INTEGRATED CATCHMENT MANAGEMENT PLANNING – DEALING WITH UNCERTAINTIES TO ACHIEVE AN OPTIMAL RESULT

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ABSTRACT

Understanding future uncertainties is critical for the development of a realistic and successful capital investment plan. For the Grey Lynn catchment the main uncertainties were as follows:

- The stormwater solutions in most areas involved partial separation, which takes stormwater from the roads into the new stormwater system, reducing flow into the combined lines. The impact of this on overflow performance is uncertain
- The effect of planned upgrades to the Watercare trunk network.

A phased programme was developed. The first phase consisted of projects that will deliver immediate benefit with limited capital investment, and are not dependent on future uncertainties. The subsequent phases occur after the effect of the uncertainties can be measured, and will complete the programme to achieve the target level of service (LOS) in the catchment.

The benefits of this approach are the deferral of capital expense, the minimisation of sunk costs for assets that may become obsolete in the near future, the provision of benefits in the short-term to address community concerns, and the layout of a path towards addressing target LOS.

Additionally, the integrated approach to drainage planning taken in this catchment mean cost efficiencies and the ability to programme projects together, allowing construction disruption to be minimised.

KEYWORDS

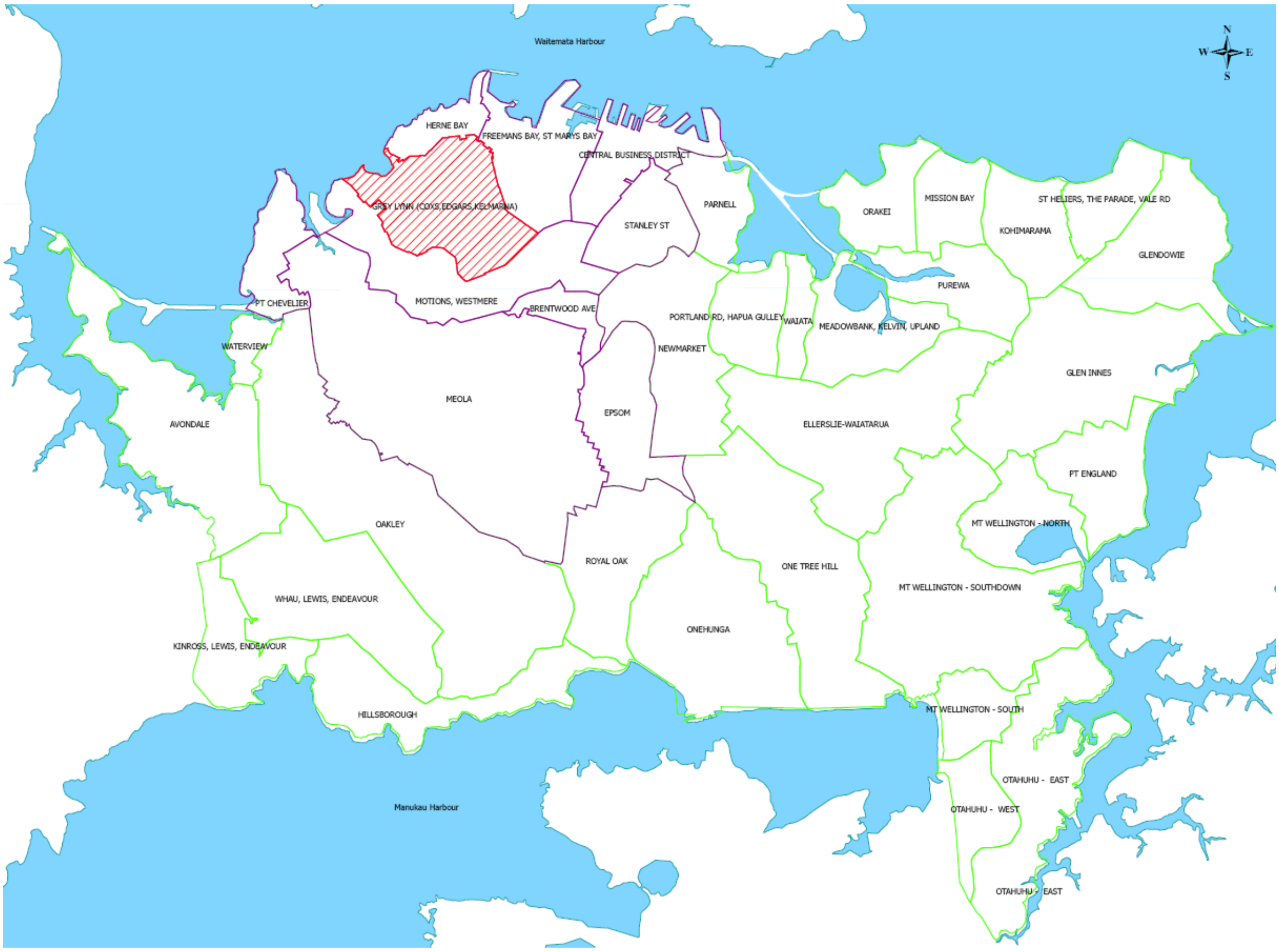
Integrated catchment management planning, uncertainty

1 INTRODUCTION

1.1 CATCHMENT CHARACTERISTICS

The Grey Lynn catchment is located in the north-west of the Auckland City isthmus, as shown in Figure 1 below. It is approximately 420ha in size, consisting mainly of residential area with some smaller commercial, business and light industrial areas. The drainage networks in the catchment are mostly a combination of combined sewers and separate stormwater lines, with small pockets of fully separated areas. Most of the separated areas were separated in the 1970s, and the degree of private separation is unclear. The central Cox's catchment was mostly separated in 2000, with completion of the final cross-overs planned in the near future.

