WIGRAM BASIN UPGRADE – RETROFITTING AN EXISTING BLUE-GREEN ASSET

Kate Purton (Beca Ltd) & Peter Christensen (Christchurch City Council)

ABSTRACT (500 WORDS MAXIMUM)

Wigram Basin is located in Canterbury Agricultural Park, Christchurch, on the Paparua Stream just upstream of its confluence with the Ōpāwaho/Heathcote River. The original Wigram Retention Basin was constructed in 1993 primarily as a flood retention basin, but included a wet pond for treatment. The design anticipated changes in the catchment over time and included concept design for future additional treatment and storage.

Since the basin was constructed the upstream catchment developed, with industrial and residential developments and the construction of the Christchurch Southern Motorway just upstream of the site. The impervious area and contaminant load in the catchment have increased, with the upstream waterway having some of the worst water quality in Christchurch.

The development of the adjacent site into the Ngā Puna Wai Sports Hub provided an opportunity to excavate material from Wigram Basin site and fill the Ngā Puna Wai site, providing significant cost savings and enabling the basin upgrade project.

The Wigram Basin Upgrade Project, currently under construction, involves modifying the existing basin to provide additional flood storage and add 3.4 hectares of wetland for treatment. The project is part of a wider Ōpāwaho/Heathcote River floodplain management programme of works to mitigate downstream flooding which worsened as a result of changes to drainage patterns following the Canterbury Earthquake Sequence. The project also contributes to another key community aspiration which is to improve water quality in the river.

The drive for additional storage and treatment needed to be balanced with the existing environment, land use and stakeholders. Canterbury Agricultural Park, within which the basin sits, is used by multiple stakeholders for a range of activities including horse riding, polo and the Agricultural & Pastural (A & P) show, as well as walking, running and cycling. The original Wigram Basin project included landscaping/planting at the wet pond margins and around the wet pond, as well as a network of walkways. Over time the plants have become well established (creating important habitat for birds), fish have established in the basin, and the walkways have become popular.

This paper discusses how the project balanced these needs to achieve a successful outcome, with innovative design and a collaborative effort from a multi-disciplinary client and consultant team.

KEYWORDS

Flood storage, retrofit, wetlands, wet pond, water quality, multi-disciplinary

PRESENTER PROFILE

Kate Purton is a Senior Associate – Civil Engineering, at Beca, with over 18 years' experience in three waters civil engineering. Kate is based in Christchurch and focuses on stormwater management and engineering, working on projects in Canterbury and around the country.

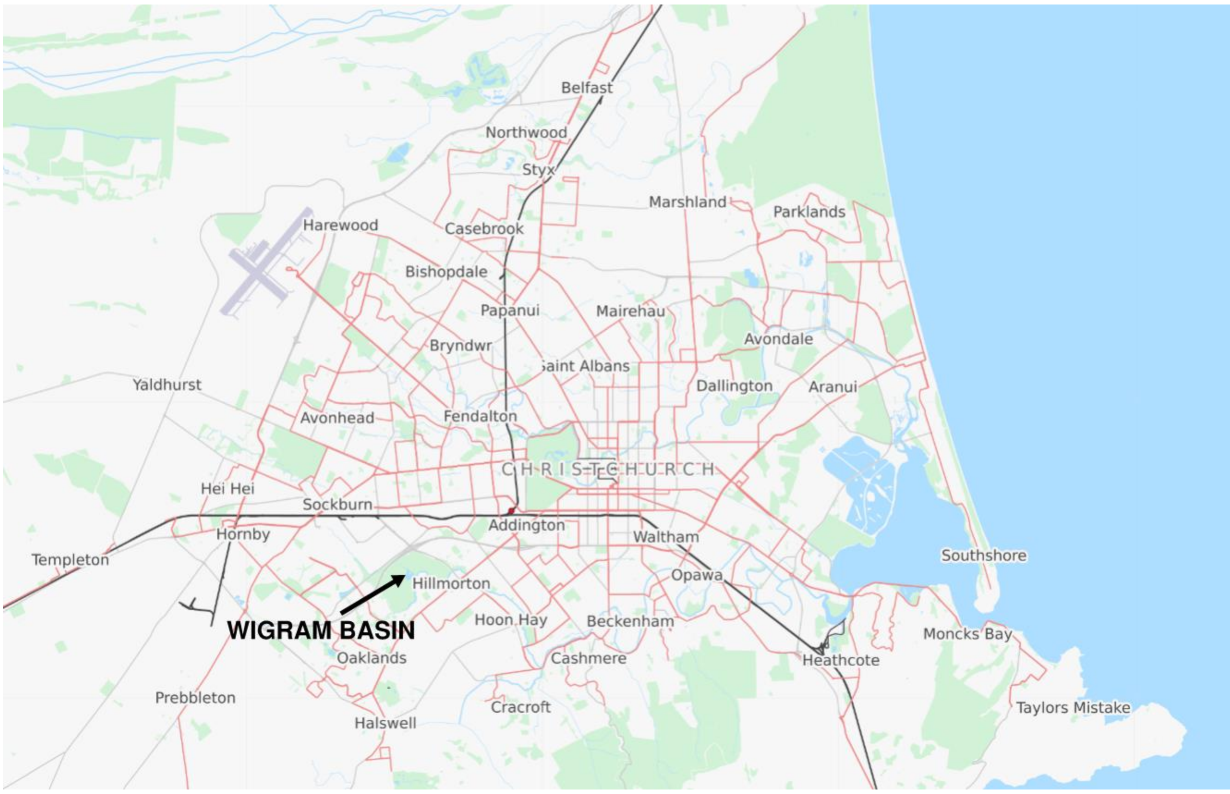
1 INTRODUCTION

The Wigram Basin Upgrade Project, currently under construction, involves modifying the existing basin to provide 220,000 m³ additional flood storage and add 3.4 ha of wetland for stormwater quality treatment.

