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LDRP 509 Knights Drain Investigation

Stormwater Management Options Assessment

Christchurch City Council

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Bringing ideas to life

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Executive Summary

Introduction

The Knights Drain catchment is being investigated as part of the Christchurch City Council (Council) Land Drainage Recovery Programme (LDRP).

The Council specified objective for the Knights Drain catchment is that, upstream of the new Knights Drain Pump Station (PS) there should be significantly improved flood attenuation storage and water quality enhancement that have reliable outcomes and low or infrequent maintenance.

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) are currently constructing the new Knights Drain Pump Station but the upstream attenuation pond assumed in their design is outside of their scope. Council is also committed to providing improvements in stormwater quality across the city as part of the Avon Stormwater Management Plan (SMP).

In order to meet this objective Council engaged Aurecon to undertake an options assessment and identification of a preferred option for provision of improved flood attenuation storage and water quality enhancement within a multi-values framework that includes assessment of the reduction of any non-flood hazards such as lateral spread. This investigation identified, evaluated and compared all reasonably practical options for achieving Councils objective.

Options Identification and Analysis

Existing constraints and opportunities within the Knights Drain catchment were identified and mapped. These mapped constraints include topography, existing stormwater network, other services, depth to median groundwater level, soil drainage potential, 2% Annual Exceedance Probability (AEP) flood depth and inundation extent, current and future land use zoning, and Hazardous Activities and Industries List (HAIL) sites listed on the ECan Listed Land-use Register (LLUR).

A number of options to improve flood attenuation storage and water quality enhancement within the Knights Drain catchment were identified. These options were assessed against site constraints and opportunities, the Council six values (ecology, landscape, recreation, heritage, culture and drainage) presented in the Waterways, Wetlands and Drainage Guide (WWDG) and a number of non-flood assessment criteria.

Upgrade Options

An options identification workshop was held with Council to discuss and agree the outcomes of options investigated and confirm which to take forward to a cost estimation and multi-criteria analysis (MCA) assessment.

The flood storage and stormwater treatment options were then combined by assuming that all options that provide increased flood storage via basins would also provide a water quality enhancement outcome in conjunction with storage in the same location.

The combined options are summarised below:

- Option 1: Provide flood storage and stormwater treatment (wetland or wet basin) in the triangular area bounded by Anzac Avenue, Pages Road and Knights Drain
- Option 2: Extend Knights Pond into adjacent residential open space to the north-west of current location and provide flood storage and stormwater treatment in this one location
- Option 3: Construct a new basin in the red zone to provide flood storage and stormwater treatment (wetland or wet basin) outcomes

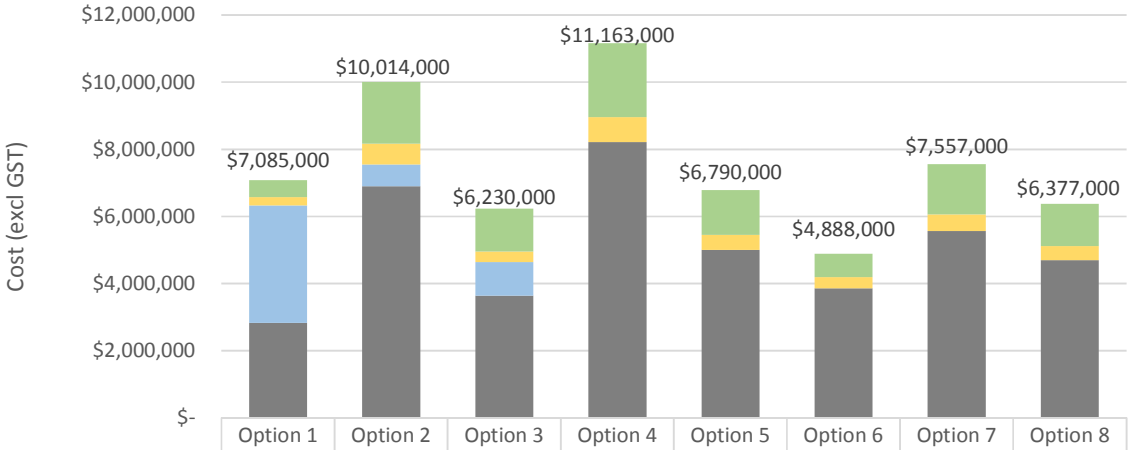
- Option 4: Construct a new basin in Bexley Park to provide flood storage and stormwater treatment (wetland or wet basin) outcomes
- Option 5: Increase the capacity of the new SCIRT Pump Station and include street-scale rain gardens for stormwater treatment
- Option 6: Increase the capacity of the new SCIRT PS and include a proprietary stormwater treatment device
- Option 7: Construct a new basin in Bexley Park to provide flood storage and street-scale rain gardens
- Option 8: Construct a new basin in Bexley Park to provide flood storage and a proprietary stormwater treatment device

Comparative Cost Estimate

Preliminary project capital cost estimates were prepared for each of the options for the purposes of undertaking a comparative cost assessment. These are presented below.

The lowest capital cost option is Option 6 with an estimated cost of $4.9M. Option 1 and Option 3 have an estimated capital cost of $7.1M and $6.2M respectively.

Comparative Cost Estimates for Upgrade Options



	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Contingency	$505,000	$1,849,00	$1,268,00	$2,203,00	$1,340,00	$689,000	$1,492,00	$1,259,00
P&G (10%)	$253,000	$617,000	$317,000	$735,000	$447,000	$345,000	$498,000	$420,000
Land Aquistion	$3,500,00	$646,000	$1,000,00	$-	$-	$-	$-	$-
Construction Cost	$2,827,00	$6,902,00	$3,645,00	$8,225,00	$5,003,00	$3,854,00	$5,567,00	$4,698,00

Multi Criteria Analysis

A MCA Workshop was completed for this project to assess the various options being considered, across a range of non-priced attribute criteria and recommend a preferred option to increase flood storage and provide water quality enhancement in the Knights Drain catchment.

The MCA showed that whilst Option 6 has the lowest capital cost it achieved a low overall MCA score and ranking based on the non-cost assessment criteria. Option 6 also scored poorly against the Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria as well as scoring lower than other options in the Resilience and Water Quality Outcome assessment criteria. Based on this Option 6 provides an overall 'low value' outcome and therefore is not recommended.

The most favourable options are Option 1 and Option 3. Neither of these two options have both the highest MCA Score and lowest capital cost. All other options assessed have a higher cost or significantly lower MCA score and ranking based on non-cost assessment criteria and are therefore not recommended as they provide a 'low value' outcome when compared against the MCA assessment criteria and objectives of this investigation.

Option 1 has the highest MCA score and non-cost attribute ranking but has an estimated capital cost $0.9M above Option 3. Option 1 also achieved the highest ranking for Resilience and equal highest ranking for the Water Quality Outcomes, Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria. Option 1 requires the purchase of privately owned residential properties. Option 1 is the only option that achieves the non-flood assessment criteria of adaptability and resilience.

Option 3 has the second highest MCA Score and ranking but has an estimated capital cost that is $0.9M lower than Option 1. Option 3 achieved the lowest ranking for Resilience and equal highest ranking for the Water Quality Outcomes and Disruption assessment criteria. Option 3 is dependent on gaining access to red zone land in a timely manner.

When the MCA assessment was completed with cost as an assessment criteria, Option 1 was identified as the option with the highest MCA score and ranking. Therefore Option 1 provides the 'best value' option based on a non-priced attribute criteria MCA assessment and when cost is included as a MCA assessment criteria.

Summary and Recommendations

On the basis of the MCA workshop, Option 1 and Option 3 are the best value options. The value placed on long term resilience and the practicalities of gaining access to land for each option influences the best option from these two.

Option 1 achieved the highest MCA score and ranking based on non-cost attributes, achieved the highest ranking for all MCA assessment criteria, has a similar capital cost as Option 3 and achieved the highest MCA score and ranking when cost was included as a MCA assessment criteria. On the basis of this, it has been concluded that Option 1 provides the 'best value' option when assessed against the Council objectives and it is recommended that this option be taken forward for detailed design.

1 Introduction

1.1 Background

The Knights Drain catchment is being investigated as part of the Christchurch City Council (Council) Land Drainage Recovery Programme (LDRP).

The Council specified objective for the Knights Drain catchment is that, upstream of the new Knights Drain Pump Station there should be significantly improved flood attenuation storage and water quality enhancement that have reliable outcomes and low or infrequent maintenance.

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) are currently constructing the new pump station but construction of the upstream attenuation pond assumed in their design is outside of their scope. Council is also committed to providing improvements in stormwater quality across the city as part of the Avon Stormwater Management Plan (SMP).

In order to meet this objective Council engaged Aurecon to undertake an options assessment and identification of a preferred option for provision of flood attenuation storage and water quality enhancement within a multi-values framework that includes assessment of reduction of any non-flood hazards. This investigation identified, evaluated and compared all reasonably practical options for achieving Councils objective.

This report presents the findings from the Knights Drain catchment investigation undertaken to achieve the Council objective for this catchment.

1.2 Scope of Work

The scope of work for this study is summarised below.

- Site walkover of the Knights Drain catchment
- Data collection and review. This includes all relevant design reports and hydraulic model results
- Gaps analysis and identify any work required to fill identified gaps. Prepare Gaps Analysis memo
- Investigate constraints and opportunities within the catchment, including but not limited to; topography, stormwater network connectivity, existing services, depth to median groundwater level, soil drainage potential, land use changes, Hazardous Activities and Industries List (HAIL) sites and existing open spaces. Existing constraints and opportunities will be mapped. These maps will be used to identify water quality enhancement and flood storage options within the catchment and assess the technical viability of these options
- Identify a number of options to improve flood attenuation storage within the catchment
- Identify a range of water quality enhancement options available within the catchment
- Complete a non-cost attribute qualitative options analysis for all options identified to achieve the water quality enhancement and flood attenuation storage objectives. All options will be qualitatively assessed against the identified constraints and opportunities, the Council six values (ecology, landscape, culture, heritage, recreation and drainage) and a number of non-flood hazard criteria. The non-flood hazard assessment criteria are earthquake impacts, operations and maintenance, safety considerations, adaptability and resilience and, constructability and deliverability
- Options identification meeting at Council to discuss all options investigated and confirm options to take to a cost estimation and multi-criteria analysis assessment. Options that are unviable based on the identified project objectives were omitted from further analysis
- Complete a high-level comparative cost estimate for all options selected to proceed to the multi-criteria analysis

- Multi-criteria analysis workshop to identify the preferred option
- Prepare Options Assessment Report (this report)

2 Gaps Analysis

2.1 Previous Studies

Council provided background technical reports and previous hydraulic modelling results within the catchment to assist with this investigation.

A gaps analysis was undertaken to familiarise Aurecon with the background technical information and identify if any work is required to fill any identified gaps.

The following background reports and information have been provided to Aurecon for this investigation.

- *Knights Drain Ground Improvement Recommendations (GHD, 2016)*
- *Knights Drain Stormwater Management Preliminary Site Investigation and Groundwater Analysis (GHD, 2016)*
- *Site Appraisal: LDRP 509 Knights Drain Stage 1 - Archaeological Site A (2016)*
- *Knights Drain Issues, Options and Concept Report (Jacobs, 2015)*
- *Knights Drain Preliminary Geotechnical Appraisal Report (Jacobs, 2015)*
- *LDRP Lower Avon Consent Strategy (Jacobs, 2015)*
- *Knights Drain Geotechnical Assessment Report (Jacobs, 2016)*
- *Knights Drain Contaminated Land Preliminary Site Investigation (Jacobs, 2016)*
- *LDRP 509 SCIRT Pump station Developed Design Report 2016-08-01 (SCIRT, 2016)*
- *Aranui Knights Drain (SW) Geotechnical Assessment Report (SCIRT, 2016)*
- *Draft Knights Drain Facility Issues and Options report (Unknown, 2016)*
- *Lower Avon Aranui MIKE FLOOD Model and results (Jacobs, 2016)*

A gaps analysis was undertaken for the background information provided. A summary of the key information from the background data regarding constraints and opportunities, Council six values criteria, non-flood hazards, and maintenance and operation considerations is listed below. This information assisted with the qualitative options analysis of all flood attenuation and water quality enhancement options.

2.2 Summary of Key Background Information

Knights Drain Preliminary Geotechnical Appraisal Report

- The site is underlain by three main geological characteristics: dominantly sand of fixed and semi-fixed dunes and beaches; sand, silt and peat of drained lagoons and estuaries; dominantly alluvial sand and silt overbank deposits
- Liquefaction was observed at varying degrees from minor to moderate-severe throughout the catchment after the Canterbury Earthquake Sequence (CES)

- Land within the catchment is Technical Category (TC) 2 and 3. The nominal lateral spread for TC2 and 3 is <50 mm and >50 mm respectively
- There is a presence of loose sand and silt, peat and other organic materials and uncontrolled fill (from the former landfill on the Bexley Park site) which imply a high potential of settlement. In addition, improvement of drainage on the site has the potential to cause consolidation of the soil profile and subsequently settlement as a result of a lowered ground water table
- Lateral spreading was identified after the 22 February 2011 Earthquake along the North-Eastern extent adjacent to the Avon River and some locations at the centre of the catchment
- Proposed land drainage works such as deepening the drain or pond have an increased risk of lateral spreading and settlement. Existing drainage infrastructure is exposed to combinations of liquefaction, lateral spreading, settlement and ground shaking risks

Knights Drain Geotechnical Assessment Report

- The ground conditions at Wainoni Park, Knights Pond and PS204 has been investigated through machine boreholes, CPTs, DCPs and piezometers. Particle size distributions are recommended for two sites to provide qualitative information regarding groundwater infiltration rates at the base of the proposed pump station at the Knights Pond site
- The groundwater table at two boreholes was measured to be 1.25 metres below ground level (mbgl) and 0.95 metres below ground level (mbgl) respectively at the Knights Pond site. The groundwater table depth was measured at 0.55 mbgl at the PS204 site, approximately the same height as the adjacent Avon River water level. The groundwater level may fluctuate seasonally throughout the catchment
- The upper soil profile is predominantly of a loose sandy nature which will result in highly permeable detention pond walls and floor. The walls have potential to erode and slump if exposed to long term fluctuating water levels
- Areas of land have been identified on the Canterbury Listed Land Use Register (LLUR) as Hazardous Activities and Industries List (HAIL) sites: 32 Brightstone Crescent to the northwest is identified as: “G3 - Landfill sites”, 112 D Bexley Road to the southeast is identified as “A11 - Pest control” and, 525 and 533 Pages Road to the southwest are identified as: “G5 - Waste disposal to land” (Environment Canterbury Regional Council). These sites may be contaminated and require further investigation to undertake works in these areas

Knights Drain Ground Improvement Recommendations Report

- Results of an analysis conducted by GHD indicates that the site is underlain by liquefiable deposits (loose sands) which will contribute to liquefaction induced lateral spread in a seismic event. The two most effective options for minimising lateral spread effects on wet ponds are timber piles and soil/cement columns constructed around the basin extent

Preliminary Site Investigation and Groundwater Analysis Report

- Ground water analysis was conducted in a borehole in the location of the old Farnborough Landfill. Groundwater levels were measured at 0.93-0.94 mbgl. It was found that there was no direct evidence for landfill leachate contaminating the groundwater system

LDRP Lower Avon Consent Strategy Report

- Components of the proposed works of the project include removal of PS204, enlargement of Knights Pond, establishment of Knights Pond Pump Station and upgrade of Knights Drain. Additional options are provided. The majority of works may be covered under global consents. Further consents are likely required for land use consent for a pump station and earthworks on contaminated or potentially contaminated sites and a discharge permit for construction phase stormwater

Knights Drain Contaminated Land Preliminary Site Investigation Report

- Residual contamination could occur at Knights Drain and Pond during proposed works as a result of a former landfill, including asbestos
- The groundwater levels at the upstream end of the drain are typically below 1 m below ground level. A Canterbury Regional Council (CRC) groundwater monitoring well located on Walters Road (M35/1603) level ranged between 0.2 m and 0.8 mbgl for the last 35 years

Site Appraisal: LLDRP 509 Knights Drain Stage 1 Report

- There are no existing pre-1900 structures, sites of interest to Maori and potential archaeological features however there is some evidence of pre1900 occupation in the area

