URBAN FLOW DESIGN LEVEL OF SERVICE – SETTING THE STANDARD

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ABSTRACT

This paper discusses the question: what is an appropriate Design Standard (Level of Service/Level of Protection) for primary and secondary stormwater systems in urban areas? Naturally the best answer varies for existing and developing areas across the country. Currently there is a lack of national guidance to support the definition of these levels and consequently there is a range of standards in use.

Some existing New Zealand local government requirements are summarised and these are compared with the Building Code and NZS4404:2010. To add context, multiple related issues are considered including cost, asset renewal cycles, land ownership, value at risk, access, easements, community expectations, land use, climate variability and safety.

The complex challenge of achieving cost-effective stormwater management lends itself to processes such as multi-criteria analysis. However, additional steps are required to effectively incorporate community aspirations and ecological considerations. Therefore, a process methodology is proposed to assist setting appropriate design values for existing and new urban areas.

The paper suggests short and long term means to advance the application of improved levels of protection and apply precautionary risk reduction.

KEYWORDS

Urban Flooding, Secondary Flow, Catchment Management, Stormwater, Resilience, Asset Planning, Freeboard, Natural Hazards

PRESENTER PROFILE

Ian is a 3-waters infrastructure planning engineer with Tasman District Council. Over his 25 year career he has developed a keen interest in stormwater management. He is now exploring our standard of responses to the challenging world we face.

1 INTRODUCTION

This paper discusses the question: what is an appropriate Design Standard (Level of Service/Level of Protection) for primary and secondary stormwater systems in urban areas? This question tackles the interrelated concepts of design standards, levels of service and level of protection in the context of stormwater hazard versus risk.

There is a lack of national guidance to support the development of appropriate levels and consequently there is a range of standards in use (NIWA, 2014). There is also a perceived lack of urgency for implementation of more precautionary approaches in the absence of clear guidance (ICNZ, 2014). However, I suggest climate variability trends and the relatively new concept of developing resilient communities, call for faster progress.

Leading the response weighs heavily on the Government's shoulders. Whilst councils can easily specify and manage levels of service for new green-field sub-divisions, managing the final level of protection provided is more challenging. In established areas, achieving a unified standard is very ambitious due to the realities of the existing stormwater and building infrastructure. In deciding what is appropriate for a locality, Councils need to consider the extent of these limitations as well as current best practice.

The paper surveys some existing New Zealand local government requirements and these are compared with the Building Code and NZS4404:2010. To add context to the LOS setting challenge, multiple related issues are considered including cost, asset renewal cycles, land ownership, access, easements, value at risk, community expectations, landuse, climate variability and safety.

The complex challenge of achieving cost-effective stormwater management lends itself to processes such as multi-criteria analysis. However, additional steps are required to effectively incorporate community aspirations and ecological considerations. Furthermore, in the short term, adopting arbitrary freeboard standards is proposed as a better option than having none. This then provides some precautionary risk reduction whilst the extensive research required to generate locally appropriate planning rules and engineering standards is undertaken. An overall process methodology is proposed to assist setting design values for existing and new urban areas.

2 DEVELOPING LEVELS OF SERVICE

2.1 INTERNATIONAL INFRASTRUCTURE MANAGEMENT MANUAL GUIDELINES

This paper is tackling the interrelated consents of design standards, level of service (LOS) and level of protection (LOP) in the context of hazard versus risk. LOS is common language in local government circles being related to Activity Management Plans (AMPs) and Long Term Plans (LTPs). A LOS is an essential defining statement about what an organisation is going to do or provide. These are linked to performance measures and these can be split between customer (external) LOS and technical (internal) LOS (NAMS 2011).

LOP is less commonly used and the New Plymouth District Council has this to say "*Levels of service apply to stormwater provision, while levels of protection apply to flood protection systems…… For example, the **level of service** for residential property is to design stormwater infrastructure to cope with a 20 per cent Annual Exceedance Probability (AEP)*[1]*, whereas the **level of protection** for residential floors is for a one per cent AEP." (*NPDC, 2015)

2.1.1 POSSIBLE LOS/LOP EXAMPLES

- Our stormwater systems collect and convey stormwater safely through urban environments, reducing the adverse effects of flooding on people and buildings.
- Existing stormwater reticulation systems are capable of containing a 1 in 'X' year storm event.

[1] Table 4.1 from NZS 4404:2010 shown at section XX gives some conversions between AEP and the Annual recurrence interval eg 1 in 100 year terminology. For more detail refer to BOM, 2015

- No residential property shall have repeated floor level flooding.

Of these suggestions, I would only support the 1 in 'X' option in a new area. Whilst councils can easily specify and manage levels of service for new green-field construction, managing the level of protection is more challenging and may be impossible in established areas. The other two examples are simply not within Council's power to achieve.

2.1.2 POSSIBLE PERFORMANCE MEASURES

- Percentage of properties protected from x% return frequency event. (IIMM 2011)
- Percentage of properties affected by x% return frequency events per annum. (ibid)
- Number of complaints – cost of scheme, blockages, nuisance (ibid)

2.2 ACHIEVING LOS FOR PRIMARY RETICULATION

In addition to engineering standards, the required LOS may also be implicitly stated in District Plans, Catchment Management Plan (CMPs) and consent conditions. The means of achieving primary system LOS will be contract specifications for council works and engineering standards for developments. Achievement measurement will be undertaken by development and contract engineers. This should be all straight forward for new developmental areas. However the interface between new and old is where the challenges begin.

2.2.1 INFILL DEVELOPMENT LOP VARIATIONS

Most councils will have an extensive network in place, built to a variety of design standards and hence providing a single numeric value for the existing LOS or LOP is not realistic (even without climate driven rainfall variations). Maps of LOS for the existing network, generic LOP information and a design standard for new areas and renewals is a more reasonable proposition. Hutt City Council, refer box below (Capacity 2015), and Hamilton City Council (HCC, 2013) have both adopted variations to their level of service for infill development and Tauranga City Council is well advanced on a similar path.

HCC: The *minimum* primary and secondary levels of protection, as well as the freeboard, may be reduced as shown below for new drains in existing areas.

