Planning | Surveying | Engineering | Environmental

Stormwater Management Plan

Ayrburn Screen Hub

Waterfall Park Development Ltd

Document Information

Client	Waterfall Park Developments Ltd
Site Location	Ayr Avenue, Arrowtown
Legal Description	Lot 4 DP540788
CKL Reference	A20254
Office of Origin	Auckland

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The contributing authors, in their capacity as authors of this report, have read and abide by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses Practice Note 2023. Where this report relies on information provided by other experts, this is outlined within the report.

Contents

Figures

Tables

Appendices

1 Introduction

CKL has been engaged by Waterfall Park Developments Ltd (WPDL) to develop a Stormwater Management Plan (SMP) to support a Substantive Fast-Track Application for the proposed Ayrburn Screen Hub which includes filming studio and associated accommodation and facilities. The site is located at Ayr Avenue, off Arrowtown-Lake Hayes Road. The site is approximately 2km south of Arrowtown.

The purpose of this report is to outline the stormwater management objectives and best practicable stormwater management plan for the proposed development of the site in accordance with QLDC Land Development and Subdivision Code of Practice, regional and national standards, and guide development in such a way as to avoid, remedy or mitigate adverse effects on the receiving environment.

Figure 1: Site Location (Winton Provided, December 2024)

1.1 Reference Documents

The development of this stormwater management plan is guided by the following key documents, which are referenced throughout this report;

- QLDC Land Development and Subdivision Code of Practice (QLDC COP)
- Ayrburn Screen Hub Engineering Drawings by Patersons dated July 2025
- Ayrburn Screen Hub Design Report by Winton dated June 2025

2 Existing Site Conditions

The site is located between Lakes Hayes and Arrowtown, approximately 2km south of Arrowtown and is accessed via Ayr Avenue, coming off Arrowtown-Lake Hayes Road.

The site is located on Lot 4 DP 540788, being land currently zoned Wakatipu Basin Rural Amenity Zone (WBRAZ) and subject to the Ayrburn Structure Plan.

The site sits to the southwest of the Northbrook Waterfall Park development where the valley opens up into what is known as Ayrburn Farm. The historic Ayrburn stone farm buildings are located immediately to the east of site in the area known as Ayrburn.

To the west of the site are steep paddocks that extend above the site toward the Millbrook development. Currently, stormwater sheet flows from the paddocks towards the Site and is largely conveyed through an intermittent stream or cut off drains and discharges towards Mill Creek south of the site. The site itself gently sheet flows towards Mill Creek and down the bank adjacent to the creek. The site area, and condition, are shown above in Figure 1.

With respect to the hydrological and hydraulic surface flow responses under the existing condition, a “rain-on-grid” flood model has been conducted for the Screen Hub area and associated catchment upstream which extends to the southern boundary of the wider site. The extent of this rain on grid model is within the existing (wider) Mill Creek flood modelling undertaken for the wider site (including Ayrburn and Northbrook) to ensure a comprehensive assessment is undertaken. The existing scenario for the flood model includes all constructed and consented works within Northbrook Waterfall Park and Ayrburn to capture the fully developed scenario of the wider site.

3 Proposed Development

The proposal for the Ayrburn Screen Hub includes film studios, offices and workrooms, accommodation, and a wellness/gym and reception area. Figure 2 below shows the proposed site plan.

Figure 2: Proposed Site Plan

Table 1 below provides a summary of coverage areas for both pre- and post-development for the site area being developed, which include the large paddocks and bush area upstream of site which remain unchanged. The difference between pre- and post-development areas is used to estimate the net change in impervious area for the site. Figure 2 above demonstrates post- development site coverage areas.

Table 1: Net Change Between Pre- and Post-Development Areas

Surface Coverage	**Pre-development Existing Areas**		**Post-development Proposed Areas**		**Net Change**	
	(m^2)	%	**(m^2)**	%	**(m^2)**	**%**
Internal Road	0	0%	17,174	5%	17,174	7%
Filming Studio Backlot	0	0%	8,897	4%	8,897	4%
Foot paths	0	0%	3,057	3%	3,057	1%
Roof Areas	0	0%	15,559	6%	15,559	7%
Landscaping	234,000	100%	189,313	82%	-44,687	-19%
Total	**234,000**	**100%**	**234,000**	**100%**	**0**	**0%**

4 Stormwater Management Strategy and Objectives

For this site, it is proposed to adopt the stormwater management objectives outlined in the current QLDC COP to guide stormwater management. Additionally, there is a specific Proposed District Plan (PDP) water quality policy (24.2.4.2) relevant to this part of the WBRAZ, which the site is located within, and this is discussed in the following section.

4.1 Proposed District Plan Policy 24.2.4.2

The Policy States:

> "Restrict the subdivision, development and use of land in the Lake Hayes catchment, unless it can contribute to the water quality improvement in the catchment commensurate with the nature, scale and location of the proposal"

Policy 24.2.4.2 is clear that water quality leaving the site in the post-development scenario should be proven to be better than what exists currently.

As has been used elsewhere on the wider site, it is proposed to provide a treatment train approach to this site to ensure that post-development runoff water quality is an improvement of the existing scenario (farmed).

4.2 Proposed Stormwater Management Objective

High level objectives for Stormwater Management within the development area are in line with current QLDC guidance and consenting works in the catchment area, they are summarised as follows:

- ✓ **Water Quality**

Treat stormwater runoff from site with a treatment train approach, improving on existing scenario.

Devices sized based on Water Quality Flow (WQF) rate of 10mm/hr and Water Quality Volume (WQV) based on 1/3 2yr ARI event (16.2mm) from the NIWA HIRDS v4.[1]

- ✓ **Hydrological Mitigation**

Post-development peak flow should not exceed pre-development peak flow from the overall site boundary.

- ✓ **Conveyance**

Primary Conveyance of the 20yr ARI peak flow (including the effects of climate change).

Secondary Conveyance of the 100yr ARI peak flow (including the effects of climate change).

[1] Auckland Council GD01 specifies 90th percentile rainfall. QLDC confirmed, through Ayrburn Precinct and Northbrook consenting, this is 1/3 of the 2-year event (48.3mm)

5 Stormwater Management Plan

This section presents the existing stormwater management system and the proposed options assessment which aligns with the stormwater management approach implemented and/or consented across the wider site (including Northbrook Waterfall Park and Ayrburn).

5.1 Existing Stormwater Management System

Stormwater runoff from the site discharges as surface runoff to Mill Creek which runs through the middle of the wider Northbrook and Ayrburn site from the north to south. CKL have conducted a flood model for Mill Creek for pre-development and post-development scenarios to assess the peak flow for multiple rainfall events at the wider site boundary just below the Screen Hub site. This model was used as a basis for flood modelling for the Screen Hub site as it incorporates all construction and consented work for the wider Ayrburn and Northbrook development area. This includes the approved Ayrburn Haybarn bund (RM230425.EA00) in the paddock across from the Screen Hub used as flood control for wider site. The flood model report can be found in Appendix 3.

Currently there is no formal stormwater management on the Film Hub site as it is associated with rural and vineyard [2]operations. There are natural streams and gullies that receive surface flow from the contributing catchment. The site also receives flow from the Millbrook development via a piped discharge to the head of the tributary within western portion of the site.

There are several existing depression areas within the upstream tributaries which acts to retain some sediment from upstream catchment.

5.2 Proposed Stormwater Management Options Assessment

A treatment train approach was identified as the Best Practicable Option (BPO) for protecting Lake Hayes, as detailed in the following sections.

This treatment train method builds on previous Northbrook and Ayrburn development consents and their outcomes. Single-stage devices or standard stormwater ponds alone were deemed inadequate for reducing sediment and nutrient loads. The Ayrburn Film Studio project will use primary raingardens and proprietary devices, secondary central pod wetlands, and tertiary planted infiltration ponds by Mill Creek.

[2] The vineyard area is not part of the Film Hub stormwater management extents

6 Best Practicable Stormwater Management Option

Given the ultimate receiving environment is Lake Hayes, which is susceptible to nutrient loading, it was determined that a treatment train approach to treat potential contaminants within runoff generated from site is the preferred option to ensure robust treatment and reduce risk of contaminants entering Lake Hayes. This approach continues to be the best practicable option (BPO) associated with the overall Ayrburn and Northbrook development.

6.1 Catchment Description and Treatment Train

The stormwater management catchment area, unlike the overall site boundary, specifically includes only those parts of the land where use has changed, such as roads, roofs, and landscaped spaces. The rest of the site, which remains unchanged, continues to drain as it always has, with stormwater runoff flowing naturally across the surface. These unaltered areas are not included in the Film Hub's managed stormwater catchments.

With respect to the stormwater management area, there are several distinct sub-catchments (within the site) each managed using different treatment train methods, as shown in Figure 3 below.

Figure 3: Treatment Sub-Catchment Drawing

At the downstream portion of site, adjacent to Mill Creek, it is proposed to include a planted infiltration pond that will capture all runoff from site as well as a portion of existing Ayr Avenue flow and the Flower Farm site. This pond will act as polishing treatment for the entire catchment (including the mentioned Flower Farm and Ayr Avenue) and will allow for some infiltration to ground for further treatment.

6.1.1 Catchment A

The internal road is proposed to be treated first by at-source raingardens between parking bays. Runoff will infiltration through the bioretention media in the raingarden to underdrains. The primary treated water quality flow that discharges to the underdrains will be conveyed to the wetlands in the centre of the Screen Hub development. These are referred to as pod wetlands. This catchment will get tertiary treatment in the infiltration ponds at the base of the wetland. More details of the raingarden design are included in Section 7.1 below.

The raingardens are designed to handle the water quality flow. Flow in excess of this will discharge to downstream mudtanks once raingardens are saturated. The runoff in events larger than the water quality event will enter the mudtanks and into the proposed stormwater network sized for 20yr ARI event.

6.1.2 Catchment B

The large parking area adjacent to the film studio buildings (also referred to as backlot) is proposed to be treated by underground proprietary treatment devices designed to treat the entire hardstand area.

Primary treated flow will discharge to the pod wetlands at the centre of the Screen Hub for secondary treatment. This catchment will receive tertiary treatment in the infiltration ponds at base of catchment.

Hynds Up-Flo devices are currently proposed as they provide treatment with low driving head, include an internal bypass for flows above the WQF and relatively compact given site constraints. They are a good option for primary treatment, where this catchment will receive additional treatment from the pod wetlands and tertiary infiltration ponds.

6.1.3 Catchment C

The northern portion of the internal loop road is proposed to have primary treatment through in-road raingardens, as with the rest of the loop road. However, treated runoff discharging through the base of the raingarden cannot discharge to the pod wetlands given vertical (elevation) constraints. Therefore, this catchment is proposed to discharge primary treated water (via the in-road raingardens) to the swale along Ayr Avenue which will provide the secondary treatment. Ultimately this runoff discharges to the infiltration ponds to receive tertiary treatment prior to entering Mill Creek.

6.1.4 Catchment D

A portion of the internal loop road to the south is proposed to have primary treatment through in-road raingardens, as with the rest of the loop road. However, treated runoff discharging through the base of the raingarden cannot discharge to the pod wetlands given vertical constraints. Therefore, this catchment is proposed to discharge primary treated water (via the in-road raingardens) to the infiltration ponds to receive secondary treatment. This still provides a treatment train approach and high level of treatment for this road sub catchment.

6.1.5 Catchment E

The internal loop road access road up to the south is proposed to discharge to swale along the southern edge of the road to a raingarden sized to treat this road sub-catchment for primary treatment. Primary treated runoff will discharge to underdrains at the base of the raingarden and to adjacent infiltration ponds for secondary treatment.

The proposed raingarden is 35m^2 to treat this catchment.

6.1.6 Roofs

All roof areas will be clad with low contaminant generating materials, such as painted steel (Coloursteel), and will to some degree collect sediment and debris deposited by wind. The roofs in the Screen Hub will discharge to a separate stormwater network than the road water quality network.

It is to be noted that this network will discharge to the infiltration ponds and receive treatment through sedimentation and infiltration. As such the roof runoff will ultimately go through a treatment process prior to entering Mill Creek.

6.2 Overall BPO Treatment Scheme

Figure 4 below demonstrates the overall best practicable option for stormwater management for the entire site. Figure 4 also indicates the proposed treatment devices per sub catchment.

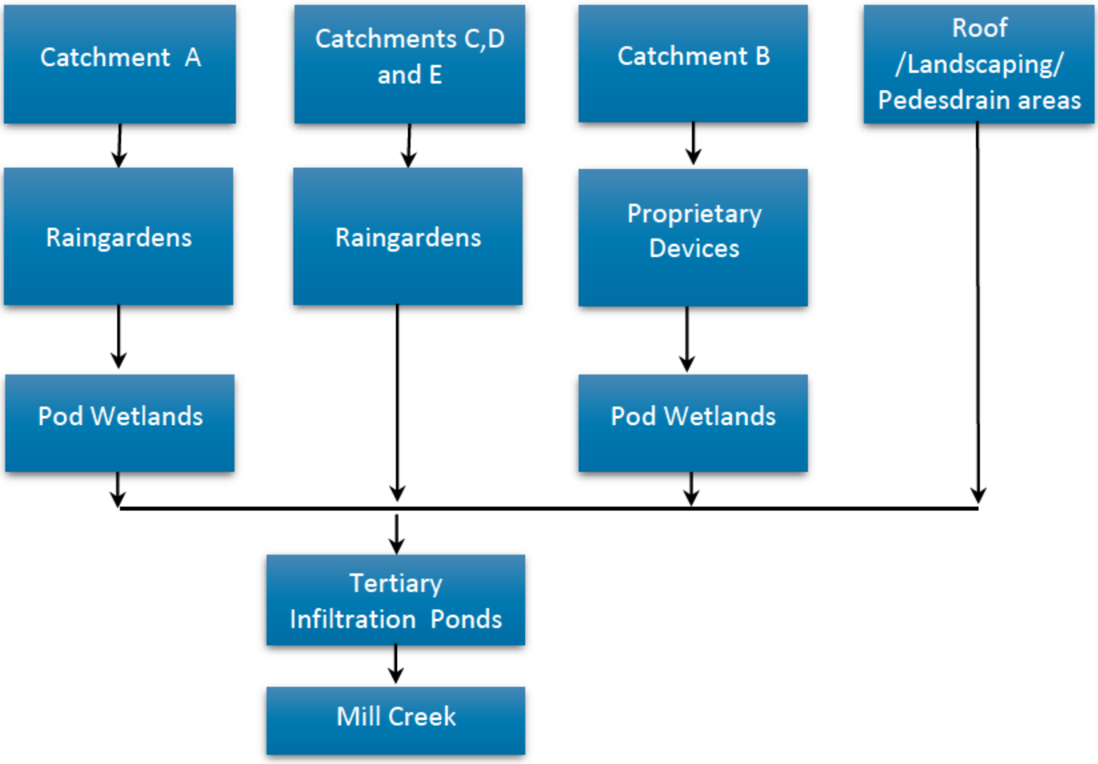


Figure 4: Diagram of the proposed stormwater management system

Paterson's 400 series drawings illustrate the stormwater management approach proposed. Section 7 below describes each component of the stormwater management system.

