards the more frequent events.

However so, as outlined in the *Table 1: Individual modelled catchment risk – all modelled catchments*, depending on each of the modelled catchments there is a variable outcome of the greatest risk:

Model	Total Damage - $	Total Building Damage
Pillans/Bureta	10year ARI	10year ARI
Matua	20/50year ARI	20year ARI
Mount South	20year ARI	10year ARI
Avenues	10year ARI	10year ARI
Waimapu	10year ARI	10year ARI
Mount North	20year ARI	10year ARI

Table 1: Individual modelled catchment risk - all modelled catchments.

The reason for this variability is due to the nature of building stock, existing infrastructure and topography, and will also vary depending on the finer scale assessed, such as to the sub catchment scale.

As outlined in the *Table 1: Individual modelled catchment risk - all modelled catchments* there is in fact a broad range of risk across all modelled catchments, the greatest being within the Matua modelled catchment. This however is the only catchment modelled to date which achieves this risk outcome and is a likely reflection of the landform itself, the age of settlement and the fact that a number of dwellings have been constructed within significant overland flowpaths that have high safety risks present.

From a risk perspective only (i.e. not considering the financial implications) a target minimum 20year ARI is shown to be able to achieve an objective of addressing the probability of event that carries the greatest risk when assessed against total damage and building damage. In this way investment can be directed to the areas that are worst affected and that are at the greatest risk of damage occurring at a consistent LoS across the city. This approach would also provide for dealing with additional risk within each catchment, if the LoS is set at 20year rather than 10year.

4 DEVELOPING A LEVEL OF SERVICE – THE COSTS OF DELIVERY

For any Council the costs of intervening need to be considered against all other options and the benefits defined. However there are many tangible and intangible benefits to intervening, and the reality is that a Council with high debt levels is unlikely to be able to intervene significantly. If it chooses to do so, then it will come at the expense of other more 'attractive' projects.

4.1 DETERMINING CAPITAL COSTS

To determine the costs of varying ARI's a range of high level infrastructure interventions were developed and high level cost estimates calculated. The designs included not only piped networks but also pipe and pump network options to appropriately consider the full range of high level options that could be implemented to alleviate the risk of flooding in localised areas through infrastructure provision alone, and being 100% loan funded by the Council as the base starting point.

Based upon assessment, and outlined in *Table 2: Estimate Percentage Difference in cost provides that concluded information,* conclusions were made about the likely costs of implementing a 10year, 20year and 50year ARI LoS to the community to protect habitable floor flooding[1] (as a percentage of cost against a 100year ARI)

[1] For the purposes of this paper a habitable floor means a floor of a building (including a basement) but does not include ancillary structures such as stand-alone garden sheds, sheds or garages.

ARI	Estimate Percentage Difference in cost
100year	-
50year	80-85
20year	70-75
10year	40-50

Table 2: Estimate Percentage Difference in cost provides that concluded information.

Using this analysis, and following development of high level concept plans for potential implementation, the cost to Council of implementing each LoS can be determined.

Table3: Rough order costs (High/Low Estimated Costs) of delivering a Citywide level of service outlines the rough order costs of undertaking this work for a citywide implementation programme[2].

