DEVELOPING THE CONCEPT OF AN ACTIVE FLOOD RISK MANAGEMENT SYSTEM IN CHRISTCHURCH

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ABSTRACT (300 WORDS MAXIMUM)

The Dudley Creek catchment in Christchurch has a long history of flooding, a risk which has been increased in many locations by the 2010/11 earthquake series. The catchment is drained by a complex network of waterways and pump stations, and includes the significant Cranford Basin rural area which has long been proposed as a strategic flood storage area. The location of Cranford Basin and shallow topography are such that some of the waterways have the potential to drain to either the Styx or Avon Rivers, or could be controlled to do so.

Jacobs has been working with Christchurch City Council to develop a strategic plan for actively managing the system of drains, pump stations and storage basins to assist in the mitigation of flooding in the Dudley catchment. Through workshops with key staff and modelling, the project has taken time to understand the complex interaction and function of the whole system in substantial detail. This detailed understanding has led to a robust conceptual understanding of the whole land drainage network which in turn has enabled an improved management plan to be developed.

A key feature of this improved concept is to actively manage the various components of the network during a flood event. This proposes installing a network of level monitors around control gates and installing remote communication technology so that control gate and pump station operations can be coordinated. Importantly, failsafe asset operation can be set in the event of communication breakdown during a storm. The logic for actively managing the network is to ensure storage basins are utilised optimally in order to reduce the flood risk to the community while minimising human intervention.

This paper describes the benefits of the process undertaken to develop the active management concept, as well as the key components of the proposed concept design.

KEYWORDS

Flood, assets, active management, Christchurch

PRESENTER PROFILE

Gareth Taylor is the Section Lead of Jacobs' Environment, Spatial, Planning, and Water section, based in Christchurch. He has high involvement in a number of land drainage recovery projects associated with the Canterbury earthquakes including Dudley Creek and the Mayoral Flood Task Force. Gareth was Project Manager of a Jacobs led team for the Cranford Basin Project.

David Cobby is a Chartered Water and Environmental Manager and Scientist who has over fourteen years' experience in consultancy and academic research environments. His technical expertise encompasses many areas of water and environmental management, focussing particularly on the sustainable management of flood risk from stormwater and groundwater. David is now based in Christchurch where he is delivering a number of Land Drainage Recovery Projects.

1 INTRODUCTION

The approximately 700ha Dudley Creek catchment in northern Christchurch, which is a major tributary of the Avon River, has a history of flooding, and floods have been documented across the area dating back to the early 1900's. The Flockton area has specific flooding issues linked to its low lying topography.

Following the 2010-11 earthquake sequence, flood risk across the Dudley Creek catchment, and particularly in the Flockton area, has increased significantly and, in the context of future development and climate change, management of flooding is a key challenge for Christchurch City Council (Council).

Largely due to the shallow topography and number of waterways, the drainage system in the Dudley Creek catchment is complex and interlinked. Figure 1 provides a schematic of some of the key features in the catchment:

- **Flood Storage:** Cranford Basin is a relatively unique ~100ha area of rough grassland and agriculture, within an otherwise heavily urbanised catchment. Essentially lying at the catchment divide between the Rivers Avon to the south and Styx to the north, the basin provides a highly strategic asset which has the potential to manage flood risk across both catchments due to its size and up-catchment position.

- **Pump Stations:** Pump Station 219 (PS219) lifts water from Cranford Basin into the lower Diversion pipe which discharges into Horseshoe Lake and the Avon River via Pump Station 205 (PS205). The Diversion is a primary watercourse and a highly strategic drainage asset within the catchment which beheads the upper Dudley Creek catchment. Following repeated flooding, Pump Station 202 (PS202), located near the confluence of Tay Street and Mairehau Drains, was constructed in 2014-15 to help alleviate flooding in the Flockton area. PS202 discharges water into the Dudley Creek Diversion scheme.

- **Watercourses:** A number of the waterways (e.g. Horners Drain, Winters Road Drain and Bullers Drain) have shallow grades such that flow can be in either direction depending on the focus and timing of inflows and the operation of control structures and pumps.