Knights Drain Issues, Options and Concept Report

- This project investigated the issues and options for the broader East Aranui catchment including Knights Drain and the piped drainage catchments between Pages Road and Wainoni Road, relating to restoring the condition of the drain and flood extents to those which existed prior to the earthquake sequence
- A significant portion of the catchment has subsided between 100 and 1,000 mm, particularly in areas of the Avon River end of the catchment and near Wainoni Park. The area between Knights Drain and Pages Road is below the mean high water level and properties along Pages Road and Portchester Street have settled to a greater extent than the adjacent road
- Following the CES, the remaining proportion of timber-lined drain is in a poor state of repair and PS204 was visibly rotated but still functional
- The ground to the north-west of Knights Drain is at a higher elevation than the ground directly south-east of the drain. The private properties bordered by Knights Drain, Anzac Drive and Pages Road have the lowest elevation in the catchment. This area is reliant on the continued operation of back flow devices and PS204 to avoid regular tidal flooding. The land immediately south of Knights Drain either side of Pages Road appears to be lower than the road and surface water will pond and be unable to drain away easily unless it is connected to the drainage network
- Hydraulic modelling to predict flooding extents during the 2% AEP flood event coinciding with a 20% AEP dynamic tide was undertaken. The area of low lying residential ground levels at the 20% AEP high tide has significantly increased following the CES. This demonstrates that the area has become more vulnerable during high tide events and will have significantly reduced hydraulic gradient available during such events
- The hydraulic modelling concluded that the capacity of all gravity catchments is limited by the tail water conditions created at the tidal interface. All are susceptible to overdesign flood and tide events and sea level rise resulting from climate change and over time will become more reliant on back flow prevention devices, storage and pumping of stormwater in order to provide the same level of service. Drainage is almost entirely reliant on the reticulated network with secondary overland flow paths down roads not activating without first flooding low lying areas to a significant depth
- Following the earthquake, silt was removed from the pump station wet well every two days from PS204 and the pumps are refurbished every 3 months due to pump impellor erosion issues
- The Knights Drain Pond base has heaved and/or infilled with sediment. Knights Pond was designed to be inundated during normal operation however it is no longer submerged after the removal of the downstream control weir. Therefore at its current elevation it provides limited hydraulic benefit or water quality improvement. Aquatic habitat to the stream channel is affected by lower water levels
- Performance summaries for 16 different options to restore the condition of the flood extents to those prior to the earthquake sequence are presented in Table 4-16 according to flood risk change and the 6 values for catchments

Draft Knights Drain Facility Issues and Options Report

- This report was incomplete at the time this report was written
- The site is not significantly contaminated by leachate, the triangle of land in Bexley bounded to the south by Pages Road and to the east by Anzac Drive is considered suitable for an off-line forebay (580 m^2 wetted surface area when full) followed by a wet pond (4,310 m^2 surface area when full) for the Knights Drain catchment. It is recommended that the private properties from 537 to 589 Pages Road are purchased for this option. Flood Storage Option 1 on Figure B1 (refer Appendix B) is in the location of these properties on Pages Road.
- Hydrological modelling confirmed that the proposed detention basin storage is sufficient to restrict house flooding to pre-quake levels and meet pump operational requirements

Aranui Knights Drain (SW) Geotechnical Assessment Report

- Development of Knights Drain pond site involves construction of a new stormwater pump station, a sheet-piled forebay pond and a small electrical building. The pump station structure design is founded on a shallow flanged unreinforced concrete raft foundation to reduce potential differential settlements and buoyant uplift
- The site is underlain by loose sands and silts to approximately 6-10 mbgl. The median groundwater level in this area is approximately 8.8 mRL to 9.0 mRL (0.5 mbgl)

LDRP 509 – SCIRT Pump Station Developed Design Report

- Detailed design report of new stormwater pump station with two pumps with a combined capacity of 675 L/s located on Knights Drain west of Anzac Drive

Lower Avon Aranui MIKE FLOOD Model

- The Lower Avon Aranui MIKE FLOOD model and results were provided for this investigation

Hydraulic modelling was undertaken for the 2% AEP 1 hour design flood event.

2.3 Site Visit

A site walkover of the Knights Drain catchment was undertaken on the 10 March 2017 by members of the Aurecon project team. This investigation identified existing stormwater infrastructure in the catchment along with general constraints and opportunities that need to be considered when identifying options to improve flood attenuation storage and provide water quality enhancement within the catchment. A selection of site photographs taken during the site walkover are presented below.

Image 1: Knights Drain

Image 2: Knights Pond & new Pump Station

Image 3: Pages Road

Image 4: Bexley Park beside Pages Road

Image 5: Open space beside Knights Pond

Image 6: Pages Road

Image 7: Knights Drain (upstream timber-lined reach)

Image 8: Knights Drain (downstream vegetated reach)

2.4 Key Findings

The data collection, review and gaps analysis identified that no additional work was required to complete this investigation.

The background technical reports have sufficient information to assist with the non-cost attribute qualitative options analysis for both flood attenuation storage and water quality enhancement options within the Knights Drain catchment.

3 Constraints and Opportunities

Existing constraints and opportunities within the Knights Drain catchment were identified and mapped using GIS data provided by Council. These maps are presented in Appendix A and include:

- Topography (based on post-earthquake LiDAR survey)
- Existing stormwater network
- Existing services (wastewater, water supply and stormwater)
- Depth to median groundwater level
- Soil drainage potential
- 2% Annual Exceedance Probability (AEP) post-earthquake peak flood depth and inundation extent
- Current land-use zoning
- Future land-use zoning from the revised district plan
- HAIL sites identified on the ECan Listed Land-use Register (LLUR)

These maps were used to assist in identifying water quality enhancement and flood storage improvement options within the catchment and assessing the technical viability of these options.

4 Qualitative Options Analysis

A number of options to improve flood attenuation storage and provide water quality enhancement within the Knights Drain catchment were identified. These options are presented in Table 1 and Table 2. The location of these flood attenuation storage and water quality enhancement options are presented in Appendix B.

These options were then assessed against site constraints and opportunities, the Council six values and non-flood assessment criteria. It was agreed with Council that the non-flood assessment criteria to be used for this project would comprise earthquake impacts, operations and maintenance, safety considerations, adaptability and resilience and, constructability and deliverability.

Table 1 and Table 2 presents the outcomes from the non-cost qualitative options analysis for the flood storage improvement options and water quality enhancement options respectively. Options that were disregarded as impractical or unfeasible from this analysis are identified in these tables along with reasons for discounting them. All options discounted during the non-cost qualitative options analysis were omitted from further assessment in this investigation.

Table 1 Qualitative Options Analysis for Flood Storage Improvement Measures

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints & Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
1	Provide flood storage in low-lying residential area bounded by Anzac Drive, Pages Road and Knights Drain	Purchase existing residential properties to expand the Knights Pond flood storage	▪ This is the existing low point in the catchment ▪ Location adjacent Knights Drain, Knights Pond and new pump station (PS) ▪ No service relocations required ▪ Groundwater is very shallow in this location and in-situ soil is poorly drained ▪ There are existing residential properties in this location that are inundated in a 2% AEP flood event ▪ The land is zoned residential ▪ No HAIL sites in this location but the adjacent Knights Pond is a HAIL site with a persistent pesticide bulk storage and use HAIL activity	▪ Enhanced landscape and drainage outcomes ▪ If the storage basin was wet there would be an enhanced ecology outcome	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ A pond in this location keeps all stormwater measures in one location adjacent to the existing Knights Drain and PS. This reduces operations and maintenance requirements ▪ Adequate space to allow for community safety and Safety in Design (SiD) considerations ▪ Provides a resilient outcome for low-lying properties that will be impacted by sea level rise ▪ **This location currently comprises existing flood prone residential properties that would need to be purchased to allow a flood storage basin to be constructed in this location**	☺ This option is considered viable due to limited site constraints and existing residential properties in this location being flood prone
2	Extend Knights Pond into adjacent open space north-west of the current pond location	Expand basin further north-west to provide additional flood storage without purchasing residential properties. Utilise new SCIRT PS	▪ This land is higher than the invert of Knights Pond ▪ Location adjacent Knights Drain, Knights Pond and new PS ▪ No service relocations required ▪ Shallow depth to groundwater ▪ **This location is identified as a HAIL site with a landfill site HAIL activity. Site remediation may be required to construct a storage basin in this location. The adjacent Knights Pond is a HAIL site with a persistent pesticide bulk storage and use HAIL activity** ▪ This land is zoned as both open space and residential	▪ Enhanced landscape and drainage outcomes ▪ If the storage basin was wet there would be an enhanced ecology outcome	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ A pond in this location keeps all stormwater measures in one location adjacent to the existing Knights Drain and PS. This reduces operations and maintenance requirements ▪ Adequate space to allow for community safety and SiD considerations ▪ Would allow existing flooding in Farnborough Street to potentially also be improved ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **Some residential land would need to be purchased that is currently not flood prone**	😐 This option is considered potentially viable due to the existing land fill HAIL site and requirement to purchase residential land that is not flood prone
3	Construct new storage basin in red zoned land	Basin located to east of Anzac Drive in the red zone	▪ The red zoned land to the east of Anzac Drive is at a similar elevation to Knights Pond so stormwater can be drained to a storage basin in this location by gravity ▪ There are existing stormwater reticulation networks and utility services located within previous road corridors. These would need to be avoided or relocated ▪ Groundwater is very shallow in this location and in-situ soil is poorly drained ▪ There are no residential properties in this location ▪ HAIL sites could be avoided in this location	▪ Enhanced landscape and drainage outcomes ▪ If the storage basin was wet there would be an enhanced ecology outcome ▪ Sufficient land available to also potentially enhance recreation and cultural outcomes	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ Council can currently only access existing services located within drainage reserves in the red zone ▪ Adequate space to allow for community safety and SiD considerations ▪ Location would be easy to access for maintenance but does result in stormwater measures for the catchment being located in two separate locations ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events	😐 This option is considered potentially viable due to uncertainties around the future use of the red zone land

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints & Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
			▪ **This land is currently residential red zone and will be zoned specific purpose flat land recovery in the revised district plan**		▪ **The future use of this land is unknown and will be identified by Regenerate Christchurch. Therefore Council cannot currently use this land which impacts the deliverability of this project**	
4	Construct new storage basin in Bexley Park upstream of low-lying residential properties	Store floodwater further upstream in the catchment and release this floodwater when the existing reticulation network has capacity. This could prevent inundation of low-lying residential properties	▪ The existing topography in Bexley Park adjacent to Pages Road is higher than Pages Road so significant excavations would be required to construct a storage basin ▪ No service relocations required ▪ The groundwater depth in this location is greater than 2.5m ▪ Bexley Park is zoned as open space ▪ **This location is identified as a HAIL site with a landfill site HAIL activity. Site remediation may be required to construct a storage basin in this location**	▪ Enhanced landscape and drainage outcomes ▪ Potential recreation impact as the existing playground and dog park in Bexley Park may need to be relocated ▪ If the storage basin was wet there would be an enhanced ecology outcome	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ Adequate space to allow for community safety and SiD considerations. However the storage basin would be located adjacent a community park which has an increased safety risk to the community ▪ Location would be easy to access for maintenance but does result in stormwater measures for the catchment being located in two separate locations ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events	😐 This option is considered potentially viable due to the existing land fill HAIL site
5	Increase capacity of the new SCIRT PS to reduce need for additional storage at Knights Pond	Upgrade capacity of new PS and downstream reticulation network if required	▪ The new PS is located at the Knights Pond ▪ There is adequate room for a larger PS ▪ There is an existing stormwater reticulation network from Anzac Drive to the Avon River through the red zone. This infrastructure may require upgrading ▪ Existing infrastructure upstream of the PS may require upgrading to be able to convey the 2% AEP flow to the PS ▪ The Knights Pond site is a HAIL site with a persistent pesticide bulk storage and use HAIL activity. This is unlikely to require any site remediation measures ▪ The new PS is located in open space zoning but this will change to a transport zone in the revised district plan ▪ Groundwater is very shallow in this location & in-situ soil is poorly drained	▪ No change to the current landscape, recreation, ecology and cultural outcomes provided by the current Knights Pond configuration	▪ Adequate space to construct foundations for the PS that can withstand potential seismic impacts ▪ Increased operational and maintenance requirements but this would all be located in one common location ▪ No increased safety risk to the community ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **This PS is currently under construction. Unlikely to be considered favourable to upgrade PS as it is inconsistent with design philosophy of new PS** ▪ **Lessor reliability with complete reliance on pumping** ▪ **Higher operational risk of blockage and power outage**	😐 This option is considered potentially viable because the construction of a new pump station has recently been completed
6	Soakage basin	Discharge floodwater above the capacity of Knights Pond and the new PS to ground via rapid soak pits	▪ **The lower section of the Knights Drain catchment has shallow groundwater and poorly drained soil that is not suitable for soakage to ground** ▪ **The upper proportion of the catchment has well drained soil but relatively shallow depth to groundwater in road reserves which also makes these areas unsuitable for soakage to ground** ▪ **Most undeveloped open spaces within the catchment in which soakage devices could be located are identified as HAIL sites with a landfill HAIL activity. These sites may therefore not be suitable for soakage devices due to the risk of groundwater contamination**	▪ This option will provide an enhanced drainage outcome for the Knights Drain catchment ▪ No landscape, recreation, ecology or cultural enhancement	▪ **The in-situ soils within the catchment are prone to liquefaction and this would prevent the soak pit from functioning adequately** ▪ A soak pit is difficult to maintain or monitor its performance ▪ No increased safety risk to the community ▪ The performance of a soak pit would be impacted by changing in groundwater levels that may occur from sea level rise ▪ A soak pit is easy to construct. Given the expected low soakage rates in this location the soak pit would need to have a large volume to store floodwater ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events	☹ This option was dismissed due to shallow depth to groundwater and poorly drained soil with low infiltration rates making discharge to ground via soakage unviable
7	On-site attenuation tanks	Install a tank on all properties in the catchment to attenuate all roof areas. The tanks could be either above or below ground	▪ This solution is not impacted by the catchment topography or poorly drained soil ▪ **Less than 15% of impervious area in the catchment comprises roofs. All road areas and external trafficable areas would not be captured by the on-site attenuation tanks. It**	▪ This option will provide an enhanced drainage outcome for the Knights Drain catchment	▪ Above-ground onsite attenuation tanks are unlikely to be impacted by seismic events ▪ **Long/risky delivery programme due to private property access requirements** ▪ No increased safety risk to the community	☹ This option was dismissed as it would not provide sufficient increased flood storage,

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints & Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
			is expected that the tanks would be unable to provide an adequate overall storage volume to prevent the inundation of existing floors in a 2% AEP event ▪ **The shallow depth to groundwater and limited stormwater reticulation network extent make the use of below-ground tanks typically unviable** ▪ **The tanks would need to be located on existing dwellings in private property. It would be difficult to obtain approval to install tanks in private property given that above-ground tanks would be required in most locations** ▪ A number of existing properties comprise HAIL activities but this is unlikely to impact the ability to provide above-ground storage tanks	▪ **This option is likely to impact both landscape and recreation outcomes for a number of existing dwellings**	▪ The onsite attenuation tanks could be retrofitted to provide rainwater harvesting and reuse in the future if the onsite storage was no longer required ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **Permission to access a large number of private properties is required to retrofit the onsite attenuation tanks**	site constraints make installation of on-site tanks difficult and permission is required to construct on-site attenuation tanks on a large number of private properties
8	Increase capacity of gravity reticulation network	Construct larger pipes to convey floodwater from Knights Pond to the Avon River for a larger design storm event. This would prevent the need for additional flood storage in the catchment Existing infrastructure upstream of Knights Pond may need to be upgraded to conveyed increased flows to the PS	▪ This option is not impacted by the site topography, shallow groundwater depth or poorly drained in-situ soil ▪ There is an existing stormwater pipe passing from Knights Pond through the red zone to PS204 and the Avon River. This existing stormwater pipe has a 750mm diameter and is expected to have a 20% AEP capacity ▪ **The capacity of the stormwater network is influenced by the Avon River tailwater level and capacity of PS204. Upgrading the size of the existing stormwater pipe is unlikely to result in a significant increased capacity unless PS204 was also upgraded as the network cannot drain with a high tailwater level when the Avon River is in flood** ▪ There are no residential properties in this location ▪ No HAIL sites in this location ▪ **This land is currently residential red zone and will be zoned specific purpose flat land recovery in the revised district plan**	▪ No landscape, recreation, ecology or cultural enhancement ▪ Unlikely to provide a significant drainage enhancement unless PS204 and upstream network were also upgraded	▪ **The land in the red zone is susceptible to damage from seismic events and this would impact the effectiveness of the reticulation network. This option is not very resilient to future seismic events** ▪ No increased safety risk to the community ▪ The enlarged pipe size would require deep excavations and dewatering ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **The future use of this land is unknown and will be identified by Regenerate Christchurch. Therefore Council cannot currently construct infrastructure in this land which impacts the deliverability of this project**	☹ This option was dismissed because upgrading the size of the existing stormwater pipe is unlikely to result in a significant increased capacity unless PS204 was also upgraded as the network cannot drain with a high tailwater level when the Avon River is in flood
9	Below ground storage	Construct below ground storage within road corridors or open spaces within the catchment	▪ **The Knights Drain catchment has shallow groundwater which makes below-ground storage tanks unviable** ▪ There is an existing stormwater reticulation network in which below-ground storage tanks could discharge to. But the depth of these pipes means that below ground storage tanks would need to be shallow. Therefore the tanks would require a large footprint to provide adequate storage ▪ There are a large number of existing utility services that make it difficult to construct below ground tanks in the road reserve	▪ This option will provide an enhanced drainage outcome for the Knights Drain catchment ▪ No landscape, recreation, ecology or cultural enhancement	▪ **Below ground storage tanks are likely to be susceptible to damage in seismic events** ▪ Below ground storage tanks are difficult to maintain and monitor its performance ▪ No increased safety risk to the community ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **The performance of below ground storage tanks could be impacted by a change in groundwater levels that may occur from sea level rise**	☹ This option was dismissed due to the shallow depth to groundwater making below-ground storage unviable
10	Provide storage in distributed street-scale stormwater treatment devices	Provide storage in street-scale treatment devices such as rain gardens or swales	▪ Groundwater is typically shallow throughout the catchment and in-situ soil is poorly drained. This requires rain gardens to discharge to the piped reticulation network ▪ There is limited existing piped stormwater network within the catchment in which rain gardens can be discharged into. This means that rain gardens could not be provided in all	▪ The construction of swales or street-scale rain gardens will provide an enhanced landscape and ecology outcome ▪ This option will provide a marginal drainage benefit	▪ Street-scale rain gardens and swales can be designed to accommodate potential seismic impacts ▪ **A large number of street-scale rain gardens and/or swale requires significant ongoing maintenance by Council** ▪ Rain gardens would create an increased drop height from the footpath level to the surface level of	☹ This option was dismissed because it will not provide sufficient increased flood storage in a 2% AEP event

