BUILDING IN A BATHTUB –WHERE TO NEXT IN KILBIRNIE?

Tim Strang, Wellington Water, Petone, Lower Hutt

ABSTRACT

Kilbirnie sits on low lying land in Wellington, marginally above high tide level. The suburb floods frequently, including internal flooding to businesses and dwellings during extreme events. The flooding is at odds with plans to intensify the area by recent district plan changes.

Investigations are currently underway to develop options for the western side of the catchment. This has become a high profile project, and has involved a series of community meetings and presentations to attempt to marry community expectations with funding levels.

Pump-stations and pipe solutions will provide a way of making the situation liveable while longer term solutions are developed. The longer term solution is expected to include upgraded infrastructure, new district plan controls, resilient building designs and individual responses to flooding events. The changing climatic conditions and controls will demand a new level of community engagement to achieve understanding and buy-in.

KEYWORDS

Stormwater flooding, climate change, resilience, planning controls, Kilbirnie, Wellington, stormwater pump stations

PRESENTER PROFILE

Tim Strang has previously fulfilled a number of roles in private and public organisations and is currently Chief Advisor – Stormwater at Wellington Water. Wellington Water is a council controlled organization that provides 3 waters services for Wellington, Lower Hutt, Upper Hutt, Porirua and the greater Wellington bulk water network.

1 INTRODUCTION

The geography of the Kilbirnie West catchment causes it to be prone to flooding, which under current conditions can occur in a 2-year return period rain event (50%AEP) if it coincides with high tide. The upper and middle reaches of the catchment are steep hills while the lower catchment is relatively flat and mainly reclaimed land. This reclaimed land rises several metres above the original foreshore, which follows the approximate alignment of Kilbirnie Crescent and Rongotai Road and remains a low point. The original foreshore is very low in places and barely above the high tide level.

The regular flooding in Kilbirnie impacts on the liveability of the area and means that the full development potential of the suburb is not able to be realised. The area ticks many of the boxes for development, including being within walking distance of the airport, having good public transport links and being close to the Mt Victoria green space as well as Lyall Bay beaches, the Miramar Peninsula and Evans Bay boating area. In the future a coastal cycling route has been proposed that will provide a scenic and safe cycling route from

Kilbirnie to the central business district. The area has also recently been zoned as a medium density development area, meaning that is has been primed for intensification.

Around five years ago a major stormwater upgrade was completed on the eastern side of the catchment by the construction of the Tacy Street pump station designed for around a 2% annual exceedance probability level of service under current climatic conditions, although the current level of service is limited by the current capacity of the gravity mains that drain to it. The 5.5 m^3/s capacity pumpstation has significantly reduced the flood risk to properties in the east, but has provided little benefit to the west catchment.

2 SIZE OF THE PROBLEM

2.1 EXISTING FLOOD RISK

The Kilbirnie catchment and stormwater network have been modelled using an integrated 1D/2D modelling approach for the pipe network and surface water flows (Infoworks ICM). The low hydraulic gradient over the catchment meant that careful consideration of inlet capacity was needed and covered off by individual modelling of each sump.

Modelling results for the 10% annual exceedance probability event under a high tide scenario with current climate conditions is presented in Figure 1. The results show the impact of the pumpstation on the east side of the catchment, with heavier flooding on the west.

Figure 1. 10%Annual Exceedance Probability Results under current climatic conditions

Modelling results for the 1% annual exceedance probability event under the scenario of high tide combined with 16% increase in precipitation due to climate change and a 1m increase in sea levels are presented in Figure 2. Under this scenario the Tacy St Pumpstation has reached capacity and is no longer effective at mitigating flooding on the eastern side.

Figure 2. 1%Annual Exceedance Probability Results under slightly grim climate change scenario

2.2 WATER QUALITY ASPECTS

In general water quality issues have not been a big focus of stormwater management in the Wellington area, but the introduction of the Proposed Natural Resources Plan (Greater Wellington 2017) and the National Policy Statement on Freshwater Management (Ministry for the Environment 2014) will require water quality to be considered as part of the overall stormwater management strategy that is developed over the next 3 years as part of the global consenting process.