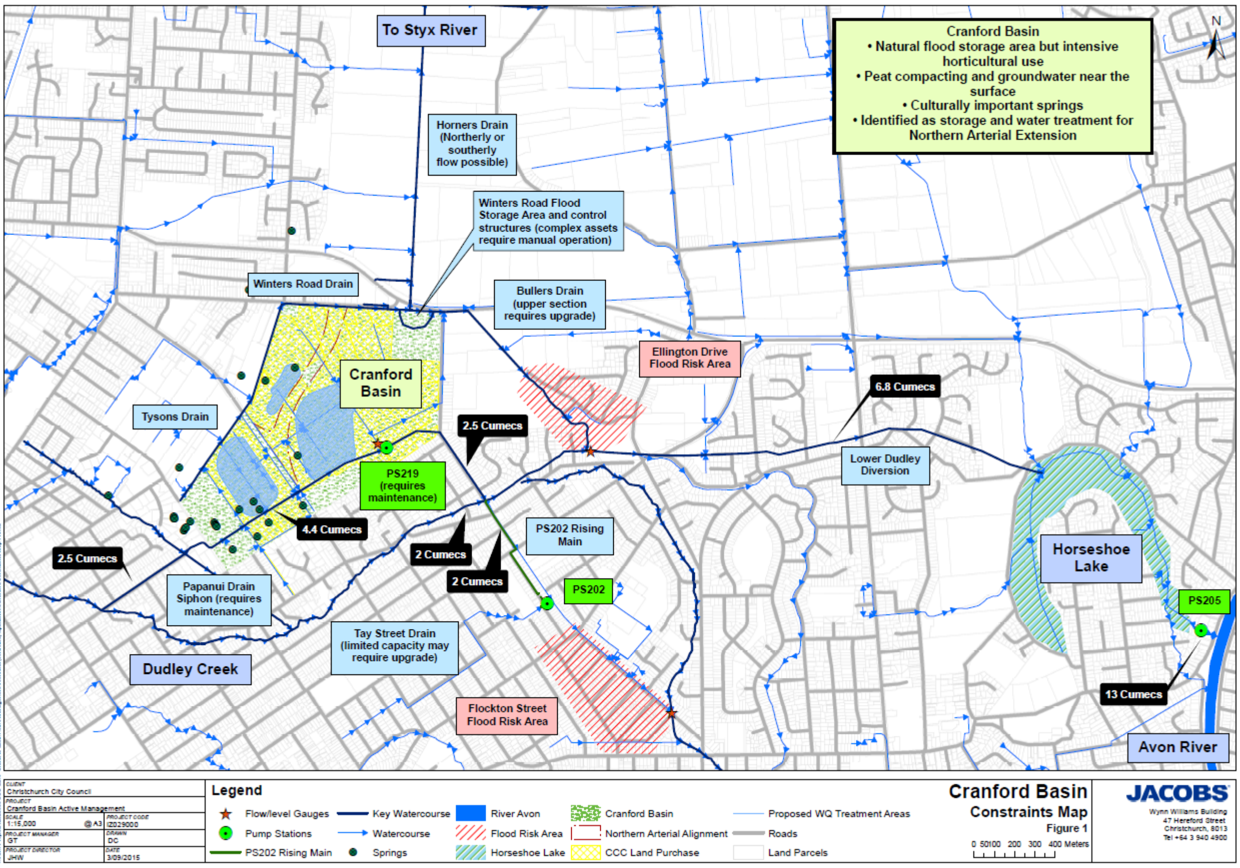

Figure 1: Schematic map of issues and key catchment features

This paper describes investigations undertaken into minimising flood risk to the Flockton Street area, as well as other locations at risk in the Dudley Creek catchment. Whilst simple robust passive flood management systems are typically sought, this paper describes pre-feasibility appraisal of an active management system which offers more effective management of the complex hydraulic system.

The active management solution described here includes a mixture of gravity, pumped, automatically/remotely controlled structures and manual override elements. The concept focuses on active operation of pump stations and flow control gates based on rainfall forecasts and water level monitoring feedback; operation of assets is optimised through a logic-based control driven by feedback from a flow/level monitoring network. Importantly, the safe defaults and ability for manual override of the automated logic is retained. The ability to actively manage available assets to react to varying rainfall patterns (including storms centred on particular catchments, longer duration events, events with multiple peaks etc.) is intended to provide maximum benefit and adaptability to future changes in climate and development and spatial differences in rainfall patterns.