Figure 1: Location of Grey Lynn catchment in the Auckland City Isthmus



The combined sewer network feeds into Watercare's trunk Orakei Main Sewer either directly or via Watercare's Edgars Creek Branch and Branch 6 Cox's Creek tributary sewers. The Orakei Main sewer runs across the Grey Lynn DMA and receives wastewater and combined flows from the upstream catchments.

The stormwater lines discharge to the Waitemata Harbour via Cox's Creek. The modelled stormwater and combined networks are shown in Figure 2 below, with the blue arrows indicating key stormwater routes to the Creek.

Figure 2: Stormwater and Combined System in Grey Lynn catchment, with blue arrows showing key stormwater routes to Cox's Creek

1.2 STUDY DRIVERS AND OBJECTIVES

Cox's Creek is one of the most contaminated streams in the Auckland Region, due to both stormwater and wastewater inputs (Sinclair Knight Mertz and Tonkin & Taylor Ltd, 2004). The organic matter in stormwater inputs is understood to lead to anaerobic conditions especially during low flow, resulting in odour issues (Larcombe, 2005). Wastewater overflows regularly discharge into the Creek, including during low flow conditions, which create aesthetic issues and may exacerbate odour issues. In addition, median enterococci levels exceeding marine bathing guidelines have been recorded at Coxs Bay in both dry and wet weather (Sinclair Knight Mertz and Tonkin & Taylor Ltd, 2004).

The Creek runs through public reserve and playing fields, and has a high public profile (photographs 1 and 2 below show two views of the Creek). The community are aware of the overflow issues and there is increasing public pressure to take action to improve the condition of the Creek.

The objective of this Grey Lynn Capital Investment Plan (CIP) study was to identify preferred remedial options to mitigate flooding and wastewater/combined system overflow issues.

Photograph 1: View of Cox's Creek and Mangrove Swamp

Photograph 2: Reach of Cox's Creek

Additionally, there are a number of properties in the catchment that experience habitable floor flooding and this is predicted to increase as development increases impervious area if nothing to alleviate flooding is implemented.

2 SYSTEM PERFORMANCE ANALYSIS

2.1 STORMWATER

2.1.1 TARGET LEVEL OF SERVICE

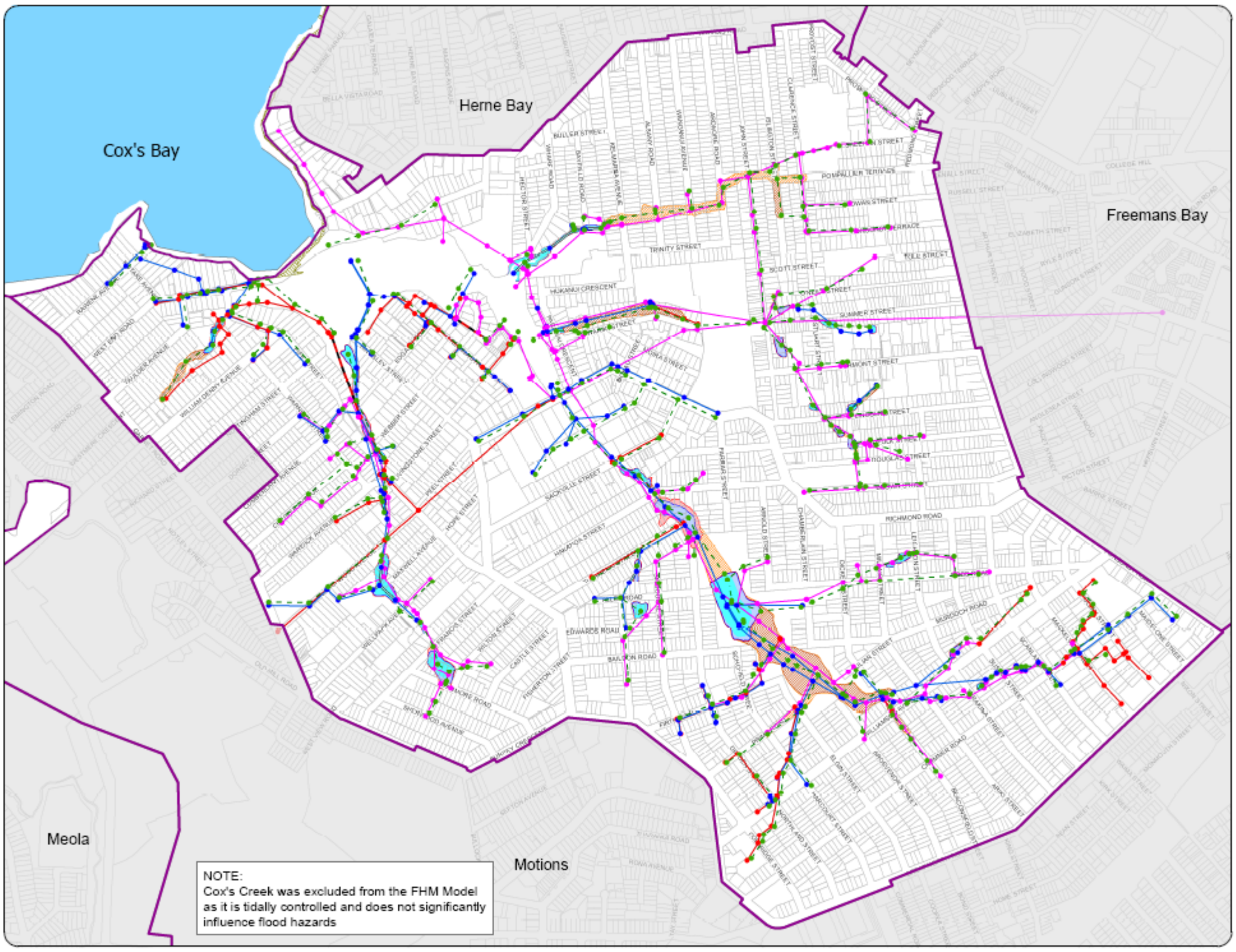
The target level of service for flooding in Auckland City is that no habitable floors should flood in the 50 year ARI Maximum Probable Development storm event. For this project, solutions have been developed to mitigate both residential and commercial habitable floors that are either predicted to flood or to be within 500mm of flooding.