Kilbirnie stormwater is discharged to Evan's Bay, an area that has elevated contaminant levels in sediments –possibly due to historical industrial practices combined with lower flushing rates than other parts of the harbour. While the stormwater management strategy has not yet been developed, Wellington Water recognizes that significant projects should be compatible with the introduction of water quality measures in the future.

2.3 ESTIMATED DAMAGES

There are very few New Zealand specific studies available that can be used to develop a relationship between depth of flooding and cost of damages. One of the most comprehensive and widely used studies was undertaken in 1990 following flooding from the Hutt River. The results are reported in Hutt River Flood-Plain Management Plan (Agricultural Engineering Institute, 1992). The damage costs associated with these levels of flooding have been updated from the original study to present day costs. The construction costs were updated using Rawlinsons New Zealand Construction Handbook. Chattels replacement costs were adjusted using Consumer Price Index (CPI) data obtained from Statistics New Zealand.

Damage costs for a number of return period events were estimated based on a survey of existing floor levels compared to predicted flood extents, as presented in Table 1.

Table 1 Damage Cost Assessment

Event Probability	Estimated Direct Damage Costs
20% annual exceedance probability	$222,082
10% annual exceedance probability	$369,776
2% annual exceedance probability	$553,182
1% annual exceedance probability	$1,763,534

Estimated damage costs were multiplied by 1.5 to approximate direct and indirect costs, integrated to give an average annual damage cost for any one year and then summed on a net present value basis to give the estimated damages for a 50 year infrastructure life, as presented in Table2.

Table 2 Average Costs

	Estimated Direct and Indirect Costs
Average annual damage costs	$213,635
NPV cost based on 50year life, 7%interest	$2,948,319

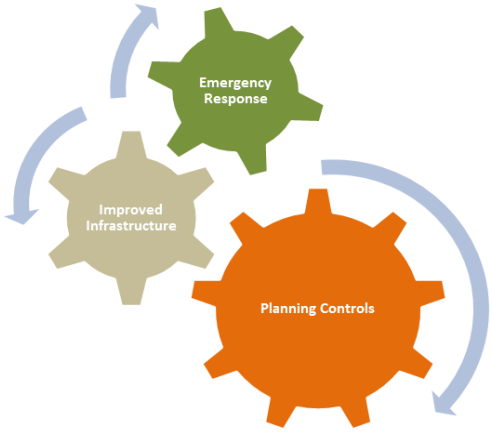
Achieving a desirable cost benefit ratio under conventional assessment would require keeping the cost of any upgrade works well below the estimated long term damage costs on a net present value basis. In some historical cases a cost benefit ratio of 2 or more was desirable – which for Kilbirnie would leave only around $1.5M available for any upgrade works.

What this assessment does not consider is the opportunity cost if development does not go ahead due to the flood prone conditions. This could be accounted for by considering development scenarios, and making an economic assessment of the long term benefits that the developments could provide for Wellington City Council. This extended economic assessment has not been considered by Wellington Water to date, but could potentially form part of business cases going forward.

3 REDUCING THE RISK OF FLOODING

3.1 TYPES OF APPROACHES

Reducing the risk of flooding could take the form of enhancing emergency response, improving the stormwater infrastructure or implementing planning measures. Wellington Water is planning to use all these approaches to reduce long term flooding risk.



3.2 EMERGENCY RESPONSE

Having contractors on-alert when extreme rainfall is predicted means that we can ensure we get the best out of existing systems by keeping inlets clear through an event. There may also be opportunities to install flood defense like sandbags around problem areas, and the visible presence of contractors gives support to residents who are battling the weather alone.

Predicting when extreme rainfall will come and the exact path it will travel is challenging in small catchments like Kilbirnie seeing as flooding is normally in response to intense localized outbursts. There may be less than half an hour between the start of the intense burst and the resulting flooding.