2 CATCHMENT CONCEPTUALISATION

The drainage system in the Dudley Creek area is complex and interlinked and has been the focus of much investigation, observation and modeling prior to this study. In order to summarise available information from key staff, reports and models, time was invested at the beginning of the study to develop a robust technical understanding of the key hydraulic features in the catchment. This facilitated a whole system approach to understanding the current operation of the catchment and was fundamental to designing improvements.

A further benefit of the upfront interviews and review of existing information was that a number of ‘no regrets’ actions were highlighted at the earliest stage of the study. These actions were recommended to maximise the operation of the existing drainage system and prepare for more detailed design of any system upgrades, regardless of which longer-term works are implemented. These actions aim to return the system to its design standard rather than providing any betterment, but will not interfere with longer-term interventions.

Distilling the assembled evidence to its key concepts provided the following overall philosophy from which options were developed:

- Installing and/or modifying some assets (e.g. flow control gates) was required to improve existing flood management, whether or not the system ultimately becomes actively controlled. For example, one pump station was not operating optimally because the incoming flow through a constrained watercourse was below the maximum capacity of the pump. Therefore, channel upgrade works were identified to convey more water to the pump station from one part of the catchment. In another watercourse feeding the station, a control gate was identified to be sited downstream of the pump station to enhance the backwater to the station.

- Because pump stations will discharge into a piped network in favour of gravity inflows into the same pipe, maximizing pump outflows required allowance to be made for gravity parts of the system to operate at reduced discharge without causing uncontrolled flooding.

- Significant parts of the gravity system have shallow topography and are therefore sensitive to downstream conditions into which they discharge. Promoting maximum discharge from these watercourses/pipes early in a flood event keeps flood storage available to be utilized when gravity discharge is no longer possible. Cranford Basin has significant storage potential (beyond the 1 in 50 target event) and is best used once PS219 can no longer safely discharge without causing increased flooding elsewhere.

- Whilst active management can optimize use of available assets, the assets should have safe default settings (in event of asset failure or communications failure) that replicate the existing situation as far as possible. In this way, failure of the system will make things no worse than the existing situation.

3 WHOLE SYSTEM HYDRAULIC MODELLING

A detailed hydraulic model was developed in DHI’s MIKE FLOOD software which was interrogated to understand the mechanisms of flooding operating in the catchment post-earthquake and compare these theoretical predictions with observations. Representations of pump stations and existing control gates were important, and highlighted that at some notable pump stations, a lack of recorded observational data made verification of the models’ operation difficult.

Given the likelihood of a major roading scheme being constructed through Cranford Basin at some point in the future (http://www.nzta.govt.nz/projects/christchurchmotorways/northern-arterial), the baseline scenario for the study was taken as the basin topography modified to include the likely road embankment footprint and ground levels adjacent to the road corridor lowered to manage stormwater runoff volume and quality. To complete this maximum probable development assumption, climate change allowances were included in the hydrology.

Through analysis of time series of 1D flows and levels in watercourses and the piped network, as well as 2D overland velocity animations, a comprehensive picture was developed of the mechanisms of flooding operating with the existing infrastructure. The time-based results particularly helped to understand flows which reverse at points during the flood event.

This sensitivity to hydrological forces emphasised the difficulty of designing a robust flood management system and the potential benefits of a solution which is able to respond to an evolving flood scenario. Within the constraints of the pre-feasibility study, only a limited number of potential flood scenarios could be explored in the model. However, the value of testing final system designs against a range of different flood scenarios (i.e. assuming storms are centered on different parts of the catchment) to verify that the active control logic is robust is clear.

4 SUPERVISORY CONTROL AND DATA ACQUISITION

Operational reliability is critical during flood events, when poor weather could cause unpredicted events such as network outages. Therefore the Supervisory Control and Data Acquisition (SCADA) system considers that data must be reliable (received consistently during adverse events), accurate in quality to inform decision and controls and timely (received quickly to inform decisions and controls). The system must also have safe defaults which will not cause worse flooding than currently experienced, with components able to be manually controlled when required.