	Primary	Secondary	Freeboard
Residential	10%	2%	200 mm
Commercial/Industrial	10%	2%	50 mm
Key Public Facilities	10%	2%	200 mm
Arterial Roads	10%	5%	-

3 SURVEY OF CURRENT PRACTICE

3.1 COUNCIL DESIGN AND FREEBOARD LEVELS

LGA	Component	Design/LOS	Freeboard
Auckland (ARC,	Primary Secondary	10 year ARI 100 year ARI	500mm habitable rooms

LGA	Component	Design/LOS	Freeboard
1999[2])			
Christchurch (CCC, 2013)	Residential Industrial Commercial	Primary 20% AEP secondary 2% AEP For all buildings	400mm 300mm 300mm
Hamilton (HCC, 2013)	Residential Industrial Commercial Secondary flow	2 year ARI 1 hour storm 5 year ARI 1 hour storm 10 year ARI 1 hour storm 100 year ARI TOC storm	500mm (200mm)[3] 300mm 300mm
Kapiti Coast (KCDC, 2012)	All urban areas	10% AEP Primary and 1% AEP secondary	Varies with locality 0.3-1.0m
Nelson	Residential Industrial Commercial Major communal facilities	6.67% AEP (1 in 15 year ARI)	500mm (200mm)[4] 300mm 300mm 600mm (supply of electricity, telecommunications water supply and wastewater
New Plymouth (NPDC 2015)	Residential floors Residential land Industrial floors Commercial floors	20% AEP Primary and 1% AEP secondary 20% AEP Primary and secondary 10% AEP Primary and 1% AEP secondary 10% AEP Primary and 1% AEP secondary	As per NZS 4404:2010
Tasman (TDC 2012 & 2013)	New systems [5]	20 year ARI primary and 100 years ARI secondary	500mm
Tauranga (TCC 2014)[6]	All	10 year ARI primary and 50 year ARI secondary	As per NZS 4404:2010
Wellington (WCC 2012, Capacity 2015)	Residential Industrial Commercial	10% AEP primary 1% AEP for residential and communal building floors 10% AEP primary 2% AEP for commercial/industrial floors.	500mm (200mm)[7] for secondary 300mm above open channels for primary

[2] Auckland City Council stormwater management documents are currently undergoing extensive revision.
[3] 200mm for non-habitable outbuildings – all adopted from NZS4404:2010 or an alternative calculation to potentially allow a lower freeboard if sufficient data exists.
[4] 200mm for non-habitable outbuildings – all adopted from NZS4404:2010 or an alternative calculation to potentially allow a lower freeboard if sufficient data exists.
[5] Tasman District Council has approved different standards being 10 year ARI for new residential areas and 20 year ARI for town centre areas, however these are yet to be reflected in the Engineering Standards and Policies.
[6] TCC is currently reviewing its LOS for the existing urban area
[7] 200mm for non-habitable outbuildings – a mix of NZS4404:2010 and E1 standards is evident in the detail.

3.2 THE BUILDING CODE

The Building Code comes from Schedule 1 of the Building Act 2004 and the code requires performance standards that are then supported by Acceptable Solutions (AS) and Verification Methods (VM) documents. "E1 Surface Water" is the relevant Code clause and this has two key performance requirements:

"E1.3.1 Except as otherwise required under the Resource Management Act 1991 for the protection of other property, *surface water*, resulting from an event having a 10% probability of occurring annually and which is collected or concentrated by *buildings* or *sitework*, shall be disposed of in a way that avoids the likelihood of damage or nuisance to *other property*." And

"E1.3.2 *Surface water*, resulting from an event having a 2% probability of occurring annually, shall not enter *buildings" (*being limited to *housing*, *communal residential* and *communal non-residential buildings)* (MBIE, 2014).

3.2.1 ACCEPTABLE SOLUTION E1/AS1

The first clause generally means that urban buildings will be discharging stormwater to the edge of their sites at a 10% AEP level. Therefore, unless soakage or another disposal option is viable, the council's stormwater network should be able to cope with the 10% AEP flows coming off each section. The alternatives for a lower primary LOS situation are that secondary flowpaths are triggered relatively early or every site needs to incorporate detention. My experience in Hamilton[8] which has a 50% residential area LOS suggests that the cost impact of requiring detention of the runoff flow difference between an existing single house and a two house redevelopment is in the order of $5000 of on-site work. Therefore, where redevelopment is intense the community is potentially financially better off with an upgraded council system than individual detention solutions.

An associated issue for design is the time of concentration (TOC). At paragraph 3.2.2. of the acceptable solution the requirement for drains is that they be sized for the 10% AEP *10 minute duration* event (MBIE, 2014). Thus each site will most probably be discharging, at peak, a higher flow than the mains are sized for as the pipe catchment TOC will typically be longer and the associated rainfall intensity less. However, most sites will have a 100mm NB lateral connection (potentially pressurized) and hence this will govern their actual flow contribution.

3.2.2 CLAUSE E1.3.2

The calculation of the run-on secondary flow water depth that needs to be prevented from entering a building is somewhat difficult for the average building developer due to the cost of adequate modelling and so practically the council needs to set the lead either through flood modelling or setting floor level requirements. The E1/AS1 document has some leads on freeboard such as the general requirement to be 150mm above the road crown or lower part of the section. However this floor freeboard guidance does not apply to:

- catchments over 2500m^2;
- known flooding areas;
- sites adjacent to a watercourse or secondary flow path; or
- low-lying areas.

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[8] Much of Hamilton has good soakage, but increasing development intensity has caused widespread issues.

These caveats mean that it often doesn't apply, which leaves almost a total vacuum of freeboard guidance. The exception is provided at AS/VM1 section 4.3.1 where flood water from secondary flow is 100mm deep from a trafficked area[9] to a dwelling the floor freeboard shall be 500mm to allow for the impact of waves or 150mm in all other cases.

I support this wave based requirement, but question:
- on how many consents has it been applied?
- why are other freeboard risks not catered for? (refer McComb, 2012)

The Insurance Council of New Zealand is also concerned that the application of the Building Act is insufficiently precautionary in hazard areas that will worsen over time such as those subject to flooding and sea level rise (ICNZ, 2014).