In the future, Wellington Water hopes to improve emergency response through tools that will enable us to more successfully predict the path of extreme rainfall. We are currently trialing a NowCast flood forecasting pilot project that utilizes rainfall radar to provide up to an hour warning of intense rainfall.

3.3 IMPROVED INFRASTRUCTURE

Traditionally, utility companies have focused on upgrading infrastructure as the primary means of reducing flooding risk. Typical infrastructure approaches are listed in Table 3.

Table 3 Infrastructure Approaches

Increase Primary System Capacity	More or larger pipes Optimise existing hydraulics Pump Stations Improved Inlets At-source or in-line attenuation
Increase Secondary System Capacity	Re-profile roads Overland flow paths Detention basins
Reduce the impact	Install flood walls Elevate buildings Resilient building products

For Kilbirnie, a variety of potential approaches were considered and further details are given in Section 4.0. While there was initially a strong commitment from the project team to come up with innovative solutions that were less hard-engineered, in practice none of the soft-engineered solutions were considered feasible and cost effective.

3.4 POLICY AND PLANNING MEASURES

National and regional initiatives such as the national policy statement on urban development and natural hazards strategy support the implementation of policy and planning measures. These provide an alternative and complementary non-infrastructure approach that hold the promise of both mitigating any increase in flooding due to new development, while also progressively increasing the resilience of the catchment. Typical planning measures are listed in Table 4. Water quality and water sensitive urban design has also been included since, while it doesn't necessarily address flooding, it needs to be considered at the same time for optimum outcomes.

Table 4 Planning Controls

Control	**Typical Implementation**
Flood hazard areas	District plan change
Recommended building heights	District plan change
Designated overland flow paths	District plan change
Hydraulic neutrality policy	Bylaw or code of practice
Water quality and water sensitive urban design	Bylaw or code of practice

3.5 COMMUNITY WORKSHOPS AND COMMUNICATION

A number of updates to the community have been provided through the local Kilbirnie Residents Association. These have generated considerable discussion and have been useful for the project team to stay focused on the agreed programme, and of continuing to be conscious of the effect of the flooding on the community.

Initially the updates focused on the infrastructures upgrades that would be completed, but overtime the approach expanded to also cover maintenance, emergency response and planning measures.

4 INFRASTRUCTURE OPTIONS

4.1 APPROACHES CONSIDERED

The options selection process began with a workshop on 10th August 2016. WCC planners, Wellington Water staff, and the MWH team attended, and developed a long list of potential options. The project team sought to come up with a range of both infrastructure and non-infrastructure options to reduce the regular flooding while also being compatible with longer term upgrades to achieve a 1% annual exceedance probability level of service under a climate change scenario of 16% increase in rainfall intensity combined with 1m of sea level rise.

Table 5 Long List of Options

	Option	Comment
A	Do nothing (control)	Continued application of mitigation measures, such as regular cleaning of sumps within the infrastructure network. Left in as a baseline to compare other options against.
B	Storing water in Kilbirnie Park	Kilbirnie Park is higher than the adjacent low lying areas that flood. In addition, Kilbirnie Park was identified by WCC as a former landfill site and is likely contaminated. Unsuitable to store water in. Storage opportunities in the upper catchment are very limited due to the steep topography.
C	Increasing soakage area through solutions such as permeable pavements, infiltration basin, rain gardens	Increased soakage areas would assist with flooding reduction, however minimal suitable sites exist within the catchment due to the steep topography, geology, past land use (landfill) and shallow ground water table in low lying areas.
D	Property raising	Most commercial properties are not suitable for raising (brick construction or slab on grade). More suited to residential properties.
D	Purchase properties	Not in line with WCC planning objectives for Kilbirnie development. Very expensive given large number of flood properties and property values.