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints & Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
			streets unless the existing stormwater network is extended ▪ **Rain gardens will typically provide an attenuation benefit in smaller flood events such as 20% AEP but there effectiveness in providing adequate flood storage to prevent inundation of floors is minimal in larger events such as 2% AEP and/or longer duration rainfall events of a lower AEP** ▪ There is a large number of utility services within the road corridors which would need to be protected or relocated to construct street-scale treatment devices ▪ **Construction of swales would require the removal of all kerbs and regrading surface levels in the road berm** ▪ There are no HAIL sites in the road corridors		the rain garden. These devices also store stormwater above the surface for longer which has a slight increase in safety risk to the community ▪ This option provides a flood storage and water quality outcome. The rain gardens could be designed to meet the requirements of the Avon SMP ▪ Rain gardens would be constructed in the road corridor so can be easily delivered however they are likely to be impacted by the large number of existing utility services in the road corridor ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **Replacing existing kerbs with swales would require widespread works and could be undesirable to the community**	
11	Provide storage basin in private land near upstream end of Knights Drain	Construct storage at upstream end of Knights Drain	▪ This land is higher than the invert of Knights Drain so significant earthworks would be required ▪ Location is adjacent Knights Drain and nearby Knights Pond and the new PS ▪ No service relocations required ▪ Shallow depth to groundwater ▪ **This location is identified as a HAIL site with a waste disposal to land HAIL activity. Site remediation may be required to construct a storage basin in this location** ▪ This land is zoned residential and comprises some existing buildings	▪ Enhanced landscape and drainage outcomes ▪ If the storage basin was wet there would be an enhanced ecology outcome	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ A pond in this location keeps all stormwater measures in one location adjacent to the existing Knights Drain and PS. This reduces operations and maintenance requirements ▪ Adequate space to allow for community safety and SiD considerations ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events ▪ **Some residential land would need to be purchased that is currently not flood prone**	☹ This option was dismissed because residential land that is not flood prone and comprises existing buildings would need to be purchased and this location in a waste disposal to land HAIL site
12	Storage basin on west of Anzac Drive between Birch Street and Wetlands Grove	Divert stormwater to new basin outside the Knights Drain catchment. Utilise existing stormwater network through red zone for outlet to the Avon River	▪ **The ground levels adjacent Anzac Drive and in the potential basin location are higher than the ground level of Knights Pond and the depth to groundwater in this location is shallow, making is unviable to drain stormwater to this location and provide adequate storage above the groundwater level** ▪ There are existing stormwater networks through the red zone that could be used to drain the basin ▪ There are existing Orion cables adjacent Anzac Drive ▪ There is shallow groundwater in this location ▪ This land is zoned both open space and residential but there are no houses in the potential basin location. The land will be zoned open space and transport in the revised district plan ▪ This location is identified as a HAIL site with a landfill site HAIL activity. Site remediation may be required to construct a storage basin in this location	▪ Enhanced landscape and drainage outcomes ▪ If the storage basin was wet there would be an enhanced ecology outcome	▪ Adequate space for the storage area to mitigate lateral spread and other potential seismic impacts ▪ Basin would be away from Knights Pond and PS which has a larger operational and maintenance requirement than one central stormwater management area ▪ Adequate space to allow for community safety and SiD considerations ▪ **Significant earthworks would be required within an area with landfill site HAIL activity** ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events	☹ This option was dismissed because it is not physically viable to drain stormwater to this location and provide adequate increased flood storage above shallow groundwater levels

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints & Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
13	Remove overflow from upper catchment	Regrade overland flow (OLF) paths so stormwater overflow from the Carisbrooke Street area of catchment does not enter Knights Drain	▪ The upper area of the Knights Drain catchment has a piped reticulation network that does not discharge to Knights Drain. When the capacity of this network is exceeded in a 2% AEP event overland flow will drain down Portchester Street and Pages Road towards Knights Drain ▪ **Removing this part of the catchment will reduce floodwater draining towards Knights Drain. However reducing the catchment area alone is unlikely to prevent flooding of low lying properties in the Knights Drain catchment. An alternative measure to provide additional flood storage in the Knights Drain catchment would also be required** ▪ **Preventing this floodwater draining down Portchester Street would require changes in carriageway levels to alter overland flow paths. This would have an impact on existing utility services** ▪ There are no HAIL sites in this area of the catchment	▪ No landscape, recreation, ecology or cultural enhancement ▪ Unlikely to provide a significant drainage enhancement unless undertaken with other measures	▪ **Widespread construction works would be required to regrade overland flow paths and ensure all road reserve berms match kerb levels** ▪ Potentially increased grade on berms and footpaths ▪ The existing residential properties in the low-lying part of the Knights Drain catchment would be retained and these properties would remain at risk from sea level rise and large flood events	☹ This option was dismissed because reducing the catchment area alone will not provide increased flood storage. Further flood storage measures would be required further downstream in the catchment

Notes:

1. The site constraints and opportunities are presented on the figures in Appendix A. These include catchment topography, existing stormwater network, existing utility services, median depth to groundwater level, soil drainage potential, 2% AEP post-earthquake flood depth and extent, current land-use zoning, future land-use zoning and HAIL sites on the ECan LLUR.
2. The Council six values are landscape, recreation, ecology, culture, heritage and drainage as identified in the Council Waterways, Wetland and Drainage Guide (WWDG).
3. The non-flood assessment criteria are earthquake impacts, operations and maintenance, safety considerations, adaptability and resilience and, constructability and deliverability.
4. This column identifies whether the option is viable, potentially viable or not viable based on an assessment against the constraints and opportunities, Council six values and non-flood assessment criteria. ☺ 😐 ☹
5. Notes in bold describe non-favourable characteristics for the selected option.

Table 2 Qualitative Options Analysis for Stormwater Treatment Measures

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints and Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
1	Wetland or wet basin in catchment low point	Purchase existing residential properties bounded by Anzac Drive, Pages Road and Knights Drain to construct a stormwater treatment device near Knights Pond. This could be a conventional wetland, wet basin or floating wetland	▪ This is the existing low point in the catchment. Contributing catchment is 38 hectares ▪ Adjacent Knights Drain, Knights Pond and new PS ▪ No service relocations required ▪ Groundwater is shallow in this location & in-situ soil is poorly drained which will prevent the treatment device drying out ▪ Flood storage could be provided above the wetland normal water level ▪ The land is zoned residential ▪ No HAIL sites in this location but the adjacent Knights Pond is a HAIL site with a persistent pesticide bulk storage and use HAIL activity	▪ Enhanced landscape and ecology outcomes ▪ If flood storage was provided above the treatment device then a drainage outcome would also be achieved	▪ Functionality of wetland not significantly impacted by seismic events or could be remediated ▪ Ensures that all stormwater management facilities are located in one common location in the catchment ▪ Higher maintenance requirements when compared to a dry or wet pond ▪ A wetland or wet basin can adapt to changing groundwater levels that may occur as a result of sea level rise ▪ Adequate space to allow for community safety and SiD considerations ▪ This location currently comprises existing residential properties that would need to be purchased to allow a flood storage to be constructed in this location	☺ This option is considered viable due to limited site constraints and existing residential properties in this location being flood prone
2	Dry basin in catchment low point	Purchase existing residential properties bounded by Anzac Drive, Pages Road and Knights Drain to construct a dry pond near Knights Pond	▪ Same constraints and opportunities as a wetland as identified above ▪ **Note that the median depth to groundwater is shallow in this location**	▪ Enhanced landscape and ecology outcomes ▪ If flood storage was provided above the basin then a drainage outcome would also be achieved	▪ Functionality of dry basin not significantly impacted by seismic events ▪ Ensures that all stormwater management facilities are located in one common location in the catchment ▪ **Lower maintenance requirements when compared to a wetland but the shallow groundwater depth will result in a boggy base that is difficult to maintain**	☹ This option was dismissed due to shallow groundwater depths making it unviable to maintain a dry basin in this location

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option [4.]
			Site Constraints and Opportunities [1]	Council 6 Values [2]	Non-flood Criteria [3]	
					▪ Adequate space to allow for community safety and SiD considerations ▪ This location currently comprises existing residential properties that would need to be purchased to allow a flood storage to be constructed in this location	
3	Infiltration basin / infiltration swales	Construct end of line infiltration basin and/or infiltration swales distributed throughout the catchment	▪ **The lower section of the Knights Drain catchment has shallow groundwater and poorly drained soil that is not suitable for infiltration to ground** ▪ **The upper proportion of the catchment has well drained soil but relatively shallow depth to groundwater in road reserves which also makes these areas undesirable for infiltration to ground** ▪ **Most undeveloped open spaces within the catchment in which infiltration devices could be located are identified as HAIL sites with a landfill HAIL activity. These sites may therefore not be suitable for infiltration devices due to the risk of groundwater contamination**	▪ Enhanced landscape and ecology outcomes	▪ **The in-situ soils within the catchment are prone to liquefaction and this would prevent infiltration devices from functioning adequately after a seismic event** ▪ No increased safety risk to the community	☹ This option was dismissed due to shallow depth to groundwater and poorly drained soil with low infiltration rates making discharge to ground via infiltration unviable
4	Rain garden (end of line) in catchment low point	Purchase existing residential properties bounded by Anzac Drive, Pages Road and Knights Drain to construct a rain garden near Knights Pond	▪ Same constraints and opportunities as a wetland, dry basin and wet basin as identified above ▪ **Note that the median depth to groundwater is very shallow in this location and the in-situ soil is poorly drained** ▪ **The piped stormwater network is not deep enough to collect treated stormwater from the underdrains within a rain garden**	▪ Enhanced landscape and ecology outcomes	▪ **The in-situ soils within the catchment are prone to liquefaction and this may prevent the rain garden from functioning adequately after a seismic event** ▪ No increased safety risk to the community ▪ A rain garden has a higher maintenance requirement when compared with a dry basin or wet basin ▪ An end of line rain garden in this location would not be resilient if groundwater levels were to increase as a result of sea level rise ▪ A rain garden in this location would need to be lined to prevent saturation of the filter media	☹ This option was dismissed due to shallow depth to groundwater, poorly drained soil and stormwater network invert levels making an end of line rain garden t unviable
5	Street-scale rain gardens within Knights Drain catchment. This includes other street-scale bioretention devices such as stormwater tree pits	Construct street-scale rain gardens throughout the Knights Drain catchment instead of providing an end-of-line treatment device	▪ Groundwater is typically shallow throughout the catchment and in-situ material is poorly drained. This requires rain gardens to discharge to the piped reticulation network ▪ There is limited existing piped stormwater network within the catchment in which rain gardens can be discharged into. This means that rain gardens could not be provided in all streets unless the existing network was extended ▪ There is a large number of utility services within the road corridors which would need to be protected or relocated to construct street-scale treatment devices ▪ There are no HAIL sites in the road corridors	▪ The construction of street-scale rain gardens will provide an enhanced landscape and ecology outcome ▪ This option will provide an improved but not significant drainage outcome	▪ Street-scale rain gardens can be designed to accommodate potential seismic impacts ▪ **A large number of street-scale rain gardens requires significant ongoing maintenance by Council** ▪ Rain gardens would create an increased drop height from the footpath level to the surface level of the rain garden. These devices also store stormwater above the surface for longer which has a slight increase in safety risk to the community ▪ Rain gardens would be constructed in the road corridor so can be easily delivered however they are likely to be impacted by the large number of existing utility services in the road corridor ▪ Rain gardens in the lower catchment may need to be lined to prevent saturation of the filter media	😐 This option is considered potentially viable because street-scale rain gardens can discharge to the existing stormwater reticulation network in the catchment and groundwater depths increase further upstream in the catchment
6	Replace kerbs with swales	Remove all existing kerbs on construct vegetated swales	▪ The existing stormwater network would need to be modified to accommodate the vegetated swales ▪ There is a large number of utility services within the road corridors which may need to be	▪ The construction of swales will provide an enhanced landscape and ecology outcome	▪ Swales can be designed to accommodate potential seismic impacts ▪ **Swales require higher ongoing maintenance by Council**	☹ This option was dismissed due to high maintenance requirements and

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option [4.]
			Site Constraints and Opportunities [1]	Council 6 Values [2]	Non-flood Criteria [3]	
			protected or relocated to construct vegetated swales ▪ **Construction of swales would require the removal of all kerbs and regrading surface levels in the road berm** ▪ There are no HAIL sites in the road corridors		▪ **Replacing existing kerbs with swales would require widespread works and could be undesirable to the community**	disruption to the community associated with replacing kerbs with swales
7	Proprietary stormwater treatment device	Construct proprietary stormwater treatment device i.e. StormFilter etc in existing reticulation network	▪ This option is not influenced by topography, depth to groundwater or poorly drained in-situ soils ▪ There is an existing piped stormwater network in which a proprietary stormwater treatment device could be retrofitted into. The depth of the stormwater network will be adequate ▪ There are no HAIL sites in the road corridors ▪ There are a large number of existing utility services in the road corridors that may clash with the treatment devices footprint	▪ No enhanced landscape, recreation or cultural outcomes ▪ Enhanced ecology outcome in downstream waterways	▪ Proprietary treatment devices are not significantly impacted by seismic events ▪ A proprietary treatment device has a higher maintenance requirement when compared with a dry basin or wet basin	☺ This option is considered viable as a proprietary stormwater treatment device can be retrofitted into the existing stormwater network
8	Construct stormwater treatment device in red zone	Treatment device could comprise a wet basin, dry basin or wetland	▪ This land has a similar level to the current Knights Pond ▪ There is an existing stormwater pipe passing from Knights Pond through the red zone to PS204 and the Avon River ▪ Groundwater is very shallow in this location & in-situ soil is poorly drained ▪ The stormwater network cannot drain by gravity when the Avon River tailwater level is elevated as a result of high tides and flood events ▪ There are no residential properties in this location ▪ No HAIL sites in this location ▪ **This land is currently residential red zone and will be zoned specific purpose flat land recovery in the revised district plan**	▪ Enhanced landscape and ecology outcomes ▪ If flood storage was provided above the basin then a drainage outcome would also be achieved	▪ This area is susceptible to impacts from seismic events ▪ Creates a new stormwater management facility that requires ongoing maintenance ▪ Adequate space to allow for community safety and SiD considerations ▪ **The future use of this land is unknown and will be identified by Regenerate Christchurch. Therefore Council cannot currently construct infrastructure in this land which impacts the deliverability of this project**	😐 This option is considered potentially viable due to uncertainties around the future use of the red zone land
9	Permeable pavement	Replace all roads within the catchment with permeable pavement	▪ Groundwater is typically shallow throughout the catchment and in-situ material is poorly drained. This requires permeable pavement to discharge to the piped reticulation network ▪ There is a large number of utility services within the road corridors which would need to be protected or relocated to reconstruct roads with permeable pavement ▪ There are no HAIL sites in the road corridors ▪ The existing stormwater networks would need to be reconstructed	▪ The construction of permeable pavement would provide an enhanced ecology outcome in downstream waterways ▪ This option will provide an improved drainage outcome	▪ **Permeable pavements are not recommended for roads with high traffic loads and volumes in the Council permeable pavement design criteria technical report developed for the Avon SMP** ▪ **Permeable pavement requires significant and specific maintenance** ▪ Permeable pavement would provide an enhanced safety outcome as there would be less stormwater flow and ponding on road carriageways ▪ This option requires a complete rebuild of all roads within the Knights Drain catchment	☹ This option was dismissed because permeable pavement is not viable for roads with high traffic loads and volumes such as Pages Road
10	Stormwater harvesting and reuse in Bexley Park	This option would capture the water quality event and store it in a storage tank or basin to be used for irrigation of Bexley Park. Therefore the contaminated first flush flows would not leave the catchment. A pump, storage tank and irrigation network would be required and potentially a treatment device to provide some contaminant removal prior to reuse of water	▪ This option is not influenced by topography, depth to groundwater or poorly drained in-situ soils ▪ There are no HAIL sites in the road corridors ▪ There are a large number of existing utility services in the road corridors that may clash with the treatment devices footprint ▪ A new PS, rising main, storage tank and irrigation network would be required	▪ Enhanced ecology outcome in downstream waterways due to a reduction in the frequency of runoff events leaving the Knights Drain catchment and removal of stormwater pollutants	▪ This option is not impacted by seismic events ▪ A stormwater harvesting and reuse system has ongoing operational and maintenance requirements ▪ No increased safety risk to the community ▪ **This system is only effective if the captured irrigation water is reused before the next rainfall event. There is more rainfall events in the winter months when irrigation demands are low so the captured stormwater is unlikely to be reused**	☹ This option was dismissed because stormwater harvesting and reuse is unviable due to the local climate and low irrigation demand for Bexley Park