3.3 NZ4404: 2010 SUBDIVISION AND DEVELOPMENT STANDARD

The 2010 update to this standard provided firm guidance in relation to stormwater level of service design and is a good base level. Key passages are:

Table 4.1 – Recommended AEP for design storms

Function	AEP (%)	Return period (years)
Primary systems –		
Rural	20	5
Residential and rural residential areas	10	10
Commercial and industrial areas	10	10
All areas where no secondary flow path is available	1	100
Secondary systems	1	100

4.3.5.2 Freeboard

The minimum freeboard height additional to the computed top water flood level of the 1% AEP design storm should be as follows or as specified in the district or regional plan:

Freeboard	Minimum height
Habitable dwellings (including attached garages)	0.5 m
Commercial and industrial buildings	0.3 m
Non-habitable residential buildings and detached garages	0.2 m

The minimum freeboard shall be measured from the top water level to the building platform level or the underside of the floor joists or underside of the floor slab, whichever is applicable.

These provisions provide for a higher standard compared to the Building Code and offer potentially the easiest path for a council to rapidly implement a precautionary approach. A better longer term approach is to have more local information as the Kapiti Coast District Council development guidelines suggest: "*Risk and sensitivity analysis should dictate minimum freeboard height additional to the computed top water flood level of the 1% AEP design storm applied in a given situation rather than solely the nature of the development. Larger freeboards should be used for major catchments or when storm surge is a possibility. Minimum freeboard height varies across the district and consultation should be undertaken with Council staff to determine the minimum freeboard height on a locality basis. Generally the minimum freeboard heights vary from 0.3m to 1.0m. The minimum freeboard shall be measured from the top water level to the building platform level or the underside of the floor joists or underside of the floor slab, whichever is applicable.*" (KCDC, 2012)

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[9] "500 mm where *surface water* has a depth of 100 mm or more and extends from the *building* directly to a road or car park, other than a car park for a single dwelling."

4 CONTEXTURAL CONSIDERATIONS

4.1 COST BENEFIT

The cost benefit of response actions need to be balanced between council and private landholders and between individual council projects. The level of service and freeboard setting process is balancing the private/public cost even if those responsible are not explicitly aware of it.

Setting priorities within the council programme is discussed this way by New Plymouth District Council… *In the case of a major flood event, the expectation is that the roads and grounds of properties may become flooded, provided that floor levels are not inundated. The improvements required for individual catchments or areas are identified through Catchment Management Plans. For each catchment these are prioritised on the basis of the current level of service offered versus the required level of service, and weighed against the cost required to achieve the improvement (a quasi benefit/cost appraisal).* (NPDC, 2015)

This is a very similar approach to that adopted by Tasman District Council for the 2015-25 LTP where a project prioritising method allocated one point for a flooded section, five points for a flooded floor and 10 points for each recurrence of floor flooding for each section.

Photograph 1 shows a house built up in Hamilton in 2013 in response to the Rapid Flood Assessment information referred to in section 4.4. Although this was not required by the Council, the owner preferred to adopt a reasonable precautionary level. The house is still slab-on-ground but the pad is raised as the red arrows highlight. The extra cost of this work was $3000 (PC, 2015). This type of risk minimisation work is much cheaper than retrofitting which Auckland City Council is finding costs an order of magnitude more (PC, 2014).

Photograph 1 example of building up in response to flood hazard information

4.2 ASSET RENEWAL CYCLES

Most communities will have blocks of major stormwater infrastructure installation interspersed with periods of incremental growth. The older cities have core networks that are reaching the end of their service life, especially those built of brick or subject to exceptional loads. However, I suspect most stormwater infrastructure in the country is less than 50 years old and built of reinforced concrete. Therefore, the network should have a long potential life ahead. This creates the quandary that it is inefficient to dig up serviceable pipes to install larger ones due to a change in the

LOS. Sometimes a duplicated pipe can be installed but service clutter becomes an increasing problem. So if advancing the renewal of pipes to allow an improved primary LOS does not make sense, then improving the LOP via secondary flow or freeboard needs to be pursued.

4.3 LAND OWNERSHIP

The extent of subdivision, parcel size, title type and ownership can make or break proposals to extend primary or secondary stormwater services unless the council decides it must happen at whatever cost. Using the RMA designation or Public Works Act compulsory acquisition path changes the pain from heavy negotiating with landholders to compliance with rigorous bureaucratic processes. Getting ahead of development and defining or securing stormwater reserve needs early is the ideal path. Even then, the details of securing adequate access arrangements through ownership or easements can be problematic. Additional complexity arises from developers' tendency to flatten sites to facilitate slab-on ground construction. These changes can severely interrupt flowpaths and elevate floor level flooding risk.

4.4 COMMUNITY EXPECTATIONS AND CONSULTATION

My experience is that community expectations of council stormwater quantity management will oscillate between “there is no problem” to its “totally inadequate” depending of what storm events have occurred in recent years. This contrast has been highlighted to me between Hamilton City Council where Council staff determined that the city had only experienced one event of 10% or less probability (one in 10 year ARI) in the 22 years to 2013 and Tasman District Council that has had two 0.2% AEP (one in 500 year ARI) events since 2011. The Hamilton community was much more concerned with potential loss of property value from flooding notations on title and the Tasman community wants stormwater flooding to be kept outside their building and ideally off their section. Parts of Nelson and Christchurch have also suffered through larger events recently and some statements by council representatives have implied that a higher level of flood protection will be delivered by the council.

The MfE view is “Community consultation on LTCCPs (sic) may therefore represent an important vehicle to gather community views on how councils should respond to climate change, and what levels of service are considered relevant for longer term planning in a changing climate. Community input into the options available for stormwater management is essential. With the uncertainty in climate change predictions, it is likely that there will be a variety of options that could be implemented, ranging in scale, complexity and cost. The community needs to be consulted to establish the level of protection they wish to have now, and maintain in the future”. (MfE, 2015) However, many members of the community do not understand either the ARI or AEP ways of expressing rainfall variation probabilities and the associated cost of raising the standard. Therefore, strong Council leadership is required to summarize the technical detail and guide the community to the key tradeoffs. Similarly clear national guidance is needed to support local government

4.5 LANDUSE

Landuse is related to the land ownership discussion above but also has a significant impact on stormwater management because of the significant increase in runoff that occurs along the development continuum between wilderness forest and the city CBD. The current and future landuse in the catchment will drive both the runoff that needs to be managed and the value at risk than needs to be protected. How far into the future the vision is cast is also a significant. These are critical factors in determining the appropriate LOS.