The Wigram Basin is on the Paparua Stream (formerly Haytons Road Drain or Haytons Stream) immediately upstream of its confluence with the Ōpāwaho/Heathcote River, and discharges into the Ōpāwaho/Heathcote River.

This paper explores the history of the basin, the triggers for the upgrade, and the innovative design of the retrofit.

Figure 1: Location Plan



2 HISTORY

2.1 WATERWAYS WETLANDS / SIX VALUES APPROACH

In early 1990s, the new Christchurch City Council (formed in 1989 from the amalgamation of the Christchurch Drainage Board and several existing district councils), adopted a new approach to surface water management. This new approach, moved away from the traditional focus on drainage, and towards a more multi-disciplinary approach to surface water management considering six 'values' (ecology, landscape, recreation, heritage, culture and drainage).

The original Wigram Basin design was an early example of this six values approach.

The Council's Waterways, Wetlands and Drainage Guide, first published in 2003, provides more detail on this approach.

2.2 ORIGINAL BASIN DESIGN

The original basin was designed in 1992 and constructed in 1993, primarily as a flood retention basin but also to provide stormwater quality treatment. It consisted of:

- A 2.6 ha online wet pond with 22,000 m³ of permanent water volume
- A control structure at the wet pond outlet, with a 750 mm diameter outlet pipe to the Ōpāwaho/Heathcote River
- An adjacent dry basin, which the wet pond spills to in larger events, providing an additional 135,000 m³ storage (up to embankment level) for up to the 2% AEP event
- An embankment around the dry basin, with 20 m spillway to the Ōpāwaho/Heathcote River for over-design events.

The design included an HDPE liner under the wet pond base, and silt liner around the margins, to keep water in the pond and to meet Regional Council requirements to keep permeability to a minimum. A period of high groundwater led to issues with the HDPE liner floating during construction, and an underdrainage system was added.

The design also included extensive landscape plantings, described in the design as five types or zones: submerged macrophytes (naturally established); emergent plants; amphibious sward; swamp shrubland; and kanuka woodland. The emergent plants and amphibious sward were designed to trap sediment and improve nutrient removal, with the swamp shrubland and kanuka woodland providing a buffer. The planting was also to provide habitat for wildlife and a link to the Ōpāwaho/Heathcote River riparian plantings.

The design anticipated development in the catchment leading to increased runoff and contaminant loads and included a concept design for adding further treatment (a sediment forebay and a primary wet pond) upstream of the basin, converting the basin to a secondary wet pond.

3 CHANGES OVER TIME

3.1 CATCHMENT DEVELOPMENT

Since the design and construction of the basin in the mid-1990s the catchment has changed with new residential and commercial/industrial development in the lower part of the Paparua Stream/basin catchment, increasing impervious areas and contaminant loads.

There has also been development in the upper part of the catchment discharging to soakage, effectively reducing the catchment size in small events, although in larger events, when the capacity of the soakage systems is exceeded, these areas will still contribute runoff to the Wigram Basin.

3.2 WIGRAM BASIN

3.2.1 LANDSCAPE AND ECOLOGY

Over time the plants have become well-established, providing landscape, recreation, and ecology values within the park. The site is listed in the District Plan as a Site of Ecological Significance.

Photograph 1: Established vegetation at Wigram Basin

The plants have created habitat for birdlife, with wading birds and waterfowl nesting and roosting in areas around the wet pond edge. These include notable indigenous species of pied stilt and NZ scaup[1].

Fish have also become established in the wet pond, including a large population of short fin eels[2].

3.2.2 MODIFICATIONS

Since the original basin construction, a number of modifications were made to improve the treatment performance and storage capacity. These were different to the upstream sediment forebay and primary wet pond that had been conceived as potential extensions of the original design.

In 1998, upstream of the basin, weirs and swales were added to create a sedimentation forebay and two (primary and secondary) overflow swales upstream to limit wash out of accumulated sediment in higher flows.

---

[1] EOS Ecology, *Bird nesting during construction activities around Wigram Basin* memorandum from Shelly McMurtrie (EOS Ecology) to Kathryn Collie (Beca), 28 May 2018.

[2] EOS Ecology, *Fish passage within the expanded Wigram Basin* memorandum from Shelly McMurtrie (EOS Ecology) to Kathryn Collie (Beca), 3 April 2018.