Option No.	Option Name	Description	Qualitative Analysis Criteria			Viability of Option (4.)
			Site Constraints and Opportunities (1)	Council 6 Values (2)	Non-flood Criteria (3)	
11	Provide stormwater treatment devices (wet pond or wetland) in Bexley Park upstream of catchment low point	Over treat upstream catchment area to account for no treatment in lower areas downstream of treatment device	▪ The existing topography in Bexley Park adjacent to Pages Road is higher than Pages Road so significant excavations would be required to construct a treatment basin in this location ▪ No service relocations required ▪ The groundwater depth in this location is greater than 2.5m ▪ Bexley Park is zoned as open space ▪ **This location is identified as a HAIL site with a landfill site HAIL activity. Site remediation may be required to construct a treatment basin in this location**	▪ Enhanced landscape and ecology outcomes ▪ If flood storage was provided above the basin then a drainage outcome would also be achieved	▪ Functionality of treatment device not significantly impacted by seismic events ▪ Creates a new stormwater management facility that requires ongoing maintenance ▪ The treatment device would be at a higher elevation which would make it more resilient against sea level rise ▪ Adequate space to allow for community safety and SiD considerations	😐 This option is considered potentially viable due to the existing land fill HAIL site
12	Catchpit inserts	Install catchpit inserts on all sumps within the Knights Drain catchment	▪ There is an existing stormwater reticulation network within the catchment in which catchpit inserts can be installed ▪ **Catchpit inserts do not provide an adequate contaminant removal efficiency and are therefore not a Council approved treatment device** ▪ This option is not impacted by other site constraints	▪ Enhanced ecology outcome in downstream waterways	▪ Functionality of treatment devices not impacted by seismic events ▪ **A large number of catchpit inserts requires significant ongoing maintenance by Council** ▪ No increase in safety risk to the community. SiD implication associated with maintaining a large number of treatment devices in the road corridor ▪ Easy to install in existing sumps throughout the catchment	☹ This option was dismissed because catchpit inserts do not provide adequate contaminant removal efficiency
13	Construct stormwater treatment device in open space north-west of the current Knights Pond location	Treatment device could comprise a wet basin, dry basin or wetland	▪ This land is higher than the invert of Knights Pond ▪ Location adjacent Knights Drain, Knights Pond and new PS ▪ No service relocations required ▪ Shallow depth to groundwater ▪ **This location is identified as a HAIL site with a landfill site HAIL activity. The adjacent Knights Pond is a HAIL site with a persistent pesticide bulk storage and use HAIL activity. Site remediation may be required to construct a treatment device** ▪ This land is zoned as both open space and residential	▪ Enhanced landscape and drainage outcomes ▪ If the treatment device was a wetland or wet pond there would be an enhanced ecology outcome	▪ Adequate space for the treatment device to accommodate lateral spread and other potential seismic impacts ▪ A treatment device in this location keeps all stormwater measures in one location adjacent to the existing Knights Drain and PS. This reduces operations and maintenance requirements ▪ Adequate space to allow for community safety and SiD considerations ▪ **Some residential land would need to be purchased that is currently not flood prone**	😐 This option is considered potentially viable due to the existing land fill HAIL site and requirement to purchase residential land that is not flood prone
14	Construct stormwater treatment device in open space near upstream end of Knights Drain	Treatment device could comprise a wet basin, dry basin or wetland	▪ This land is higher than the invert of Knights Pond ▪ Location adjacent Knights Drain, Knights Pond and new PS ▪ No service relocations required ▪ Shallow depth to groundwater ▪ **This location is identified as a HAIL site with a waste disposal to land HAIL activity. Site remediation may be required to construct a treatment device** ▪ This land is zoned residential and comprises some existing buildings	▪ Enhanced landscape and drainage outcomes ▪ If the treatment device was a wetland or wet pond there would be an enhanced ecology outcome	▪ Adequate space for the treatment device to accommodate lateral spread and other potential seismic impacts ▪ A treatment device in this location keeps all stormwater measures in one location adjacent to the existing Knights Drain and PS. This reduces operations and maintenance requirements ▪ Adequate space to allow for community safety and SiD considerations ▪ **Some residential land would need to be purchased that is currently not flood prone**	☹ This option was dismissed because residential land that is not flood prone and comprises existing buildings would need to be purchased and this location is a waste disposal to land HAIL site

Notes:

1. The site constraints and opportunities are presented on the figures in Appendix A. These include catchment topography, existing stormwater network, existing utility services, median depth to groundwater level, soil drainage potential, 2% AEP post-earthquake flood depth and extent, current land-use zoning, future land-use zoning and HAIL sites on the ECan LLUR.
2. The Council six values are landscape, recreation, ecology, culture, heritage and drainage as identified in the Council Waterways, Wetland and Drainage Guide (WWDG).
3. The non-flood assessment criteria are earthquake impacts, operations and maintenance, safety considerations, adaptability and resilience and, constructability and deliverability.
4. This column identifies whether the option is viable, potentially viable or not viable based on an assessment against the constraints and opportunities, Council six values and non-flood assessment criteria. ☺ 😐 ☹
5. Notes in bold describe non-favourable characteristics for the selected option.

5 Stormwater Management Options Selection

A number of options were identified to provide increased flood storage and water quality enhancement outcomes in the Knights Drain catchment.

An options identification meeting was held at Council to discuss all the options investigated and confirm the options to take forward to a cost estimation and multi-criteria analysis (MCA) assessment. The viable and potentially viable options are summarised below:

Flood Storage Improvement Options

- Flood Storage Option 1: Provide flood storage in low-lying residential area bounded by Anzac Drive, Pages Road and Knights Drain
- Flood Storage Option 2: Extend Knights Pond into adjacent residential zoned open space north-west of the current pond location
- Flood Storage Option 3: Construct new storage basin in red zoned land
- Flood Storage Option 4: Construct new storage basin in Bexley Park upstream of low-lying residential properties
- Flood Storage Option 5: Increase capacity of new SCIRT pump station (PS) to reduce the need for additional storage at Knights Pond

Stormwater Treatment Options

- Water Quality Option 1: Wetland or wet basin in catchment low point bounded by Anzac Drive, Pages Road and Knights Drain
- Water Quality Option 5: Street-scale rain gardens within Knights Drain catchment
- Water Quality Option 7: Proprietary stormwater treatment device
- Water Quality Option 8: Construct stormwater treatment device (wet pond or wetland) in the red zone
- Water Quality Option 11: Provide stormwater treatment device (wet pond or wetland) in Bexley Park upstream of catchment low point
- Water Quality Option 13: Construct stormwater treatment device (wet pond or wetland) in residential zoned open space north-west of the current Knights Pond location

The flood storage and stormwater treatment options were then combined by assuming that all options that provide increased flood storage via basins would also provide a water quality enhancement outcome in conjunction with storage in the same location. There are a number of viable options in which the flood storage and water quality enhancement are not located in the same location.

The location of the flood attenuation storage and water quality enhancement options are presented in Appendix B.

The combined options are summarised below:

- Option 1: Provide flood storage and stormwater treatment (wetland or wet basin) in the triangular area bounded by Anzac Avenue, Pages Road and Knights Drain (flood storage option 1 combined with WQ option 1)
- Option 2: Extend Knights Pond into adjacent residential open space to the north-west of current location and provide flood storage and stormwater treatment in this one location (flood storage option 2 combined with WQ option 13)
- Option 3: Construct new basin in the red zone to provide flood storage and stormwater treatment (wetland or wet basin) outcomes (flood storage option 3 combined with WQ option 8)
- Option 4: Construct a new basin in Bexley Park to provide flood storage and stormwater treatment (wetland or wet basin) outcomes (flood storage option 4 combined with WQ option 11)
- Option 5: Increase the capacity of the new SCIRT PS and include street-scale rain gardens for stormwater treatment (flood storage option 5 combined with WQ option 5)
- Option 6: Increase the capacity of the new SCIRT PS and include a proprietary stormwater treatment device (flood storage option 5 combined with WQ option 7)
- Option 7: Construct a new basin in Bexley Park to provide flood storage and street-scale rain gardens (flood storage option 4 combined with WQ option 5)
- Option 8: Construct a new basin in Bexley Park to provide flood storage and a proprietary stormwater treatment device (flood storage option 4 combined with WQ option 7)

A comparative cost estimate was undertaken for these options and these options were also included in the MCA.

The location of the combined flood attenuation storage and water quality enhancement options are presented in Appendix B.

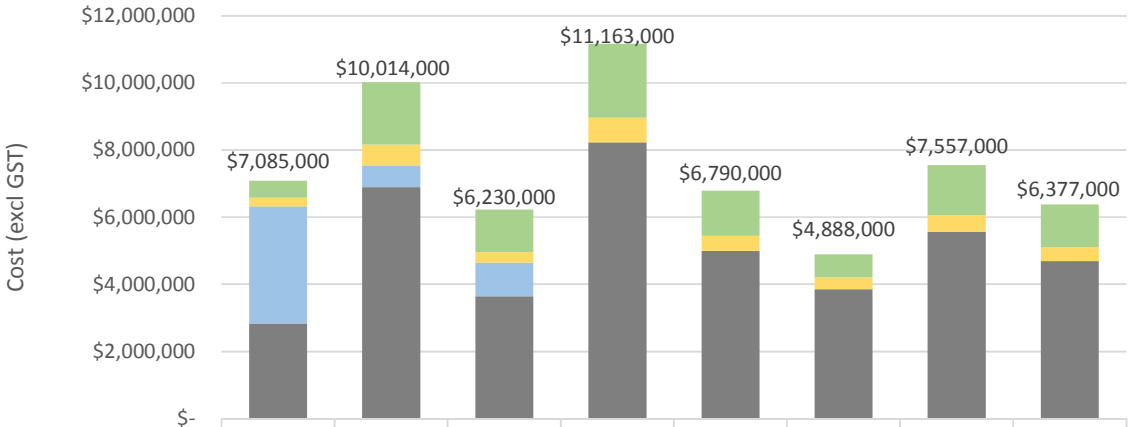
6 Comparative Cost Estimates

6.1 Summary

Preliminary project capital cost estimates were prepared for each of the upgrade options for the purposes of undertaking a comparative cost assessment.

The capital cost estimates for all options are shown graphically in Figure 1. The cost for each option has been separated into construction, land acquisition, preliminary and general, and contingency.

Figure 1 Comparative Capital Cost Estimates



	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Contingency	$505,000	$1,849,00	$1,268,00	$2,203,00	$1,340,00	$689,000	$1,492,00	$1,259,00
P&G (10%)	$253,000	$617,000	$317,000	$735,000	$447,000	$345,000	$498,000	$420,000
Land Aquistion	$3,500,00	$646,000	$1,000,00	$-	$-	$-	$-	$-
Construction Cost	$2,827,00	$6,902,00	$3,645,00	$8,225,00	$5,003,00	$3,854,00	$5,567,00	$4,698,00

6.2 Rates Development

In order to develop comparative preliminary cost estimates for each option, base rates were built up to cover each component of the work. These rates were then applied to the assessed quantities for each option in order to develop the preliminary cost estimates.

The general approach taken to developing the base rates was:

- Pipes and other stormwater infrastructure
  - Tender rates available from recent contracts used to derive selected rate
- Bulk Earthworks
  - Tender rates from recent contracts used to derive selected rates. This includes the rate to dispose potentially contaminated material from land fill sites to Kate Valley landfill
- Miscellaneous Items
  - Rates for miscellaneous and specialist items (e.g. geosynthetic clay liners, proprietary stormwater treatment device and demolishing existing residential dwellings etc) based on advice from suppliers and contractors
  - The cost to purchase existing residential dwellings bounded by Pages Road, Anzac Drive and Knights Drain was provided by Council at $3.5M
  - The cost to purchase existing undeveloped residential land from private land owners and red zone land from the Crown was estimated based on typical rateable land values in the Wainoni area and increased by 10% above 2016 rateable land values
  - The cost to upgrade the existing Knights Drain and new pump station was based on previous cost estimates undertaken by Jacobs in the Knights Drain catchment
  - The cost to construct street-scale rain gardens was based on previous rain garden construction costs in the city that were provided by Council

- % allowance added for P&G, contingency and professional fees (design, resource consents, building consents, procurement, construction management, etc). The P&G and consulting/ consenting costs have been assumed to be 10% of the construction costs. A contingency of either 20%, 30% or 40% was adopted for each of the options to reflect the level of uncertainty and risk associated with the different options. Option 1 and Option 6 have a 20% contingency. Option 3 has a 40% contingency associated with uncertainties in the cost of constructing infrastructure in the crown owned red zone. The remaining options have a 30% contingency which is typically associated with constructing stormwater infrastructure in existing land fill HAIL sites

The rates used in developing the cost estimates are considered to be appropriate for the purposes of undertaking a preliminary cost comparison between the various options being considered.

6.3 Limitations

The cost estimates were prepared for the purposes of allowing a high level comparative assessment of the various options and should not be relied upon to provide an estimate of the likely total project cost of any option.

Aurecon has taken all reasonable care to derive cost estimates based on recent contract rates, information provided by suppliers and experience with similar projects.

7 Multi Criteria Analysis

7.1 What is MCA?

Multi-Criteria Analysis (MCA), sometimes referred to as Multiple-Criteria Decision Analysis, is used in decision making where a range of possible outcomes or options can be described with respect to a series of quite different assessment criteria. It is a technique that can be used in technical and non-technical settings where typically multiple conflicting criteria are evaluated in making decisions.

Structuring complex problems well and considering multiple criteria explicitly lead to more informed, robust and better decisions. Typically a unique optimal solution does not exist. Rather, it is necessary to use judgement and preferences to differentiate between solutions. Quite often there is a 'trade-off' between the various option assessment criteria. For these reasons the MCA process is well suited to a consensus approach to group decision making particularly involving expert technical panels that are well versed in the problem at hand.

Commonly in multiple criteria problems some criteria will be more important than other criteria in assessing the value of the alternative solutions. To bring the assessment criteria into a common assessment base the MCA process allocates weightings to the various criteria. There are many different ways to allocate weightings but one common technique is called the 'analytical hierarchy process' or AHP. Essentially the AHP process orders assessment criteria in a hierarchy from most important to least important and then uses this hierarchy, through comparative pairings, to establish the level of preference of one criterion over those criteria below it in the hierarchy. This process allocates numerical weightings to all the criteria.