2.1.2 MODELLED LEVEL OF SERVICE

The stormwater system performance was analysed for both existing and future conditions, using the following TP108 rainfall events: 10 year, 50 year and 100 year ARI. The methods used were in line with Metrowater's Modelling Framework (Metrowater, 2005). The following conclusions were reached:

- 30 residential and three commercial habitable floors are predicted to flood in the 50 year Maximum Probable Development (MPD) storm event, while a further 42 residential habitable floors are predicted to be within 500mm of flooding. This compares to 27 residential and 3 commercial predicted to flood in the 50 year Existing Development (ED) storm event, with a further 37 residential habitable floors predicted to be within 500mm in this event. Figure 3 shows the modelled flood plains and hazardous overland flow extents in Grey Lynn for the MPD events.
- Much of the system in Grey Lynn is combined sewer. This means that flooding is likely to be contaminated with wastewater.

Figure 3: Modelled Flooding and Hazardous Overland Flow areas in Grey Lynn for the Future Scenario



Most flooding is due to a lack of capacity within the primary drainage system leading to overland flow and flooding. The Grey Lynn catchment is formed as a result of a series of valleys which have been cut off by the road network, creating potential ponding areas with large volumes. In general, the predicted floor floods either occur within these ponding areas, or are due to houses being situated within the natural valleys which act as paths for overland flow. These scenarios are illustrated in Photographs 3 and 4.

Photograph 3: View from road into predicted ponding area in Grey Lynn

Photograph 4: Houses situated lower than road in overland flow path

While it was not within the scope of the Grey Lynn CIP to examine stormwater quality, it is noted that stormwater quality monitoring has shown that the sediment in Grey Lynn contains very high levels of lead, zinc, polycyclic aromatic hydrocarbons (PAHs), and copper (Sinclair Knight Mertz and Tonkin & Taylor Ltd, 2004). Contaminated stormwater and a lack of flushing contribute to poor water quality in Cox's Creek (Larcombe, 2005). The first flush of stormwater contaminants may not always discharge through the combined sewerage network, instead being flushed into the receiving environment during flood events (Sinclair Knight Mertz and Tonkin & Taylor Ltd, 2004).

2.2 WASTEWATER

2.2.1 TARGET LEVEL OF SERVICE

The target level of service for wastewater and combined systems in the Grey Lynn catchment is two spills per year, per location. For this project the best practicable option has been developed to either meet this Level of Service (LOS) or, where this is not practical, to reduce spill frequency.