In addition to the above proposed treatment train approach for the Screen Hub, it is proposed to include a sediment retention pond within Mill Creek, just upstream of the Ayrburn Farm boundary and below the inlet from the Screen Hub site. Several of these sediment retention ponds have been used in the catchment upstream of the site and have proven to be efficient and effective at removing sediment from Mill Creek prior to entering Lake Hayes and improving the water quality of the lake. This is described in Section 8.2.1

7 Proposed Stormwater Management Components

The following sections describe the treatment devices that are the stormwater management system components proposed for the site.

7.1 Raingardens

Twenty-one (21) bioretention devices (raingardens) are proposed within the internal road to provide primary treatment and recharge groundwater where possible. There is also one larger raingarden proposed at the base of the southern access road, adjacent to tertiary infiltration ponds. The raingardens will have 500mm of bioretention media which a saturated hydraulic connectivity (Ks) rate of 750mm/hr[3].

Soakage testing was undertaken near the proposed internal road which resulted in a relatively low soakage rate of 30mm/hr. Assuming 50% reduction factor, the design rate is 15mm/hr. Soakage calculations are supplied in Appendix 2.

The raingardens are unlined and designed to have a retention layer to allow some runoff to infiltrate to ground, however an underdrain will be set above the retention layer to convey treated runoff to the downstream wetland system.

Appendix 2 demonstrates the sizing for all raingardens.

7.1.1 Sensitivity Analysis for Raingardens

Following peer review[4]feedback, a sensitivity test was conducted on the biofiltration media infiltration rates in the raingardens to assess sizing and treatment efficiency. The design uses a K value of 750mm/hr, which was compared to the Christchurch City Council's (CCC) preferred rate of 300mm/hr for raingarden sizing.

The raingarden design is based on the WQF associated with the contributing catchment and as such the raingarden size in the original design will provide for 40% of the WQF. Conversely if the WQF is used the raingarden with K = 0.3m/hr is 2.5 times larger than the design provided.

To determine the likely contaminant removal efficiency of a raingarden designed with a K value of 300mm/hr but sized according to the original K = 750mm/hr design, the proportion of the Water Quality Flow (WQF) treated by the raingarden was compared to estimated removal efficiencies, as shown in the table below.

[3] Ks=750mm/hr which aligns with GD01 water quality raingarden filter media Ks less than or equal to 1000mm/hr
[4] Peer review undertaken by Peter Christensen, Storm Environmental Ltd.

Table 2: Relative levels of treatment efficiency for removal of TSS[5]

Table 3-1 Relative levels of removal efficiency	
Practice Volume	Efficiency
150% of WQV	82%
100% of WQV	75%
75% of WQV	70%
50% of WQV	60%
25% of WQV	50%
10% of WQV	40%
5% of WQV	30%

It is to be noted that the Contaminant Load Model (CLM) applied standard raingarden designs to typically achieve TSS contaminant removal rates of 90%. In contrast, the table referenced above indicates a 75% removal rate when treating 100% of the WQF. For this sensitivity comparison we are assessing the removal rate as per the above table, as such in reality the smaller raingarden design is likely to achieve higher removal rates.

The TSS treatment efficiency of raingardens designed to accept and manage 40% of the Water Quality Flow (WQF) is estimated at 56%.

The following table shows the resulting treatment efficiency comparisons, parameters and outcomes of the updated sizing vs the original results.

Table 3: Contaminant removal rates - Raingarden K=0.3/hr

Treatment device	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Bioretention % removal rates (original design)	60%	40%	90%	90%	90%
Bioretention % removal rates @ 56% removal efficiency (40% WQF)	34%	22%	50%	50%	50%

Further details of the sensitivity analysis are provided within the SMP Sensitivity Report, appended for reference, Appendix 5.

7.1.2 Raingarden summary

The raingarden designs are based on a higher infiltration rate of K=0.7m/day. However, sensitivity analysis shows that using a lower infiltration rate of 0.3m/day, with smaller raingarden (footprints), achieves about 56% of the treatment efficiency of a full-sized raingarden with the higher K value.

Additional analysis of water quality through these reduced-efficiency raingardens, supported by contaminant load modelling (see Section 9.7.2), indicates that surface water leaving the fully developed site will actually be of better quality than under current conditions. Therefore, for this stage of the design, intended to support the Fast Track Substantive Application, this Stormwater Management Plan recommends using the lower K value (0.3m/day) for the raingarden media.

[5] Auckland Regional Council TP10 2003, Table 3-1

7.2 Pod Wetlands

Treated runoff from part of the internal road and the backlot parking area (Catchment A and Catchment B), after filtering through the raingardens, will be conveyed to a series of small wetland pods in the centre of the Screen Hub site. The wetlands are designed to treat the WQV (16mm rainfall event) from the sub-catchments and provide secondary treatment after the raingardens.

The pod wetlands will be 400mm deep with deep marsh plants to allow for both uptake of nutrients through plants and settlement of sediment. The wetlands will be connected by a series of culverts and risers to convey water between them and control the level of the wetlands. This allows runoff to cascade between each pod and receive treatment through the entire system of pods.

7.3 Tertiary ponds

At the terminus of the Screen Hub catchment, it is proposed to convert the lower lying area and existing construction Sediment Retention Ponds (SRP) adjacent to Mill Creek to two shallow infiltration ponds planted with vegetation. This will provide tertiary treatment for Catchment A and Catchment B catchments, secondary treatment for the remaining roading, and treatment for low contaminant generating surfaces like the roof, pervious area and pedestrian tracks. As such acting as polishing treatment for the entire catchment.

Soakage testing was undertaken in this location and resulted in a relatively high soakage rate of 400mm/hr. Assuming 50% reduction factor, the design rate is 200mm/hr will provide enough infiltration to ground that the entire contribution catchment will soak to ground in a water quality event (1/3 2yr ARI+CC). This provides additional protection to the stream and receiving environment through reduced sediment loading, temperature reduction and filtration through the ground. In events larger than the water quality event, the ponds will fill up and reduce velocities from upstream catchment prior to spilling over into Mill Creek.

See Appendix 2 for soakage calculations.

These ponds will be inundated in 100yr event from Mill Creek flow, however, are protected from inundation in the 20yr ARI and smaller events. The velocity during 100yr ARI event was assessed in the flood model and was found to be less than 0.1 m/s with the pond and slightly higher where flow spills into and out of the ponds (via broad flowpath) from Mill Creek. These is considered very low and means there is a reduced risk of resuspending of sediment in the ponds or damaging vegetation. It is to be noted that the tertiary ponds have a filtration base, as such sediment is unlikely to be within the base of the pond. The velocity and depth maps around these ponds can be seen below in Section 8 and in Flood Model Report in Appendix 3.

7.4 Proprietary Devices

Hynds Up-Flo devices are currently proposed for the Catchment B catchment (Filming Hub Backlot parking). There are several devices that are applicable, however, Hynds Up-Flo were chosen given their relatively small size and internal bypass system. They provide good primary treatment. Table * below shows the removal efficiencies according to Hynds study.

Table 4: Removal Efficiency of Hynds Up-Flo

	TSS	TP	TN	Zinc	Copper
Removal Efficiency	87%	48%	39%	59%	70%

8 Catchment Sediment Management

The changes in land use in the Lake Hayes catchment from bush to farmland and residential developments has meant over time the lake quality has degraded as sediment and nutrient loading has built up

As per section 4.1 there is a there is a specific Proposed District Plan (PDP) water quality policy (24.2.4.2) relevant to this part of the WBRAZ, which the site is located within, that need to be adhered to.

The Policy States:

> "Restrict the subdivision, development and use of land in the Lake Hayes catchment, unless it can contribute to the water quality improvement in the catchment commensurate with the nature, scale and location of the proposal"

Sediment management forms an integral part of meeting this objective and thus sediment management devices are proposed to enhance and promote more sediment retention and will be monitored for sediment build up.

The Ayrburn Film Studio application includes enhancement of sediment removal through introduction of sediment ponds, which is detailed in the following subsections.

8.1 Existing Sediment Management

In an effort to improve the water quality in Lake Hayes and reduce the amount of existing sediment reaching the lake, a few inline sediment retention ponds have been built in the upper reaches of the catchment which have proven to retain significant amounts of sediment.

There are two major existing inline sediment retention ponds within the catchment, upstream of Ayrburn and Northbrook Waterfall. These two ponds are located near Wharehuanui, approximately 8km upstream of site. They are called Puku Nui and Puku Iti ponds. Locations of each pond are shown below in Figure 5.

It is to be noted there are also existing inline ponds within the wider Ayrburn and Northbrook site, within Mill Creek, which have proven to be successful in removing sediment.

Figure 5: Location of exiting sediment retention pond in catchment

The basic details of each of the sediment ponds are below.

Puku Nui

- Constructed in Feb 2024
- Volume= 750m^3
- Approximate time to fill pond with sediment= 13 months (70% full after 10 months)

Puku Iti

- Constructed in April 2023
- Volume= 540m^3
- Approximate time to fill pond with sediment= 12 months

The combined total volume of the two existing ponds is 1290m^3.

These existing in-line sediment retention ponds were built around 2021yr-2022yr.

As part of the overall site's stormwater management strategy, CKL and Winton have analysed the turbidity data from instream data loggers from 2019 to today at locations upstream of Northbrook Site and at the downstream of boundary of wider site to determine the effectiveness of these ponds.

This assessment has proven that the existing ponds within the site have had a significant positive impact on the water quality and removal of sediment[6]. A copy of the report is appended, Appendix 5.

[6] This efficacy has been documented in the memo titled "Mill Creek Example Measures, Winton, 7 November 2024"

8.2 Proposed additional Sediment Management Ponds

As outlined in Section 8.1, the current ponds are effective in removing sediment from Mill Creek To further improve sediment retention before water enters Lake Hayes, an additional inline pond is proposed for the lower catchment and two inline ponds in the upstream tributary stream are proposed as part of the Screen Hub development.

The details of these ponds are also described in the sections below and Figure 6 presents locations of these ponds

Figure 6: Proposed Sediment Management Scheme Plan

8.2.1 Mill Creek In-line Sediment Retention Pond

The purpose of this device is to capture sediment within Mill Creek which is generated from the entire Mill Creek catchment surface runoff. The pond will be cleared when sediment builds up, with the overall objective to enhance sediment management within the Mill Creek catchment.

Unlike localised stormwater devices serving only the Screen Hub, this pond provides catchment-wide benefits by capturing sediment generated throughout the Mill Creek catchment that ultimately reach Lake Hayes. The selected location, near the lower reaches of Mill Creek, is strategically positioned where approximately 80% of the catchment contributes flow. The flat topography at this site promotes low stream velocities, encouraging sediment deposition and retention before flow continues toward Lake Hayes.

This location also provides resilience to upstream ponds (e.g., Puku Iti and Puku Nui), acting as a final barrier to intercept sediment in the event of upstream ponds reaching capacity.

Compared to existing upstream ponds, the proposed pond is larger and positioned to intercept greater flow volumes, offering a robust, sediment removal measure for the catchment.

Further downstream, the steeper gradient towards Lake Hayes makes sediment retention less feasible; thus, the selected site represents the most effective opportunity for sediment capture.

The pond's design matches the existing stream profile and ensures minimal disturbance to flow dynamics while providing critical protection to Lake Hayes' water quality and will have the following dimensions:

- Top Length=67m
- Top Width=17.5m
- Depth=2m

For maintenance purposes there is a diversion channel designed so stream flow can diverted from away from this in-line pond when the pond needs to be cleared of sediment. This clearing of sediment will be conducted during a dry weather period.

8.2.1.1 Estimated sediment removal

The volume of the proposed pond is 900m^3, larger than existing ponds upstream (which are 750m^3 and 540m^3). Assuming the upstream ponds are cleaned when full and therefore operational, they will remove a large portion of sediment transported from upstream of them. Therefore, the sediment expected to be deposited in the proposed Ayrburn in-line sediment retention pond would largely be from runoff downstream of Puku Iti pond and upstream of this project's pond.

The catchment area upstream of Puku Iti is 19.93km^2 compared to the catchment area downstream of Puku Iti but upstream of proposed pond which is 13.55km^2. Both catchments consist of farmland, residential areas, and steep vegetated hills.

To roughly estimate the volume of sediment removal a comparison of both the catchment and characteristics of such provide a quantitative basis for assessment.

The Ayrburn catchment is 70% of the Puku Iti catchment and the proposed Ayrburn sediment retention pond is also 70% of the volume of the of Puku Iti and Puku Nui ponds combined volume. It can therefore be concluded that the proposed pond may fill up with sediment roughly every year and remove 900m^3 of sediment annually based on the analytical data presented thus far from the upstream pond performances.

It should be noted that this is a high-level estimate based on the two larger inline ponds upstream.

However, there are smaller in-line sediment retention ponds within Northbrook Waterfall Park site, directly upstream of this proposed pond, that have proven to remove sediment and are being maintained and cleared regularly. All of these smaller inline ponds, plus any ponds outside of this site that are not documented already, will also help to remove sediment from the catchment wide runoff upstream of the proposed pond and reduce the amount of sediment that reaches this pond, so possibly it could fill with sediment at a slower rate than estimated.

8.2.1.2 Velocity Assessment

The velocities through the proposed sediment pond were assessed for various storm events to ensure they are low enough for sedimentation to occur. The assessment for the velocity was undertaken using 1D flow modelling

A 1-D HEC-RAS model was run through the pond for 2/3 of 2yr and the 2yr ARI event. Baseflow within the stream is considered by the 2/3 of 2yr ARI event and is regarded as the typical annual recurrence rainfall event. The 2yr ARI event was also considered for sensitivity of flow response within the sediment pond. The peak velocity map for 2yr ARI event (given this is the higher of the two events with respect to flow) and associated cross sections assessed in the model are shown below in Figure 7.