During normal flow regimes, the system should only require plant exerciser cycles to maintain operability. During high flow events, operators may need to manually override the control logic to achieve optimal operation; particularly if a safe default is triggered as result of communications failure. Any manual intervention will need to be based on accurate and timely data from field sensors.

5 LAND USE PLANNING

A key element to realizing the success of the scheme and using active management to trigger flood storage at the optimum time in a flood, is land ownership. As set out in the Avon Stormwater Management Plan (CCC, 2015) Council purchases land as part of a long term strategy to meet its stormwater management obligations, as well as providing opportunities to implement environmental and other enhancements. To ensure that flood risk to private land is not increased as a result of this stormwater scheme, likely land ownership was used to guide the design of the bunds to constrain flood water within Council-owned land in Cranford Basin, and used to defer further consideration of other potential storage basins until such time as appropriate land becomes available.

6 THE CONCEPT DESIGN

The overall concept design comprises static structures (watercourse and structure upgrades, raising of flood embankments) and the logic by which flow control gates and pump stations can be actively managed. Whilst many of the structures are designed to operate based on monitoring of water levels elsewhere in the system, operation of some requires setting at the 'start of the event'. In the absence of flood forecasting on the watercourses in question, the 'start of the event' may best be defined based on an extreme rainfall warning or observation of rising water levels in the system. The ability to manually start the event through human intervention is also possible should the network operator decide this is required (i.e. wet antecedent conditions and a large rainfall is predicted).

The key structures (existing and proposed) are shown schematically in Figure 2:

- Winters Road Drain gate: At the start of the event, set the gate to two-thirds open to maximise flow down Bullers Drain and into the lower Diversion. When levels in Ellington Drive area rise to a level above which flooding may result, partially close the gate to divert flow into the Winters Road storage area. This mostly closed setting is the safe default.

- Mairehau Drain gate: At the start of the event, close the gate to promote backflow to PS202 and maximise discharge from the pump. When water levels in Tay Street Drain rise to a level above which flooding could occur, open the gate to allow flow to drain southwards along the Mairehau Drain by gravity. However, if at any time the levels either side of the gate indicate northerly flow in Mairehau Drain then open the gate to draw water up from the Flockton Street area to PS202. Fully open is the safe default setting.

- PS219: At the start of the event, allow PS219 to continue to discharge its maximum 2.5m3/s capacity into the lower Diversion. When flow in the lower Diversion, downstream of the confluence with Bullers Drain, reaches 4.8m3/s, turn off the two large screws at PS219 to continue to pump only a baseflow allowance (0.07m3/s). Only pumping baseflow with the small screw is the safe default.

- Horners Drain Control Gate: In the foreseeable future, Council is not likely to own the land around Horners Drain which would flood to a greater extent than currently if the control gates were fitted and operated. Therefore, this element of the scheme is deferred.

- Cranford Street Control Gate and Cranford West Bunding: The substantial volume of storage provided by bunds around the east side of Cranford Basin could accommodate flows in excess of the 1 in 200 event (depending on freeboard requirements) with climate change. Therefore, until greater catchment flows are generated, additional storage on the west side of Cranford Basin will not be required.

- SCADA: A SCADA system was proposed which is connected to the various pump stations, flow control structures and level sensors by means of microwave links with a repeater station, potentially with wired communication links to provide additional robustness. This SCADA system would allow the network of pump stations and flow control structures to function as an integrated system. Access to the SCADA controls from a computer (or mobile phone) via the Council network would allow for manual operation of drainage assets based on field conditions. In the event of a SCADA system failure, each active asset would default to standalone operation rules based on water levels at the asset. As a worst case scenario assets could be manually operated by personnel physically located on site.