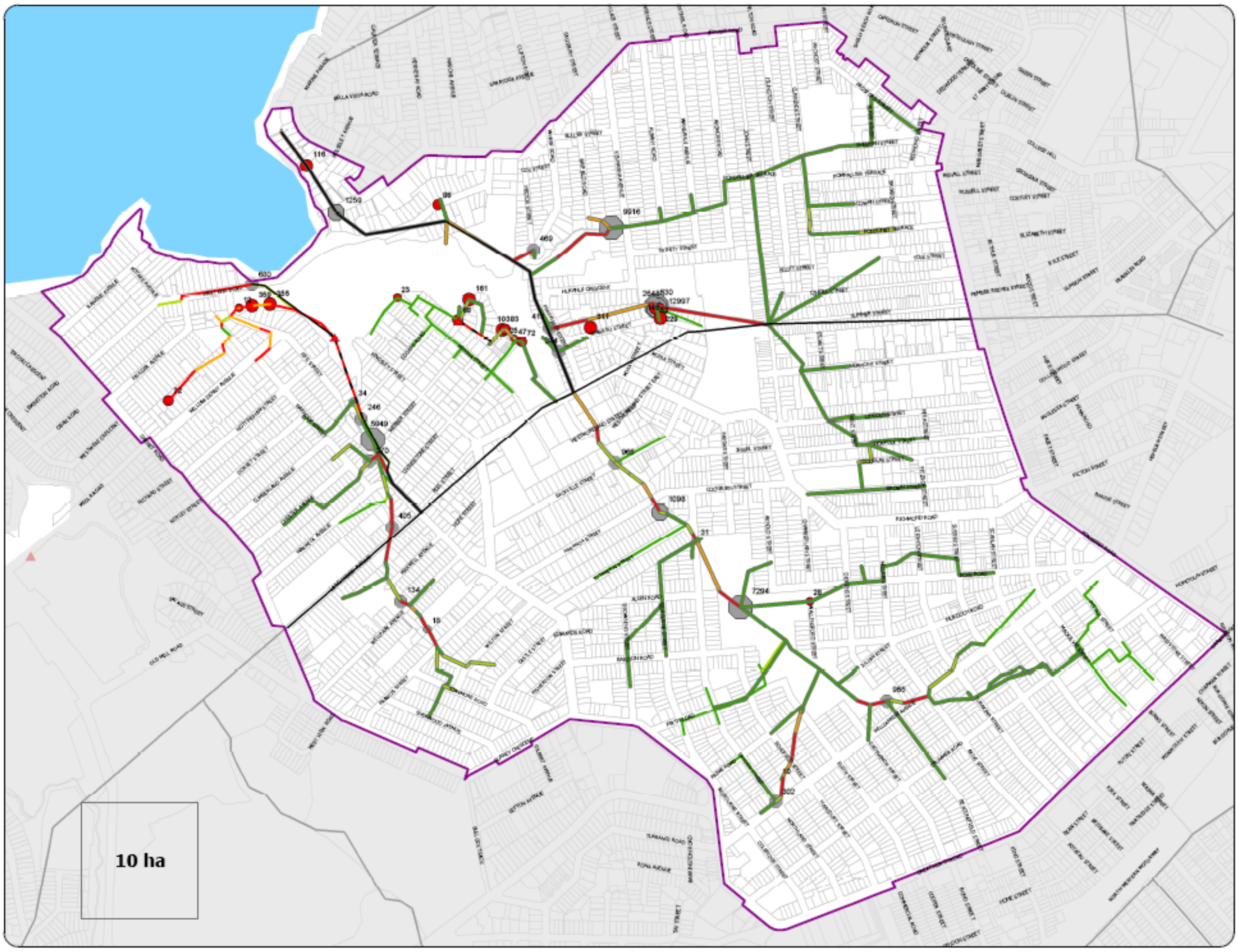
2.2.2 MODELLED LEVEL OF SERVICE

The wastewater level of service was defined for both the existing and future (2051) scenarios through running five year Long Time Series (LTS) simulations, and averaging the results to define an average annual Level of Service. As much of the catchment is combined, wet weather response is likely to increase as the impervious percentage of the catchment increases in the future. In line with the Regional Approach developed by Metrowater for stormwater flooding (Metrowater, 2005), the calibrated fast response area for each stormwater subarea loading to the combined system was increased in proportion to the predicted change in impervious area between existing and Maximum Probable Development, while the calibrated slow response area was decreased.

The modelled level of service was as follows:

- There are 28 locations in the Metrowater network in Grey Lynn that are predicted to exceed the target Level of Service – that is, to overflow more than two times per year, on average (MPD scenario). These locations are shown in Figure 4 below. The main overflow locations, with modelled frequency of greater than 50 spills per year in the MPD scenario, are all constructed overflows and are as follows: Fife St (114 spills per year), Grey Lynn Park (82), Tawariki St (190), Kelmarna Ave (83) and Wharf Rd (60).
- In part due to these overflows, Cox's Creek has very poor water quality, and the water in Cox's Bay regularly exceeds guidelines for contact recreation (Sinclair Knight Mertz and Tonkin & Taylor Ltd, 2004). Other reasons for the poor water quality are contaminated stormwater runoff, organic matter and poor turnover of water in the bay leading to anaerobic conditions.
- The wastewater system is highly dependent on the Watercare network in this area. Many overflows in the Metrowater network are due to the throttle connections between Metrowater and Watercare that limit flow to the trunk sewers. It is understood that the Orakei Main already runs full during a 1 year ARI storm event (Watercare, date unknown), hence increasing conveyance to Watercare is generally not a reliable option in the short-term for the solution of local network problems.

Figure 4: Modelled Overflow Locations for the Future Scenario



3 OPTIONS DEVELOPMENT

3.1 OPTIONS DEVELOPMENT PROCESS

The general process of options development for the Grey Lynn catchment was as follows:

- Whole-catchment solutions were examined (e.g. diversions, separation)
- Area-specific solutions were examined. Workshops were held between AECOM, Metrowater and Watercare staff to determine which solutions should progress for further analysis
- The relationship between stormwater and wastewater options was considered, as both issues (flooding and overflows) are related
- Proposed options were analysed using a mixture of modelling and feasibility design as applicable
- The options were assessed based on cost versus benefit criteria
- Workshops with Metrowater and Watercare were carried out to ensure solutions were appropriate
- Options were prioritised based on costs and benefits achieved, as well as necessary timing e.g. where downstream options need to occur first.

3.2 STORMWATER

The following options were investigated for stormwater:

- Increasing conveyance capacity
- Detention ponds

- Diversions - it may be feasible to divert peak stormwater flows out of the catchment such that they are no longer conveyed by the main network and streams in the catchment, or to divert flows from one sub-catchment to another
- Management of overland flow through bunding, re-routing, property purchase or raising floors.

For most flooding areas, increasing the conveyance capacity was assessed as being the best practicable option. This has the additional benefit of routing more flow to Cox's Creek, thereby assisting to flush the Creek and to mitigate odours.

For the combined areas of the catchment, providing additional stormwater capacity generally means some degree of separation. Full separation can be expensive and unnecessary from a flooding perspective, therefore this study proposed that 'partial separation' be undertaken – that is, to lay new stormwater lines and route road runoff and flood basins to these lines. Private properties would remain plumbed to the combined system. This will mitigate habitable floor flooding and reduce the flow to the combined system, while avoiding the significant cost and disruption, inconvenience and consenting of private separation.

3.3 WASTEWATER

The following options were investigated for wastewater:

- Increasing conveyance capacity – it was found that there was little opportunity for increasing conveyance capacity, as the trunk system has insufficient capacity to receive more flow
- Diversions – two opportunities for diverting flows to the Watercare trunk system at an upstream point were recommended
- Storage tanks – these were found to be the best practicable option for many areas, and are discussed further below
- Controlled Sewer Overflows (CSO) modifications – there were some opportunities for consolidation of CSOs
- Separation – full separation was found to be significantly more expensive than other options and was therefore not recommended. However the effect of partial separation as per the recommended stormwater solutions was considered
- I/I reduction – this was recommended as an option for the one separated area where high inflow was observed.

For most overflows, storage tanks were found to be the best practicable option to reduce spill frequency.

3.3.1 UNCERTAINTIES

All catchment planning has a degree of uncertainty as plans are usually formulated for some future design horizon. These uncertainties are usually around population growth, change in catchment imperviousness, and consequent changes in rain response within the drainage system. However for the Grey Lynn catchment there are two key additional uncertainties around the development of wastewater options – the effect of stormwater options (that is, partial separation), and the effect, if any, of Watercare's trunk solution (the Central Interceptor). These two factors could potentially have a large effect on the performance of the drainage system and, consequently, the best practicable options for overflow mitigation.