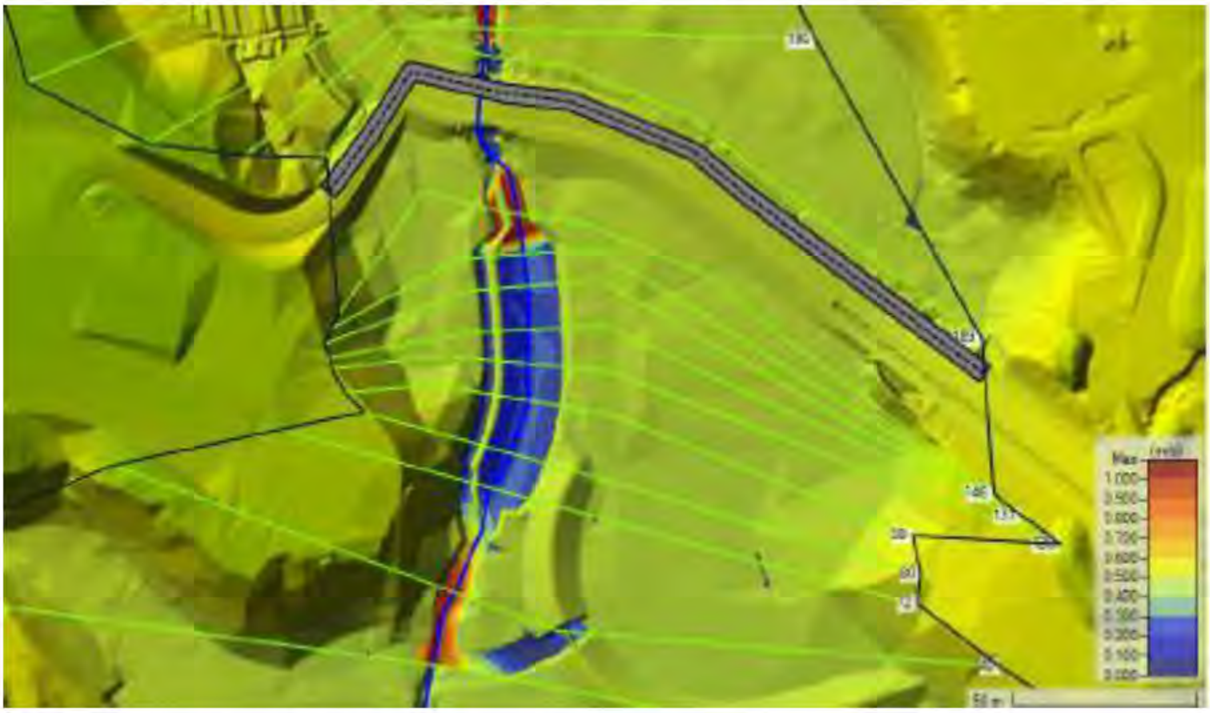


Figure 7: HEC-RAS 1D model Velocity Map and Cross Sections

With reference to the cross sections shown in the figure above the average velocity through the pond at each cross section for both rainfall events are shown below.

Table 5: Peak Velocity in Pond for 2/3rd 2yr and 2yr ARI Event

Cross Section	Sediment Pond Peak Velocity (m/s)	
	2/3 2yr ARI	2yr ARI
131	0.17	0.23
120	0.16	0.22
99	0.16	0.22
80	0.16	0.21
72	0.18	0.25

In both events the average velocities through the pond are low enough (below 0.25m/s[7]) that when the peak flow arrives it won't resuspend sediment built up in the pond. It should be noted that these are peak velocities associated with the peak flow from entire upstream Mill Creek catchment arriving to the proposed inline pond, prior to this occurrence the velocities will be lower as the flow is less (than the peak flow) and sedimentation can occur.

Larger events were also considered, such as rainfall events with recurrence intervals above the 2yr. During the larger than 2yr events the flow extends into the flood plain and outside of the pond, due to limited stream capacity. Below Figure 8 and Figure 9 show the velocities in both 20yr and100yr ARI events respectively.

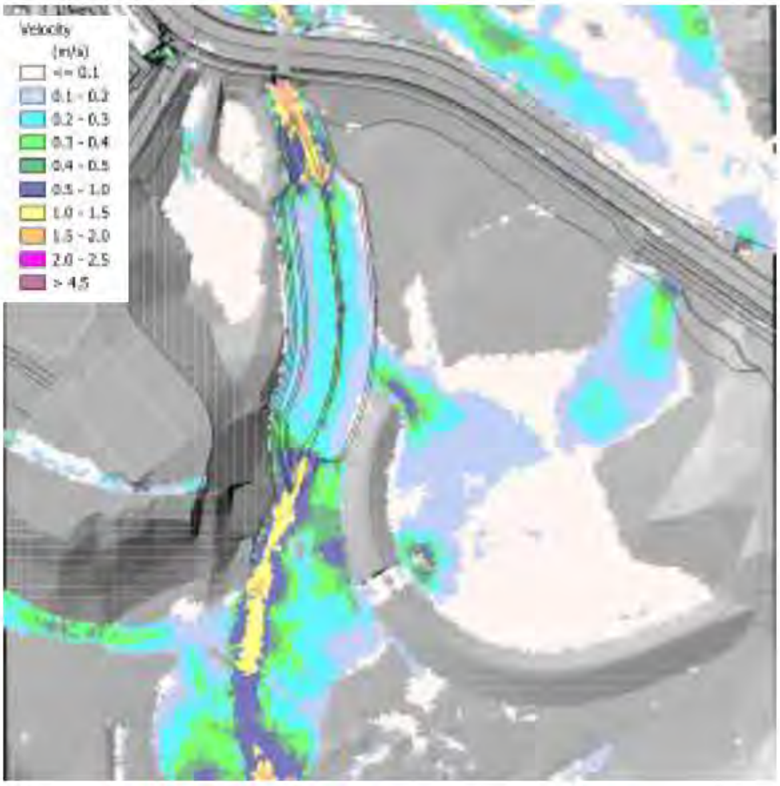


Figure 8: ICM Model 20yr Velocity Map

[7] Stormwater Management Devices in the Auckland Region (GD01), Auckland Council, Dec 2017, p.279

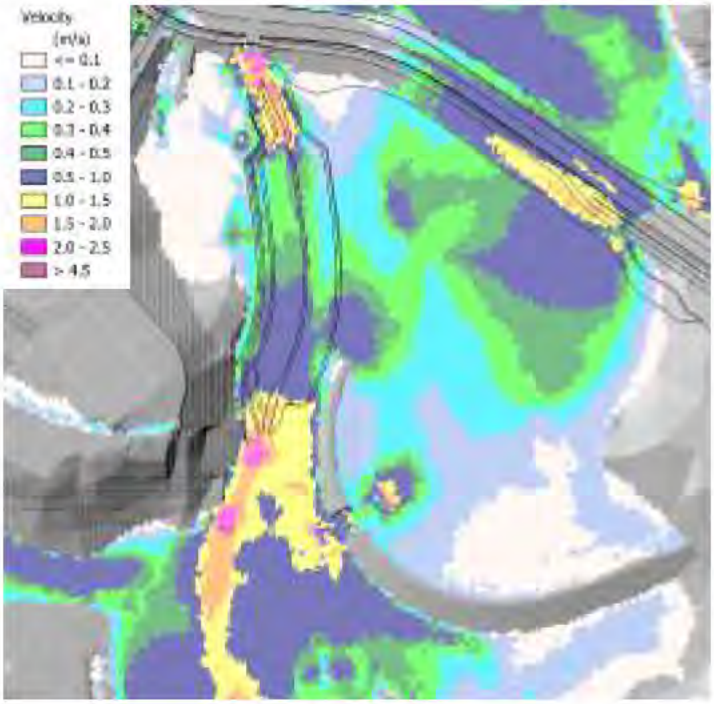


Figure 9: ICM Model 100yr Velocity Map

As seen in the figures above, the velocities are elevated in larger events. In the 20yr ARI event the velocities are largely below 0.25-0.3m/s to avoid re-suspension in the pond and much of the surrounding flood plain. The velocities are higher outside of the pond where the stream channel is narrower, which is expected in an event like this. However, there is confidence that if the pond is full of sediment and a 20-yr event occurs, there should be minimal re-suspension of sediment within the pond, protecting Lake Hayes from further sedimentation in a 20yr rainfall event.

In the 100yr the velocities are higher than the 20yr (as expected) within the pond and the flood plain. These velocities may may cause erosion and re-suspend sediment in pond. This is commonly experienced and expected during such extreme events

8.2.2 Upstream Tributary (Stream) In-line ponds

Pond D (Existing Depression Area):

Pond D is an existing pond, which is within the tributary and located downstream of the spring and Millbrook Village piped discharge. This pond is essentially capturing all of the upstream catchment flows. This pond will be cleaned and enhanced to improve its ability to slow stormwater flow and trap sediment effectively. By retaining and settling suspended solids, Pond D will reduce sediment loads before they continue downstream toward Lake Hayes, contributing to improved catchment-wide water quality.

Pond E (New Sediment Trap Pond) Pond E is a proposed new pond to be constructed further downstream, near the convergence point of runoff from vineyard areas and the cycle trail. Positioned strategically just before the tributary enters a subterranean section, Pond E will capture and settle sediments transported in surface runoff from these contributing areas. This new pond is designed to enhance sedimentation efficiency, intercepting sediments at a critical control point to prevent downstream transport and protect Lake Hayes.

Figure 10: Pictorial location of proposed pond E

Figure 11: Pictorial location of proposed pond D

9 Contaminant Load Modelling

CKL assessed contaminant loading for the site in existing (farmed sheep and beef) and proposed conditions in order to determine if the proposed stormwater treatment approach would improve the water quality of the stormwater discharging from site. Given nutrient loading is an issue in Lake Hayes, the focus was on Phosphorus, Nitrogen and TSS, however heavy metals are also considered.

Auckland Council Contaminant Load modelling methodology is used in the assessment. Although this methodology is applicable to a different climate and geology it is currently the main methodology used across the country and also adopted by the Christchurch City Council (CCC).

9.1 Total Phosphorus and Total Nitrogen Yields

The Ministry for Environment conducted contaminant loading for different land uses in New Zealand for Total Nitrogen (TN) and Total Phosphorus (TS). Table 6 below demonstrates the contaminant yield for each type of land use.

Table 6: Land use specific yields for Total Nitrogen and Total Phosphorus

Landuse	LCDB4 category	TN specific yield (kg/ha/year)	TP specific yield (kg/ha/year)	Reference-land use type
Urban	Built-up Area (settlement)	8.0	0.8	MfE (2002) -Urban
Exotic	Exotic Forest	2.8	0.35	MfE (2002) -Exotic
Dairy	High Producing Exotic Grassland	25.0	1.00	MfE (2002) -Dairy
Sheep and beef	High Producing Exotic Grassland	9.0	1.96	MfE (2002) -Hill
Lifestyle	High Producing Exotic Grassland	5.2	0.46	MfE (2002) -low intensity pasture
Crop and Orchard	Orchard, Vineyard or Other Perennial Crop	15	No Data	Plant & Food

The existing grass areas within the Film Hub stormwater management area (within the overall site) are considered to be assessed as sheep & Beef in light of its current zoning and potential use. Farmed areas produce high nutrient loading given animal faeces. Additionally, they can be assumed to have occasional spraying of pesticides to manage weeds.

The proposed land use is considered urban given this section of site is being converted to a commercial park area. This is considered a conservative assumption given the daily use of the proposed carparks and accessways will be significantly lower than an urban road. However, most nutrient loading in an urban environment comes from pet waste, fertilizer of garden, and atmospheric depositions. It is not expected that the Ayrburn Screen Hub will have much, if any pet waste and the use of fertilizers on site will be limited. Atmospheric deposition cannot be controlled. Therefore, the actual nutrient loading in the post-development scenario is expected to be lower than what is presented above. Given the use of fertilizer can be limited for this development proposal, it is assumed that post-development nutrient loading will be reduce by 30% compared to above table levels.

9.2 Total Suspended Solids and Heavy Metal Yields

Total Suspended Solids (TSS) and heavy metals loading was assessed based on the contaminant yields applied within the Auckland Council's contaminant load model (CLM). TPH below stands for Total Petroleum hydrocarbons, not considered here given the low vehicle traffic. Table 7 below demonstrates TSS yields for different and uses.

Table 7: Auckland Council's Land Use Specific Contaminant Yields

	AREA	Contaminant yield g m-2 year-1			
		TSS	Total zinc	Total copper	TPH
Roofs	galvanised steel unpainted	5	2.24	0.0003	0
	galvanised steel poor paint	5	1.34	0.0003	0
	galvanised steel well painted	5	0.20	0.0003	0
	galvanised steel coated	12	0.28	0.0017	0
	zinc/aluminium surfaced steel	5	0.20	0.0009	0
	zinc/aluminium surfaced steel coated long run and tiles	5	0.02	0.0016	0
	concrete	16	0.02	0.0033	0
	copper	5	0.00	2.1200	0
	other materials	10	0.02	0.0020	0
Roads	<1k vpd	21	0.004	0.0015	0.033
	1k-5k vpd	28	0.026	0.0089	0.201
	5k-20k vpd	53	0.110	0.0369	0.838
	20K-50K	96	0.257	0.0858	1.947
	50k-100k vpd	158	0.471	0.1570	3.564
	>100K vpd	234	0.729	0.2431	5.519
Paved	Residential paved	32	0.195	0.0360	0
	Industrial paved	22	0.590	0.1070	0
	Commercial paved	32	0.000	0.0294	0
Perviou	Urban grasslands and trees	45	0.001	0.0003	0
		92	0.003	0.0006	0
		185	0.006	0.0013	0
	Urban stream channels (length x	6,000	0.210	0.0420	0
	Construction sites	2,500	0.088	0.0180	0
	Slope	5,600	0.196	0.0390	0
		106,0	0.271	0.0740	0
Rural	Exotic production forest	35	0.001	0.0002	0
	Slope	104	0.003	0.0007	0
		208	0.007	0.0015	0
	Stable forest	14	0.000	0.0001	0
	Slope	42	0.001	0.0003	0
		83	0.002	0.0006	0
	Farmed pasture	152	0.005	0.0011	0
	Slope	456	0.016	0.0032	0
		923	0.032	0.0065	0
	Retired pasture	21	0.000	0.0001	0
	Slope	63	0.002	0.0004	0
		125	0.004	0.0009	0

Based on the above contaminant yields, the existing farmed scenario has the following contaminant yields: TSS is 152 g/m^2/yr, Zinc as 0.005 g/m^2/yr and Copper as 0.0011 g/m^2/yr, given it would be considered farmed pasture on flatter land.

For the proposed scenario, different land uses were used for each surface type. The following were used: Zinc, aluminium surfaced steel for roofs, <1k vehicle per day for roads, urban grasslands and trees for pervious area, and Commercial paved for footpaths. However, the commercial paved area has significant levels for copper which is not expected in foot paths for this site development. The Auckland CLM yield levels for paved areas considers carparks and footpaths[8]. Carparks are expected to have high heavy metals due to car breaks, but footpaths should have next to no levels (very low levels). Additionally, heavy metals in paved areas in the studies supporting the Auckland CLM were found to come from adjacent building facades that had copper cladding or downpipes. The buildings proposed for this development will use low contaminant generating facades and downpipes. TSS on footpaths are from adjacent grassed areas. The concrete footpaths themselves produce little to no contaminants. Therefore, the paved commercial copper yields in the Auckland CLM are assumed to be much higher than what is generated from footpaths within this proposed development and the copper yield is assumed to be zero here.

The filming studios 'backlot' parking area is assumed to be the same as road contaminant given the paved commercial levels are skewed for areas with copper cladding or signs or large landscape areas adjacent to these areas, which this specific area would not have. The roads yield with vpd<1000 seems to be a more appropriate estimate.

9.3 Pre- and Post-Contaminant Yields

Using the above assessment for contaminant yields, Table 8 and Table 9 below identifies the contaminant loading for the pre- and post-development scenario respectively. which is the area where contaminants may be generated in relation to this application.