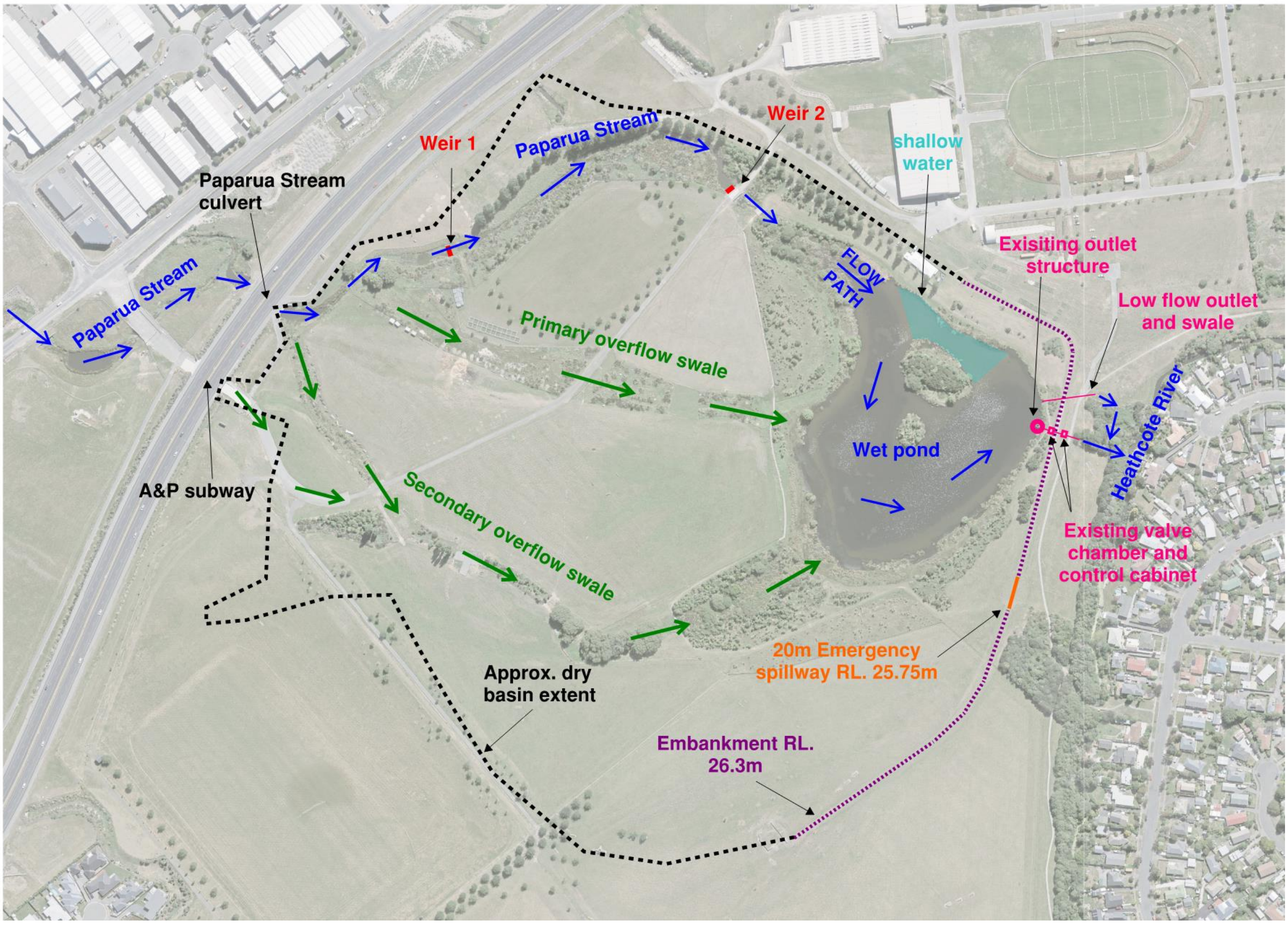
In 2010 the embankment surrounding the dry basin was raised, increasing the level of the spillway to the Ōpāwaho/Heathcote River and providing additional storage in the dry basin.

In 2010/11 the Christchurch Southern Motorway (CSM1) was constructed upstream of the basin, and with a culvert and subway under the motorway designed for the 1% AEP flow in the Paparua Stream.

In 2012 a low flow outlet from the wet pond was added, discharging to the river via a soakage swale, to improve low flow treatment.

The existing basin layout at the start of our project is shown in Figure 2.

Figure 2: Existing Wigram Basin (as at 2016) layout



3.3 CANTERBURY AGRICULTURAL PARK

Since the construction of the basin there has also been development within Canterbury Agricultural Park, including an equestrian area and horse trails. The park is now used by a number of stakeholders, including:

- General public, with the reserve popular for walking, running, and dog walking
- Canterbury A&P Association (grazing, equestrian activity and A&P show parking)

- Canterbury Riding for the Disabled (equestrian activities)
- Halswell Pony Club (equestrian activities)
- Christchurch Polo Club.

4 BASIN WATER QUALITY

The basin water quality has been monitored at various times by Christchurch City Council and Environment Canterbury and their consultants (including NIWA, Lincoln Environmental and EOS Ecology), as well as University of Canterbury students as part of post-graduate work.

The results vary but show relatively high suspended sediment, heavy metals and nutrients in the basin discharge, indicating that additional treatment would be beneficial.

5 CANTERBURY EARTHQUAKES

The 2010/11 Canterbury Earthquake Sequence increased the flood risk in the Ōpāwaho/Heathcote River downstream of the basin, due to:

- Loss of channel capacity due to bank slumping, lateral spread, and increased sedimentation from liquefaction ejecta
- Tectonic uplift at the mouth of the river
- Land settlement in places (resulting in lower land levels adjacent to the river)[3].