4.6 CLIMATE CHANGE (VARIABILITY)

"The Resource Management Act Amendment Act (March 2004) requires councils to 'have particular regard to the effects of climate change"[10] (MfE, 2015).

In response to the RMA change and Ministry for the Environment (MfE) guidelines, most councils have adjusted their design rainfall to account for moderate global warming resulting in higher peak rainfall. Typically these figures are a 2°C rise and a 16% increase in rainfall intensity. If this was the extent of the long term change it could be reasonably easily catered for. However, my admittedly unsubstantiated, expectation is that we will see higher rainfall sooner and more regularly. Hence I suggest more action is needed than what is strictly required by current laws.

MfE guidelines state that climate change is expected to affect design calculations in a number of ways, through increasing the intensity and frequency of heavy rainfall events and through changing the antecedent moisture loading of soils and the average water contained in storage ponds. And "Catchment characteristics and infrastructure (i.e. soil characteristics, presence of ponds) can have a significant influence on modelled flows and water levels. More complex rainfall modelling may need to be applied where catchments are large with a complex topography, or have specific characteristics that warrant a more detailed investigation of changes in rainfall characteristics and their effect on fast and slow run-off" (MfE, 2015).

This level of detail can and should be accounted for in comprehensive 1D-2D modelling exercises. For shorter term reactions it raises the flag for uncertainty which can be managed by precautionary rules such as 1% AEP design plus freeboard.

4.7 RECREATION, CULTURAL AND BIO-DIVERSITY AREA VALUES

Designing the stormwater drainage system to maximise the efficient transport of stormwater as the only criteria is generally not a realistic or sensible approach. Most of the time stormwater corridors can effectively serve as recreation, cultural and conservation spaces. By planning for these multiple uses, the effective cost-benefit of the system to the community improves considerably. The public are known to welcome and help plant "urban ecological corridors" but are less forthcoming with concrete drains.

4.8 THE ROLE OF LIMS

Land Information Memorandums (LIMs) are a key place where councils can communicate natural hazard information to the public. Councils are required to provide the flood hazard information that they know in the District Plan or on LIMs[11], but this knowledge can be required to meet a high quality threshold before release.

Hamilton City Council released draft Rapid Flood Assessments information to the public in April 2012. This showed that approximately half the city was at risk of flooding. Many people did not understand that the modelled flooding was mainly related to overland flow from 100 year ARI incident rainfall rather than the Waikato

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[10] The Resource Management (Energy and Climate Change) Amendment Act 2004 introduced a "other matter" into Part II of the RMA, requiring that particular regard be given to the effects of climate change (section 7(i)).

11 LIM contents are listed in s44A(2) of the Local Government Official Information and Meetings Act (LGOIMA)

River rising. Regardless of the details of the modelling, the primary concern of the majority of the public that I spoke with at the information sessions was the impact on their property value. They DID NOT want the information recorded on the LIMs. Hamilton City Council subsequently decided that only detailed modelling results were of sufficient quality to formally release and hence many properties will not have formal warning of the flood risk until this modelling is complete.

In a similar vein Kapiti Coast District Council has experienced the brunt of public concern in regard to its coastal erosion and hazard information and has withdrawn the initial results (Stuff, 2013). These examples are a reminder that reaching a balance point between warning people of a reasonable flood hazard and not unduly reducing property values is difficult. There is risk for councils on both sides of the equation.

5 GENERAL LOS SETTING METHODOLOGY

My general suggested methodology for LOS/LOP setting is.

Step	Task	Implementation
A	Review Corporate/ Community Objectives	Derived from legislation or community input, councils will have objectives that relate to public safety, protection of assets, and natural hazard management. These then justify a LOS/LOP related to stormwater management and hence design standards and rules to deliver these.
B	Draft LOS/design standard	The main thrust of this paper
C	Consult with Community, Refine and adopt LOS/ Standard	Many councils will achieve this step via the Long Term Plan consultation or a special consultative process. If stormwater management issues are "hot" then managing this step well will be critical to balance the (desired service) versus (the willingness to pay). The IIMM part 2.2 has further guidance and case studies. These are normal council processes, but are critical to embedding the standards and policies necessary to support resilience against stormwater hazards.
D	Review, Maintain and improve	These are normal council processes. Best achieved via either the Catchment Management Plans (CMP) or Activity Management Plans (AMP)