Effect of Partial Separation

Many of the recommended mitigation options for flooding issues in Grey Lynn involve augmentation of conveyance capacity. This provides the opportunity for partial separation – that is, taking the road runoff to the new stormwater lines. This is the cheaper component of separation, as opposed to full separation which also includes private property. Partial separation will reduce the flows into the existing combined lines, and therefore should reduce overflow frequencies and volumes.

The drainage network in Grey Lynn is complex, and the flow split between existing combined/wastewater/stormwater lines as well as the ratio of public/private contributing area is not known. Therefore, the effect of partial separation on overflow performance cannot be exactly predicted.

To understand the *potential* effect of partial separation on overflow performance, the road area was subtracted from the fast response percentage in the model. (For example, if the road area was 50% of total impervious area in that subarea, then the fast response percentage was halved.) The partial separation scenario for both ED and MPD scenarios was run using the five year rainfall series to allow it to be compared to the existing scenario. The model predicts that overflow volumes and frequencies can be significantly reduced. It should be noted that this only provided an estimate of effects, which has a large degree of uncertainty due to the complexities of the catchment. Gauging and model adjustment will be required post-partial separation to confirm the effect on the overflow performance.

Effect of Trunk Solution

The Grey Lynn combined and wastewater systems flow to Watercare's Branch 6 and Orakei Main sewers. To understand the effect of the Watercare system on Metrowater CSO performance, the 1 year design storm event was run with two different Watercare boundary conditions – assumed near pipe full and with free outfalls. This allowed identification of those CSOs that are influenced by conditions in the Watercare trunk line.

The Orakei Main (ORM) currently exceeds capacity in the 1 in 1 Year storm event (Watercare, date unknown). Watercare has proposed the concept of a Central Interceptor – notionally a conveyance and/or storage tunnel that will initially extend from the Mangere WWTP to Chamberlain Park, with a possible future phase continuing to the Auckland CBD. Watercare's primary drivers for this include required conveyance capacity for future growth, asset redundancy to manage failure risk and reduction of wastewater overflows. The Central Interceptor may reduce flows in the Orakei Main and therefore reduce overflows from the local system that is influenced by the trunk conditions, and/or may provide future capacity to take combined flow from the Grey Lynn area. This solution is likely to be at least 15 years away. Therefore all mitigation options had to take into account the fact that the CI may in future provide more trunk capacity and those options should be future-proofed accordingly.

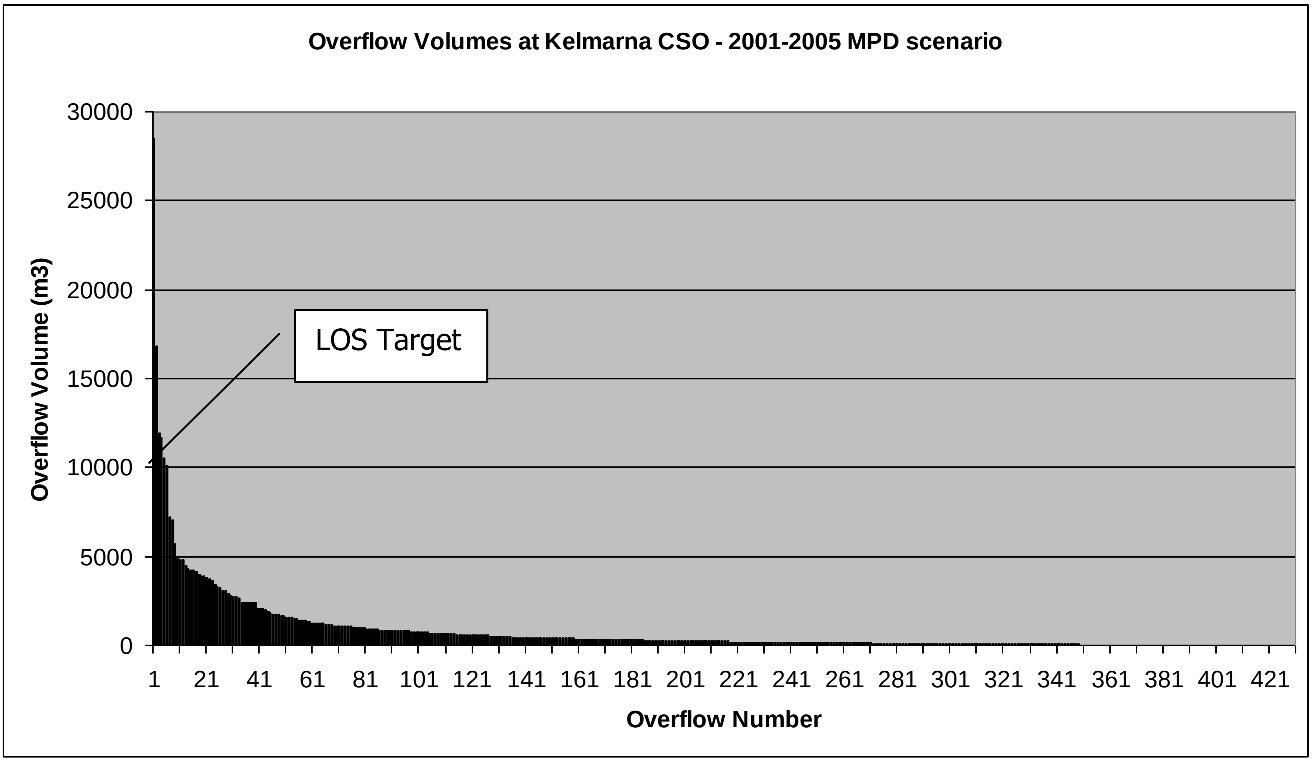
3.3.2 WAYS OF LOOKING AT SIZING OF STORAGE OPTIONS

As discussed above, for most overflows local storage was found to be the best solution. The "10^{th} event" has been used to understand the storage volumes needed to prevent overflows from occurring. This is based on the five year LTS analysis, which runs the model for a five year period. At each predicted spill location, all overflow events have been listed in order from highest to lowest volume. The "10^{th} event" is the 10^{th} largest overflow event in that five year period. It was agreed that containment of this 10^{th} largest event is equivalent to the target LOS of two spills per year. Hence initial tank volumes were based on the volume predicted to spill in this event.