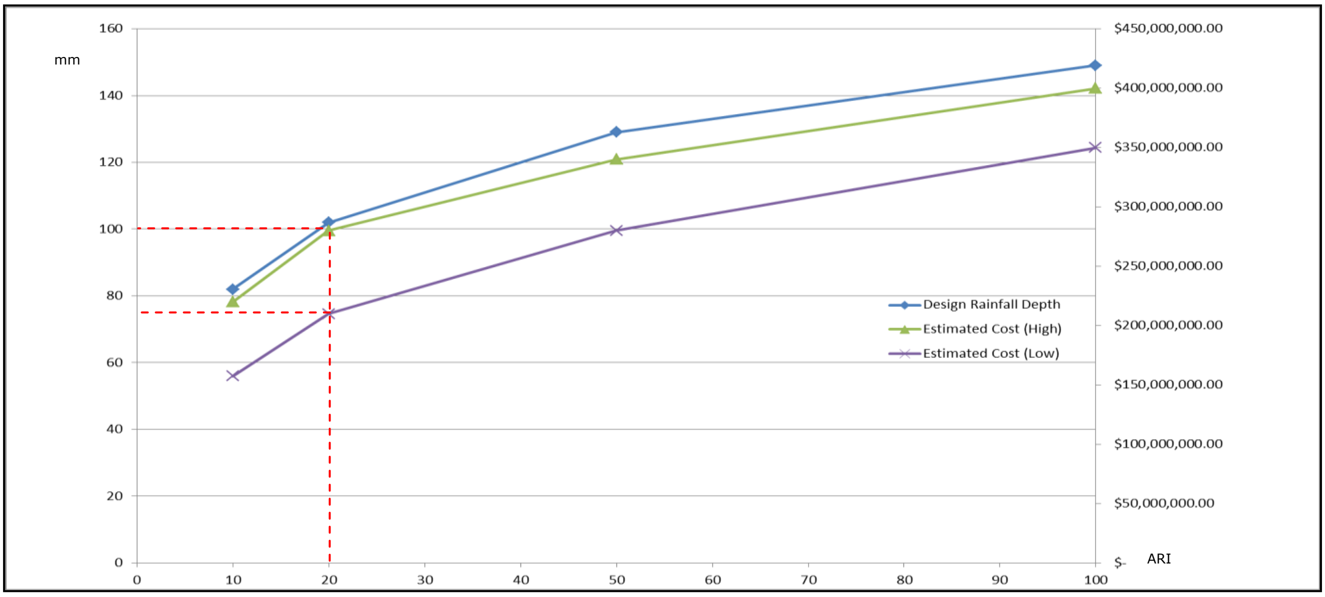
AEP	ARI	2 hour storm duration Design Rainfall Depth Estimates (2005) in mm	Estimated Percentage difference of 0.01% AEP Costs (High/Low)	Estimated Costs (High)	Estimated Costs (Low)
0.01	100	149	-	$400,000,000	$350,000,000
0.02	50	129	80-85	$340,000,000	$280,000,000
0.05	20	102	70-75	$280,000,000	$210,000,000
0.10	10	82	40-50	$220,000,000	$157,500,000

Table 3: Rough order costs (High/Low Estimated Costs) of delivering a Citywide level of service.

To aid in understanding and completeness, the total costs (as above) were also graphed against the varying design depths for each ARI as outlined in the Infrastructure Development Code (IDC) and provided in *Figure 9: High/low estimated rough order costs ($) graphed against the design rainfall depths (mm).* The purpose of this approach was to test the cost of implementation against the varying design depths of rainfall that a LoS would be required to provide for[3].

[2] Costs are in 2015 dollars and therefore do not include local government CPI.
[3] Note: 20year ARI High/Low cost identified in red dotted line.

Figure 9: High/low estimated rough order costs ($) graphed against the design rainfall depths (mm).



The analysis shows a clear correlation. This is likely to be because as the design event is increased the cost to the Council to provide that service will increase, as a greater volume of stormwater would be required to be catered for through infrastructure provision and conveyed away so damage does not occur. The results more importantly identify that the rough order cost percentages for each ARI are likely to have validity in determining costs to Council going forward of providing each LoS.

4.2 DETERMINING OPERATIONAL COSTS

Generally, for every $10M spent on capital works within Tauranga, the following year's operational costs (operations, maintenance, and depreciation and interest) will increase approximately $0.55M, with this then being an ongoing operational cost for the life of those installed assets.

As an example, if the desired LoS cost Council is $300M to implement, then once capital works were delivered the operations, maintenance, depreciation and interest costs that exist today would double over the 30year program, being an additional $15M a year in today's dollars and requiring an operational budget of $30M at the end of the LoS delivery.

Table 4: Mid-point estimated rough order costs ($) graphed against the design rainfall depth (mm) and operational/rates impact outlines the varying costs to the community (operational costs) of delivering each of the varying LoS, including the estimated percentage increase in rates which will be applied once the varying LoS are completed.