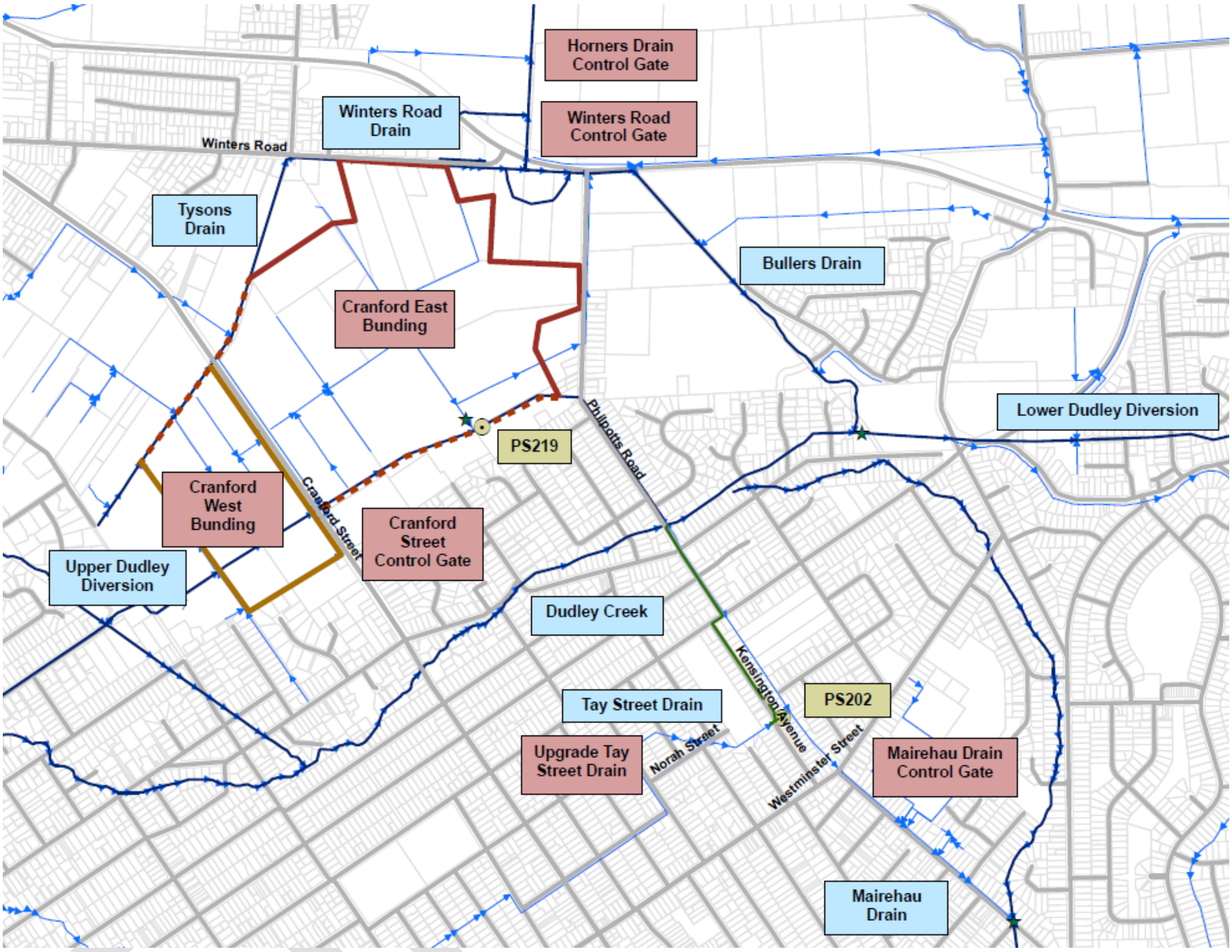

Figure 2: Schematic showing scheme components in red boxes

7 CRANFORD SCHEME BENEFITS

The Cranford Basin Active Management Scheme is expected to have the following benefits (as shown in Figure 3):

- PS202 would pump an additional 9,000m^3 in a 1:50 event (10% increase) and 12,000m^3 in a 1:10 event (24% increase). It is likely that this volume would otherwise add to flooding in the Flockton Street area, where flood levels in the 1:50 event decrease by up to 0.1m. Furthermore, this reduced flow suggests the potential to reduce the scale of works proposed downstream in the Dudley Creek as part of the Lower Dudley Creek Remediation project or, in combination, provide greater overall capacity to the Dudley Catchment.