Once all the criteria are weighted each of the solution options is assessed against the weighted criteria creating a *weighted value assessment,* and thus an overall ranking, for each option.

7.2 Application

The MCA process described above is most useful where teams of people are working on complex problems involving human perceptions, preferences and judgements. Typical applications include making a choice within a set of defined alternatives, ranking within a set of alternatives from most to least preferable or assessing the relative merit (the scale of the value) within a set of options. The process is rigorous, structured and robust and analyses complex problems within a consistent value based framework.

7.3 MCA Analysis for the Knights Drain Catchment

7.3.1 Purpose

The purpose of this MCA Workshop was to assess the various options being considered, across a range of criteria and recommend a preferred option to improve flood storage and provide water quality enhancement in the Knights Drain catchment.

7.3.2 Methodology

The MCA process considered financial or cost based assessment criteria alongside non-monetary qualitative or technical criteria. To ensure an initial focus on assessing the value and technical or operational quality of the various options under consideration the approach was to separate the value assessment process from the cost assessment process. The monetary aspects are assessed at the end of the MCA process.

The following steps were followed:

Step 1: Identifying and prioritising the assessment criteria

Possibly the most important step in the MCA process was identifying the key criteria that would best describe the value of each option (noting some option groups can be quite diverse in their make-up) and then ordering the criteria from highest to lowest priority. Identifying the assessment criteria was undertaken by a panel of specialists well versed in the technical, qualitative and operational aspects of the project as well as the range of possible options. Investigation work was undertaken prior to the MCA assessment workshop to properly define the likely assessment criteria candidates which were confirmed, added to and prioritised in the workshop.

Step 2: Weighting the assessment criteria

Once the assessment criteria were agreed and ordered (essentially putting greater priority on those assessment criteria higher up the hierarchy) the relative weight of each assessment criteria was then assessed. This was done through an application of the 'analytical hierarchy process' or AHP. The particular incarnation of the AHP applied uses the following paired comparison process.

Each assessment criterion was progressively compared with assessment criteria lower in the hierarchy and at each paired comparison the assessment team was asked to identify to what degree the higher order criterion was preferred over the lower order criterion using the table shown in . Using this table, where there was a 'major preference' for the higher order criterion over the lower order criterion a 4 was allocated and where there was 'no preference' a 1 was allocated and similarly with a 'medium preference' and a 'minor preference'. This step was completed by progressively working through the Assessment Criteria pairings. The Dashboard then automatically calculated the weightings of all Assessment Criteria to the base 10.

Figure 2 Preferencing and Rating Criteria

Assessment Criteria Preference Measurement		Rating against Assessment Criteria	
4	Major Preference	1	Poor
3	Medium Preference	2	Fair
2	Minor Preference	3	Good
1	No Preference	4	Very Good
		5	Excellent

Step 3: Assessing the options

Once all the Assessment Criteria were 'weighted' the assessment team rated each of the Options against the weighted Assessment Criteria using the rating variables shown in . For example, one represents a 'poor' response to the criteria through to a five which represents an 'excellent' response to the criteria.

The assessment team worked through each criterion assessing each Option against that criterion and then moved to the next criterion. The MCA Dashboard automatically calculated the Weighted MCA Score for each option and allocated an overall ranking.

Step 4: Mapping MCA value score versus cost

The MCA Dashboard generally uses Net Present Values (NPV) in establishing the cost of each option. Because the ongoing costs for the options were not known the options were compared using capital costs.

The cost assessment was prepared prior to the MCA workshop and recorded on an independent spreadsheet and then 'switched' into the MCA Dashboard Value for Money Chart once the MCA Value Scores had been established. As depicted in Figure 3 the Value for Money Chart graphically represents the relative cost-benefit value of each Option in one chart. Options with a high MCA Score and a low cost provide the best value Options i.e. the top left corner of the Chart and vice versa.

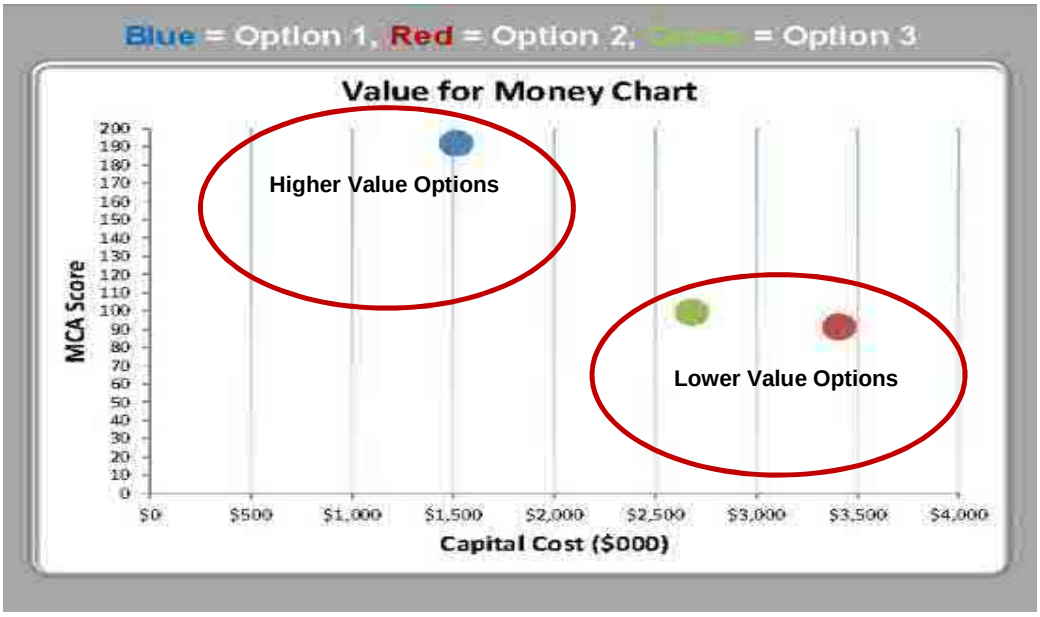
Step 5: Sensitivity Analysis

As a means of 'truthing' the analysis and assessments done in the above steps it is important to test the assumptions, priorities and preferences captured in the Dashboard with various types of sensitivity analysis. An important feature of a MCA assessment is that any entry, rating or preference can be adjusted at any time until the assessment team has fully tested and confirmed the outcomes of the assessment. The sensitivity analysis typically involves:

- Re-ordering, re-preferencing or adding new Assessment Criteria
- Testing the impact of removing Assessment Criteria from the assessment
- Reviewing and testing alternative cost data assumptions
- Adding and testing new Options

The MCA Dashboard is a flexible and interactive tool that allows for the quick assessment of 'What if?' queries. Importantly the Dashboard does not provide a decision on an option selection but rather provides robust and structured advice into the decision making process.

Figure 3 Typical Value for Money Chart



7.3.3 Assessment Team

The assessment team (which met on 5 April 2017) included the following members:

- Tom Parsons, Graham Harrington, Karissa Hyde, Peter Wehrmann, Mark Mullen, Barry Woodland – Christchurch City Council
- Mark Stone (MCA Facilitator), Regan Smith, Gareth Bailey – Aurecon

The assessment team was well versed in the Knights Drain catchment stormwater network being upgraded, the existing flooding issues and the various flood storage and water quality enhancement options being considered.

7.3.4 Options Description

For the purpose of the MCA analysis, the options were identified by the following brief descriptions:

Option 1: Storage/treatment in triangular area

Option 2: Storage/treatment to North-west of Knights Pond

Option 3: Storage/treatment in Red Zone

Option 4: Storage/treatment in Bexley Park

Option 5: Upgrade SCIRT PS and Rain Gardens for Treatment

Option 6: Upgrade SCIRT PS and proprietary SW treatment device

Option 7: Basin in Bexley Park and Rain Gardens for treatment

Option 8: Basin in Bexley Park and proprietary SW treatment device

7.3.5 Defining and Prioritising Assessment Criteria

Prior to the workshop, a draft list of potential criteria was circulated for comment.

The draft list of assessment criteria was as follows:

Figure 4 Pre Workshop List of Assessment Criteria

Resilience
Constructability
Ease of implementation / disruption
Operations and maintenance
Non-drainage values

The first task during the workshop was to review the above list and confirm the final list of non-priced attributes (Assessment Criteria) that represent the key issues for consideration.

One Assessment Criteria was added to the pre workshop list being “Water Quality (WQ) outcomes”.

The “Constructability” and “Ease of Implementation” Assessment Criteria were combined and “Disruption” included as an independent Assessment Criteria.

There was also a change in the order of the criteria with some criteria being elevated to give them a greater weighting.

The final agreed list of assessment criteria, in order, was as follows:

Figure 5 Final Value Criteria

Resilience
WQ outcome
Non-drainage values
Operations and maintenance
Constructability / Ease of implementation
Disruption

To expand upon the brief descriptions in Figure 5 above.

Resilience:
This includes resilience against ongoing flooding, resilience against climate change impacts such as sea level rise and resilience against future seismic events. The Resilient Greater Christchurch Plan identifies earthquakes, flooding and sea level rise as acute and chronic shocks to greater Christchurch.

Water Quality (WQ) Outcomes:
This covers the level of stormwater treatment that is expected to be achieved with the proposed water quality device for each option. An objective of this investigation was to provide water quality outcomes in the Knights Drain catchment with reliable outcomes and this is covered by this assessment criteria.

Non-drainage Values:
This includes an assessment against the Council six values (ecology, culture, recreation, landscape, and heritage).

Operations and Maintenance:
This includes the ease at which the stormwater management areas can be operated and maintained. An objective of this investigation was to provide an outcome with low or infrequent maintenance and this is covered by this assessment criteria.

Constructability / Ease of Maintenance:
This covers site constraints, access to land, land acquisition and other non-flood assessment criteria.

Disruption (Traffic, private/public, local businesses)
This includes disruption caused by lane closures or complete road closures, the temporary loss of parking or access to private residences and to businesses, the temporary loss of use of public spaces and private land.

In prioritising the Assessment Criteria, the assessment team were conscious that the key requirements of this project are to increase flood storage, provide water quality enhancement with a reliable outcome and low or infrequent maintenance.

Safety was removed, not because it is not considered as important as any other criteria but because there were no options that had inherent risks or indeed advantages over other options from a safety perspective.

7.3.6 Weighting of Value Criteria

The assessment team used the methodology described in Section 0 above to undertake the weighting process for the Assessment Criteria (Refer Figure 6 below).

Figure 6 Criteria Weighting Summary

No.	ASSESSMENT CRITERIA	1	2	3	4	5	6	7	8	9	10
1	Resilience										
2	WQ outcome	2									
3	Non-drainage values	2	2								
4	Operations and maintenance	3	3	2							
5	Constructability / Ease of implementation	3	3	3	3						
6	Disruption (public and new infrastructure)	4	4	4	4	3					
7											
8											
9											
10											
	Preferencing Total	**14**	**12**	**9**	**7**	**3**	**1**	**0**	**0**	**0**	**0**
	Equalized (to 10) Preferencing Total	**10**	**9**	**7**	**6**	**3**	**2**	**0**	**0**	**0**	**0**

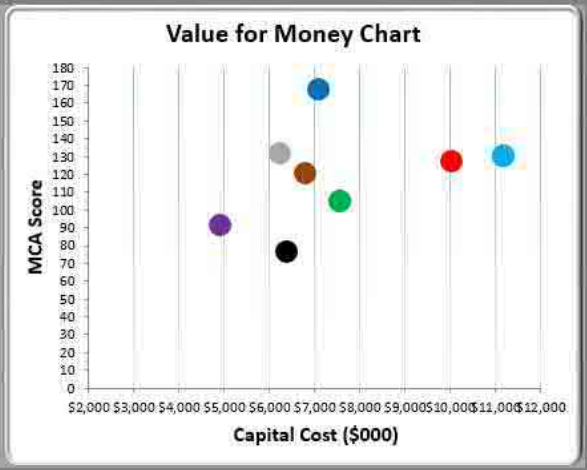
7.3.7 Assessing Options – MCA Scores

To establish the MCA Scores the assessment team applied the 1 to 5 rating for each Option against each Assessment Criteria as described in Section 7.3.2, with 1 being poor and 5 being excellent. (Refer Figure 7 below). This assessment provided the following MCA Scores and overall non-priced rankings:

Figure 7 MCA Rankings

PROJECT: Knights Drain Investigation

No.	ASSESSMENT CRITERIA	1	2	3	4	5	6	7	8	9	10
1	Resilience										
2	WQ outcome	2									
3	Non-drainage values	2	2								
4	Operations and maintenance	3	3	2							
5	Constructability / Ease of implementation	3	3	3	3						
6	Disruption (public and new infrastructure)	4	4	4	4	3					
7											
8											
9											
10											
	Preferencing Total	**14**	**12**	**9**	**7**	**3**	**1**	**0**	**0**	**0**	**0**
	Equalized (to 10) Preferencing Total	**10**	**9**	**7**	**6**	**3**	**2**	**0**	**0**	**0**	**0**



No.	OPTIONS	OPTIONS ASSESSMENT						WEIGHTED OPTIONS ASSESSMENT										TOTAL	RANK
1	Option 1: Storage/treatment in triangular area	5	5	5	5	2	4	50	44	34	28	6	7	0	0	0	0	167	1
2	Option 2: Storage/treatment to North-west of Knights Pond	2	5	4	5	1	4	20	44	27	28	3	7	0	0	0	0	128	4
3	Option 3: Storage/treatment in Red Zone	2	5	5	4	2	4	20	44	34	22	6	7	0	0	0	0	132	2
4	Option 4: Storage/treatment in Bexley Park	2	5	4	5	2	4	20	44	27	28	6	7	0	0	0	0	131	3
5	Option 5: Upgrade SCIRT PS & rain gardens for treatment	3	5	3	3	3	1	30	44	20	17	9	2	0	0	0	0	121	5
6	Option 6: Upgrade SCIRT PS & proprietary SW treatment device	3	3	1	2	5	2	30	26	7	11	15	3	0	0	0	0	92	7
7	Option 7: Basin in Bexley Park & rain gardens for treatment	2	5	3	3	1	1	20	44	20	17	3	2	0	0	0	0	105	6
8	Option 8: Basin in Bexley Park & proprietary SW treatment device	2	3	1	2	2	4	20	26	7	11	6	7	0	0	0	0	76	8

A summary of why the ratings were assigned by the assessment team as shown in Figure 7 is presented below:

- Options that provide excellent resilience against ongoing flooding, climate change impacts and future seismic events were assigned a rating of 5 for resilience. Only Option 1 achieved this rating as this is the only option that provides resilience against ongoing flooding and climate change impacts to existing low-lying residential properties in the Knights Drain catchment. All other options achieved a rating of either 2 or 3 depending on their resilience against future seismic events.
- It was assumed that a wetland/wet pond and rain garden would achieve an equivalent and overall excellent water quality enhancement outcome and therefore these options were all assigned a rating of 5 for water quality outcome. The two options that include proprietary stormwater treatment devices were assigned a rating of 3 for water quality outcome as these devices provide a good water quality outcome, but not as good as would be achieved with a wetland/wet pond or rain garden.
- It was assumed that all options with a wetland/wet pond for stormwater treatment would provide a very good or excellent non-drainage values outcome and therefore these options were assigned a rating of 4 or 5 for non-drainage values. Options with a rain garden were assumed to provide a good non-drainage values outcome, but not as good as a wetland/wet pond, and therefore these options were assigned with a rating of 3 for non-drainage values. Options with a proprietary stormwater treatment device provide limited non-drainage value benefit and were therefore assigned a rating of 1 for non-drainage values.
- It was assumed that all options with a single stormwater management area to provide increased flood storage in conjunction with water quality enhancement provide a very good or excellent operations and maintenance outcome and therefore these options were assigned with a 4 or 5 for operations and maintenance. Options that include devices in a number of locations (i.e. street-scale rain gardens) and options with proprietary stormwater treatment devices were assigned a rating of either 2 or 3 for operations and maintenance. A proprietary stormwater treatment device requires more frequent maintenance and their effectiveness is influenced by operational considerations.
- The lowest risk options from a constructability / ease of implementation perspective included upgrading the SCIRT PS, including a proprietary stormwater treatment device into the existing stormwater reticulation network, options with no land purchase and options that are not located in HAIL sites. These options achieved the highest rating for constructability / ease of implementation. Options that include land purchase / access and/or are located in HAIL sites achieved a lower rating of 1 or 2 for constructability / ease of implementation.
- It was assumed that all options with a single stormwater management area outside the road corridor would provide limited disruption and therefore these options were assigned a rating of 4 for disruption. Options with street-scale stormwater treatment devices were assigned a rating of 1 or 2 as these options provided a greater disruption to the community during construction and ongoing maintenance.