6 PROPOSED UPGRADE

6.1 ŌPĀWAHO/HEATHCOTE RIVER FLOODPLAIN MANAGEMENT PROGRAMME

Following the earthquakes, Council investigated the post-earthquake flood risk and floodplain management options as part of its Land Drainage Recovery Programme. A programme of work was developed for management of the Ōpāwaho/Heathcote River which includes:

- Additional storage basins in the upstream catchment
- Dredging the river between Hansen Park and into the Woolston Cut
- Construction of 'low' stopbanks along sections of the river between Hunter Terrace and Hansen Park to minimise underfloor and road flooding

[3] Jacobs, *Ōpāwaho/Heathcote River Floodplain Management Plan, Options to Mitigate Post-Earthquake Frequent Flooding*, 18 October 2017.

- Application of the Council's Flood Intervention Policy, which includes offer of voluntary purchase, for those at frequent flood risk which has been exacerbated by the earthquakes.

The Wigram Basin Upgrade is one of the locations of additional storage in the upstream catchment.

6.2 WATER QUALITY

The primary driver for the upgrade was additional storage for flood mitigation. However, including wetlands in the design allowed for greater storage (as they could be lower) while also adding additional treatment to the system. As noted in section 4, the water quality of the outflow from the existing basin was variable and high in suspended sediments and metals, and at times nutrients. Adding a wetland, downstream of the existing wet pond, increased the total volume of the flood storage while also providing treatment, so was included in the proposal.

6.3 NGĀ PUNA WAI

The 32 ha site immediately to the south of the Wigram Basin was being developed by Council into the Ngā Puna Wai Sports Hub, to replace the QEII sports facility irreparably damaged in the Canterbury Earthquake Sequence and to provide additional sport facilities in South-West Christchurch. The development of the Ngā Puna Wai Sports Hub, which includes athletics track and field, hockey pitches, rugby league fields, tennis courts, sports hub buildings and community fields, required fill. This presented an opportunity to excavate additional storage in Wigram Basin area and dispose of the material as fill on the Ngā Puna Wai site, presenting a significant cost saving for both projects.

A further advantage was that stormwater from Ngā Puna Wai could be directed to Wigram Basin for treatment and attenuation. This meant that no stormwater basin was required at Ngā Puna Wai, saving space and cost.

6.4 DESIGN BRIEF

The design brief for the Wigram Basin Upgrade was:

- To service a catchment of approximately 670 ha.
- To provide additional flood storage, by excavation within the existing dry basin area, to reduce downstream flooding in larger ($\geq$10% AEP) events
- To provide wetland treatment, ideally full first flush treatment (in Christchurch this is considered to be treating runoff from a 25 mm water quality storm), primarily for heavy metals and suspended sediment, and secondarily for nutrients
- To work with a limited footprint (permanently wet area and additional dry basin) defined in consultation with stakeholders
- To minimise the peak discharge
- To minimise the frequency of ponding on the dry basin.

As a number of these requirements were seemingly contradictory, this required options to be developed and tested, and the design optimised.

7 DESIGN

7.1 INTRODUCTION

The following sections describe the design process and final design, with a focus on the more unusual and/or interesting aspects.

7.2 DESIGN PROCESS

7.2.1 CONCEPT

Initial calculations showed that the available footprint was insufficient to provide wetland treatment for the full first flush runoff from the catchment in accordance with Council's normal design approach.

The concept design, to maximise treatment and storage, was:

- Modify the existing wet pond – to work as a first flush basin providing settlement and buffer storage to control the flow rate into the wetland.
- Create a new wetland – to provide wetland treatment of the outflow from wet pond under normal flow conditions and small storm events, prior to discharge to the river.
- Back-flooding over the wetland – to provide additional storage and some treatment, in larger events.
- Modify the existing dry basin – lowering ground levels over the dry basin to provide additional storage in major storm events.

A layout plan and initial sizing of these elements was undertaken using spreadsheet calculations. However, to design a basin upgrade which would perform well under day-to-day conditions and smaller events, we needed to better understand the low flow and small event hydrology and the interaction between sequential events. It was decided that, due to the dynamic nature of the system, hydraulic modelling would be useful.

Event based hydrologic and hydraulic models had already been developed by others (Jacobs/DHI) to understand the Ōpāwaho/Heathcote River and floodplain performance in larger events and flood conditions (10 year to 200 year events). However, a new continuous simulation model would assist in understanding how the basin would perform in low flows and small events.

7.2.2 HYDROLOGIC MODELLING

Hydrologic modelling of the catchment was carried out in HEC-HMS v4.2, using a long term continuous rainfall record. Hourly rainfall depths were obtained for the period from January 1955 through to December 2016 (62 years).

Table 1: Rainfall record statistics

Statistic	Depth	Year
Average annual rainfall	587 mm	N/A
Wettest year	913 mm	1978
Driest year	308 mm	1988

The hydrologic model incorporated a baseflow component, pervious runoff (using a deficit and constant loss model), and impervious runoff (using a fixed runoff percentage).