- Bunds around Council-owned land in Cranford Basin on the east side of Cranford Street will permit a total volume of 332,000m^3 to be stored, if raised to a height permitting ponding to 14.5m (with 400mm freeboard). This is an increase of 110,000m^3 (50%) compared with the 1:50 baseline ponding level. This additional storage volume could potentially be utilised by increased flows from the surrounding catchment.

- By storing water in Cranford Basin and limiting discharge from PS219 into the lower Diversion, capacity is available for PS202 and gravity outflows (e.g. Bullers Drain and Dudley Creek) to discharge into the Diversion and thus reduce upstream flood risk whilst maximising use of the Lower Diversion.

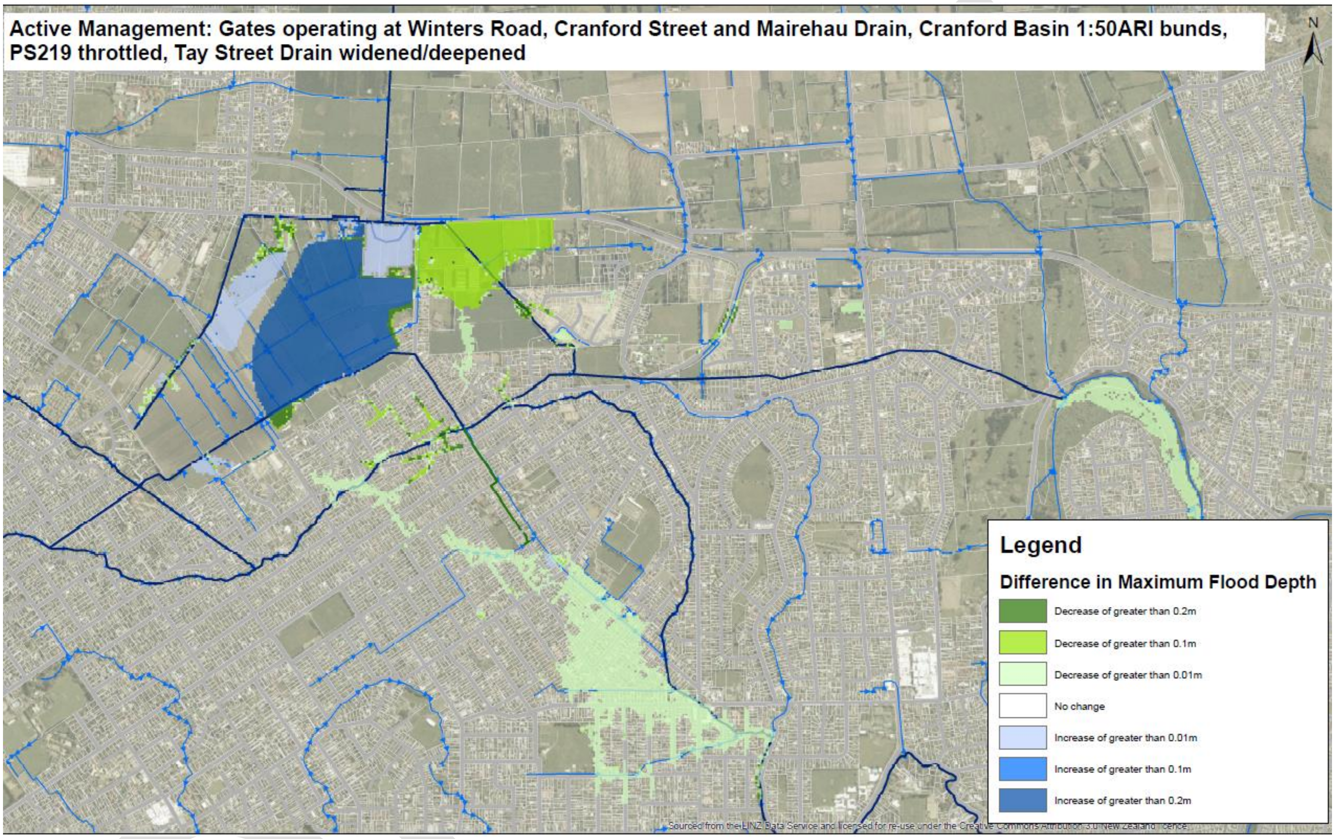

Figure 3: The scheme benefits in a 50 year ARI with Maximum Probable Development and Climate change