5.1 THE MFE HAZARD EVALUATION PROCESS

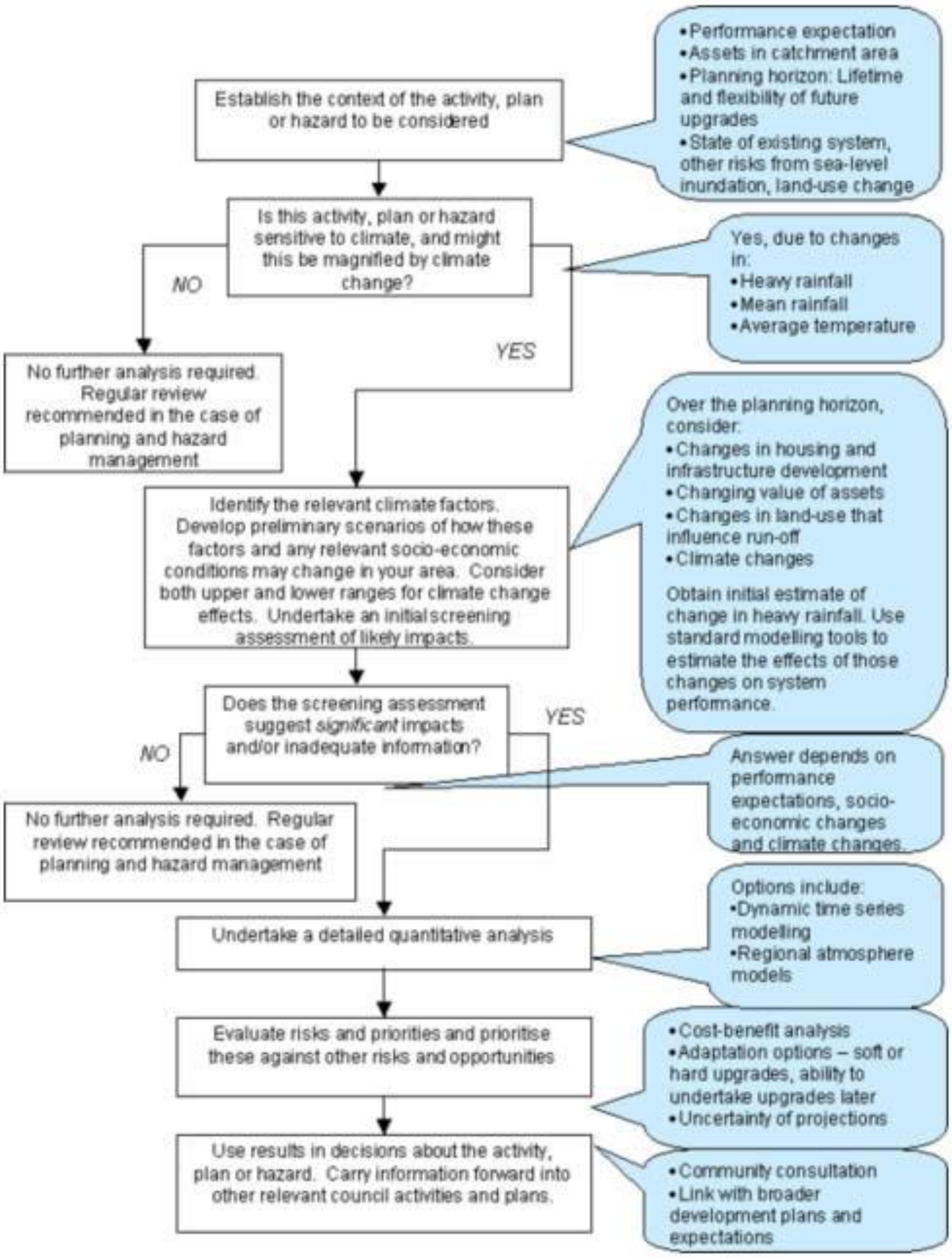
"An increase in heavy rainfall events is one of the key projected changes resulting from climate change. Since heavy rainfall events are key drivers for the design of stormwater systems, climate change would appear to require consideration in the design and upgrade to ensure those systems continue to meet their design criteria throughout their planned lifetime." (MfE, 2015)

The booklet Preparing for Climate Change (MfE 2008a), published by the New Zealand Climate Change Office of the Ministry for the Environment, contains material to facilitate a screening assessment of the relevance of climate changes on stormwater system performance. Subsequent MfE documents move to implementation. Establishing the context of the evaluation for climate change associated stormwater hazard overlaps extensively with what was required previously. Key elements include:

- Rainfall - current and predicted climate based changes;
- Current seasonal to inter-decadal cyclic variation in peak rainfall;
- Existing stormwater system – extent, capacity, age, condition, ownership;
- Catchment – scale, shape, soils, slopes;
- Vegetation – type, coverage and harvesting rotation;
- Ponding or overland flow hazards;
- Tidal effects and coastal inundation;
- Recreation and bio-diversity area linkages;
- Community feedback – is consultation needed?
- Political and financial policy;
- Existing and proposed land use;
- Land ownership, availability and maintenance access;
- Value at risk;
- Planning horizon,

Figure 2 shows the processes recommended by the MfE in their documents relating to climate change adaption. (MfE, 2015)

Figure 2: MfE Stormwater Hazard Review Process



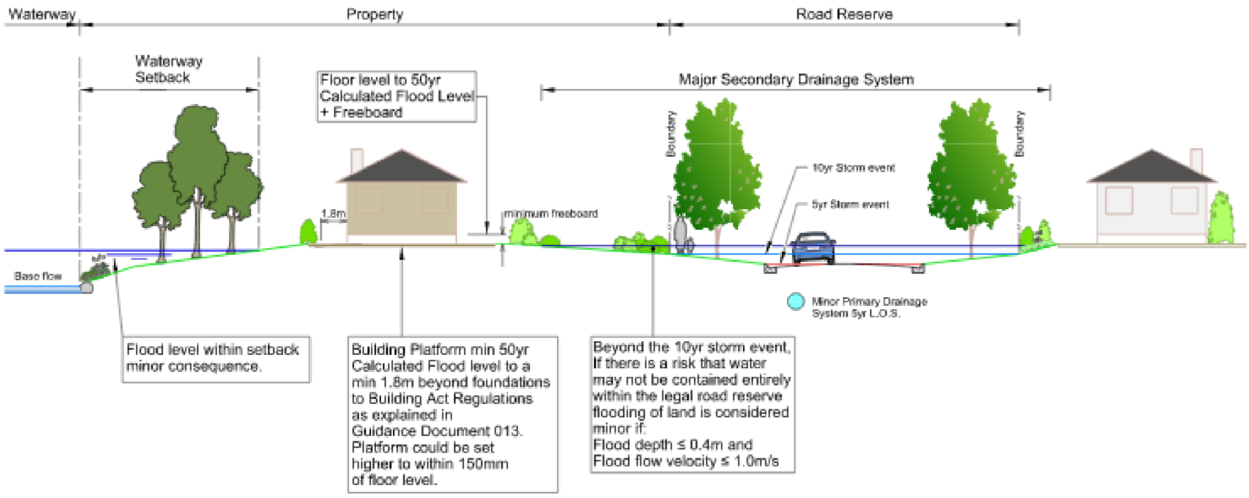
The information available (model results, cost estimates, assessment of effects) can be used to develop a plan for implementation of stormwater works. It will need to be determined whether or not works can be staged (i.e. climate change upgrades incorporated sometime in the future, or upgrades implemented now), and also whether climate change should be managed via 'hard' engineering options (e.g. pipe upgrades), or through secondary systems such as overland flow paths. This is particularly important, given that there is some uncertainty with respect to the likely magnitude of climate change effects (MfE, 2015).