In many cases, the volume of spill predicted in the 10^{th} event was very large, and the construction of a tank of this size would be infeasible or uneconomic. Additionally, in the future the Central Interceptor may provide additional capacity in this area, or partial separation may reduce flows, and such large tanks may not be necessary. It was agreed that it would be acceptable to propose solutions that would not necessary achieve the target LOS, however would still improve system performance. For these reasons, for each issue area storage volumes were analysed using the following methodology.

For each spill location, all overflow events were listed in order from highest to lowest volume. This is shown in Figure 5 for the Kelmarna CSO. To achieve a (theoretical) 100% reduction in overflow frequency, the tank size would be equivalent to the largest spill volume. To achieve the LOS target of two spills per year, the tank size would be equivalent to the 10^{th} largest spill volume. As an example, the Kelmarna overflow has a predicted frequency of approximately 420 spills over five years. The 10^{th} largest overflow event in this period has an approximate volume of $5000m^3$, which is the tank volume required to meet the LOS target. This would prevent 98% of spills at this overflow. With smaller tank sizes than this, the frequency reduction can be quantified and compared to the cost of the tank. An analysis was done of different levels of spill prevention and their cost using two different metrics.

Figure 5: Overflow Volumes for Kelmarna CSO for a five year period, ordered from highest to lowest

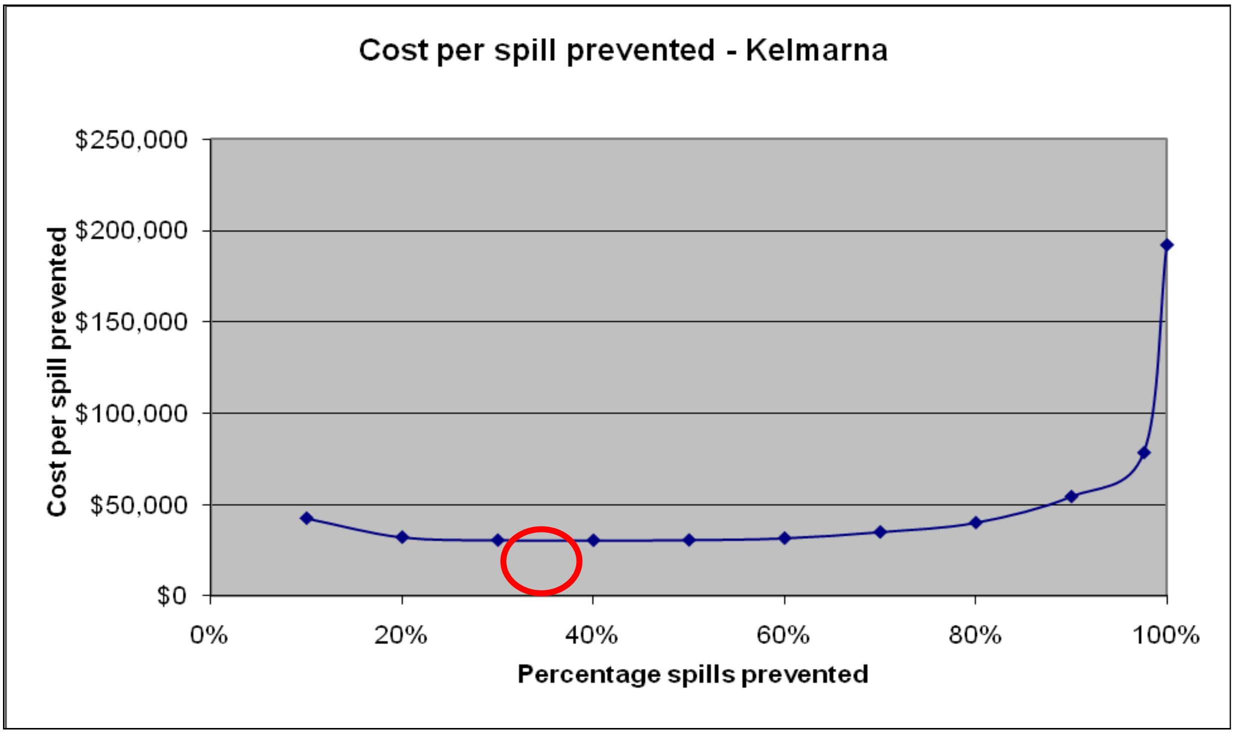


Firstly, by converting the tank cost to a $/overflow event eliminated, the theoretically most economic tank size can be calculated. When a larger number of spills are prevented, there are economies of scale due to the installation of a larger tank, however the incremental cost of storing each extra spill is larger – for example the difference in volume between storing 400 and 401 spills is 59m^3, while the difference between storing 100 and 101 spills is 1m^3. When a smaller number of spills are prevented, the installation of a tank is not as economical; however with very small volume increases a larger reduction in overflow frequency can be gained. In many cases this storage volume is quite low. Where this is the situation, a modified diversion chamber that provides some storage and screening (used in the UK for low amenity environments) was recommended for consideration as an interim improvement option. These chambers would store small, highly concentrated overflows. These often occur during relatively dry conditions and may not be easily flushed through Cox's Creek, hence having a high public impact. This solution would provide some immediate benefit, while allowing further spending to be deferred until the effect of partial separation and the Central Interceptor on overflow performance can be confirmed. A mechanical screen has been installed at the Kelmarna CSO as an interim solution to reduce the effect of visuals in Cox's Creek from this overflow site.