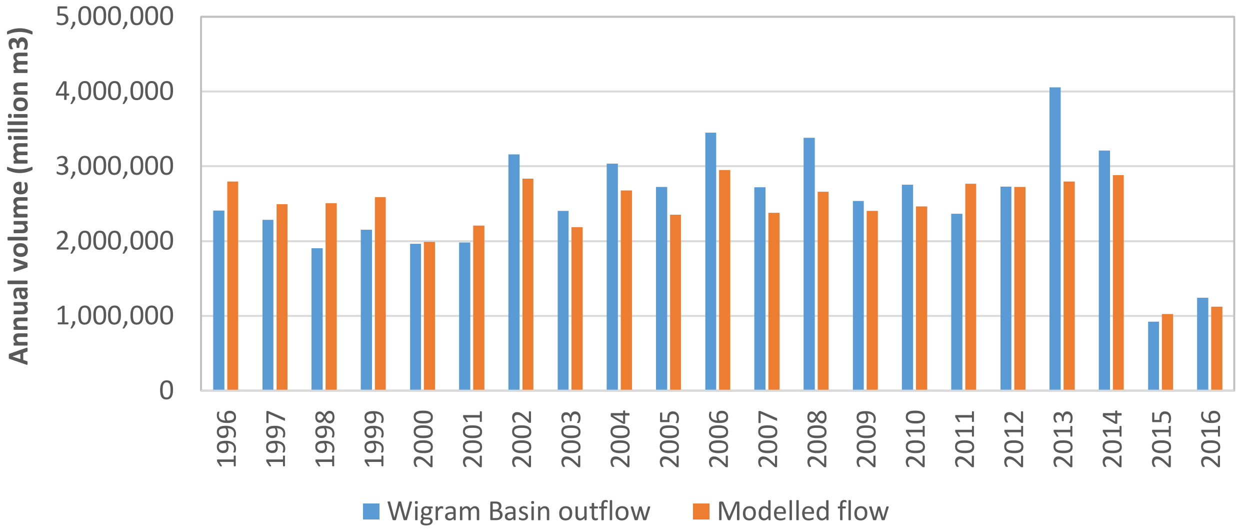
In terms of calibration data, there was no flow or level data record for the Paparua Stream, however there was a water level record for the existing basin from 1996, contours of the basin design, and a rating curve for the existing outlet structure. Using this information, a synthetic flow record was back-calculated for outflow from the basin, and then for the inflow into the basin (allowing for storage volume and assuming no loss to soakage as the basin is lined).

This analysis yielded a surprising finding. From 2015 onwards, the runoff volume into the basin appeared to have decreased significantly. Investigations were carried out as to whether this was real issue, or just faulty data, and into possible causes. This investigation included reviewing the water level data for anomalies, comparison of aerial photographs, obtaining anecdotal accounts of stream flows, review of subdivision design drawings, and site investigations. It was concluded that this decrease in inflow volume was real and the likely cause was informal soakage via backflow from the stream into the stormwater basin subsoil drainage systems in a large subdivision upstream.

The synthetic flow record developed from the water level record was used to calibrate the model. This was carried out by comparing measured and modelled flow in: hydrographs; frequency curves (flow rate vs percentage exceedance); and annual volume. The informal soakage in upstream subdivision was included in the model, and runoff and infiltration parameters were adjusted until a good fit was achieved.

The final calibrated model results good results for volume and acceptable results for flow. Figure 3 shows the measured and modelled annual volume.

Figure 3: Measured and modelled annual volume



7.2.3 HYDRAULIC MODELLING & OPTIONS TESTING

A hydraulic model of the proposed Wigram Basin Upgrade was built in InfoWorks ICM. The model used the runoff hydrograph from the hydrologic modelling (described above) as the basin inflow time series. The model included the proposed Wigram Basin upgrade as a series of storage nodes, pipes, and hydraulic controls (orifices and weirs).

The hydraulic model was then used to test performance for a range of options including:

- Changing the discharge to the Ōpāwaho/Heathcote River
- Changing the residence time in the wetlands
- Changing the bund heights between the various components of the system
- Changing the buffer storage operating characteristics and volume in the wet pond.

Key performance measures reported for various options included:

- Frequency and duration of elevated water levels in the wet pond
- Percentage of inflow volume going through the wetland, including the percentage going through the low flow outlets, and the percentage going over spillways
- Frequency and duration of ponding in the dry basin.

An example time series plot from the modelling, showing water levels in the wet pond and wetland is included in Figure 4.

Figure 4: Sample time series plot of wet pond and wetland water levels (from continuous modelling)