E	Flood walls	Flood walls are new technology (currently being tested in the Wellington region). They are only suitable in specific situations and are reliant on user attentiveness and proactive maintenance.
F	Transfer of flow from the west to east catchment for discharge via Tacy Street Pump Station	The transfer of stormwater reduces the level of service in the East catchment and would require substantial pipe upgrades to facilitate it.
G	Risk control through changing planning and development processes	This option is valid and should feature in any long term solution. New developments must take catchment flooding into consideration when setting habitable floor levels and contribute to improved stormwater management.
H	Preventing buses from driving down Kilbirnie Crescent in storm events	This option is valid and should feature in any short term solution (until surface flooding frequency is significantly reduced); though it does nothing to stop flooding from occurring, it improves public perception and can stop wave run up from entering houses which has been noted as a problem.
I	Adding additional sumps to the existing network	Lack of sump capacity has been identified as a problem but increasing capacity will not address the underlying pipe capacity issue.
J	Upgrading the network (increased sump capacity, larger pipes and installing a pump station)	Will meet both the Primary Driver and the Project Objective
K	Providing temporary pumps at flooding locations	To be effective relatively large pumps and temporary pipelines would be required. It would be impractical to deploy these assets within the timeframe required to prevent flooding given the short time of concentration for the catchment (<30 minutes).

4.2 SHORTLISTED OPTIONS

Shortlisted options were identified based on a high level feasibility assessment, using the Infoworks ICM model to assess expected performance. After the assessment, it was clear that upgrading the network would need to form part of any long term strategy to achieve 1% annual exceedance probability level of service under a climate change scenario of 16% increase in rainfall intensity combined with 1m of sea level rise.

Several options identified warranted further investigation to determine their effectiveness at reducing frequent flooding in the short term. These options were reconfigured and taken forward for more detailed modelling:

1. Do Nothing (control)
2. Property Raising and Flood Walls
3. Do Minimum
4. Upgrading the Network

For each option, the total number of residential and commercial properties that are predicted to flood in a 10% annual exceedance probability event is given in the Table 6 based on a 200mm freeboard allowance.

Table 6 Expected Outcomes of shortlisted options

	10% AEP event	
Option	**Residential Floor levels flooded (% change from 1)**	**Commercial floor levels flooded (% change from 1)**
1 (Do Nothing)	10	26
2(Property raising)	0 (100%)	2 (92%)
3(Do minimum)	2 (80%)	19 (27%)
4a Stage 1 (Network upgrade)	1 (90%)	26 (0%)
4b Stage 1 (Network upgrade)	1 (90%)	2 (92%)

While the property raising option provides the best level of service in a 10% AEP, the overall costs were estimated to be comparable to the network upgrades, but with a big loss in amenity and useability of the area due to the long continuous lengths of impermeable walls. The property raising option was therefore seen as something that would be better to progressively implemented through planning controls when land is developed, or to address specific localised flooding issues.

4.3 PREFERRED OPTION

The preferred Option was Option 4b Stage 1. This involves construction of a 5m3/s pump station immediately downstream of the confluence of the two trunk mains on the existing outfall pipeline, a new DN1200 pipeline approximately 305m long from the Bay Road – Rongotai Road intersection to Evans Bay Parade, as well as additional sump capacity. The proposed layout is shown in Figure 3.