5.2 FLOOR LEVELS AND FREEBOARDS

Setting freeboard and/or floor levels starts to move the discussion from hazard management to risk mitigation. Christchurch City Council has a long history of flooding and that has been intensified in some areas by the earthquake sequence. It is not surprising that the Christchurch City Council web-based information is above average including the following quote and Figure 1.

“It is important to remember, Christchurch is a flat, low-lying city and there have always been areas prone to flooding. The Council has always set minimum floor levels in these areas and updates these as required” (CCC, 2014).

Figure 1: Christchurch City Council flooding guidance



Currently, web-accessible information for Christchurch includes 50 and 200 year floor levels. Hamilton City Council has only started setting floor levels with the new District Plan in 2012 and Tasman District Council only specifies floor levels in relation to coastal inundation (TDC, 2013).

Without high quality modelling and good community education, setting floor levels can create the potentially unjustified public impression that the risk of buildings inundated is low or create legal challenges. However, not setting floor levels in many cases leaves the risk too high. This is a key challenge for councils.

5.3 IDENTIFY, PROTECT AND RETROFIT SECONDARY FLOW PATHS

Protection is offered by the combination of primary and secondary stormwater systems and freeboard. Due to the Building Code a suggested minimum primary LOS is 10% AEP. Going higher than this is only recommended for areas where there is a high value at risk. In other areas having the flow paths activated more often is beneficial to remind people what they are for i.e. an application of the old wisdom “use it or lose it”.

Few councils seem to have tackled the thorny issue of really protecting secondary flow paths. Whilst, generically most council engineering standards require these to be located in public spaces or protected by easement, the reality is probably much less clear cut. For older established areas roads were often built up and houses built on piles. For newer areas the subdivision might be designed to deliver its 1% AEP flow to the boundary, but can the downstream system accept it without back up or downstream flooding? My experience suggests that secondary flow routes are largely unknown, unprotected and hence unmanaged. There is no hope of council delivering on it's LOP goals if this situation prevails.

Fortunately recent advances in LiDAR, GIS and other modelling technology have allowed cost–effective modelling to proceed. The Auckland City Council stormwater team has been leading contributors to related discussions in recent year (Irvine 2014). I acknowledge that these models and the underlying data collection processes are not perfect. For example LiDAR has an inbuilt error range and will generally not pick up fences and other obstructions to the average height within the grid. Therefore the real flow path can be distinctly different from the model. Field verification will allow many of these issues to be identified and setting a freeboard above the modelled flood surface allows for a margin of error that will hopefully mean floors remain dry.

The level of effort that goes into these processes is best decided based on the context assessment discussed at section 5.1. What is the effective LOS, What is the value at risk? How sensitive is the cost of damage to flood height?

A final caution on secondary flowpaths is the need to consider public safety and damage from flood waters. There is currently no set New Zealand standard of safety thresholds and a range of formulas/plots exist. These suggest that around 0.5m depth and/or 1m/sec velocity that vulnerable people have an elevated risk and by 1.0m depth and/or 2m/sec velocity most people are in danger. Potential vehicle and built infrastructure damage will also often need consideration.

5.4 DISTRICT AND REGIONAL PLAN CHANGES

Amending the planning documents to account for stormwater levels of protection is the strongest measure that councils can take as is foreshadowed by S106 of the RMA where subdivision[12] can be refused where land may be subject to "inundation from any source". Until the council's planning documents underpin flood risk mitigation, engineering standards and Building Code-based decisions can undertake a rear-guard approach, which is not ideal.

Raising the standard of property protection will inevitably lead to legal challenge from developers. In a related, vein Tasman District Council has successfully defended two decisions in the Environment Court during 2014. These related to inappropriate subdivision and development in coastal locations subject to present and projected future hazard risks (amongst other reasons). Both Court decisions reinforce the wisdom contained in the National Coastal Policy Statement (NZCPS, 2010) with respect to development in hazard-prone coastal locations. The first case involved an appeal to the proposed rezoning of land (from Rural to Rural 1 Coastal) under Plan Change 22, to allow subdivision of a pocket of land in the highly desirable, but vulnerable, coastal location of Ruby Bay. The present stormwater and coastal inundation risk and projected future coastal inundation hazard would reduce the

[12] The lack of "and development" here makes Council's position much weaker with regard to Landuse consents.

amenity of the sections such that the development would be ultimately unsustainable. The second case involved a proposed small subdivision on Kina Peninsula where the sites were only slightly vulnerable but the access route was already under threat from coastal erosion.

In both cases the risk to the house floor levels could be avoided by sufficient elevation and making the houses relocatable. Hence the impact of the hazard could be mitigated to some degree for a period. Hazard exposure was the principal reason behind declining the PC22 appeal and was a significant element in the Kina appeal decision. Generally speaking, in both cases the Council's successful argument was these proposals were poorly planned and unnecessarily placed new buildings in a known or projected hazard environment. These cases build confidence that, at least in the coastal setting, councils can defend precautionary decisions that "look at the long run" as encouraged by the Insurance Council. Unfortunately there is no similar mandatory NPS under the RMA relating to urban stormwater flooding.

6 PULLING IT TOGETHER

6.1 AN EXAMPLE FORM CHRISTCHURCH

The following extracts from Christchurch City Council (CCC 2015) provide an example of the public communication of a relatively mature flood mitigation process:

Flood Management Areas were identified in Christchurch before the Canterbury earthquakes as areas that are prone to flooding, as a result of major tidal or rainfall events, and which are vulnerable to the effects of climate change as a result of rising sea levels.
Variation 48 was made operative 31 January 2011.
Why were Flood Management Areas introduced? Flood Management Areas were identified to help reduce future damage to the city from major floods and sea level rise by: • addressing scientific information regarding anticipated sea level rise in Christchurch of up to half a metre during this century; and • acknowledging that the minimum floor levels for homes set at a one in 50-year flood event by the Building Act were not adequate for Christchurch's more flood-prone areas. These levels needed to cater for a one in 200-year event.
What are the new floor levels in the Flood Management Areas?
The new floor levels are high enough to prevent water entering buildings in major flood events; thereby significantly reducing damage and not being unreasonably expensive to achieve.
The Flood Management Areas include a guideline floor level of 11.8m above Christchurch City Datum in tidal areas. They also use levels for a one in 200-year flood plus freeboard for assessment in non-tidal areas. The higher of the two will apply in any location.
All local authorities have a freeboard level; this tends to vary from 300mm to 500mm. Freeboard in Christchurch has been 400mm for many years.