ARI	Mid-Point Rough Order Cost to deliver LoS	Approx. Annual Operational Expenditure *(when implementation completed (in 2015 $))*	% increase in rates when LOS delivered (based on 2014 base rates level)
100year	$375,000,000	$34,000,000	15
50year	$300,000,000	$31,000,000	13
20year	$250,000,000	$28,500,000	11
10year	$190,000,000	$25,000,000	8

Table 4: Mid-point estimated rough order costs ($) graphed against the design rainfall depth (mm) and operational/rates impact.

4.3 CONSIDERING THE FINANCIAL IMPLICATIONS

To aid in options assessment the below table has been produced, providing a summary of the pro's and con's of each ARI and the cost (capital and operational) implications.

Table 5 – Assessment of Varying Levels of Service, Capital Costs, Operational Costs and Benefits outlines the cost of delivering a LoS which focuses on not only reduction in risk to people's safety, but a reduction in the damage state of buildings through flood effects. The greatest cost to Council would be in reducing the flood level throughout the city to below all flood affected habitable floors in the LoS event.

Based upon this analysis the costs of delivering stormwater infrastructure to achieve a risk reduction of safety to persons and risk of building damage (above current level of service) in brownfields areas (currently developed areas) is significant. The scale is such that the investment required and associated increased rate rises, operational costs and debt is one in which it is difficult to justify in terms of the benefits which would be achieved.

It is clear from the above assessment that the costs to deliver any LoS to reduce the risk of damage from intense rainfall events are high (both in terms of capital and operational costs).

Further, it is clear that stormwater improvement works only benefit a small proportion of the total City and its building stock. Any potential benefit, when considered against the operational and capital costs are, once again, difficult to justify in terms of financial prudent management and the requirements of the Local Government Act 2002.

In considering this analysis, it is noted that:

- No social considerations have been provided for or assessed;
- No environmental considerations have been provided for or assessed;
- No costs per property benefited from flood reduction (in terms of valuation of property as the flood hazard would be reduced or removed) have been undertaken.
- No direct or indirect benefits to individual landowners or potential development opportunities that may occur through flood risk reduction being provided through an improved network have been undertaken.

- No cost considerations to the costs to landowners of delivering individual protection as required by a future regulatory approach have been undertaken.

- All have been undertaken at a citywide level based upon noted assumptions outlined in this report. It is recognised that there may be some flood risk reduction projects (yet unspecified) at a sub catchment or local/street level that may yield different results.

- The focus is only on determining the cost of damage (economic costs) and the number of buildings that are likely to suffer some form of damage in a modelled flood event.

- Evaluation of damage has been done using only the Riskscape package. It is recognised that other approaches to damage assessment are available, but in the work reported on in this paper Riskscape was used to ensure a consistent approach across the entire city.

However the matters that were not included in the assessment will ultimately have an impact on the benefits of undertaking work, the reality is that the assessment work undertaken shows a significant quantum of capital and operational costs for the Council are essentially difficult to justify in terms of the benefits which would be achieved when considered against the requirements of the Local Government Act 2004 and the requirements of prudent financial management.

	100 year ARI LoS	50 year ARI LoS	20year ARI LoS	10year ARI LoS
Extrapolated number of buildings at risk from damage (total building damage)	1369	*(no data)*	765	475
Estimated Timeframe to delivery LoS	37.5 years	30 years	25 years	19 years
Estimated Capital Cost (mid-point)	$375,000,000	$300,000,000	$250,000,000	$190,000,000
Estimated Cost per Property Protected (from building flood damage)	$273,922	-	$326,797	$400,000
Approx. increase in OPEX costs p.a.	$550,000	$550,000	$550,000	$550,000
Approx. Additional Annual increase in OPEX (at conclusion of LoS delivery above 2014/15 OPEX level)	$18,100,000	$15,100,000	$12,600,000	$9,100,000
Approx. Accumulation of a total operational cost (at conclusion of LoS delivery)	$386,000,000	$255,700,000	$178,750,000	$104,500,000
Approx. % of total rates rise (at conclusion of LoS delivery)	15	13	11	8
Pros	• Delivers a high LoS, and provides protection up to the 100year ARI (1% AEP event), providing significant protection from damage resulting from extreme rainfall events.	• Delivers same LoS within the brownfield areas of the City, as is provided within the greenfield/urban growth areas. • Reduces the risk of damage occurring in response to the 2% AEP event.	• Focus on highest risk within Matua and Mount North Modelled Catchments. • Reduces the risk of damage occurring in response to the 5% AEP event.	• Focuses on greatest risk within each of the modelled catchments to date, noting exemptions within Matua and Mount North. • Reduces the risk of damage occurring in response to the 10% AEP event.