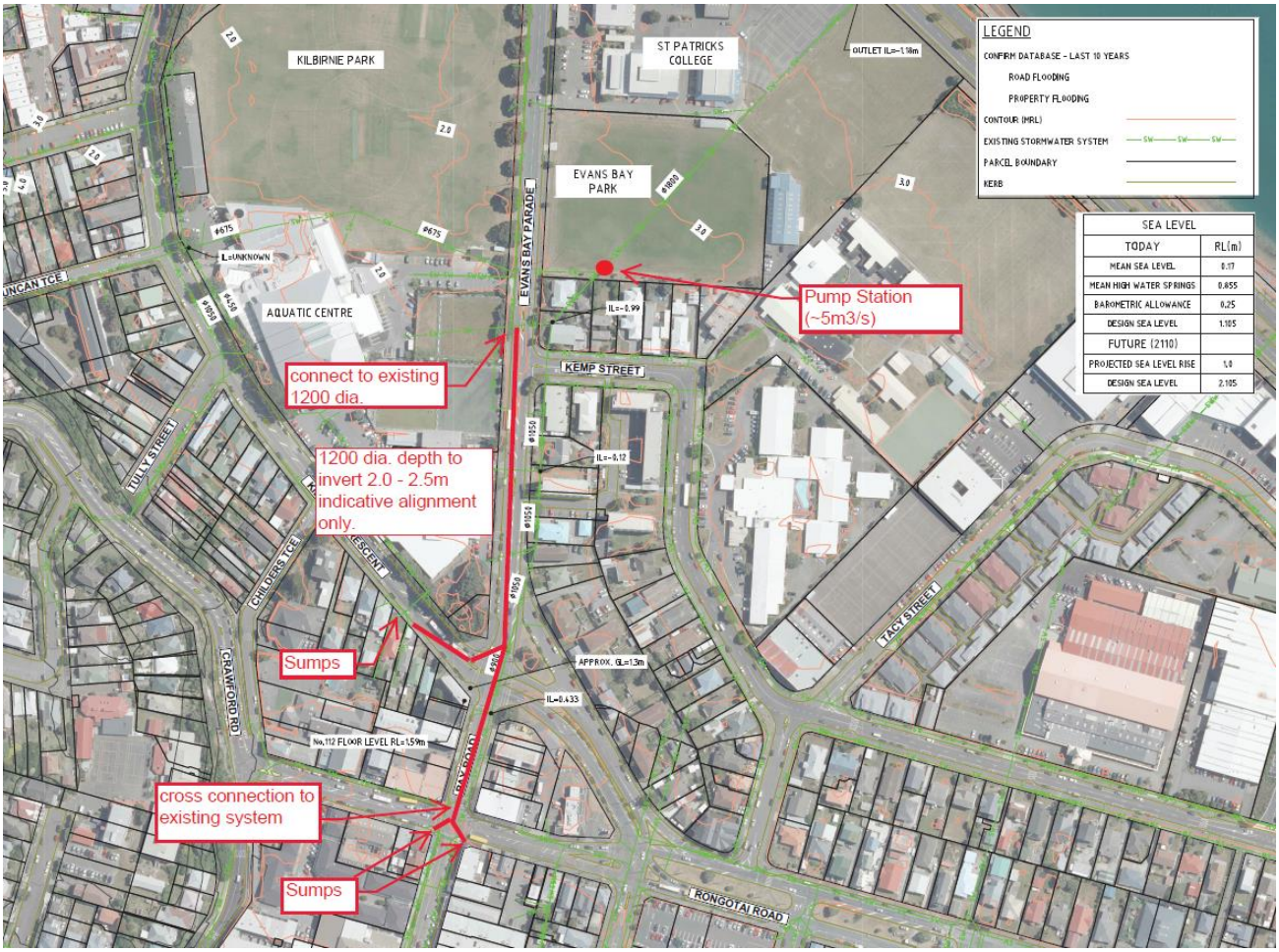


Figure 3: Option 4b proposed layout

This option provides a minimum 2% AEP level of service to the priority area in Bay Road and the south end of Kilbirnie Crescent, which currently has the highest concentration of flooding properties. The flooding adjacent to the nearby Aquatic Centre is reduced as the pump station improves the outlet condition for the existing trunk pipeline draining this area although the benefit is less as there is no upgrade to the pipeline (in the 10%AEP event 5 flooding properties reduces to 1 after completion of the upgrades) .

A map of predicted flood effects during a 2%AEP event with the Option 4b Stage 1 upgrades installed is shown in Figure 4.