7.3.8 Value for Money

As discussed previously, Aurecon used Capital costs for cost comparisons in the MCA Dashboard.

The capital costs of each of the options considered is shown in Figure 8 below.

Figure 8 Option Costs

Option Costs & Values				
Option No.	Description	Weighted Value Assessment	Capital Cost ($,000)	Capital Cost ($M)
1	Option 1: Storage/treatment in triangular area	167	$7,085	$7.1
2	Option 2: Storage/treatment to North-west of Knights Pond	128	$10,014	$10.0
3	Option 3: Storage/treatment in Red Zone	132	$6,230	$6.2
4	Option 4: Storage/treatment in Bexley Park	131	$11,163	$11.2
5	Option 5: Upgrade SCIRT PS & rain gardens for treatment	121	$6,790	$6.8
6	Option 6: Upgrade SCIRT PS & proprietary SW treatment device	92	$4,888	$4.9
7	Option 7: Basin in Bexley Park & rain gardens for treatment	105	$7,557	$7.6
8	Option 8: Basin in Bexley Park & proprietary SW treatment device	76	$6,377	$6.4

These capital costs are represented in the Value for Money Chart shown in Figure 9 below.

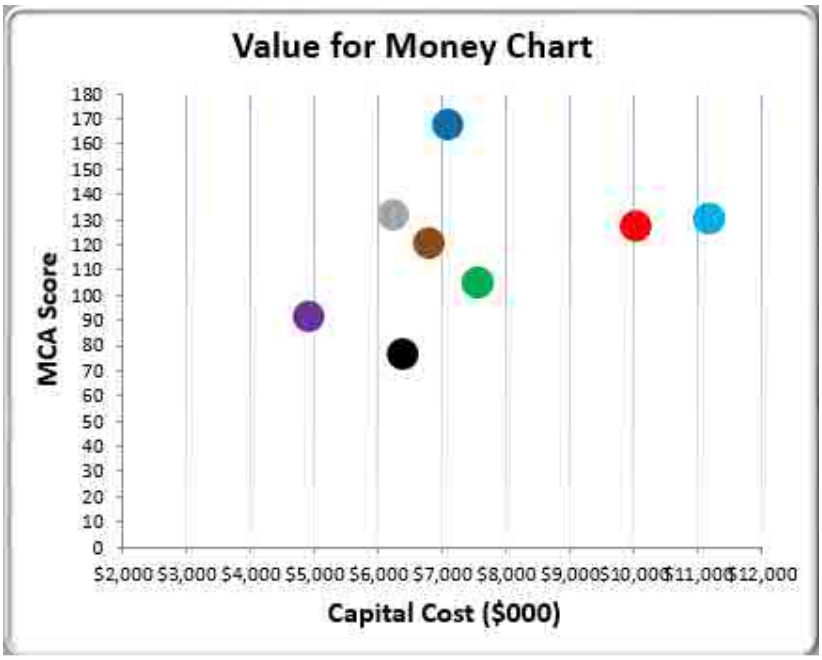
It can be seen from Figure 9 that Option 6 has the lowest capital cost but achieved a low overall MCA score and ranking based on the non-cost assessment criteria. Option 6 also scored poorly in the Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria as well as scoring lower than other options in the Resilience and Water Quality Outcome assessment criteria. Based on this Option 6 provides an overall 'low value' option and therefore is not recommended.

The most favourable options are Option 1 and Option 3. Neither of these two options have both the highest MCA Score and lowest capital cost.

Option 1 has the highest MCA Score and non-cost attribute ranking but has an estimated capital cost $0.9M above Option 3. Option 1 also achieved the highest ranking for Resilience and equal highest ranking for the Water Quality Outcomes, Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria.

Option 3 has the second highest MCA Score and ranking but has an estimated capital cost that is $0.9M lower than Option 1. Option 3 achieved the lowest ranking for Resilience and equal highest ranking for the Water Quality Outcome and Disruption assessment criteria.

Figure 9 Value for Money Chart



7.3.9 Sensitivity Analysis

It is always important in MCA processes to test the sensitivity of some of the assumptions and preferences made in the initial assessment.

Some testing was done during the MCA workshop, by changing the ratings of each option in response to particular assessment criteria but this resulted in little change to the individual rankings of each option and no change to the overall preferred option.

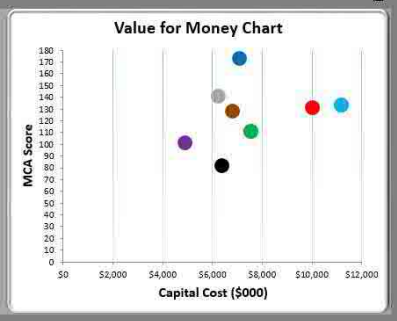
Towards the end of the workshop, a sensitivity analyse was undertaken with 'Cost' included as one of the assessment criteria. It was agreed that a cost assessment criteria would have a lower importance than most of the original criteria. The MCA was completed for the revised assessment criteria. The scoring was completed for whole of life costs, not just capital cost, so some options scored differently to the capital cost ranking e.g. option 6 has a low capital cost but higher operational cost.

The results of the assessment are shown in Figure 10 and confirm that the rankings and overall MCA outcomes remain unchanged when Cost is included as an additional assessment criteria.

Figure 10 Sensitivity Analysis (Cost included as Assessment Criteria)

PROJECT: Knights Drain Investigation

No.	ASSESSMENT CRITERIA	1	2	3	4	5	6	7	8	9	10
1	Resilience										
2	WQ outcome	2									
3	Non-drainage values	2	2								
4	Operations and maintenance	3	3	2							
5	Constructability / Ease of implementation	3	3	3	3						
6	Disruption (public and new infrastructure)	4	4	4	4	3					
7	Cost	3	3	2	1	2	1				
8											
9											
10											
	Preferencing Total	**17**	**15**	**11**	**8**	**5**	**1**	**1**	**0**	**0**	**0**
	Equalized (to 10) Preferencing Total	**10**	**9**	**7**	**5**	**4**	**2**	**2**	**0**	**0**	**0**



No.	OPTIONS	OPTIONS ASSESSMENT										WEIGHTED OPTIONS ASSESSMENT										TOTAL	RANK
1	Option 1: Storage/treatment in triangular area	5	5	5	5	2	4	3				50	45	34	26	7	6	5	0	0	0	**173**	**1**
2	Option 2: Storage/treatment to North-west of Knights Pond	2	5	4	5	1	4	2				20	45	27	26	4	6	3	0	0	0	**131**	**4**
3	Option 3: Storage/treatment in Red Zone	2	5	5	4	2	4	5				20	45	34	21	7	6	8	0	0	0	**141**	**2**
4	Option 4: Storage/treatment in Bexley Park	2	5	4	5	2	4	1				20	45	27	26	7	6	2	0	0	0	**133**	**3**
5	Option 5: Upgrade SCIRT PS & rain gardens for treatment	3	5	3	3	3	1	3				30	45	20	16	11	2	5	0	0	0	**128**	**5**
6	Option 6: Upgrade SCIRT PS & proprietary SW treatment device	3	3	1	2	5	2	4				30	27	7	10	18	3	6	0	0	0	**102**	**7**
7	Option 7: Basin in Bexley Park & rain gardens for treatment	2	5	3	3	1	1	3				20	45	20	16	4	2	5	0	0	0	**111**	**6**
8	Option 8: Basin in Bexley Park & proprietary SW treatment device	2	3	1	2	2	4	3				20	27	7	10	7	6	5	0	0	0	**82**	**8**

7.4 Conclusions and Recommendations from MCA Analysis

The purpose of the MCA Workshop was to assess the eight upgrade options being considered, across a range of criteria, and identify a preferred option to increase flood storage and provide water quality enhancement in the Knights Drain catchment.

The multi criteria analysis showed that whilst Option 6 has the lowest capital cost it achieved a low overall MCA score and ranking based on the non-cost assessment criteria. Option 6 also scored poorly in the Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria as well as scoring lower than other options in the Resilience and Water Quality Outcome assessment criteria. Based on this Option 6 provides an overall 'low value' option and therefore is not recommended.

The most favourable options are Option 1 and Option 3. Neither of these two options have both the highest MCA Score and lowest capital cost.

Option 1 has the highest MCA Score and non-cost attribute ranking but has an estimated capital cost $0.9M above Option 3. Option 1 also achieved the highest ranking for Resilience and equal highest ranking for the Water Quality Outcomes, Non-Drainage Values, Operations and Maintenance and Disruption assessment criteria. Option 1 requires the purchase of privately owned residential properties.

Option 3 has the second highest MCA Score and ranking but has an estimated capital cost that is $0.9M lower than Option 1. Option 3 achieved the lowest ranking for Resilience and equal highest ranking for the Water Quality Outcome and Disruption assessment criteria. Option 3 is dependent on gaining access to red zone land in a timely manner.

When cost was included as an assessment criteria for sensitivity, Option 1 was identified as the option with the highest MCA Score and ranking.

On the basis of the MCA workshop, Option 1 and Option 3 are the best value options. The value placed on long term resilience and the practicalities of gaining access to land for each option will influence the best option from these two.

Option 1 achieved the highest MCA score and ranking based on non-cost attributes, achieved the highest ranking for all MCA assessment criteria, has a similar capital cost as Option 3 and achieved the highest MCA score and ranking when cost was included as a MCA assessment criteria. On the basis of this, it is recommended that Option 1 provides the 'best value' option when assessed against the Council objectives and it is recommended that this option be taken forward for detailed design.

Although the results of the MCA analysis clearly identify two viable options, it is acknowledged that the MCA process is a tool to assist in the selection of a scheme to put forward for recommendation and that there may be other factors that influence the recommendation emerging from the workshop. Whilst the estimated capital cost of Option 3 is lower than Option 1, it is noted that there is less certainty around the design and associated cost for Option 3 than Option 1.

8 Summary and Recommendations

Introduction

The Council specified objective for the Knights Drain catchment is that, upstream of the new Knights Drain Pump Station there should be significantly improved flood attenuation storage and water quality enhancement that have reliable outcomes and low or infrequent maintenance.

SCIRT are currently constructing the new pump station but construction of the upstream attenuation pond assumed in their design is outside of their scope. Council is also committed to providing improvements in stormwater quality across the city as part of the Avon Stormwater Management Plan (SMP).

In order to meet this objective Council engaged Aurecon to undertake a robust options assessment and identification of a preferred option for provision of flood attenuation storage and water quality enhancement within a multi-values framework that includes assessment of reduction of any non-flood hazards.

Options Identification and Analysis

Existing constraints and opportunities within the Knights Drain catchment were identified and mapped.

A number of options to improve flood attenuation storage and provide water quality enhancement within the Knights Drain catchment were identified.

The potential options to improve flood attenuation storage and provide water quality enhancement within the Knights Drain catchment were then assessed against site constraints and opportunities, Council's six values and non-flood assessment criteria. This process identified a number of viable options to provide increased flood storage and water quality enhancement in the Knights Drain catchment.

Comparative Cost Estimate

Preliminary project capital cost estimates were prepared for each of the upgrade options for the purposes of undertaking a comparative cost assessment.

The lowest capital cost option is Option 6 with an estimated cost of $4.9M. Option 1 and Option 3 have an estimated cost of $7.1M and $6.2M respectively.

Multi Criteria Analysis

A MCA Workshop was completed for this project to assess the various options being considered, across a range of non-priced attribute criteria and recommend a preferred option to be taken forward for detailed design.

The multi criteria analysis revealed that Option 1 and Option 3 are the most favourable options. Option 1 has the highest MCA Score and non-cost attribute ranking but has an estimated capital cost $0.9M above Option 3. Option 3 has the second highest MCA Score and ranking but has an estimated capital cost that is $0.9M lower than Option 1. The value placed on long term resilience and the practicalities of gaining access to land for each option influences the recommendation of one of the two options.

Option 1 achieved the highest MCA score and ranking based on non-cost attributes, achieved the highest ranking for all MCA assessment criteria, has a similar capital cost as Option 3 and achieved the highest MCA score and ranking when cost was included as a MCA assessment criteria. On the basis of this, it has been concluded that Option 1 provides the 'best value' option when assessed against the Council objectives and it is recommended that this option be taken forward for detailed design.

9 Limitations

Aurecon has prepared this report in accordance with the project brief as provided. The scope of services, as described in this report, was developed with the Client. The contents of the report are for the sole use of the Client for the purpose of identifying a preferred option to increase flood storage and provide water quality enhancement in the Knights Drain catchment, and no responsibility or liability will be accepted to any other third party. Data or opinions contained within the report may not be used in other contexts or for any other purposes without our prior review and agreement.

In preparing this report, Aurecon has relied upon information provided by the Client and/or from other sources. Except as otherwise stated in this report, Aurecon has not attempted to verify the accuracy of completeness of this information. It has been assumed that this information is accurate and complete. If this information is subsequently found to be inaccurate or incomplete then it is possible that the findings from this investigation as expressed in this report may change.

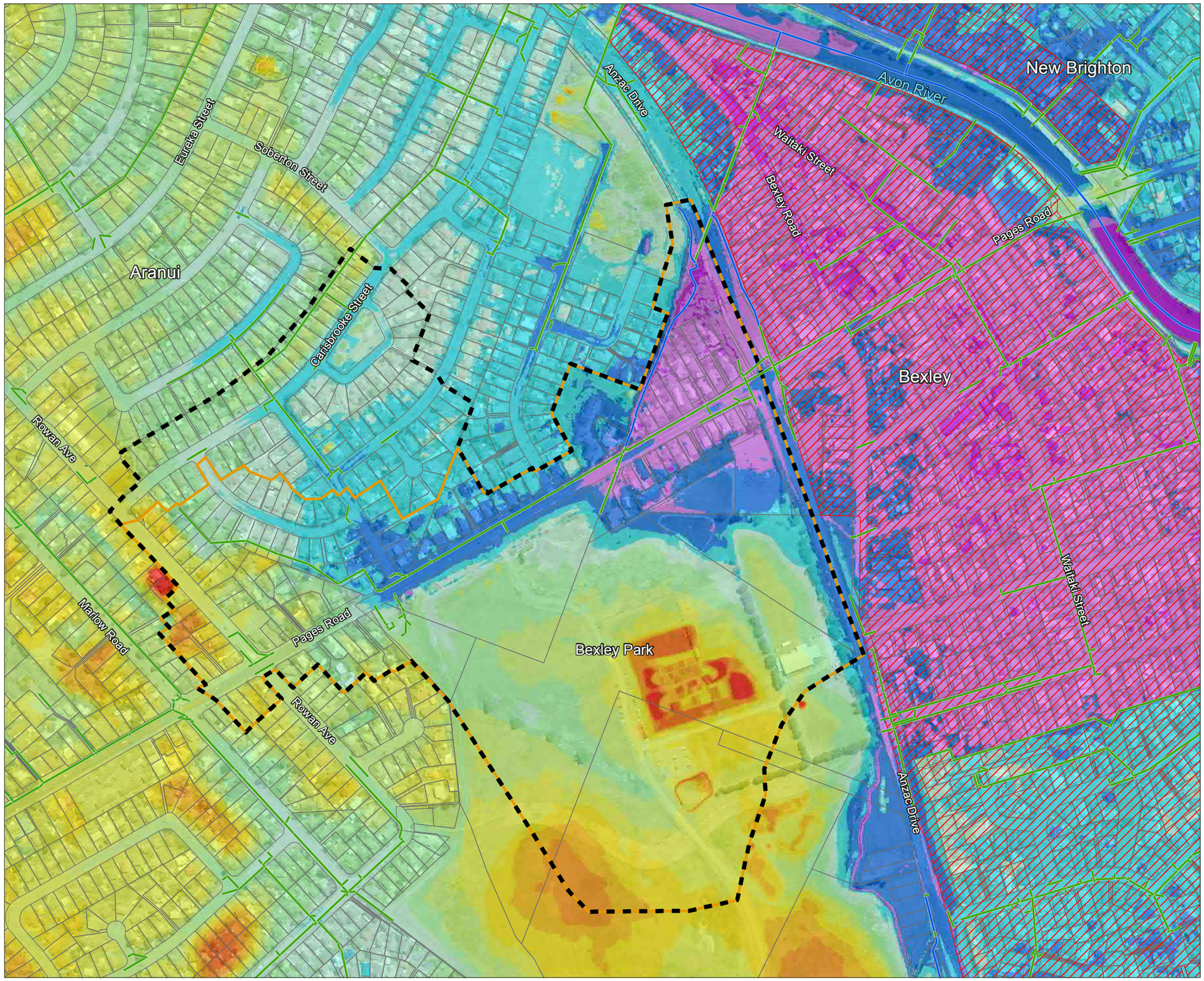
Subsurface conditions, such as groundwater levels, can change over time. This should be borne in mind, particularly if the report is used after a protracted delay.