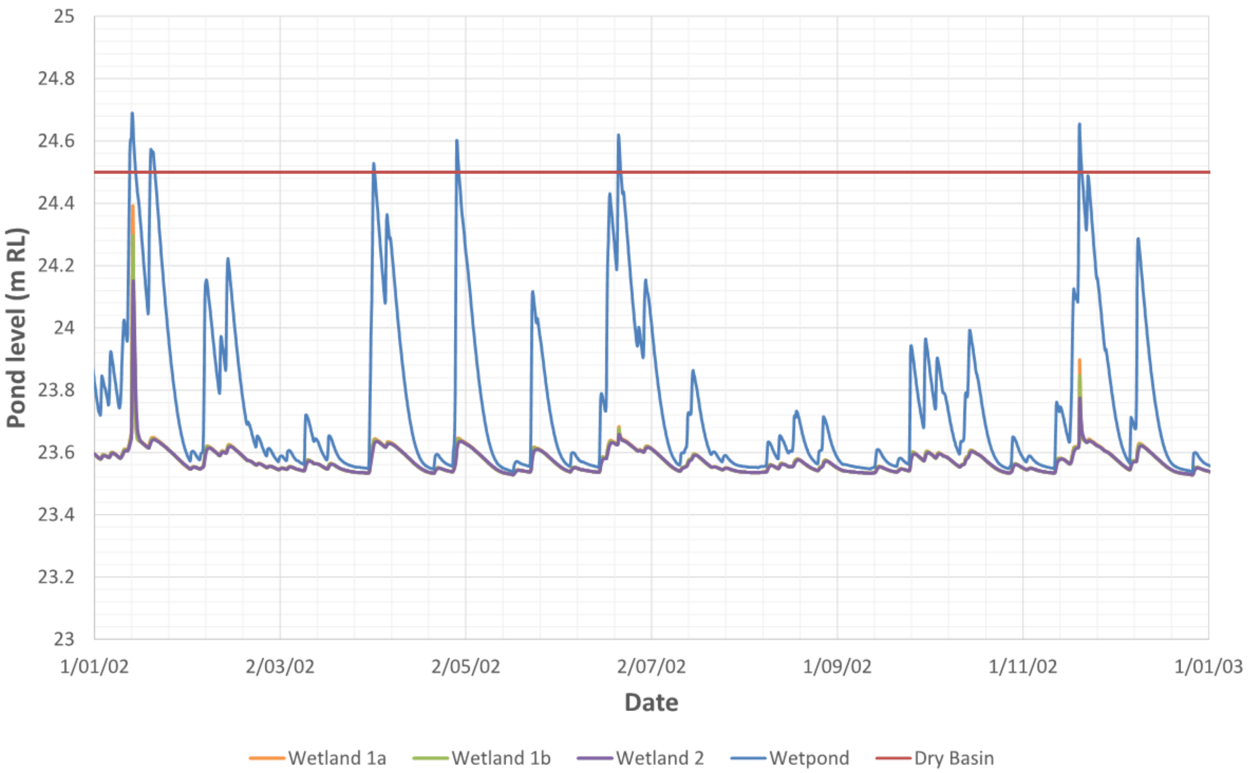


Figure 4 shows the water level in the wet pond rising rapidly in response to inflow, and then falling away again, sometimes not returning to normal before the next event arrives, raising the level again. It also shows the slower response in the wetland water level, from the buffering in the wet pond. (This figure shows three wetland cells, which was an earlier iteration of the design. The final design included one large wetland of the same total area and volume. Refer section 7.3.5.)

7.3 FINAL DESIGN

The final design for the upgrade included:

- Additional live storage in the existing wet pond to provide buffering of flows into wetland. This was achieved by modifying the existing outlet structure and increasing the live water level in the pond, leaving the low level the same.
- New 3.6 ha wetland, treating discharge from the wet pond, discharging to the river via a new outlet.
- Back-flooding over the wetland in larger events, via spillways in embankments, providing additional storage.
- Additional dry basin storage for flood peak attenuation, created by excavating to lower the base of the dry basin area without compromising usability.

This provided a total of approximately 220,000 m^3 additional live storage, up to the embankment spillway level. No changes were proposed to the levels of the existing embankment around the dry basin and spillway to the river.

The wetland has a banded bathymetry with:

- 50% of the wetland area 0.2 m deep
- 30% of the wetland area 0.45 m deep
- 20% of the wetland area 1.0 m deep

This design is shown in Figure 5 and Figure 6.