*Table 8: Pre-Development Contaminant Loading **(Farmed)***

	Area (m²)	TP Loading (g/m²/yr)	Runoff TP (kg/yr)	TN Loading (g/m²/yr)	Runoff TN (kg/yr)	TSS Loading (g/m²/yr)	Runoff TSS (kg/yr)	Zinc Loading (g/m²/yr)	Runoff Zinc (kg/yr)	Copper Loading (g/m²/yr)	Runoff Copper (kg/yr)
Farmed Grassed Area	234000	0.198	13.90	0.90	63.18	152	10670	0.005	0.3510	0.0011	0.0772
Sum	**234000**		**13.90**		**63.18**		**10670**		**0.3510**		**0.0772**

Table 9: Post-Development Contaminant Loading (untreated)

		Area (m²)	TP Loading (g/m²/yr)	Runoff TP (kg/yr)	TN Loading (g/m²/yr)	Runoff TN (kg/yr)	TSS Loading (g/m²/yr)	Runoff TSS (kg/yr)	Zinc Loading (g/m²/yr)	Runoff Zinc (kg/yr)	Copper Loading (g/m²/yr)	Runoff Copper (kg/yr)
Roads/carparks/access areas	Catchment A	3396	0.056	0.17	0.56	1.71	21	64.2	0.004	0.0122	0.0015	0.0049
	Catchment B	8897	0.056	0.45	0.56	4.84	21	168.2	0.004	0.0320	0.0015	0.0120
	Catchment D/ Catchment E/Catchment C	13778	0.056	0.69	0.56	6.94	21	260.4	0.004	0.0496	0.0015	0.0186
Foot paths		3057	0.056	0.15	0.56	1.54	32	88.0	0.000	0.0000	0.000	0.000
Roofs		15559	0.056	0.83	0.56	8.28	5	73.9	0.020	0.2956	0.0016	0.0236
Land-scaping		189313	0.056	3.18	0.56	32.80	45	2555.7	0.001	0.0568	0.0003	0.0170
Sum		**234000**		**5.48**		**54.76**		**3210.41**		**0.4463**		**0.0759**

[8] Urban Sources of Copper, Lead, and Zinc, Auckland Regional Council, Oct 2009

9.3.1 Contaminant yield sensitivity -existing condition

The peer review[9] raised questions about whether the existing land use designation of sheep and beef farming was appropriate, given that the site has not been actively grazed for some time. It was suggested that these areas would be more accurately classified as Retired Pasture or Lifestyle land use.

To reflect this, the contaminant yields were recalculated using the average yield rates from both Retired Pasture and Lifestyle land uses. Full details of the methodology and outcomes can be found in the SMP Sensitivity Report, Appendix 5.

The table below presents a summary of contaminant loads generated from the pre-development Film Hub stormwater management area, based on findings from the previously mentioned report.

*Table 10: Pre-Development Contaminant Loading (**Lifestyle vs Farmed)***

	Area (m^2)	**TP Loading ($g/m^2/yr$)**	**Runoff TP (kg/yr)**	**TN Loading ($g/m^2/yr$)**	**Runoff TN (kg/yr)**	**TSS Loading ($g/m^2/yr$)**	**Runoff TSS (kg/yr)**	**Zinc Loading ($g/m^2/yr$)**	**Runoff Zinc (kg/yr)**	**Copper Loading ($g/m^2/yr$)**	**Runoff Copper (kg/yr)**
Lifestyle	234000	0.046	10.76	0.52	121.68	86.5	20241	0.0025	0.585	0.0006	0.1404
Farmed Grassed Area	234000	0.198	13.90	0.90	63.18	152	10670	0.005	0.3510	0.0011	0.0772

9.4 Contaminant Removal Rates from Treatment Devices

Estimated removal rates of each contaminant for different stormwater management practices are assumed using NZTA's rates[10]. NZTA removal rates are considered best practice for wider NZ. Christchurch City Council[11] (CCC) also have assumed removal rates for various devices and these rates were also considered when choosing removal rates for each device. The CCC rates include a range or removal efficiencies for each device, many of the NZTA rates are within the middle of the range provided in CCC. Table 11 below shows NZTA's removal rates for various stormwater practices.

Table 11: NZTA Removal Rates for Various Stormwater Devices

[9] Peer review undertaken by Peter Christensen, Storm Environmental

[12] Refer to Section 9.5 paragraph 3

[12] Refer to Section 9.5 paragraph 3

Table 8-1 Removal Rates for Various Stormwater Practices for TSS and Nutrients					
Practice	Removal rates (%)				
	TSS	Nitrogen	Phosphorus	Zinc	Copper
Swales	70	20	30	75	60
Filter Strips	80	20	20	75	60
Sand Filters	80	35	45	90	90
Rain Gardens (normal)	90	40	60	90	90
Rain Gardens (w/anaerobic zone)	90	50	80		
Infiltration Practices	80	30	60	80	70
Wet Ponds	75	25	40	50	40
Wetlands	90	40	50	80	80
Oil Water Separators	15	0	5	5	5

The removal rates are relatively low for Phosphorus and Nitrogen in some stormwater treatment devices and given these nutrients are of particular interest in the catchment, a treatment train approach is suggested as the best practical option to treat runoff from the site.

Phosphorus and Nitrogen are removed from stormwater within raingardens as stormwater filters into/through the media and clings to the sediments and soil's structure. The nutrients are then absorbed by the roots of the plants within the devices and removed from the stormwater. Treated (Stormwater) water then drains from the bottom of the device.

Heavy metals partially cling to TSS which, when stormwater is slowed down through devices, this settles out. It is filtered through media in raingarden where it fills the void space in the topsoil and media overtime and devices usually need to be dug up and fresh soil replaced given the build-up of TSS and heavy metals in the soil. This typically happens every 25 years.

Similar nutrients in wetlands are removed through sedimentation and through plant uptake. Given the proposed pod wetlands are not designed as a traditional wetland, many of the removal efficiency rates used in this assessment are on the lower end of the range provided in CCC reporting, and lower than the NZTA rates provided above.

Ponds are less efficient at removing nutrients, however, given the water quality event can be infiltration through ground, the tertiary infiltration ponds are assumed to have similar removal rates to infiltration practices. The removal efficiency rate range for nitrogen in infiltration practices in CCC is higher than NZTA rates. Given the infiltration ponds are proposed to be planted which will provide/include nutrient uptake, a removal rate in middle of CCC value range, but higher than NZTA value was chosen. All other rates use the above NZTA value and relate to the CCC values.

The removal efficiencies of the proposed Hynds Up-Flo are provided in Section 7.4 above. The final removal rates assumed for each device is provided below in Table 12.

9.5 Treatment Train Approach

A treatment train approach is suggested to treat the proposed carpark in order to achieve high removal rates of TP, TN, TSS and heavy metals.

NZTA uses a simplified equation for the total removal of a given contaminant for two stormwater treatment devices in a series. The equation is as follows:

R = A + B – [(A x B)/ 100]

Where:
R = total removal rate
A = Removal rate of the first or upstream practice
B = Removal rate of the second or downstream practice

This equation was used to determine the total removal rate of contaminants from the catchment. It should be noted that it was applied for two devices, while the Catchment A and Catchment B receive three levels of treatment, for this assessment only the first two devices are assessed, and the tertiary infiltration ponds are not included in removal rates for these catchments in the CLM model. These catchments will receive tertiary treatment acting as polishing treatment and this adds robustness to the design in case of upstream devices have reduced efficiency. Table 12 below indicated the total removal rates for each contaminant in question.

Table 12: Total Removal Rates of Contaminants for Treatment Train Approach

Options	% TP removal	% TN removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device (Up-Flo)	48%	39%	87%	59%	70%
Infiltration Ponds	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention	60%	40%	90%	90%	90%
Bioretention @ 56% of removal efficiency	34%	22%	50%	50%	50%
Total Bioretention + Wetland	67%	53%	85%	80%	80%
Total Proprietary Device + Wetland	74%	63%	96%	84%	88%
Total Bioretention + Infiltration Ponds	73%	69%	90%	90%	85%

As seen above, it is difficult to achieve (relatively) high rates of TN removal rates in comparison to TP, TSS and heavy metals which have relatively high rates of removal based on this treatment train approach. Additionally, nitrogen and phosphorus often bind to TSS, so the high levels of TSS removal will ensure elevated levels of TN and TP removal are achievable.

9.6 Treated Stormwater Contaminant Yields

Based on the above assessment for removal rates given a treatment train approach, the overall reduction factor in Table 12 was used against the generated contaminant loading in Table 9 to determine the contaminant yield discharging from site after treatment, including the treatment of the existing carpark. Table 13 below demonstrates the pre-development runoff contaminant yields and post-development runoff contaminant yields after treatment as comparison.

*Table 13: Pre-Development **(Farmed)** and Post-Development Contaminant Yield After Treatment*

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Pre-Development	13.90	63.18	10670.4	0.3510	0.0772
Post-Development (Treated)	1.93	20.57	557.23	0.0772	0.0144
Reduced Yield	**-11.97**	**-42.61**	**-10113.2**	**-0.2738**	**-0.0628**
% Reduced	**86%**	**67%**	**95%**	**78%**	**81%**

As seen above, all contaminants of interest are reduced in the runoff from the proposed site compared to the existing situation. TSS and heavy metals are nearly fully removed from runoff and nutrients are reduced by half or one-third from the existing situation.

It should also be noted that the tertiary treatment in the tertiary pond is not considered above, as such a conservative outcome is presented. Additionally, the inline sediment (removal) pond will remove sediment and contaminants bound to sediment from the wider Mill Creek catchment and will have a positive impact on the health of Lake Hayes.

9.7 Sensitivity Analysis - Contaminant Load Model Parameters & outcomes

In response to the peer review, several CLM parameters were identified for further evaluation regarding their influence on water quality results.

The following key parameters were selected for sensitivity analysis:

- Tertiary treatment pond performance within the treatment train
- Raingarden media infiltration rates

An overview of the assessment and outcomes of the sensitivity of these parameters are presented in the following subsections.

9.7.1 CLM assessment - update to treatment train:

It is proposed to assess the efficacy of the system without the inclusion of the Tertiary infiltration pond as part of the contaminant removal. The efficacy of the ponds, which have infiltration bases, for the catchments C, D & E as a contaminant reducer is influenced by the runoff from Catchments A & B. Therefore, inclusion of these ponds as part of the treatment train is not truly reflective of the runoff arriving at different times. Therefore, for the CLM the following system has been assessed, which is the same approach as the original CLM[12]:

[12] Refer to Section 9.5 paragraph 3

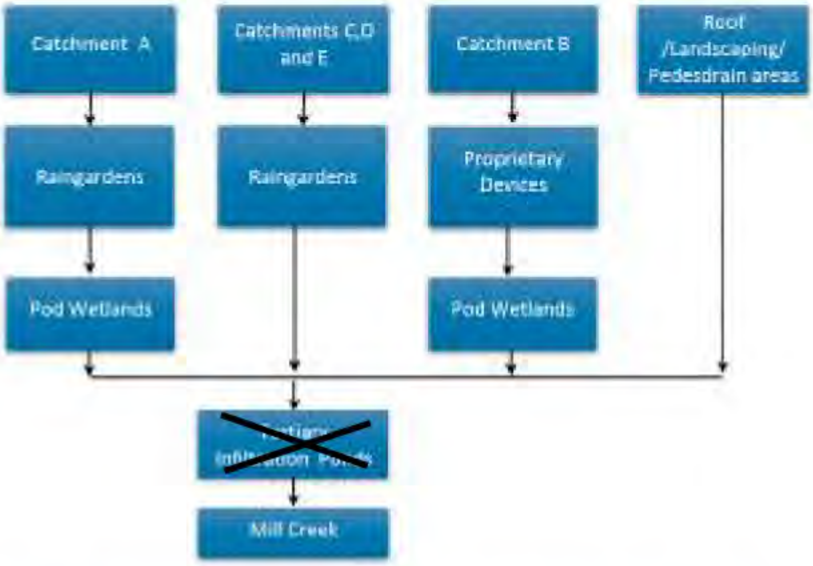


Figure 12: Diagram of the CLM assessed proposed stormwater treatment system

9.7.2 Treated Stormwater Contaminant Yields

The treatment efficacy has been updated based on the following scenarios:

- Reduced raingarden efficacy
- Reduced raingarden efficacy and no Tertiary infiltration

9.7.2.1 Reduce raingarden only

Due to reduced raingarden sizes, removal rates were assessed for a treatment train approach, accounting for lower efficiency from not treating the full WQF.

*Table 14: Pre-Development **(Lifestyle)** and Post-Development Contaminant Yield After Treatment (w reduce raingarden efficiency)*

	Runoff TP (kg/yr)	**Runoff TN (kg/yr)**	**Runoff TSS (kg/yr)**	**Runoff Zinc (kg/yr)**	**Runoff Copper (kg/yr)**
Pre-Development	10.76	121.68	20241	0.585	0.1404
Post-Development (Treated)	4.24	51.68	1785.46	0.1141	0.0302
Reduced Yield	**-5.71**	**-70.0**	**-18455.46**	**-0.4709**	**-0.1102**
% Reduced	**53%**	**58%**	**91%**	**80%**	**78%**

These results were compared with the full rain garden treatment under the previous K=0.75 outcome in the following table.

Table 15: Reduction in contaminant – compare Raingarden K values

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
K=0.75 % Reduced	**54%**	**58%**	**91%**	**82%**	**81%**
K=0.3 % Reduced	**53%**	**58%**	**91%**	**80%**	**78%**

9.7.2.2 Reduce raingarden & no tertiary infiltration ponds

In addition to the reduced raingarden treatment efficiency the removal of the tertiary infiltration ponds from the treatment train has been assessed.

Table 16: Contaminant Yield After Treatment reduced raingarden efficiency & no tertiary ponds

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Pre-Development (Lifestyle)	10.76	121.68	20241	0.585	0.1404
Post-Development (Treated)	5.36	55.27	1900.2	0.1360	0.0374
Reduced Yield	**-5.40**	**-66.408**	**-18340.65**	**-0.490**	**-0.1030**
% Reduced	**50%**	**55%**	**91%**	**77%**	**73%**

As seen above, all contaminants of interest are reduced in the runoff from the proposed site compared to the existing situation. TSS and heavy metals have been greatly reduced, and nutrients are reduced by at least half from the existing situation.

9.8 CLM summary

Based on the CLM assessment, including the sensitivity analysis, the surface runoff will be treated prior to discharge with the surface water quality entering Mill Creek, and ultimately Lake Hayes, being of higher quality than the existing conditions.

The design for the raingardens, as evaluated in section 7.1, uses a lower treatment efficiency, which will be carried forward into the next stages of design. Although the assessment did not include the tertiary ponds, these will ultimately provide an additional level of stormwater treatment. Therefore, the water quality assessment remains conservative.