This most economic tank size provides a small reduction in frequency that may or may not be acceptable. Hence a second analysis was done to graph the number of spills per year against cost. The point at where cost starts to increase exponentially can be identified, and possible tank volumes identified in this way. This provides a range of possible sizes, since the point of diminishing returns (with respect to cost and level of service) is not a precisely defined point. However as tank size increases, there is an increasing risk that the full tank capacity will not be needed in the future due to separation and/or the Central Interceptor. Conversely, smaller tanks can be expanded in the future by installing modular units.

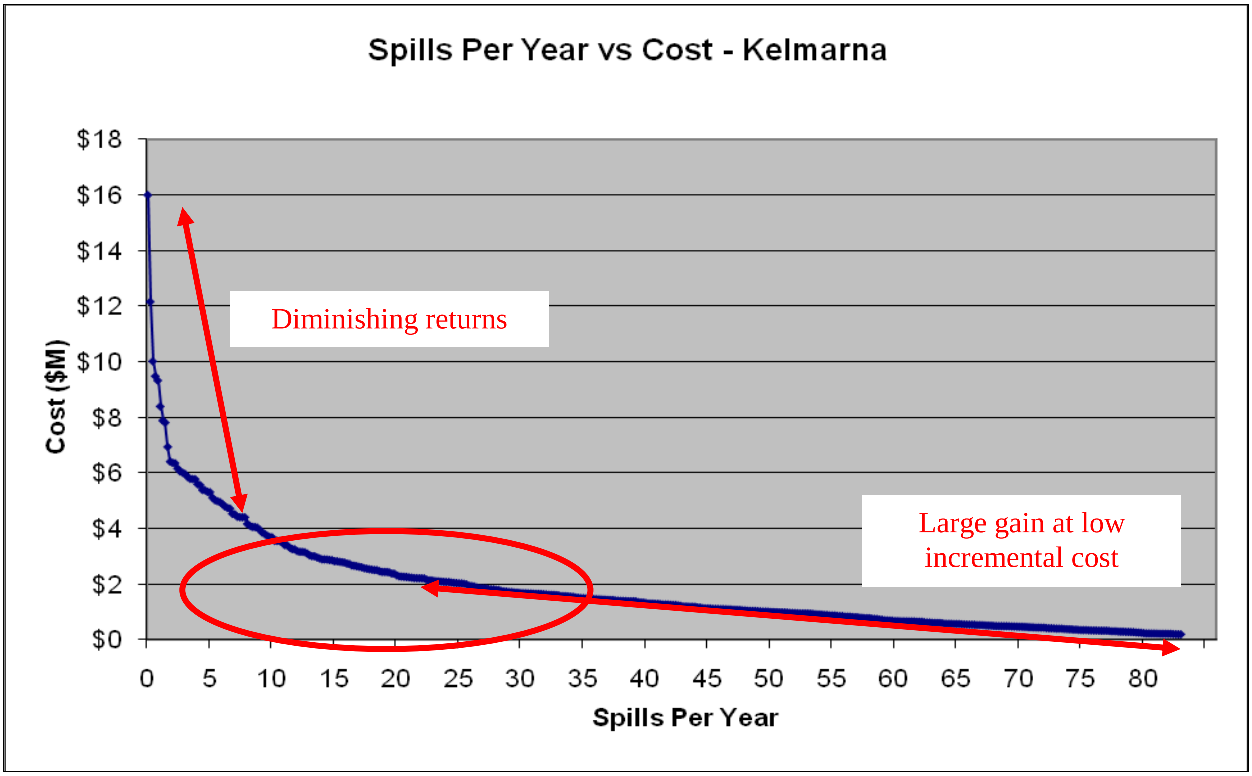
Figure 6 shows that cost per spill prevented versus percentage spills prevented for the Kelmarna CSO. The most economical tank size, in terms of the smallest cost per spill prevented, is approximately 78m^3. This would prevent approximately 30% of spills over the five year analysis period.

Figure 6: Cost per spill prevented for the Kelmarna storage tank



The second analysis, shown in Figure 7, shows the spills per year (after tank installation) against the cost for the Kelmarna CSO storage. It can be seen that the graph line is reasonably linear for costs up to between \$1-2M. Beyond this point (approximately 25 spills per year – volume 630m^3) the cost increases at a slightly higher rate (i.e. becomes more expensive) until at approximately five to ten spills per year (volume 3 500 to 1 800m^3) the cost increases rapidly. The red circle on the graph indicates a potential 'optimal' range of storage at this CSO. The optimal tank size will be determined based on the practicalities of site availability, consenting, constructability etc.