8 APPLICATION OF LEARNINGS

8.1 LEARNINGS FROM THIS STUDY

Development of the Cranford Basin Active Management Scheme required involvement from a number of areas in Christchurch City Council and a team of three consultant organisations in order to understand the catchment and successfully identify options which achieve the desired outcome; to maximize the benefit of the flood storage for the surrounding areas. A number of learnings which are applicable to other projects are:

- High value in inherent knowledge: A number of existing council and consultant staff have inherent knowledge from past experience in the catchment. We found that learning and 'bringing staff up to speed' was effective through a series of interviews and site workshops to receive and validate information. Integrating with the staff who know the system allows a project to be delivered in a 'no surprises' environment and any issues to be resolved as they arise.

- Adaptive project scoping: the project evolved as it was taken forward. Engaging Council staff across areas (e.g. asset planning, operations etc.) meant different stakeholder expectations. Having an adaptive approach to project scoping allowed these to be addressed and a scheme to be conceptualized that was accepted by all stakeholders. An outcome of this was the understanding that all individual actuated components require an automatic safe default if a communication failure occurs. This project included intermediate high level deliverables which allowed options with a 'red flag' to be removed from the project; preventing extra effort spent on options that are not feasible.

- Importance in understanding the environmental context: The catchment is a complex network of land drainage infrastructure. Understanding the existing environment and infrastructure is important to identify the flood mechanisms and options to further maximize a system. In addition a number of other works are planned which provides opportunities and constraints to the benefits of a scheme.

- Utilise existing infrastructure: Limited budgets benefit from identifying opportunities to utilise existing infrastructure. Understanding opportunities and constraints by interpreting modelling allows an adaptive management system to be developed which maximizes the potential benefit from system componentry. An additional benefit is that this allows a large benefit to be obtained through minimal capital expenditure.

8.2 HOW THE LEARINGS RELATE TO OTHER STUDIES

The four themes identified are considered to be translatable to any study process. A key consideration of a large scale stormwater scheme is identifying constraints and opportunities. Identifying these early allows the project to address those accordingly and evaluate which options should be explored further. Of importance to achieve this is integrating with the network owners to develop a scheme that is widely accepted from the outset. We believe the following principals help to achieve a path of success for a project and suggest these are incorporated:

1. invest time in engagement with stakeholders early;

2. understand the existing context and explore what can be utilised or enhanced;

3. validate ideas through focused stakeholder group workshops and interrogation of information; and

4. adaptively manage the project to address issues effectively as they arise.

Overall we acknowledge the need to have a base scope to progress a project and a focused project team. However where complex issues are involved, we have found approaching a project in this manner allows the project to evolve and avoids the risk that a project deliverable becomes irrelevant due to a narrow knowledge base. Applying this set of principles to projects will benefit the network owner and technical teams through alignment and targeting a common desired outcome.

9 CONCLUSIONS

Historical flood risk in the Dudley Creek catchment has been further increased a result of the 2010/11 earthquake sequence. Christchurch City Council has undertaken a number of works to reduce flood risk and further reductions were suspected through optimization of the Cranford Basin and Dudley Creek Diversion infrastructure. The present project required the project team to come up to speed fast which was achieved through integration with the network owners and ongoing transparent working. This allowed a scheme to be delivered that leveraged off opportunities and addressed known constraints to provide a solution that is adaptive, cost effective and reliable. Overall the scheme achieved the critical success factors of maximizing storage and existing infrastructure for the wider catchment's benefits.

Through delivery of the project we have identified a set of principles that can be applied to other projects of this type and achieve effective outcomes. We suggest these are considered at the planning stages to set the project on a course to successful and achieve outcomes relevant to the network owners requirements.

ACKNOWLEDGEMENTS

We would like to thank the many Christchurch City Council staff involved in the Cranford Basin Active Management project. Their inputs helped to shape and achieve a robust and commonly accepted scheme. We acknowledge the project team wider project team including DHI & GHD whose input allowed the project to be delivered in an efficient manner.

REFERENCES

CCC (2015) Avon River Catchment Surface Water Plan. Version 15. 10 July 2015