The cost estimates presented in this report are comparative cost estimates based on a preliminary concept design of the options being investigated.

10 References

- *Knights Drain Ground Improvement Recommendations (GHD, 2016)*
- *Knights Drain Stormwater Management Preliminary Site Investigation and Groundwater Analysis (GHD, 2016)*
- *Site Appraisal: LDRP 509 Knights Drain Stage 1 - Archaeological Site A (2016)*
- *Knights Drain Issues, Options and Concept Report (Jacobs, 2015)*
- *Knights Drain Preliminary Geotechnical Appraisal Report (Jacobs, 2015)*
- *LDRP Lower Avon Consent Strategy (Jacobs, 2015)*
- *Knights Drain Geotechnical Assessment Report (Jacobs, 2016)*
- *Knights Drain Contaminated Land Preliminary Site Investigation (Jacobs, 2016)*
- *LDRP 509 SCIRT Pump station Developed Design Report 2016-08-01 (SCIRT, 2016)*
- *Aranui Knights Drain (SW) Geotechnical Assessment Report (SCIRT, 2016)*
- *Draft Knights Drain Facility Issues and Options report (Unknown, 2016)*
- *Lower Avon Aranui MIKE FLOOD Model and results (Jacobs, 2016)*
- *Resilient Greater Christchurch Plan (CCC)*
- *Waterways, Wetland and Drainage Guide (CCC, 2003)*
- *Christchurch City Council Infrastructure Design Standard (IDS)*
- *Christchurch City Council Construction Standard Specification (CSS)*
- *Rain Garden Design, Construction and Maintenance Manual (CCC, 2015)*

Appendix A
Constraints and Opportunities Maps



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Christchurch City Council

Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Elevation (m MSL)

- 0- 0.5
- 0.5 - 1
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- 5.5 - 6.0
- >6.0

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Map by: GB

\\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A1 Topography

A3 scale: 1:5,000

0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Date: 24/02/2017 Version: 1

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A1: Post Earthquake LiDAR

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Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Date: 24/02/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A2 SW Network.mxd

A3 scale: 1:5,000

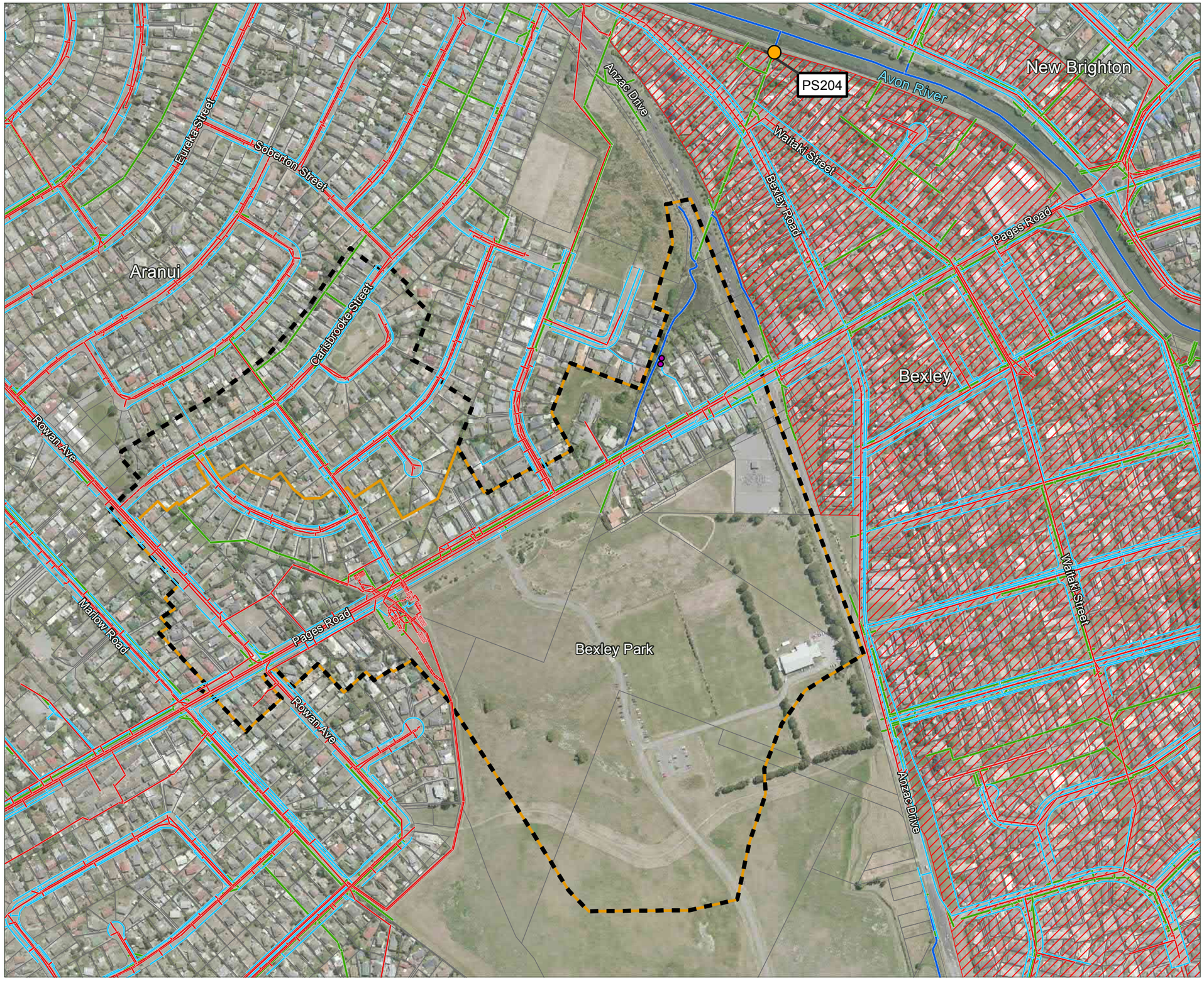
0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A2: Existing Stormwater Network



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Christchurch City Council

Legend

- Wastewater Pipes
- Water Supply Pipes
- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A3 Existing Services Network.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

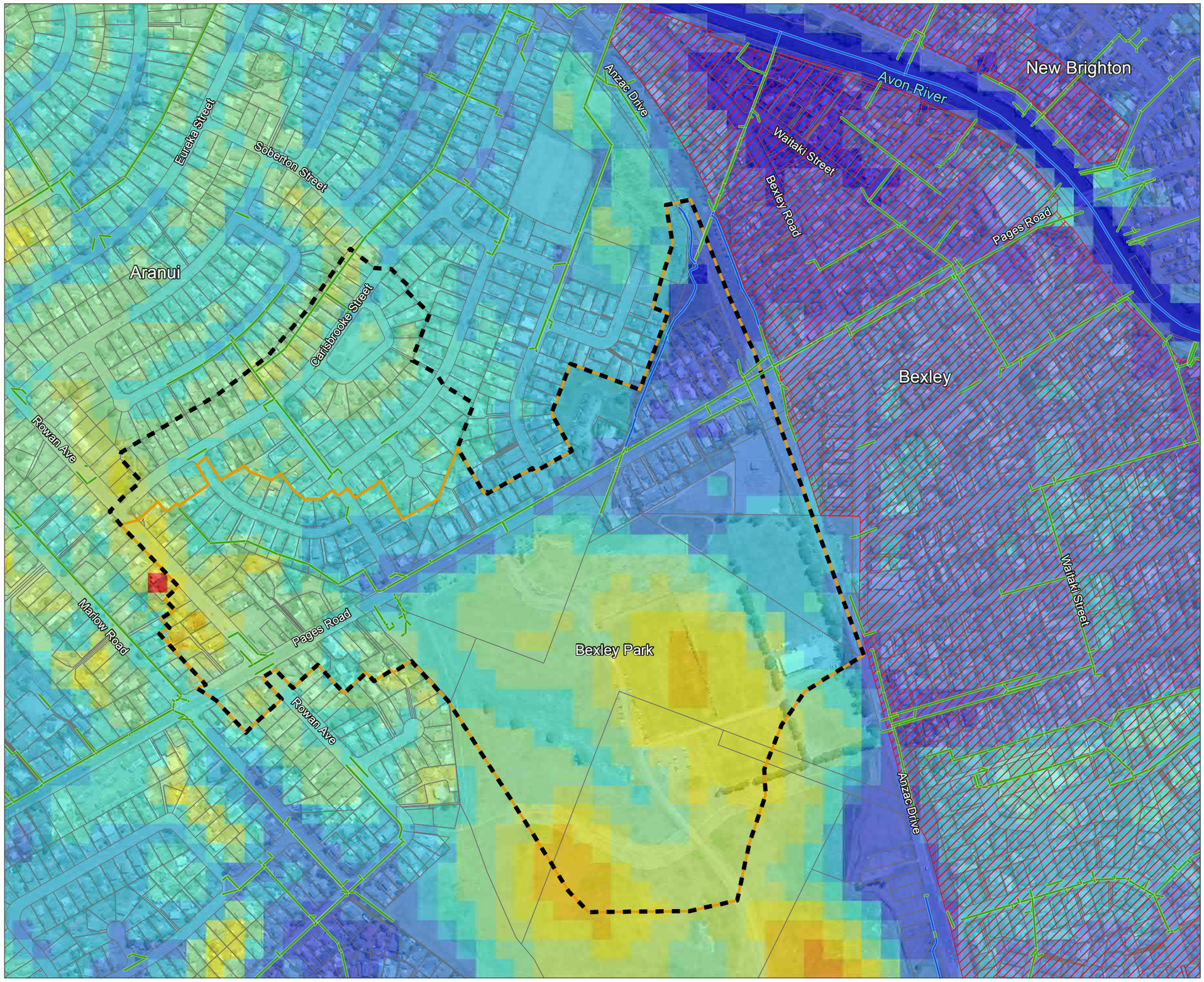
Job No: 255287

Projection: NZTM2000

Date: 24/02/2017 Version: 1

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A3: Existing Service Networks



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Christchurch City Council

Legend

- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Depth to Ground Water (m)

- 0.0- 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- >5.5

Notes:

1. Aerial photography and asset data provided by CCC
2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded
3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Date: 24/02/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A4 Depth to GW.mxd

A3 scale: 1:5,000

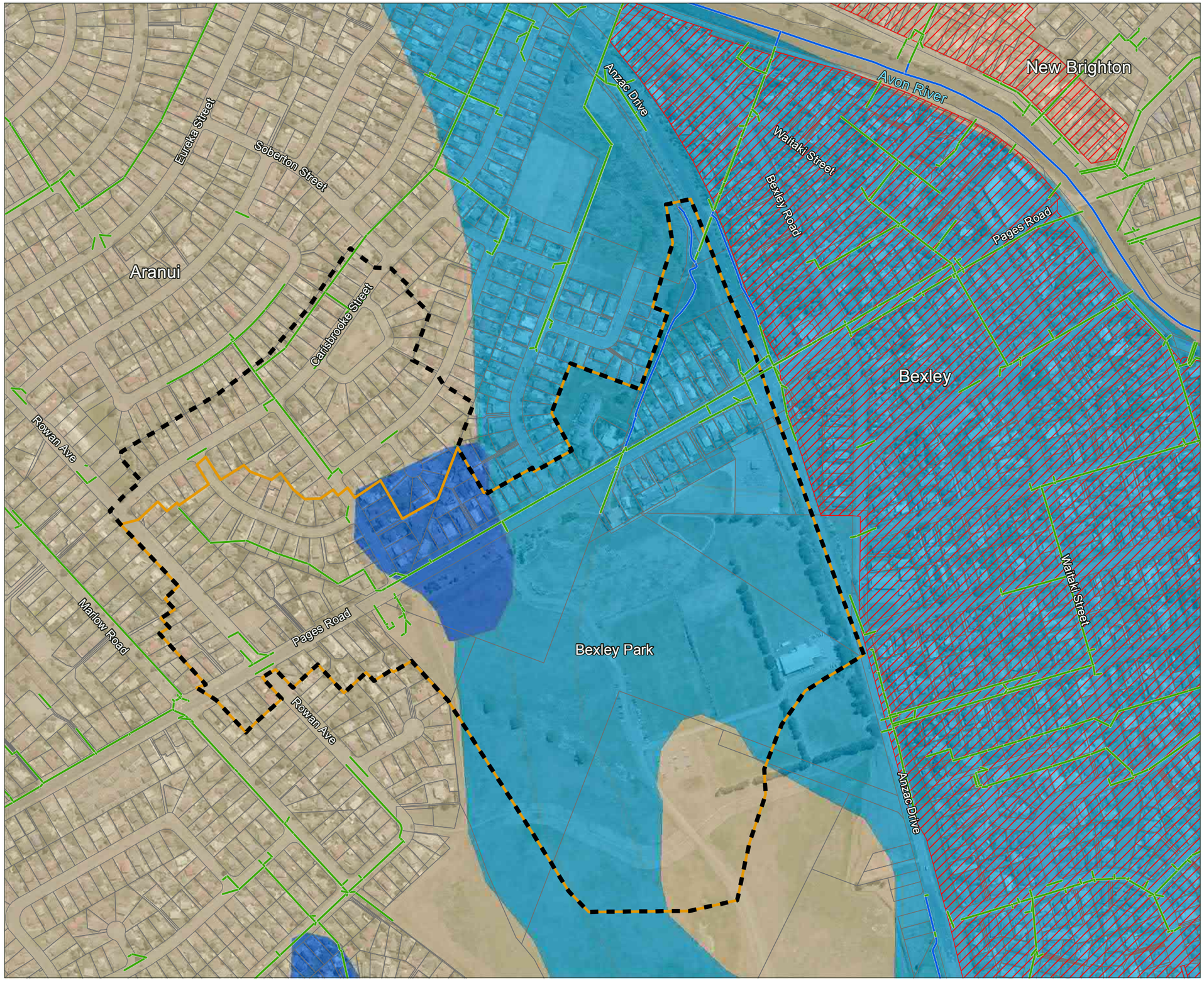
0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A4: Median Depth To Groundwater Level



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Legend

- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Soil Classification

- Well Drained
- Imperfectly Drained
- Poorly Drained
- Very Poorly Drained

Notes:

1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Map by: GB

\\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A5 Soil Drainage.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Date: 24/02/2017 Version: 1

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A5: Soil Drainage Potential

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Legend

- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Depth (m)

- >1.00
- 0.75 - 1.00
- 0.50 - 0.75
- 0.25 - 0.50
- 0.10 - 0.25
- 0.05 - 0.10
- 0.00 - 0.05

Notes:

1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

4. Flooding information shown on this map corresponds to the 2% AEP 1 hr design event. This flood modelling was undertaken by Jacobs.