Figure 7: Spills per Year against Cost for the Kelmarna storage tank

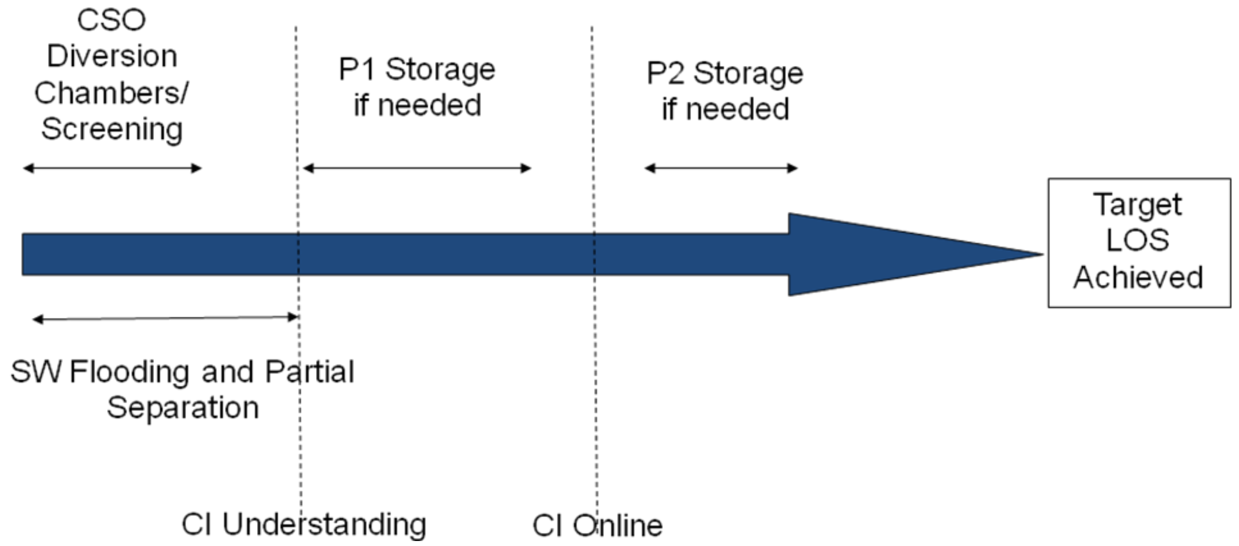


For Kelmarna, partial separation will provide some reduction in overflow volumes once this stormwater work has been completed. The Central Interceptor may provide additional trunk capacity in the future. It may not be prudent to install higher volume tanks as they may become redundant due to these projects. This analysis shows that a modified diversion chamber of approximately 80m^3 storage capacity could be installed, which would provide short-term benefit at a reasonable cost. Alternatively, or as a second phase of work in future, a storage tank with volume up to 1 800m^3 could be installed or added later as modular storage. Metrowater has already commenced site evaluation for tanks and recommendations will be forwarded to Watercare for consideration.

3.4 RECOMMENDED APPROACH

Figure 8 shows the overall approach going forward over time to achieve the target LOS in the Grey Lynn catchment.

Figure 8: Recommended timeline for Grey Lynn catchment



A staged approach was proposed to manage the uncertainties associated with this catchment.

Stage 1
This stage involves implementation of the stormwater solutions as well as wastewater solutions that are not affected by uncertainties. An increase in stormwater capacity is recommended to mitigate flooding issues in the catchment. This provides the opportunity to partially separate the area by taking road runoff to the new stormwater lines. Therefore in the short-term, for relevant areas, it is recommended to implement partial separation as per the recommended stormwater options and then assess the impact on the wastewater spill frequencies and volume. The success of this partial separation may change the optimal sizing of other solutions.

In parallel with this, modified CSO diversion chambers can provide small-scale storage that will remove the small-volume, high-impact CSO spills from the receiving environment. This also provides the opportunity to install screens where these are not currently in use. At this time the proposed wastewater diversions and CSO modifications can also proceed, as these are independent of the uncertainties.

Stage 2
Once stormwater works are complete, the catchment should be flow gauged and the future model adjusted and re-run to understand the impact of partial separation on CSO performance. At this time, the impacts of the CI on the catchment should be better understood and the second phase of works can commence. The recommendations of the Grey Lynn CIP can then be revisited in the light of this new understanding. For example, to check that additional storage is still the best practicable option as opposed to separation or an increase in conveyance capacity.

Stage 3
The CI is planned to come online around 2025. At this time, the effects on the Grey Lynn catchment can be measured and an assessment made if additional works are required to achieve the target LOS in the Grey Lynn catchment. If required, Phase 2 modular storage or other solutions can then be implemented.

The benefits of this staged approach are as follows:

- A modular approach to storage expansion means that uncertainties are managed and sunk cost minimised for assets that may become obsolete in the foreseeable future
- Capital investment can be deferred as much as possible
- Metrowater and Auckland City will be seen to be addressing public concerns in the short-term, through solutions that should have an immediate impact on the receiving environment at relatively low cost
- Implementation is based on incremental steps, which allows the solution to be adapted to changing conditions and understanding of the catchment.

4 WHERE TO NOW?

4.1 STORMWATER

The preferred options identified to mitigate flooding were taken forward to the Project Plan (concept design) stage. This stage involved further refinement of the options and estimated costs. These now form part of Auckland City's prioritized capital expenditure program for Auckland City.

4.2 WASTEWATER

Subsequent work compared the Level of Service that could be achieved at the four main overflow locations in the catchment for a range of storage tank sizes, and quantified resultant annual overflow volume, frequency, hours of operation, contaminant load reduction and first flush failures. Metrowater has commenced work on site selection and further investigation for storage tanks at three key locations, with a minimum tank size equating to 20 spills per year. Further enabling works will be the responsibility of Watercare Services, who have been involved at key milestones in the work so far.

The likely effect of the Central Interceptor on overflow performance in Grey Lynn will be determined over the next year or two. This will allow further understanding of how the local solutions should be implemented.

5 CONCLUSIONS

The following conclusions are made from the Grey Lynn CIP:

- Taking an integrated approach to stormwater and wastewater planning can have large benefits and deliver cost efficiencies
- A phased investment programme takes account of future uncertainties whilst delivering the following benefits:
  - Tangible benefits for the community in the short term
  - Deferral of capital expense
  - Minimisation of sunk cost for assets that may become obsolete in the near future
  - The layout of a path towards achieving target LOS
- The 'right' solution set for a catchment is often a work in progress. It's acceptable to not have the complete answer. Implementation is based on progressive working towards the solution, which allows the solution to be adapted to changing conditions and understanding of the catchment.

ACKNOWLEDGEMENTS

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