Cons	• Delivers a higher LoS within the brownfield areas of the City, than provided within the greenfield/urban growth areas. • Approx. 37.5 years to deliver LoS, assuming $10.5M p.a. funding. • High capital costs. • High operational costs. • Does not focus on highest assessed risk within each modelled catchments. • Difficult to implement in brownfield areas.	• Approx. 30 years to deliver LoS, assuming $10.5M p.a. funding. • High capital costs. • High operational costs. • Does not focus on highest risk within each modelled catchment or sub catchment. • Difficult to implement in brownfield areas.	• Approx. 25 years to deliver LoS, assuming $10.5M p.a. funding. • High operational costs. • High capital costs. • Provides a higher LoS above the assessed highest risk within each modelled catchment noting exemptions within Matua and Mount North. • In over design events, damage is likely to occur.	• Approx. 19 years to deliver LoS, assuming $10.5M p.a. funding. • Lower capital costs • Lower operational costs. • In over design events, damage is likely to occur.

5 CONCLUSIONS

The development of a LoS is one that has many factors to consider, and must be couched within a wider approach to flood risk management and utilise all of the tools available to it to aid in any approach to be delivered.

It is clear from the above assessment that the costs to deliver any LoS to reduce the risk of damage from intense rainfall events through infrastructure provision are high (both in terms of capital and operational costs).

Further, it is clear that undertaking stormwater improvement works only benefit of small proportion of the total City, its building stock, and any potential calculation of the benefits against those costs concludes that investment to achieve even a ten year ARI is not financially prudent.

Focusing on reducing the risk to people's safety is a core focus going forward, and where the LoS now sits in Tauranga City Council. In these areas, capital investment will be applied, however the risk to persons, based upon DxV calculations, are limited and therefore the extent of works are also limited.

For Tauranga, the conclusion has been to now recognise this and consult on this specific matter based upon the realities of the costs of delivering any LoS at all to protect habitable floors through its Long Term Plan.

The above position comes with a decision to reduce the funding towards stormwater improvement works and as outlined no longer look to deliver a significant capital works program.

To support this position, and as outlined at the beginning of this paper, there is also a need to consider a wider approach to flood risk management, that is not just infrastructure based. As such, the delivery of a LoS is now proposed to be couched within a wider approach of flood risk reduction which can be summarised as below:

- Providing comprehensive flood information, and technical advice to aid in son-site risk reduction.
- Undertaking infrastructure improvements to reduce the risk to the community's safety, where such a risk exists on private property.
- Incorporate risk-based considerations into any new planning policies and plans, including the implications of rare but very damaging floods.
- Ensuring flood emergency plans consider the appropriate responses for all magnitudes of flooding.
- Build up a fund to aid the community in clean-up; future infrastructure design and delivery; supporting the undertaking of amendments to private and public land to enable stormwater to be conveyed away from risk areas; potential land purchase and other remedial work (not otherwise provided through insurance).

This approach, however not new within the context of hazard management, is now tempered by the reality of the potential costs of doing anything more significant. By clearly spelling out the approach and adopting a specific level of service (albeit a low level of service) residents, existing business and future business are well informed of the

Council's position in regard to this matter and it paves a clear pathway to drive regulatory change and therefore landuse control.

However the approach may appear unfair and even unwise based upon the current norms applied to stormwater resolution, the costs required to resolve existing flooding problems are significant and unjustifiable in regards to financial prudent management.

REFERENCES

Cox, R.J., Shand, T.D., & Blacka, M.J. (April 2010) Australian Rainfall and Runoff Revision Projects -Project 10: Appropriate Safety Criteria for People – Stage 1 Report, Engineers Australia, Australia.