Date: 24/02/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A6 Q50 Post EQ Flood Event.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A6: 2% AEP Post EQ Flood Event

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Legend

- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Current Land Use

- Business 4 (Suburban Industrial)
- Cultural (Schools)
- Living 1 (Outer Suburban)
- Living 2 (Inner Suburban)
- Open Space 1 (Neighbourhood)
- Open Space 2 (District)

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A7 Current Land Use.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Date: 24/02/2017 Version: 1

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A7: Current Land Use Zoning

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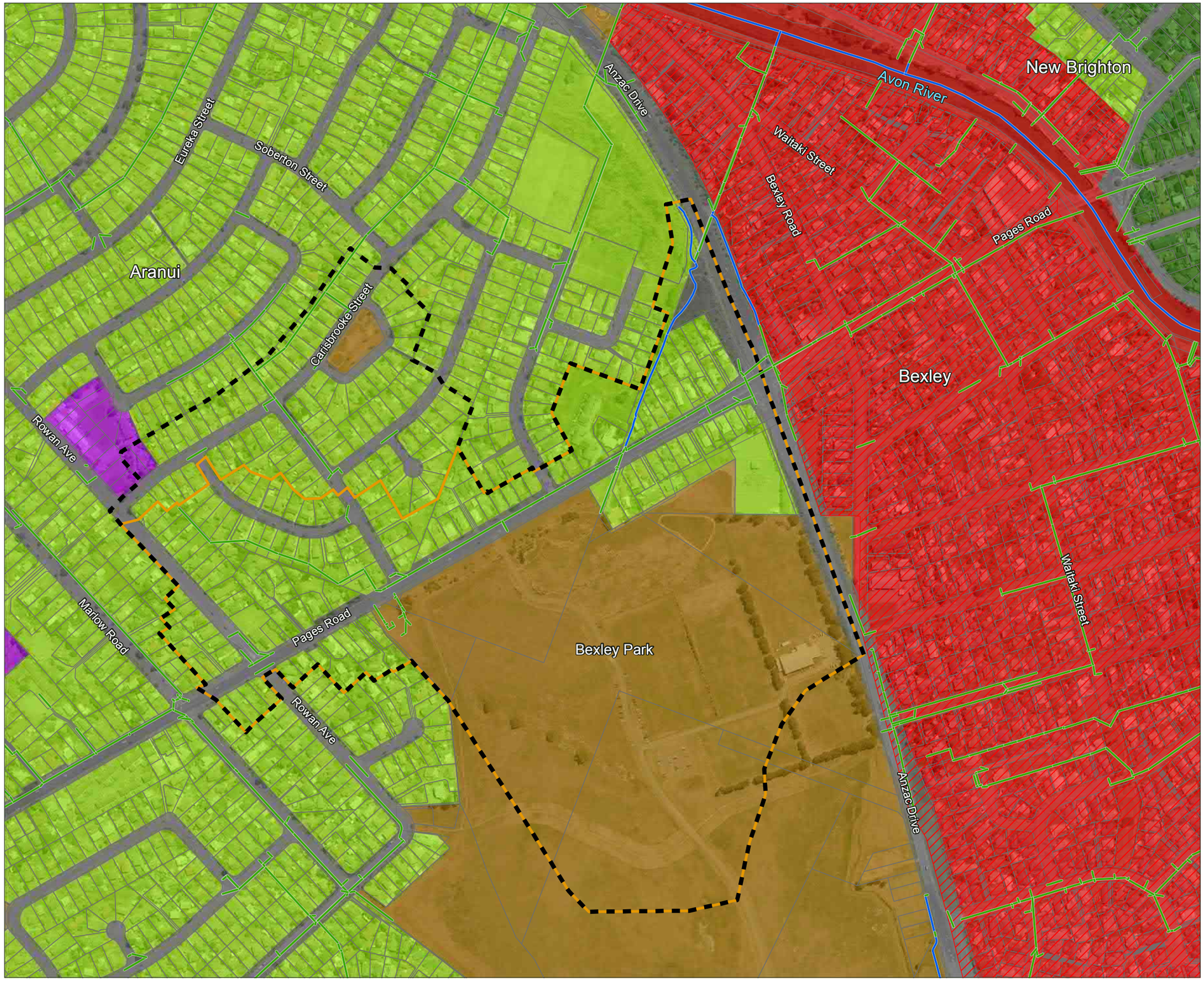
Christchurch City Council



Legend

- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

ZoneType

- Open Space Community Parks
- Residential Suburban
- Residential Suburban Density Transition
- Specific Purpose Flat Land Recovery
- Specific Purpose School
- Transport

Notes:

1. Aerial photography and asset data provided by CCC
2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded
3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices
4. The data shown on this map is from the revised district plan and is currently being incorporated into the next city zoning plan

Date: 24/02/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A8 Future Land Use.mxd

A3 scale: 1:5,000

0 50 100 150 200m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A8: Future Land Use Zoning

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Christchurch City Council

Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Topographical Catchment
- Water Quality Catchment
- HAIL Sites

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

4. This map presents HAIL sites from the ECan LLUR

Date: 14/03/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig A9 HAIL Sites.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

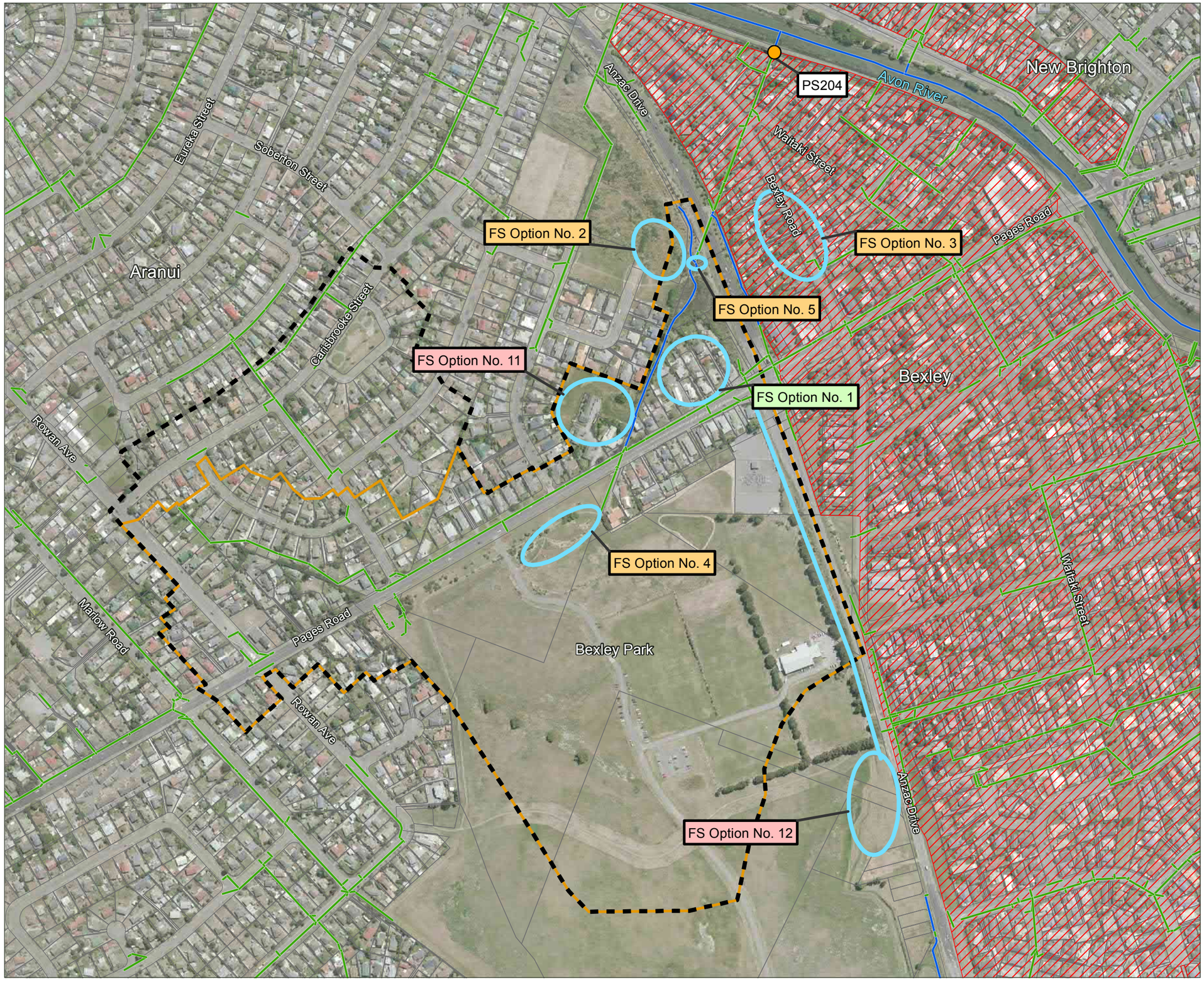
Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure A9: HAIL Sites

Appendix B
Option Location Maps



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Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

4. This figure only presents Flood Storage Options from Table 1 with a fixed geographical location. All other Flood Storage Options are not shown.

Date: 10/05/2017 Version: 2

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig B1 Flood Storage Options.mxd

A3 scale: 1:5,000

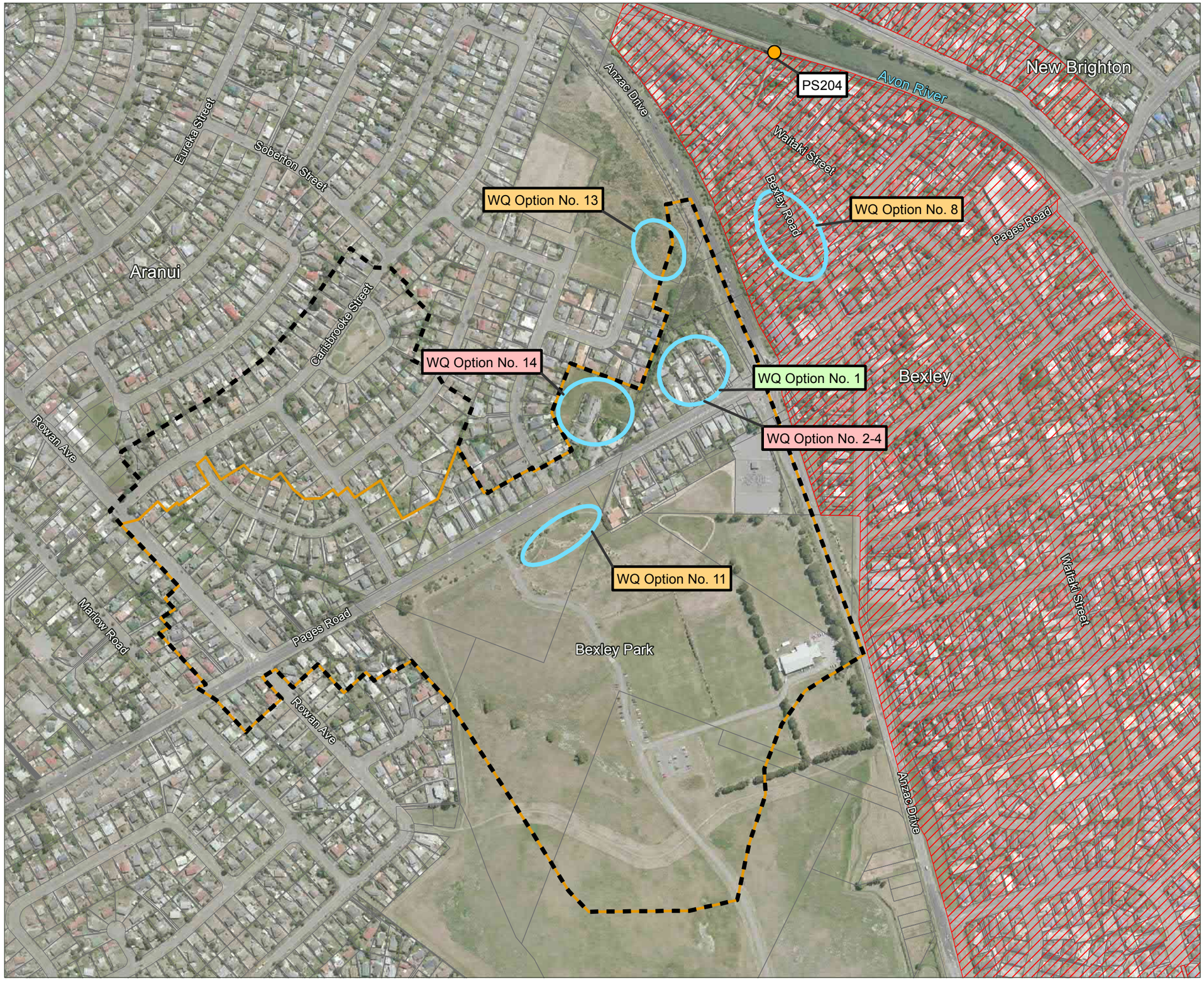
0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure B1: Flood Storage Options



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Christchurch City Council

Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

4. This figure only presents Water Quality Options from Table 2 with a fixed geographical location. All other Water Quality Options are not shown.

Date: 10/05/2017 Version: 2

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig B2 Water Quality Options.mxd

A3 scale: 1:5,000

0 50 100 150 200m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure B2: Water Quality Options

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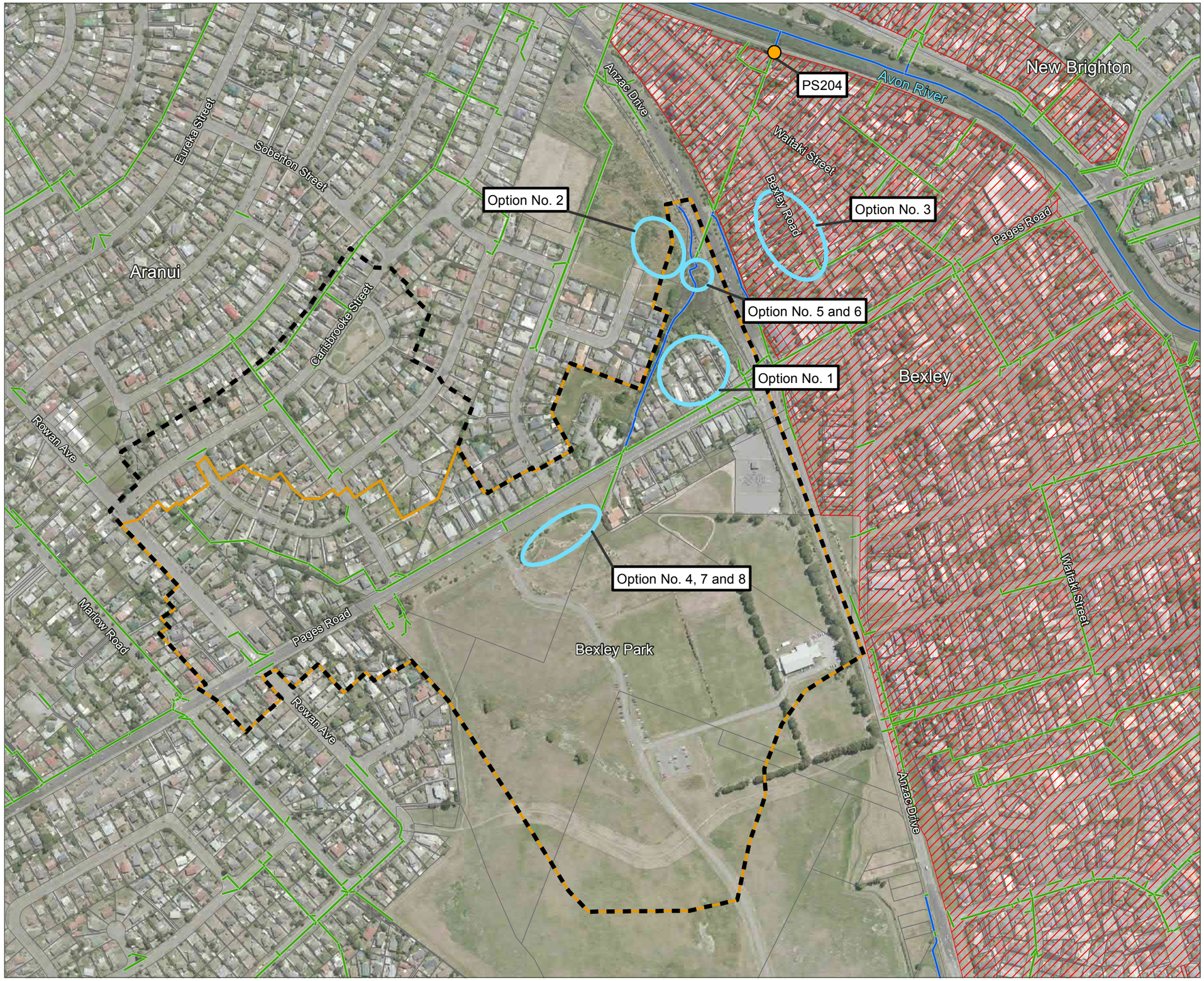

Legend

- Stormwater Pipes
- Waterway
- Cadastral Boundary
- Red Zone
- Topographical Catchment
- Water Quality Catchment

Notes:
1. Aerial photography and asset data provided by CCC

2. The topographical catchment represents the area draining to Knights Drain when the piped stormwater network capacity is exceeded

3. The water quality catchment represents the piped stormwater network catchment area that will drain to stormwater treatment devices

4. Street scale rain gardens and proprietary treatment device locations not shown for Options 5 to 8

Date: 10/05/2017 Version: 1

Map by: GB \\aurecon.info\shares\NZCHC\Projects\255287 - LDRP Knights Drain\GIS\ Fig B3 Combined Options.mxd

A3 scale: 1:5,000

0 50 100 150 200 m

Job No: 255287

Projection: NZTM2000

Christchurch City Council LDRP 509: Knights Drain Investigation

Figure B3: Combined Flood Storage and Water Quality Options

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Swaziland, Tanzania, Thailand, Uganda,
United Arab Emirates, Vietnam.