6.2 ACTION PRIORITIES

To set effective LOS and LOP for a community requires extensive research and processes to assess and balance risk and cost. These will take time and need to be managed. In the interim, reasonable precautionary risk reduction should also be undertaken. A suggested loose sequence of actions is presented below to facilitate a transition from starting to compliance to best practice.

6.2.1 PRIORITY 1: CREATE A CROSS-COUNCIL TEAM WORKING ON FLOOD RISK REDUCTION

In order to achieve the suggested level of integration between the different council departments, a team approach is needed. To achieve reasonable progress a champion is also usually required to lead the charge over several years. The effort will also need the support of the senior management team and the council to facilitate approval of policies and budgets.

6.2.2 PRIORITY 2: GET PRECAUTIONARY RULES IN PLACE FOR NEW DEVELOPMENT

The first need is to minimise the situation getting worse and that means having precautionary rules in place to minimise the potential problems. For new development areas this is potentially best achieved by amending the engineering standards for subdivision and development to require secondary flow design at 100 year/1% level with freeboards as suggested by NZS4404. If the Development Code/Manual/Standards are not referenced by the District Plan, this can be a quick and easy first step. This should still be pursued even if a District Plan change is required. In either case these generic rules should be overridden by more specific local investigation results.

6.2.3 PRIORITY 3: GATHER HISTORICAL FLOODING INFORMATION FOR BUILDING CONSENTS

A comprehensive and ongoing gathering information from current and former staff, residents, council records, NZ Fire Service, the internet etc will provide a wealth of information to support a "living" map that suggests which properties do not qualify for the E1/AS1 150mm default freeboard allowance. Then building staff can request that the applicants provide further information to support signoff under Building Code clause E1.3.2. This could be the starting point for the process of raising community awareness.

6.2.4 PRIORITY 4: DIGITALLY MAP CONTOURS TO ALLOW COMPUTER FLOWPATH MAPPING

Ideally this would be based on LiDAR, however even topographic map contours will allow catchments to be defined, a Digital Terrain Model to be created and overland flow paths and depressions to be mapped. Auckland City Council's stormwater team has been a strong contributor in documenting these processes (Irvine, 2014). Prioritisation of remedial works to define and protect these flow paths can commence. The results can potentially form the basis of interim LIM hazard notifications. OFP mapping results should be used as a point of consideration for Building and Resource consent processes.

6.2.5 PRIORITY 5: UNDERTAKE RAPID FLOOD ASSESSMENTS

Rapid flood assessments build upon the previous information to better define the spread of predicted flooding and assist priority setting for further modeling.

6.2.6 PRIORITY 6: COMPLETE LINKED 1D-2D MODELING

Full modeling provides the basis for flooding maps to be placed in District Plans that link to rules regarding the type of allowable developments, flow path protection, minimum freeboard, avoiding displacement of flood waters etc. LIMs should include a clear statement that the property is covered by a flood hazard. As part of this assessment, the level of acceptable hazard and threshold steps needs to be defined. However, as 2D modeling is expensive, selective application is required.

6.2.7 PRIORITY 7: UNDERTAKE RISK ASSESSMENTS

This ideally would be done at the same time as the full modeling but requires floor level and other private property information to be gathered which can substantially increase the investigation cost. Apart from refining floor level rules, Risk Assessment allows detailed evaluation of the cost-effectiveness of mitigation works. Tools such as the GNS-NIWA riskscape packages are emerging to support these processes (NIWA 2015).

6.2.8 PRIORITY 8: PURSUE DISTRICT PLAN AND ENGINEERING STANDARD CHANGES TO LOCK IN RESILIENT STRATEGIES

Once the preceding steps have been completed, the council will be well placed to create District Plan rules and policies that will be legally robust and effective at risk reduction. The suggested packaging of this material is on a catchment basis and the preparation of catchment management plans (CMPs) is an assumed stepping stone in the process. Full public consultation is expected at this step to achieve a high legal standing and level of community awareness.

6.2.9 PRIORITY 9: EDUCATE THE COMMUNITY

Once the new rules are in place the development community will learn the rules and have a better understanding of the flood hazard and associated risk mitigation options. The general community's understanding will lag behind and may undermine the results. Brochures and online information to educate residents should target issues such as:

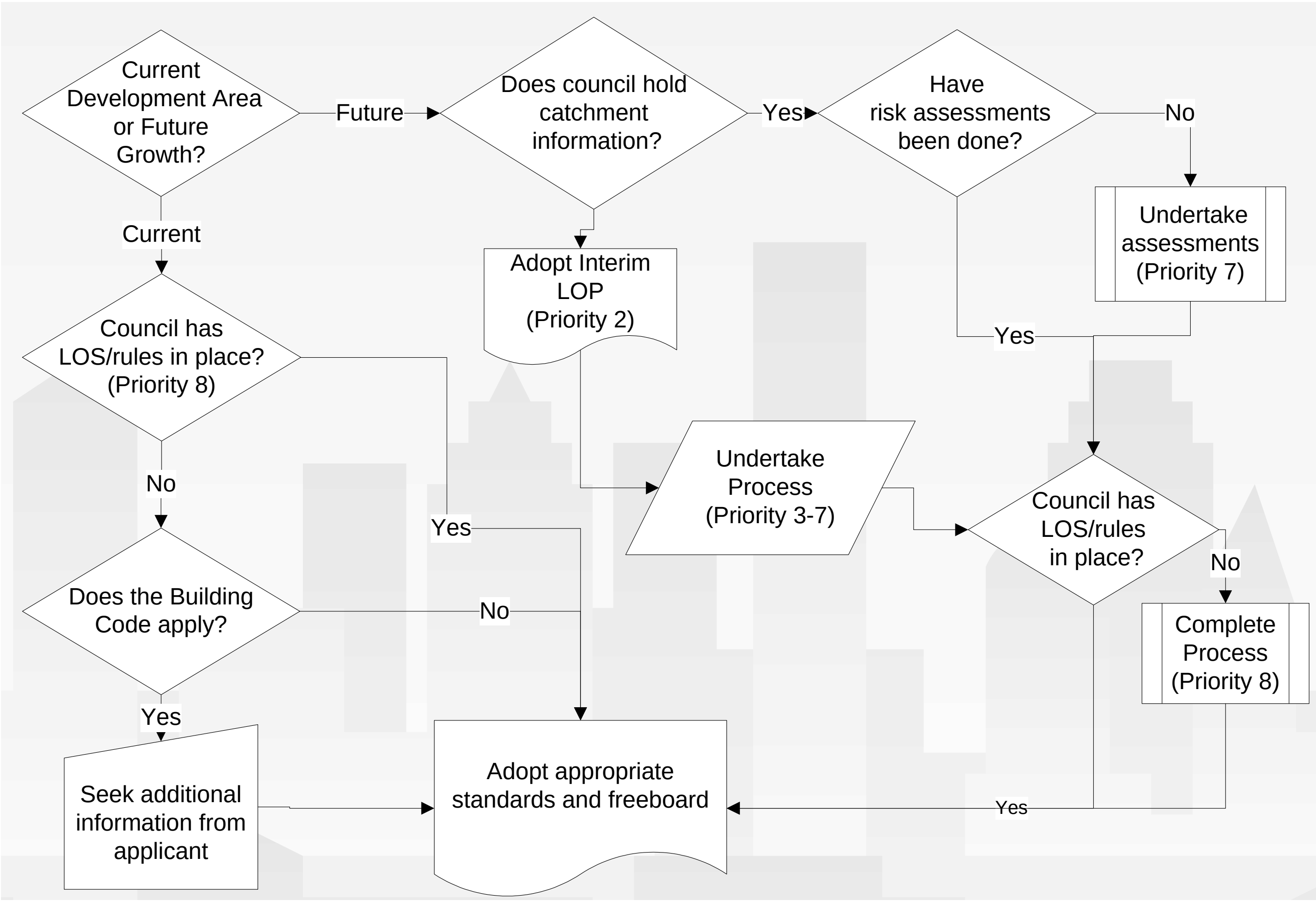
- building on piles rather than slab on ground;
- undertaking private paving and landscaping works to divert stormwater away from their buildings;
- the limits of the council stormwater system;
- not blocking secondary flow paths; and
- cleaning out or reporting the blocked catchpits;

The first two points are an attempt to lead the market away from the dominant model of slab on ground with "uninterrupted indoor-outdoor flow". Convenience based site layout facilitated many flooded floors in Richmond in April 2013. More thinking by residents about larger storms and where the water will go once the Council system is overwhelmed or blocked will allow them to help avoid flooded floors.

6.2.10 PRIORITY 10: MAINTAIN THE SYSTEM

The entire system of infrastructure, models, condition information and hazard/risk assessments needs ongoing maintenance, review and improvement to remain effective. The intensity of catchment change, climate change or other factors like earthquakes and legislation will determine how onerous this process is. Regardless, establishing systems and embedding this into the Stormwater and/or Rivers AMP and CMPs is necessary. There is also the issue of potential legal challenge to the results that justifies sound project/process management.

Figure 3: Setting LOP by priority process



Mapping these priorities against the steps from section 5 provides this summary.

Step	Task	Priority
A	Review Corporate/ Community Objectives	1 Cross-council Team
B	Draft LOS/design standard	2-7 Data gathering and Rules drafting
C	Consult with Community, Refine and adopt LOS/ Standard	8 Refine and adopt
D	Review, Maintain and improve	9 Educate the Community, 10 Maintain system

7 CONCLUSIONS

Climate variability seems likely to increase the flood hazards in urban areas. Local Government has a legislative requirement to respond to this change and setting primary and secondary levels of service and protection is an appropriate part of the overall response.

Setting locally appropriate LOS can be a slow, difficult and expensive process. This paper presents a quick overview of related issues and offers a process to facilitate level setting for New Zealand councils.

Full system and catchment research and integrated 1D-2D flood modelling are the ideal data inputs to be sought. These can then underpin a robust risk assessment and this should support a comprehensive integrated planning, building control and engineering response. Local Government can then deliver a framework of rules policies and standards that facilitate a cost-effective level of service and protection to the community.

7.1 ACTION STEPS

The following action steps are suggested to get moving in a resilient direction whilst further analysis is underway:

1: Create a cross-council team working on flood risk reduction

2: Get precautionary LOP rules in place for new development based on the secondary flow and freeboard guidance contained in NZS 4404:2010

3: Gather historical flooding information for building consent checking

4: Digitally map contours to allow computer flowpath mapping

5: Undertake rapid flood assessments

6: Complete full linked 1D-2D modelling

7: Undertake risk assessments

8: Pursue District Plan and Engineering Standards changes

9: Maintain the system

7.2 KEY SUGGESTIONS:

Key suggestions to assist the process are:

- Assess the real existing stormwater capacity thoroughly considering realistic maintenance aspects such as intake blocking.
- Use all the tools of the council under the RMA, LGOIMA and Building Acts to create a robust framework around flood risk reduction. This requires the integration of science, engineering and planning and a team effort across the council departments.
- Remember to take the public and councillors with you on the process and educate them to facilitate the cost trade off choices and helping themselves to avoid flooded floors.
- Don’t feel constrained to follow the action steps in a strictly linear fashion. Do what can be done as soon as possible, refine and improve it later.
- Note that within the spectrum of long term climate change we could have episodes of climate variability that will have a greater impact on public opinion than all the science – be prepared.
- Start now on submitting proposals for funding as, without a significant local rainfall event, it could take years for the Council to approve approved.

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