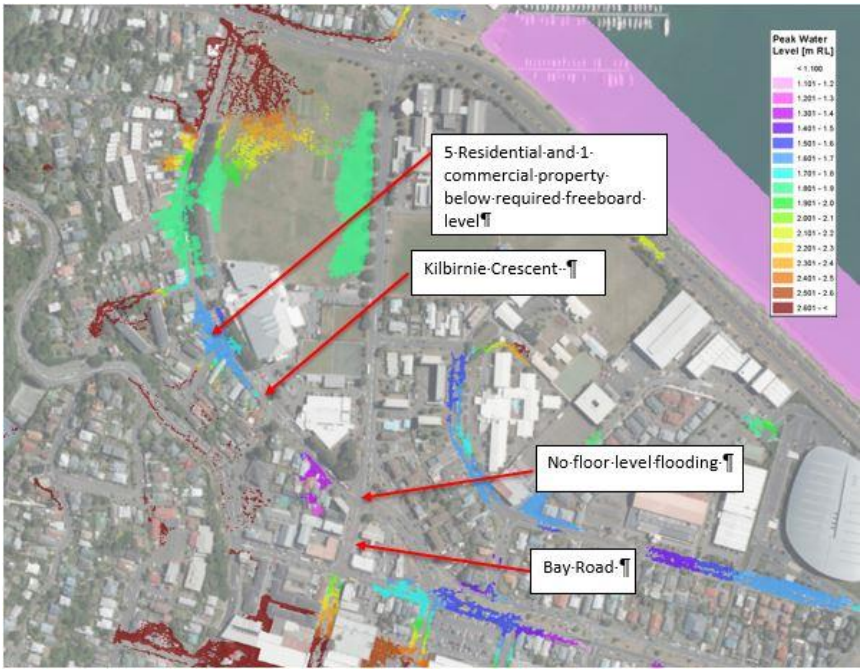


Figure 4: Option 4b - Stage 1 2%AEP Storm Flood Elevations

It is proposed that the proposed pumpstation will be future-proofed for water quality measures by providing pipework and space to allow a dedicated water quality pump to be installed in the future, which would be compatible with treatment devices such as raingardens or proprietary devices.

4.4 ESTIMATED COSTS AND STAGING

Concept level estimates have been developed for Option 4b – Stage 1 and independently reviewed to test robustness, as presented in Table 7. These estimates include an allowance for design costs.

Table 7 Expected Outcomes of shortlisted options

Component	**Cost Estimate**
Pump Station	$4M
Pipeline Upgrade	$3.5M

As the cost of the works is high relative to the estimated damages, the project team is currently investigating the effectiveness of completing either the Pump Station or the Pipeline as a sub-stage to the full Stage 1 design.

4.5 DISCUSSION: SHOULD WE INVEST IN A BATHTUB?

From a theoretical point of view it is easy to imagine that an appropriate approach to low lying areas might be to retire them over time; gradually shifting businesses and dwellings to higher areas that have more natural resilience. However, in practice it is hard to imagine such a transition when areas are in-demand with high-value land, public transport routes and good access to amenities. In the case of Kilbirnie the area has been zoned as a medium density development area, and is primed to be developed and intensified as part of an overall urban strategy.

The question then becomes: If we are going to remain in low lying areas, how much do we invest in flood protection to make them liveable and with an acceptable level of flooding risk going into the future? In the case of Kilbirnie it seems clear that an investment in infrastructure will not provide a favourable cost/benefit ratio under conventional analysis; but that a more complete analysis considering the wider financial benefits of development may well be more favourable.

Our view is that we should invest in low-lying areas if they form an important part of future growth strategies for our cities; a modest investment is sufficient to keep areas liveable, and the investment will lead to significant development opportunity and economic benefit. However, as well as investing in infrastructure we also need to be working to actively improve the long term resilience of the area over time. In terms of flood protection, we can improve resilience through policy and planning measures and by improving emergency flood response.

Effectively communicating the multi-pronged strategy is essential, as it involves considerable compromise in order to achieve the right balance between infrastructure, planning and emergency response.

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REFERENCES

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