10 Flood Assessment

The existing ICM model for Northbrook Waterfall Park and Ayrburn Domain (Mill Creek 1-D model) has been developed further here to include a rain-on-grid (2-D) flood model for the Screen Hub site area and surrounding catchment. Figure 13 below shows the existing Mill Creek Peak flow input and the rain-on-grid catchment area assessed for this application. The details of the flood assessment are described in the Flood Model Report attached in Appendix 3

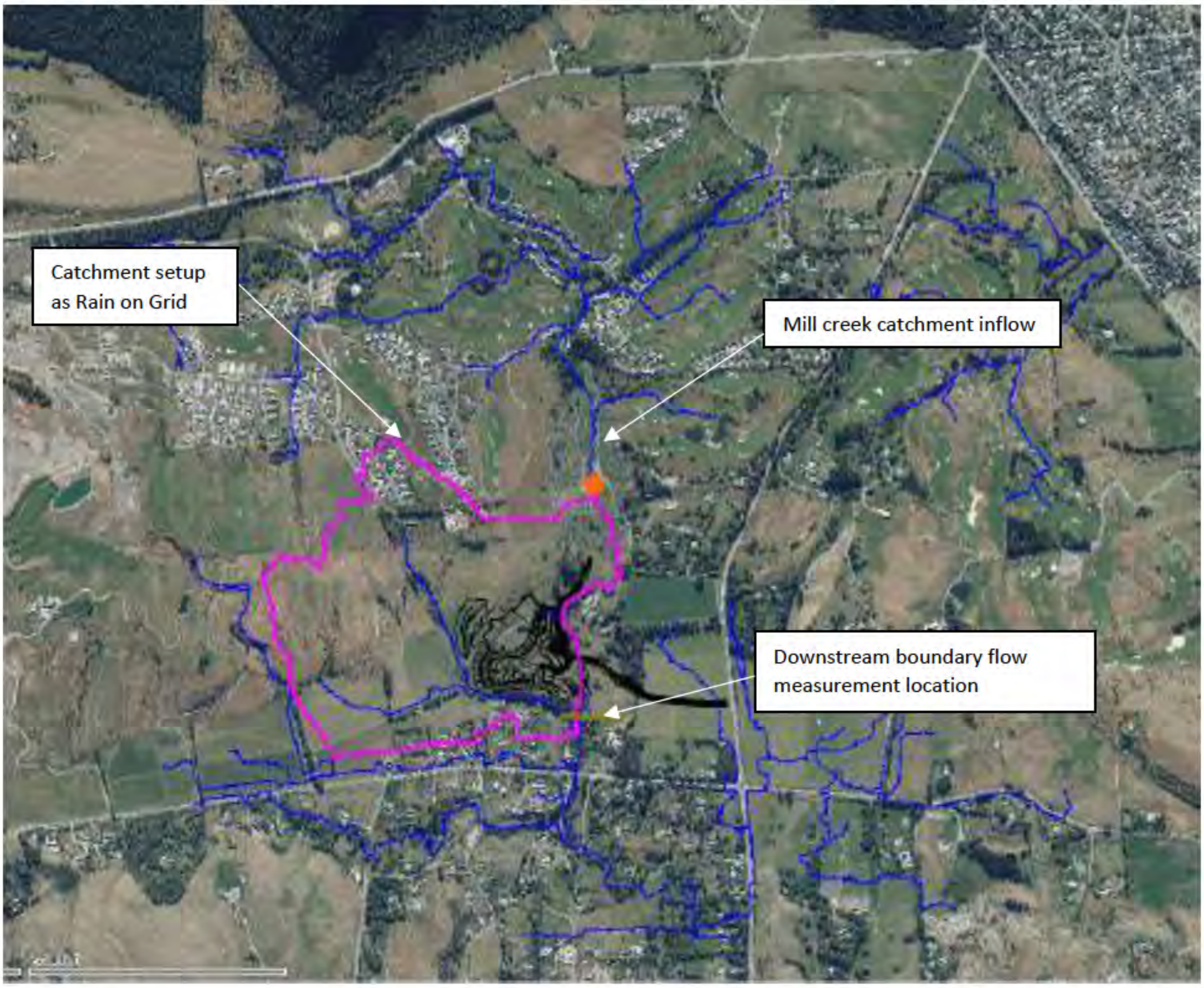


Figure 13: Screen Hub Flood Model Input and Catchment Area

The existing scenario for the flood model incorporates all constructed and consented works within Northbrook Waterfall Park and Ayrburn, representing the fully consented developed condition of the wider site, which supporting the previous projects within Ayrburn. This existing model is identified as Version 21 and includes a rain-on-grid model covering the proposed Screen Hub and surrounding area- **Existing Model** of this assessment.

For the post-development scenario, the model has been updated to incorporate the proposed Screen Hub development within the rain-on-grid catchment (Post- development Model), allowing assessment of the potential impacts of the new works on flood behaviour in the area.

10.1 Proposed 100-yr ARI Flood Assessment

The post-development scenario flood model was used to assess the risk of flooding on site and in surrounding area in 100yr ARI event. The results from the flood model are shown below.

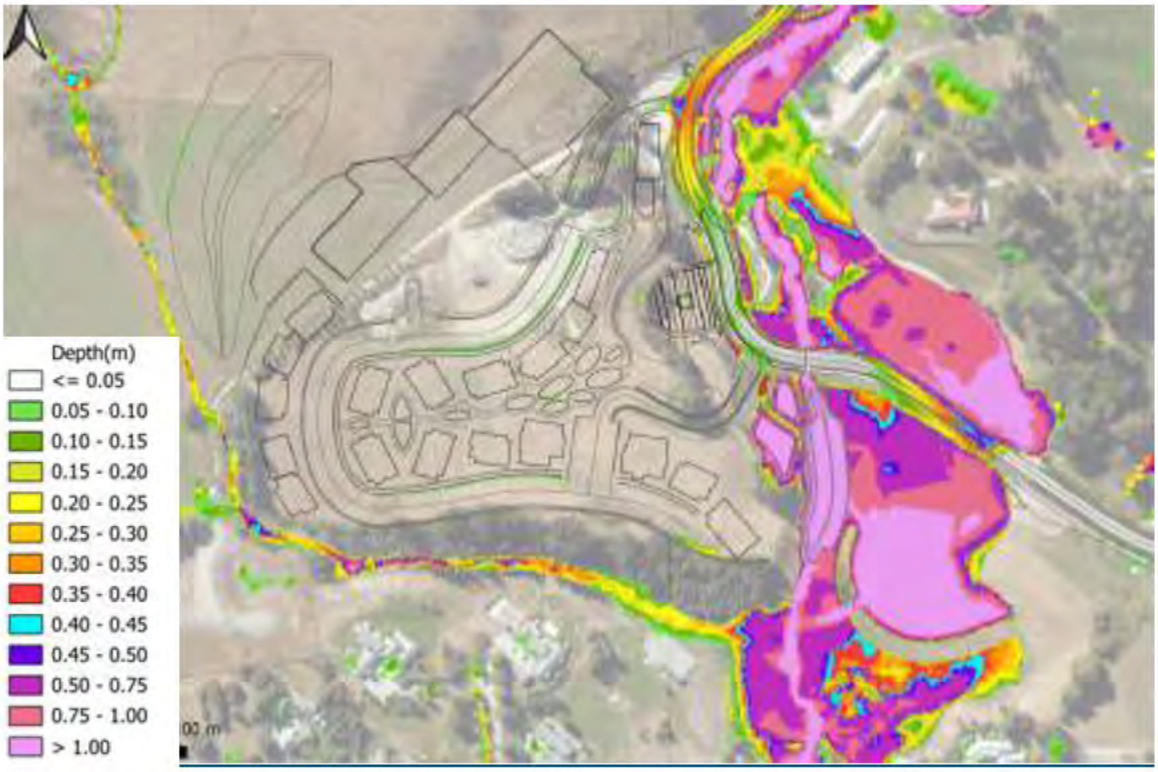


Figure 14: Post-Development 100yr ARI flood map

Figure 15: 100yr ARI flood difference map. (Post Studio minus Pre Studio)

As seen above, the upstream flow is diverted away from proposed Screen Hub development and contained within the existing intermittent stream and overland flow paths. The flooding within the proposed development is minimal and localised flooding areas are contained to landscape areas and outside of roads, carparks, footpath and away from proposed buildings.

Outside of the application site, there is flooding across Ayr Avenue downstream of the site in a 100yr ARI event, however this situation has not changed due to the addition of the Screen Hub development as the main peak flow impacting inundation along Ayr Avenue are from the Mill Creek flow, arriving after the runoff from the Screen Hub to the creek. The flood risk within the road has been assessed and consented under previous works (RM240252)[13].

There is approximately 100 to 160mm reduction in the flood depths in the post development model run, this is due to the creation of more storage capacity from the dry basins and inline ponds as part of the Screen hub development.

10.2 Pre- and Post-Development Peak Flow Assessment (Wider Southern Boundary)

The wider site (including Northbrook Arrowtown and Ayrburn Domain) post-development flows must not exceed pre-development flows at the southern boundary (see Figure 13 above). This boundary has been the assessment point for previous consents, and the proposed Screen Hub design has been assessed to ensure the post-development for the wider site does not exceed pre-development peak flows.

The results from the updated flood model, including rain-on-grid catchment area for both pre- and post-development flows is shown below in Table 17.

Table 17: Pre- and Post-Development Peak Flow at Wider Southern Boundary

Storm Event	Peak Flow at Wider Site Boundary (m^3/s) Pre-Development*	Peak Flow at Wider Site Boundary (m^3/s) Screen Hub Post development
2 Year ARI	4.29	4.24
20 Year ARI	10.15	8.92
100 Year ARI	37.65	35.75

The post-development flow is less than pre-development at the wider site southern boundary, location shown in Figure 13. Flows from Mill Creek spill into the paddock on the true left bank of the creek and the consented Haybarn bund attenuates flows from the wider catchment. This is in line with other previous consents (RM240252 and RM230425).

[13] Flood Assessment Northbrook Arrowtown Variation Application, CKL, April 2024 (RM240252)

11 Summary

A stormwater management assessment was completed for the proposed Ayrburn Screen Hub. The best practicable stormwater management plan for this site has been developed to mitigate the effects of development of the site on the receiving Mill Creek and the downstream Lake Hayes environment.

This stormwater management includes discharging stormwater runoff from internal roading and parking to raingardens followed by series of pod wetlands. This treatment train approach will ensure higher removal rates of Nitrogen, Phosphorus, and TSS which are the main nutrients of concern for the receiving environment, Lake Hayes. Some of the road area cannot discharge to the pod wetlands given height constraints, these areas will be treated by raingardens followed by an infiltration pond prior to discharging to Mill Creek. The infiltration ponds will provide treatment through infiltration to the entire upstream catchment including the low contaminant generating surfaces (roofs, footpaths, pervious areas) and provide secondary and tertiary treatment to the road and parking areas.

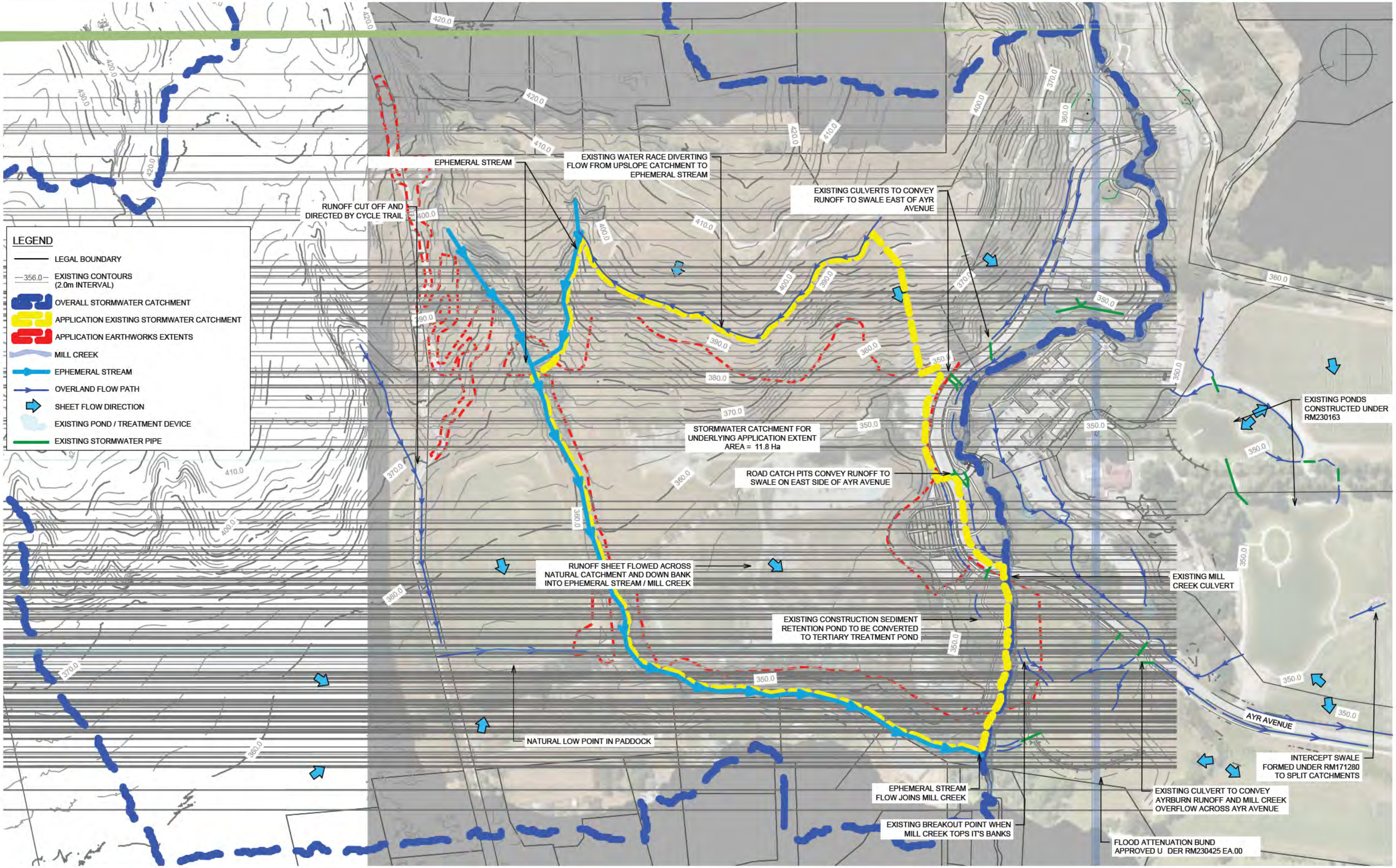
The upstream catchment runoff is diverted away from the contaminant generating areas via existing overland flow paths and streams and landscaping. This will ensure no mixing of upstream runoff with the untreated water from the road and the treatment devices function as designed.

An inline sediment retention pond within Mill Creek downstream of the Screen Hub and just upstream of the wider Ayrburn Farm southern boundary is proposed for sediment removal. This pond is designed to settle out sediment from within the creek flow, which is generated from the entire upstream catchment, prior to entering Lake Hayes. The velocities within the pond were assessed to ensure they will settle out suspended solids in the stream without resuspension in the more frequent rainfall events. It is estimated that this in-line pond will remove about 900m^3 per annum of sediment that would otherwise deposit into Lake Hayes.

A flood model was developed building on the existing Mill Creek (1-D) peak flow flood model with additional rain-on-grid model for Screen Hub and surrounding catchment. The results from the model show there is no increased flood risk within the proposed Screen Hub site or downstream of the subject site. Furthermore, the post-development flow at the wider Ayrburn Farm southern boundary is less than the pre-development flow, thus meeting the overarching flow mitigation strategy for the site.