Figure 5: Wigram Basin Upgrade layout plan

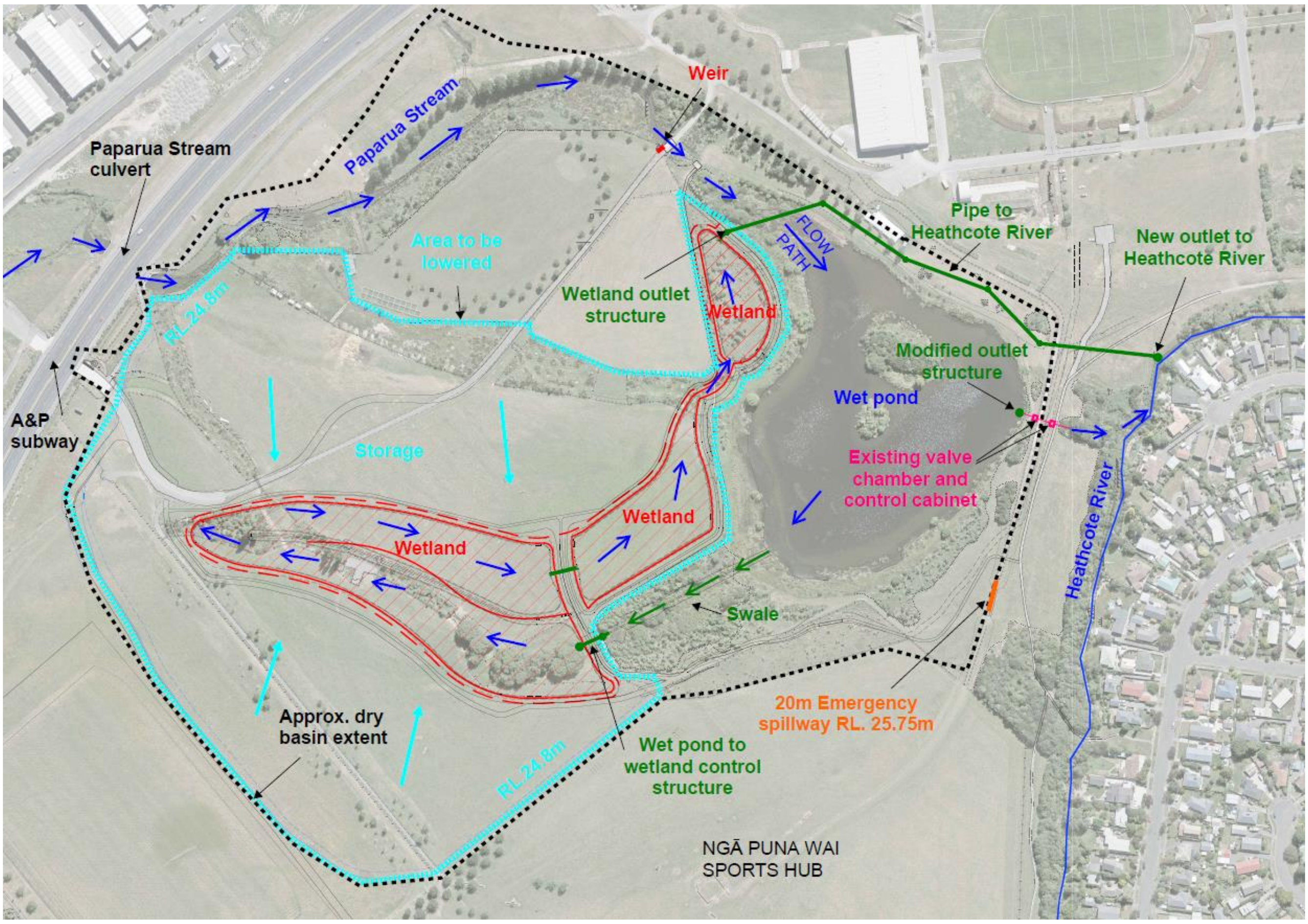
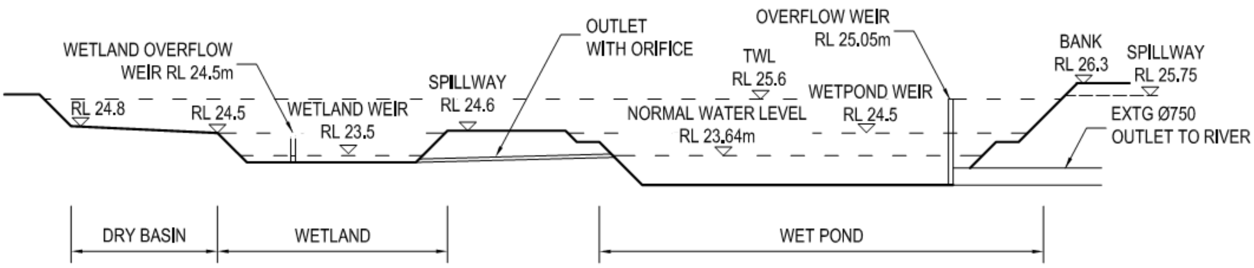


Figure 6: Wigram Basin Upgrade cross-section diagram with key levels



The water level in the wet pond is controlled by a series of weirs and spillways. In normal or low flows all discharge is via the wetland. With increasing rainfall volume and storage:

- Water will discharge to the Ōpāwaho/Heathcote River via the existing outlet structure which will be modified to control flows.
- When the wet pond water level reaches RL 24.6 m water will overflow directly into the wetland.
- When water levels exceed the combined capacity of the wet pond and wetland, water will overflow into the dry basin at RL 24.5 m.

In extreme storm events, the basin will overflow to the Ōpāwaho/Heathcote River via the existing emergency spillway (RL 25.75 m) in the embankment around the dry basin.

Based on the hydraulic modelling results, with continuous modelling of 62 years of rainfall data, in the final design:

- 92.0% of inflow volume flows through the orifices and pipes from the wet pond to the wetlands
- 3.5% flows via overflow weirs from the wet pond to the wetlands
- 4.5% flows directly from the wet pond to the Ōpāwaho/Heathcote River
- Average wetland retention time is 4.2 days

This high percentage of annual volume captured and treated in the wetland, and wetland retention time, should result in good treatment, despite the wetland footprint being well below the size that a guideline-based design would require.

7.3.1 MULTI-DISCIPLINARY DESIGN

The detailed design of the basin included inputs from a wide range of disciplines. In addition to the stormwater and civil engineering and hydraulic modelling described above, the design included inputs from a range of Council and consultant staff including landscape architects, freshwater and terrestrial ecologists, geotechnical engineers, hydrogeologists, structural engineers, mechanical engineers, electrical engineers, cost estimators and operations staff.

7.3.2 LANDSCAPE AND ECOLOGY

The detailed design layouts were designed to minimise the impact on existing vegetation.

The landscape design included removal of existing exotic trees (willows and silver birches), and extensive new native planting in a number of planting zones: wetland (shallow, deep, bench and embankment); floodplain; and dryland.

The plants were selected by landscape architects and ecologists working together, using indigenous plants endemic to the region. The wetland plants were selected to provide filtration of solids and a surface for the growth of suspended microorganisms. The continuous simulation model allowed assessment of the duration of elevated water levels in the wet pond, wetlands and dry basins. This information enabled the planting zones to be well-defined and suitable plants to be selected.

The landscape design also included pedestrian paths, a pedestrian bridge, a cycle path, a horse trail and a timber lookout structure. The paths and trails were set above the 2-year water level in the basin (established from the modelling) and separated from the basin via buffer planting (to keep people and dogs away from bird habitat).

The design of the basin changes and hydraulic structures also considered fish passage. A fish survey of the existing basin found that there were high numbers of short fin eels within the basin, and a high percentage of these were of migrating age. The survey indicated that the existing outlet structure is a significant barrier to eels migrating downstream.[4] While the hydraulic control structures provided limited opportunity to allow for fish passage, the wetland design provided an outlet for eels, should they manage to enter the wetland system (thought to be unlikely given the small entry pipes and orifices). Fish passage has been identified by Council staff as an upgrade likely to take place in the short to medium term.

7.3.3 ADAPTABILITY FOR FUTURE CHANGES

While the modelling provides a good understanding of the expected basin performance, it will not be perfect, and the basin inflow will likely change over time with changes in the upstream catchment and climate change. The hydraulic controls have been designed to allow for some flexibility. This includes:

- Orifices and weirs in control structures (manholes) are used to limit flows, rather than pipes. These can be changed in future.
- Orifices are in replaceable plates within slide gates, to make changing the size of these easier.
- Weir levels in structures are set using stopboards and slide gates, rather than the fixed concrete structure, so that these can be adjusted more easily.
- Penstocks, rather than slide gates, have been used in key locations. These can be actuated later to allow for remote or automated control.

7.3.4 SAFETY IN DESIGN

Safety in Design was incorporated into the design, with all designers considering safety in their inputs as well as formal Safety in Design workshops.

Safety during the construction and long term use of the facility (for both the public and operators) was a key consideration in a number of design elements, including: batter slopes at a maximum of 3H:1V; paths separated from normal water levels via buffer planting; use of prefabricated steel for wet pond outlet modification; adding a walkway to access the wet pond outlet; adding gratings on top of control structures.

7.3.5 VALUE ENGINEERING

Value engineering was undertaken to reduce the cost of the final design to meet budget constraints. This included:

- Changing to one large wetland, rather than two wetlands (with three wetland cells) working in parallel. This reduced the number of hydraulic structures and length of pipe required.
- Changing the connection from the wet pond to the wetland from a pipe to a swale, reducing the length of pipe required.
- Reducing the areas of dryland planting and not including new trees. This could be planted later.

---

[4] EOS Ecology, *Fish passage within the expanded Wigram Basin* memorandum from Shelly McMurtrie (EOS Ecology) to Kathryn Collie (Beca), 3 April 2018.

- Not including the timber lookout structure. This could be constructed later.

8 CONSTRUCTION

Construction of the Wigram Basin was undertaken in two stages:

- Bulk earthworks, providing fill for Ngā Puna Wai
- Basin and wetland works.

At time of writing, the bulk earthworks are complete, and the basin and wetland are under construction, with completion planned in June 2019.

9 CONCLUSIONS

The original Wigram Basin was an example of a new innovative 'six values' approach to surface water management. With changes in the upstream catchment and downstream river over time, an upgrade to the basin was required. Due to the existing land use, the area available for this upgrade was constrained.

The Wigram Basin Upgrade project required an innovative design approach to achieve additional treatment and storage within the available footprint. This included continuous simulation modelling to arrive an optimised design, and better understand the long term operational characteristics of the system.

The final design was developed by a multi-disciplinary design team of consultants and Council staff working together, and continues to advance the six values approach.

ACKNOWLEDGEMENTS

The original Wigram Basin design team for their foresight and for sharing their knowledge.

Wigram Basin Upgrade team including Christchurch City Council staff, Beca staff, EOS Ecology staff and Colin Meurk for their good work and for their assistance in preparing this paper.

Graham Levy (Beca), Mark Penrice (CCC) and Keith Davison (CCC) for their review.

REFERENCES

Beca, *Wigram Basin Extension Detailed Design Report*, 18 June 2018.

Beca, *Wigram Basin Hydraulic Modelling Report*, 20 March 2018.

Canterbury Regional Council and Christchurch City Council, *Heathcote River Floodplain Management Strategy*, November 1998

Christchurch City Council, *Waterways Wetlands and Drainage Guide*, Part B: Design, 2003.

Christchurch City Council, *Wigram Retention Basin, Operation and Maintenance Manual*, June 1996

EOS Ecology, *Bird nesting during construction activities around Wigram Basin*, memorandum from Shelly McMurtrie (EOS Ecology) to Kathryn Collie (Beca), 28 May 2018.

EOS Ecology, *Fish passage within the expanded Wigram Basin*, memorandum from Shelly McMurtrie (EOS Ecology) to Kathryn Collie (Beca), 3 April 2018.

Jacobs, *Ōpāwaho/Heathcote River Floodplain Management Plan, Options to Mitigate Post-Earthquake Frequent Flooding*, 18 October 2017.

Watts, Robert H, *The Christchurch waterways story*, Manaaki Whenua Press, Landcare Research, 2011.