Appendix 1 Drawings

(Refer to Paterson and Winton Ayrburn Screen Hub Consent Drawings, July 2025)



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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER DRAINAGE -
CATCHMENTS AND EXISTING FEATURES

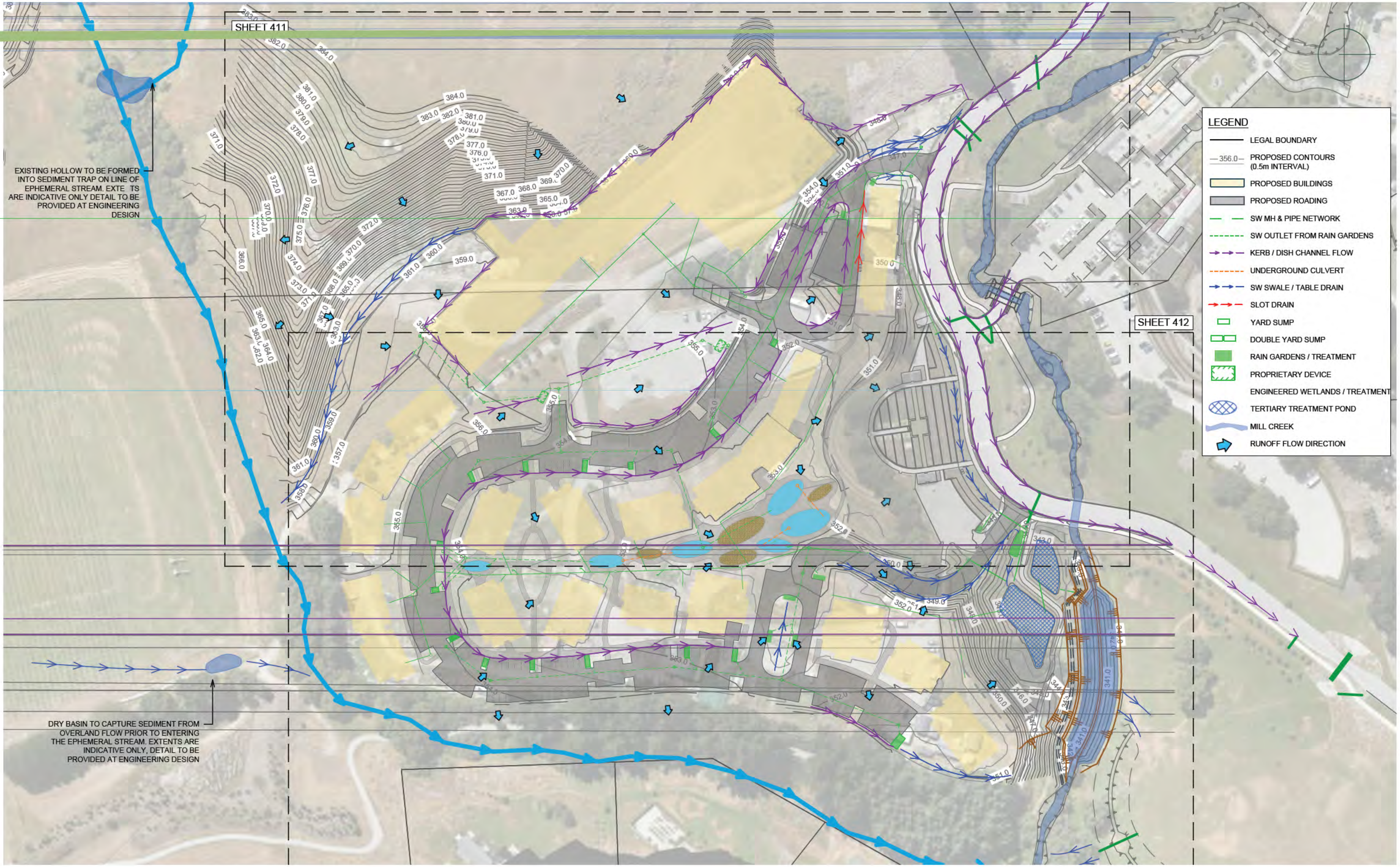
DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS FOR CONSENT

SURVEYED	PAT	05.09.2024
DESIGNED	AH	06.11.2024
DRAWN	AH	29.11.2024
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	400
REVISION	B
SCALE (A3)	1:3000



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WINTON BEST BY DESIGN

DRAWING TITLE	DATUM INFORMATION		
AYRBURN SCREEN HUB - LOT 4 DP 540788	COORDINATE SYSTEM	NZGD2000	
CONSENT DRAWINGS		MOUNT NICHOLAS CIRCUIT	
STORMWATER DRAINAGE - OVERVIEW	DATUM	DUNEHT1958	
	ORIGIN OF COORDINATES	IT X DP 23038	
	ORIGIN OF LEVELS	IT X DP 23038 : 358.566m	

REV	DRAWN	DATE	NOTE
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STATUS FOR CONSENT

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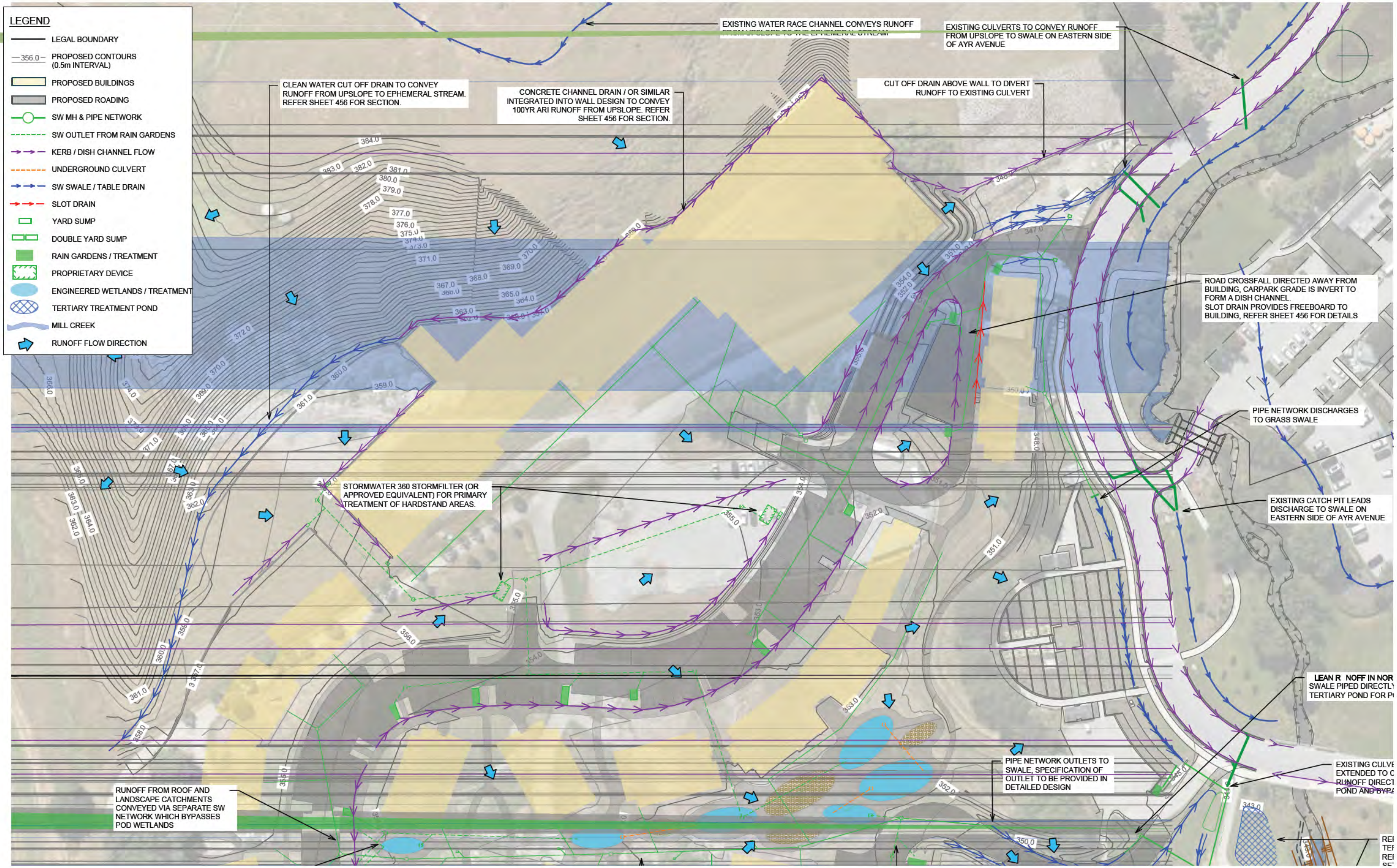
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	410
REVISION	B
SCALE (A3)	1:1500



DRAWING TITLE	DATUM INFORMATION		REV	DRAWN	DATE	NOTE					
AYRBURN SCREEN HUB - LOT 4 DP 540788	COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT	A	AH	29.11.2024	-	SURVEYED	PAT	05.09.2024	PROJECT	P240664
CONSENT DRAWINGS	DATUM	DUNEHT1958	B	SB	18.07.2025	SUBSTANTIVE APPLICATION	DESIGNED	AH	06.11.2024	DRAWING NO	001
STORMWATER DRAINAGE	ORIGIN OF COORDINATES	IT X DP 23038					DRAWN	AH	29.11.2024	SHEET	411
	ORIGIN OF LEVELS	IT X DP 23038 : 358.566m					REVIEWED	SP	18.07.2025	REVISION	B
			STATUS		FOR CONSENT		APPROVED	SP	18.07.2025	SCALE (A3)	1:1000

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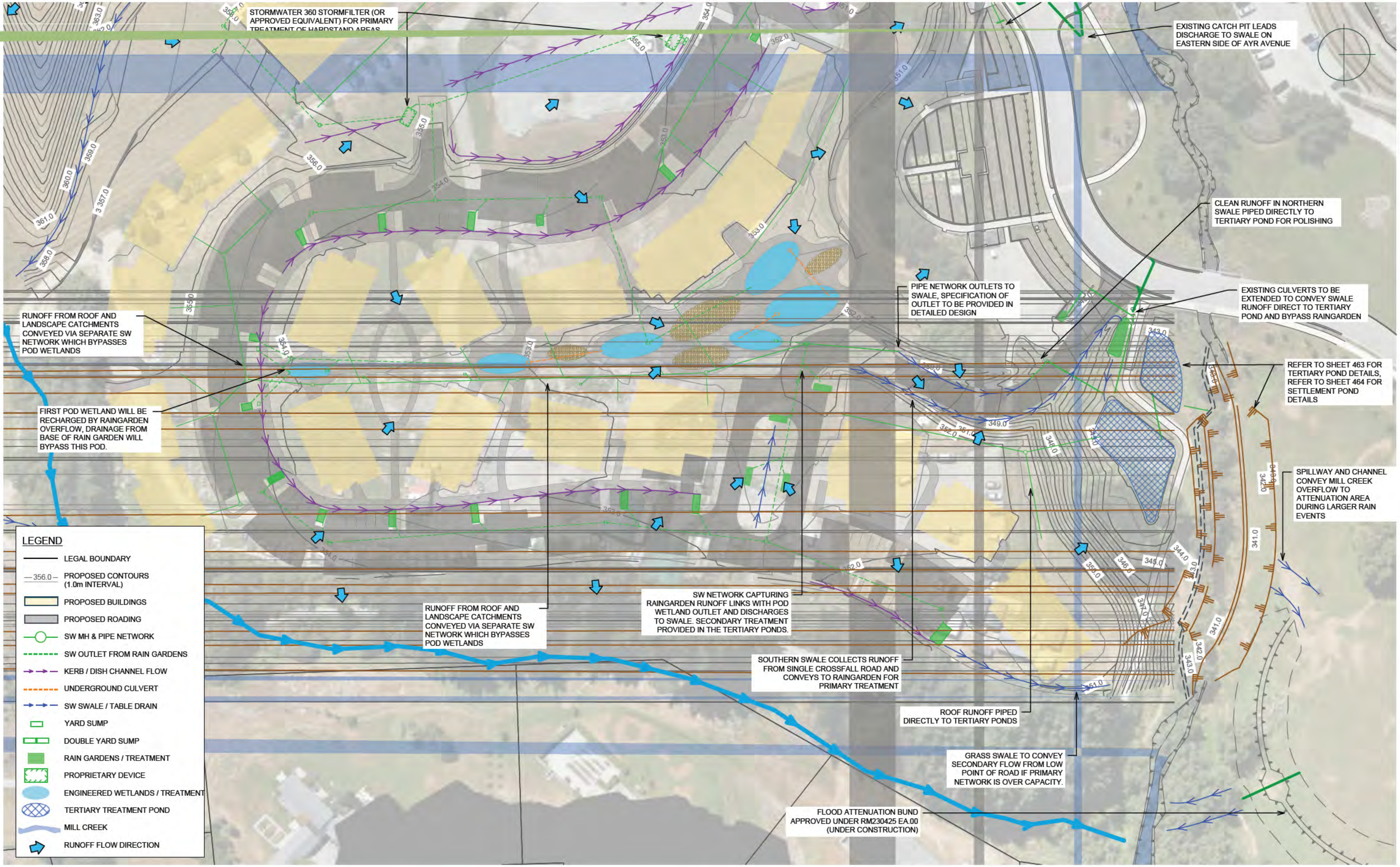
WINTON BEST BY DESIGN



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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER DRAINAGE

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
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STATUS **FOR CONSENT**

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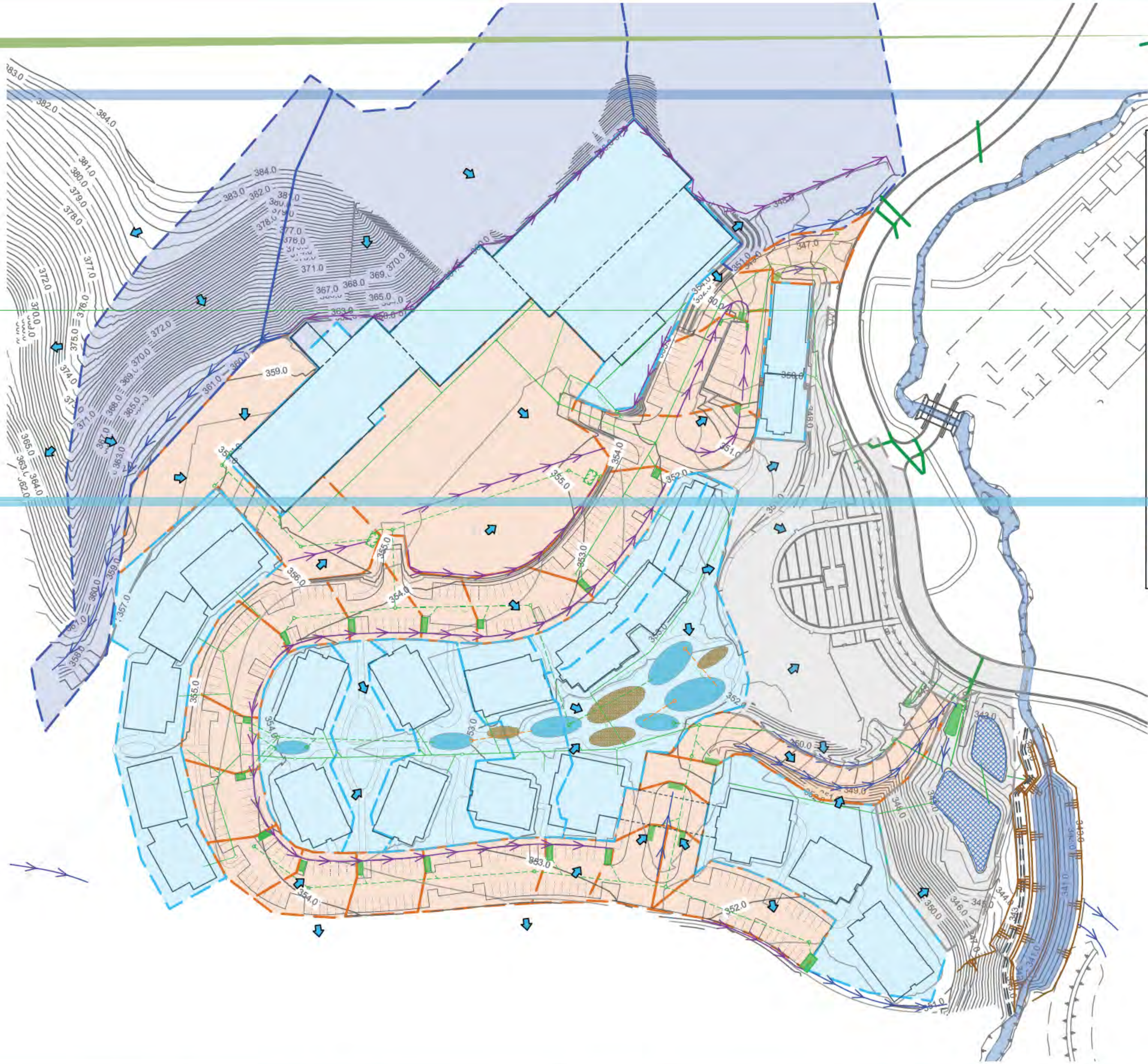
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	412
REVISION	B
SCALE (A3)	1:1000

LEGEND

1. THIS PLAN PROVIDES AN OVERVIEW OF THE STORMWATER CATCHMENTS RESULTING FROM THE PROPOSED DEVELOPMENT. REFER TO SHEETS 451 AND 452 FOR MORE DETAIL ON THE SEPARATION OF THE CLEAN AND DIRTY RUNOFF FLOWS.



LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- UPSLOPE CATCHMENT DIVERTED
- ROAD CATCHMENT (TO BE TREATED)
- ROOF/ LANDSCAPE CATCHMENT
- DOWNSLOPE CATCHMENT TO TERTIARY POND
- CLEAN RUNOFF NETWORK
- DIRTY RUNOFF NETWORK
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF FLOW DIRECTION

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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER CATCHMENT PLAN

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000
	MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS FOR CONSENT

SURVEYED	PAT	05.09.2024
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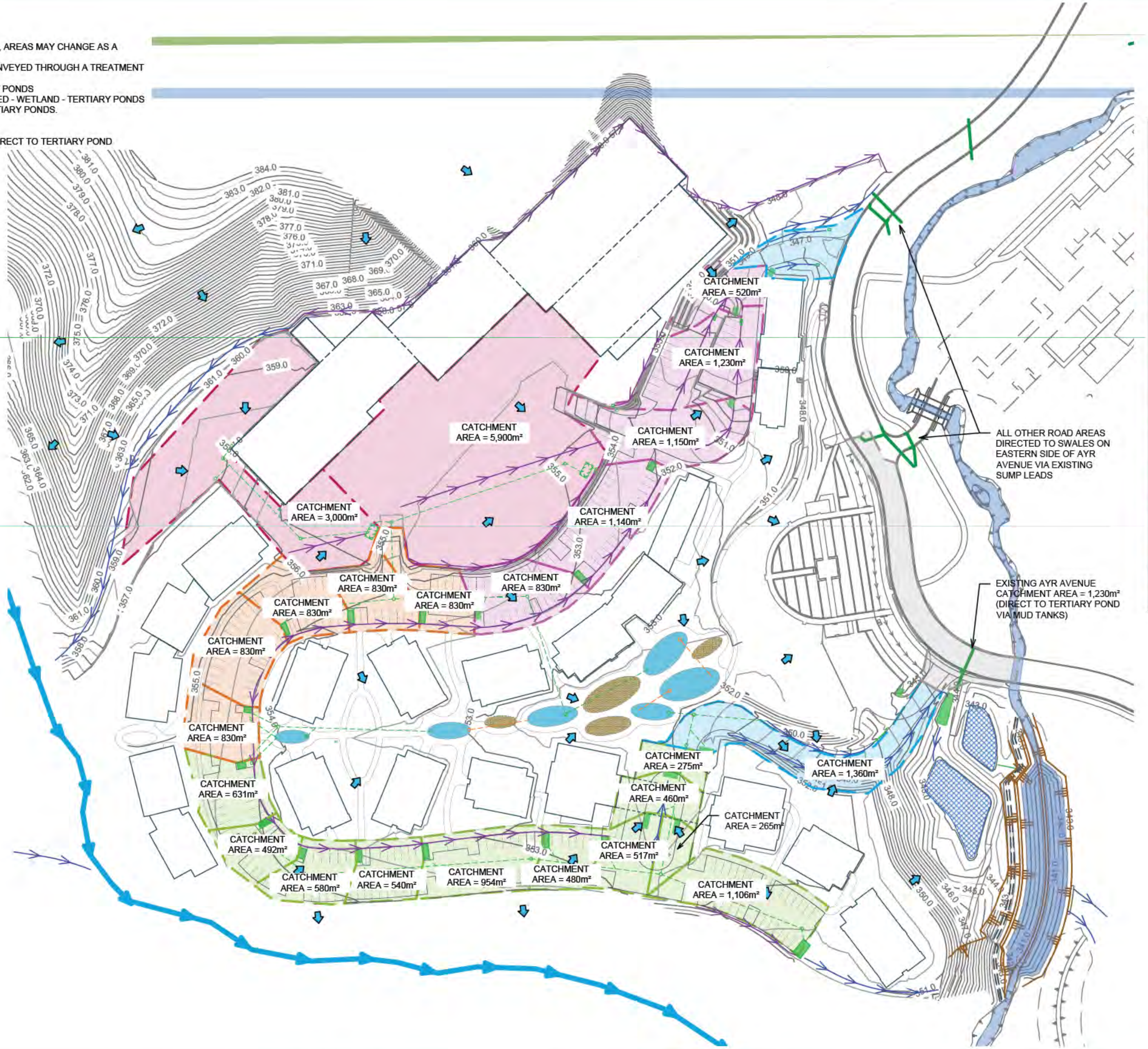
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	450
REVISION	B
SCALE (A3)	1:1500

LEGEND

1. ALL CATCHMENT EXTENTS ARE INDICATIVE ONLY, AREAS MAY CHANGE AS A RESULT OF DETAILED DESIGN
2. RUNOFF FROM ROAD / HARDSTAND AREAS IS CONVEYED THROUGH A TREATMENT TRAIN UTILISING THE FOLLOWING DEVICES;
   - 2.1. 'TYPE A' RAINGARDEN - WETLAND - TERTIARY PONDS
   - 2.2. 'TYPE B' STORMFILTER (OR SIMILAR APPROVED - WETLAND - TERTIARY PONDS
   - 2.3. 'TYPE C' RAINGARDEN - GRASS SWALE - TERTIARY PONDS.
   - 2.4. 'TYPE D' RAINGARDEN - TERTIARY PONDS.
   - 2.5. 'TYPE E' RAINGARDEN - TERTIARY PONDS.
   - 2.6. EXISTING AYR AVENUE CATCHMENT PIPED DIRECT TO TERTIARY POND



LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- TYPE A CATCHMENT
- TYPE B CATCHMENT
- TYPE C CATCHMENT
- TYPE D CATCHMENT
- TYPE E CATCHMENT
- EXISTING ROAD CATCHMENT
- ROOF / LANDSCAPE RUNOFF NETWORK
- ROAD / HARDSTAND RUNOFF NETWORK
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF DIRECTION

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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
DIRTY RUNOFF CATCHMENT PLAN

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

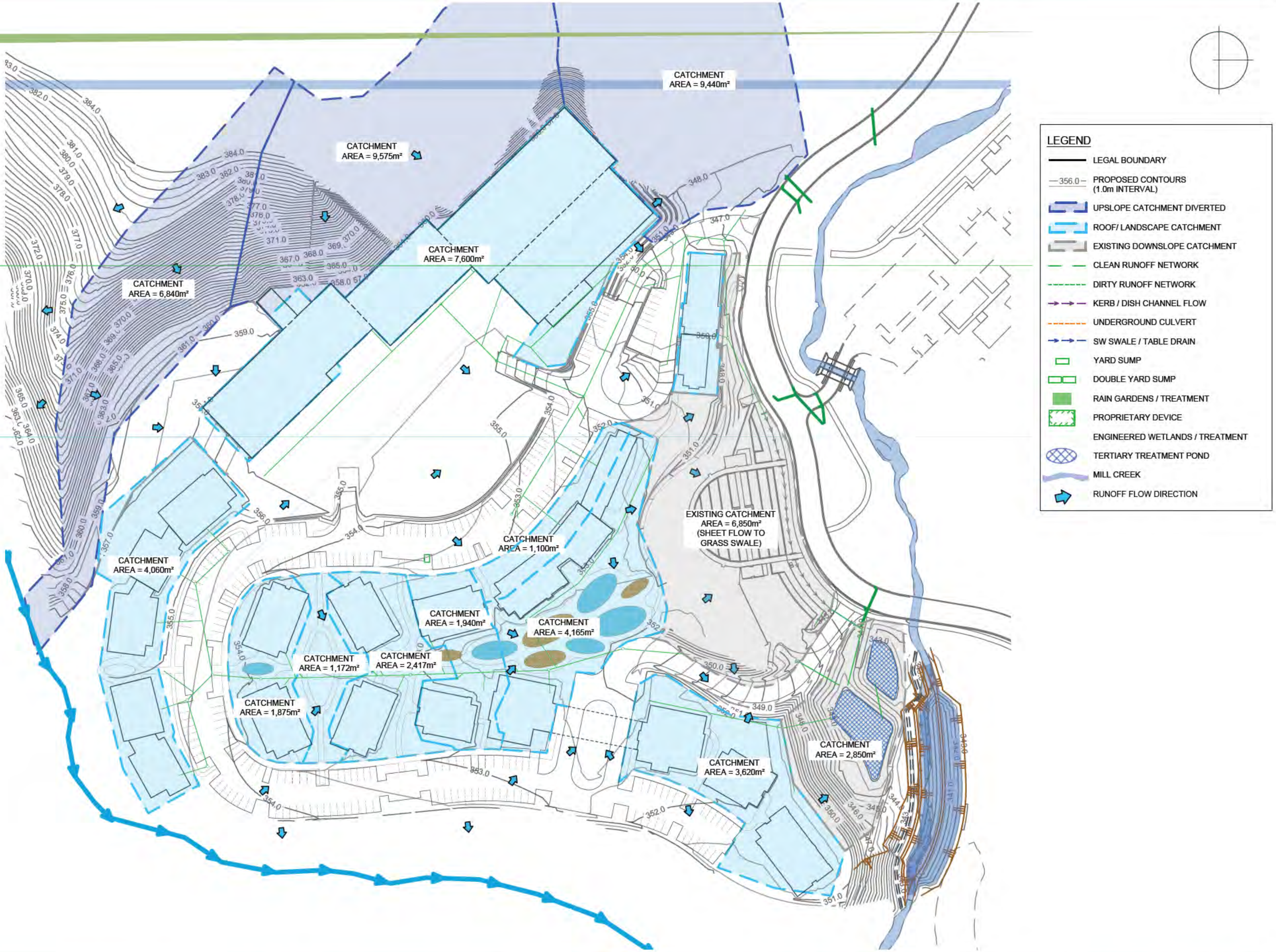
REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS FOR CONSENT

SURVEYED	PAT	05.09.2024
DESIGNED	AH	06.11.2024
DRAWN	AH	29.11.2024
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	451
REVISION	B
SCALE (A3)	1:1500

LEGEND
1. RUNOFF FROM UPSLOPE WILL BE DIVERTED AROUND THE SITE OUTLET TO EITHER THE EPHEMERAL STREAM TO THE WEST OF THE EXISTING AYR AVENUE SWALES TO THE EAST
2. RUNOFF FROM ROOF OR LANDSCAPE AREAS IS CONSIDERED CLEAN.
3. RUNOFF FROM ROOF AREAS WILL BE CONVEYED BY AN INDEPENDENT NETWORK TO BYPASS TREATMENT DEVICES.
4. WITH EXCEPTION OF THE UPSLOPE CATCHMENT ALL STORMWATER RUNOFF FROM THE SITE WILL FLOW THROUGH THE TERTIARY TREATMENT PONDS PRIOR TO DISCHARGE INTO MILL CREEK.
5. DOWNSLOPE CATCHMENT CONVEYED VIA EXISTING GRASSED SWALES TO TERTIARY PONDS.



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WINTON BEST BY DESIGN

DRAWING TITLE	DATUM INFORMATION		REV	DRAWN	DATE	NOTE					
AYRBURN SCREEN HUB - LOT 4 DP 540788	COORDINATE SYSTEM	NZGD2000	A	AH	29.11.2024	-	SURVEYED	PAT	05.09.2024	PROJECT	P240664
CONSENT DRAWINGS		MOUNT NICHOLAS CIRCUIT	B	SB	18.07.2025	SUBSTANTIVE APPLICATION	DESIGNED	AH	06.11.2024	DRAWING NO	001
ROOF / LANDSCAPE RUNOFF	DATUM	DUNEHT1958					DRAWN	AH	29.11.2024	SHEET	452
CATCHMENT PLAN	ORIGIN OF COORDINATES	IT X DP 23038					REVIEWED	SP	18.07.2025	REVISION	B
	ORIGIN OF LEVELS	IT X DP 23038 : 358.566m	STATUS		FOR CONSENT		APPROVED	SP	18.07.2025	SCALE (A3)	1:1500

LEGEND

1. THIS PLAN PROVIDES AN OVERVIEW OF THE SECONDARY FLOW PATH CATCHMENTS FOR OVERLAND FLOWS DURING THE 100yr ARI.
2. ALL SECONDARY FLOW PATHS / CHANNELS WILL BE DESIGNED TO CATER FOR THE 100y ARI FLOWS. SIZING OF ALL CHANNELS INCLUDING ASSOCIATED EROSION PROTECTION WILL BE COMPLETED AT DETAILED DESIGN.
3. PRIMARY NETWORK HAS BEEN ASSUMED TO HAVE 100% BLOCKAGE DURING THE 100y ARI EVENT IN ACCORDANCE WITH QLDC LDSCoP, AS SUCH PRIMARY NETWORK NOT SHOWN FOR CLARITY.
4. HATCH AREAS SHOWN INDICATE SECONDARY FLOW PATH CATCHMENTS. EACH CATCHMENT HAS BEEN SHOWN A DIFFERENT COLOUR TO ASSIST INTERPRETATION OF DELINEATION.

IN EVENT THE PIPED STORMWATER NETWORK IS AT CAPACITY OR BLOCKED RUNOFF WILL CASCADE OVER TOP OF WALL

LOW POINT IN CARPARK, REFER TO DETAIL A ON SHEET 456 FOR OVERLAND FLOW CONFIGURATION

CONCRETE CHANNEL (OR SIMILAR) FORMED ON TOP OF RETAINING WALL. SUBJECT TO DETAILED DESIGN

ROAD CARRIAGEWAY TRANSITIONS FROM SINGLE TO DUAL CROSSFALL

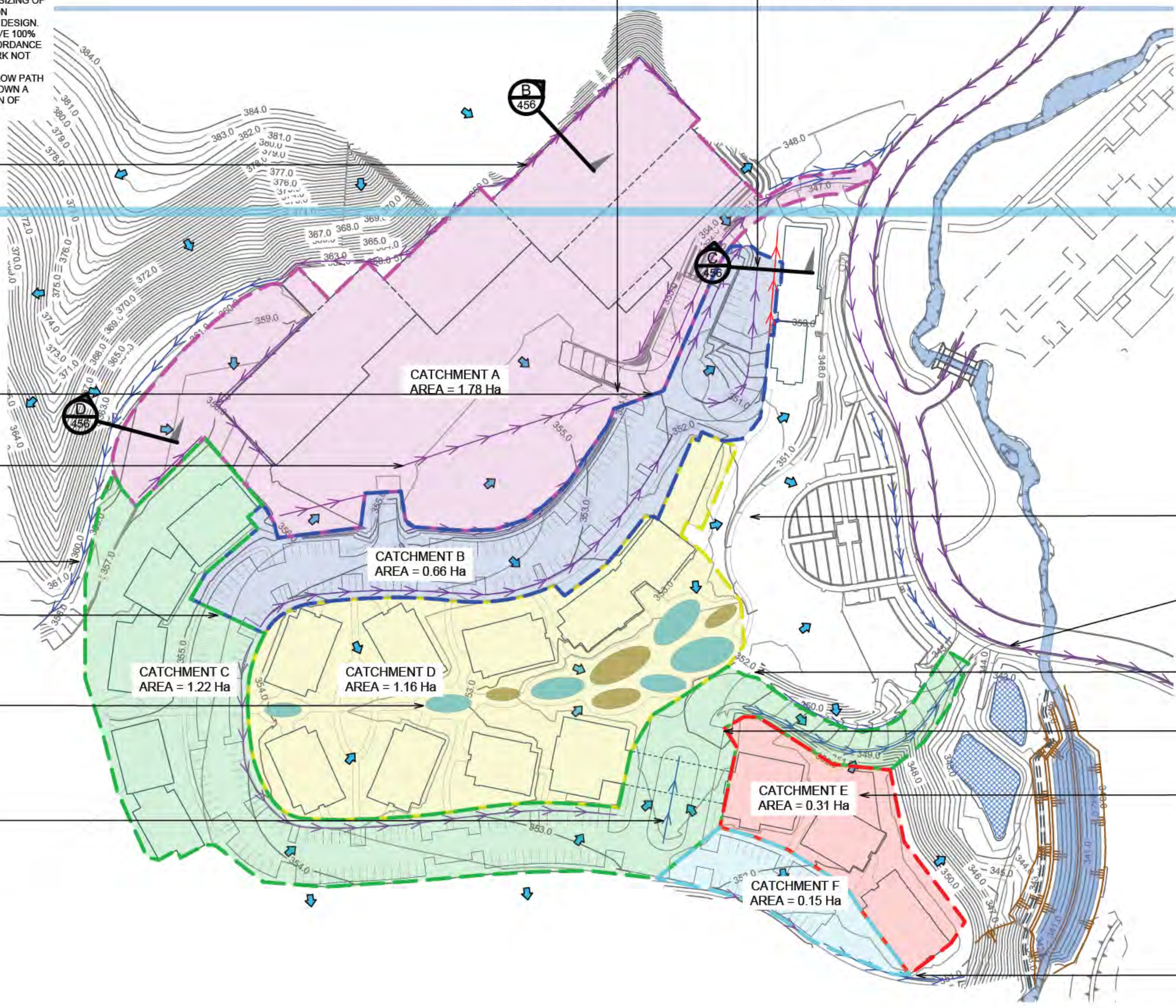
PAVEMENT FORMED WITH SHALLOW DISH TO CONVEY RUNOFF TO LOW POINT

SWALE TO CONVEY RUNOFF FROM UPSLOPE TO EPHEMERAL STREAM

CREST IN ROAD SPLITTING OVERLAND FLOW CATCHMENTS

LANDSCAPE SHAPING FORMS CENTRAL DISH TO CONVEY OVERLAND FLOW. SURFACE WATER WILL FLOW INTO POD WETLANDS. WHERE PIPED NETWORK IS AT CAPACITY AND WETLANDS ARE INUNDATED RUNOFF WILL BYPASS WETLAND AND FLOW TO LOW POINT.

LOW POINT THROUGH CENTRE OF FORECOURT TO DIRECT RUNOFF THROUGH LANDSCAPE ISLAND



RUNOFF WILL SHEET FLOW ACROSS DOWNSLOPE CATCHMENT TO ROAD SIDE SWALES IN ACCORDANCE WITH PRE-DEVELOPMENT SCENARIO.

LOW POINT OF AYR AVENUE. RUNOFF THAT OVERTOPS KERBS WILL FLOW TO MILL CREEK VIA TERTIARY PONDS

OVERLAND FLOW FROM CENTRAL LANDSCAPE AREA WILL DISCHARGE TO NORTHERN ROAD SWALE

LOW POINT IN FORECOURT, RUNOFF TO DISCHARGE TO SOUTHERN ROAD SWALE

SHEET FLOW OVER LAND

SWALE TO CONVEY RUNOFF FROM LOW POINT OF ROAD PASSED BUILDINGS AND DISCHARGE TO SHEET FLOW.

LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- KERB / DISH CHANNEL FLOW
- SW SWALE / TABLE DRAIN
- SLOT DRAIN
- OVERLAND SHEET FLOW DIRECTION
- ENGINEERED POD WETLAND
- TERTIARY TREATMENT POND
- MILL CREEK

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WINTON
BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
SECONDARY FLOW CATCHMENT PLAN

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS FOR CONSENT

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DESIGNED	AH	06.11.2024
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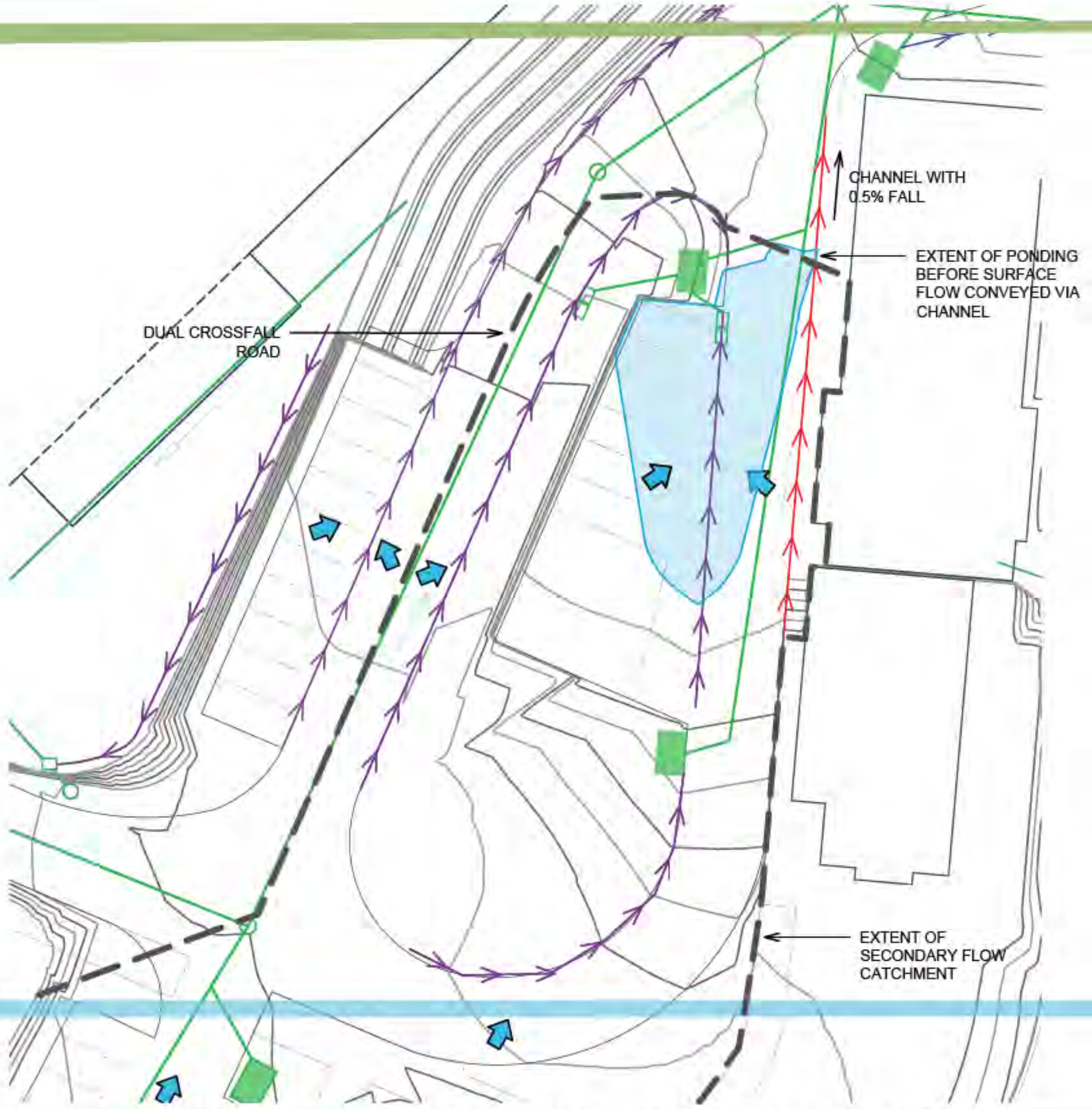
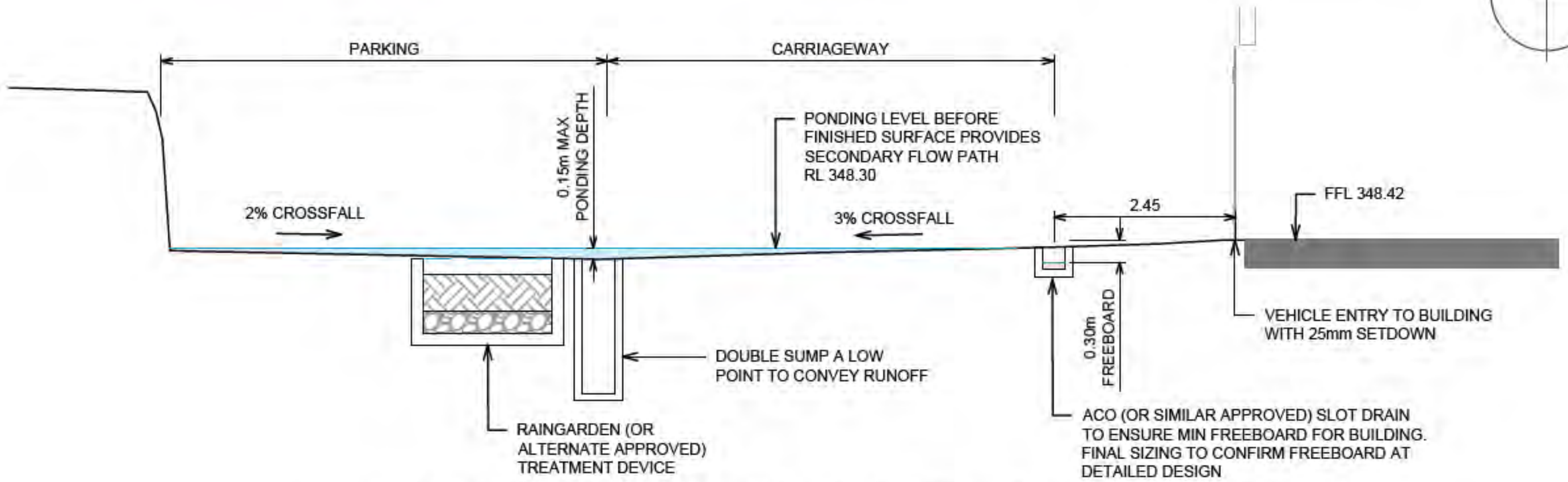
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	455
REVISION	B
SCALE (A3)	1:1500



DETAIL A - DEPOT BUILDING SURFACE PONDING

SCALE 1:500



SECTION C - DEPOT BUILDING SURFACE PONDING

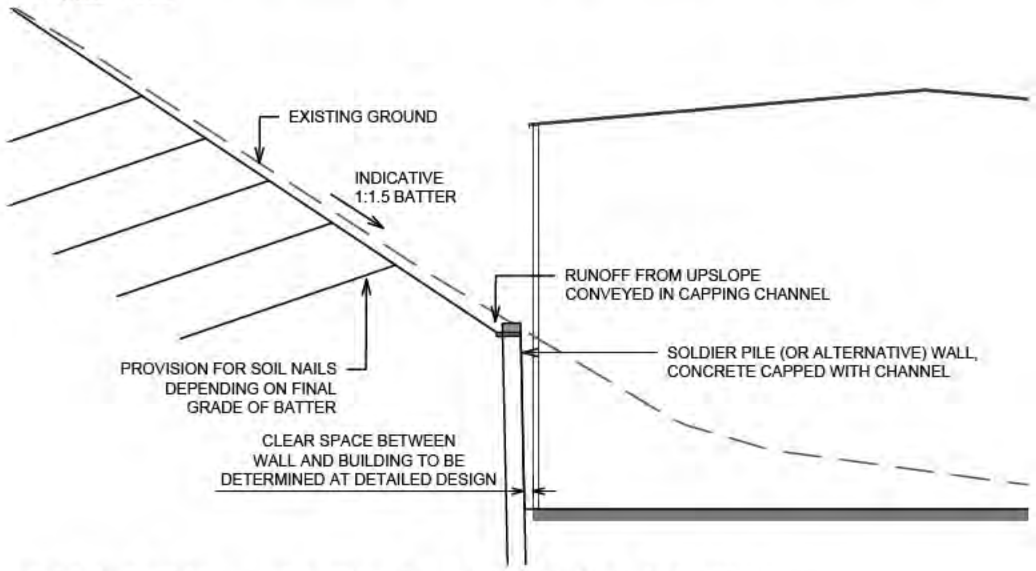
SCALE 1:100

LEGEND

1. ALL SECONDARY FLOW PATHS / CHANNELS WILL BE DESIGNED TO CATER FOR THE 100y ARI FLOWS. SIZING OF ALL CHANNELS WILL BE COMPLETED AT DETAILED DESIGN.
2. PRIMARY NETWORK HAS BEEN ASSUMED TO HAVE 100% BLOCKAGE DURING THE 100y ARI EVENT IN ACCORDANCE WITH QLDC LDSCoP. THE PONDING EXTENT SHOWN ASSUMES FULL BLOCKAGE
3. ALL RETAINING WALL AND EARTH BATTER SOLUTIONS TO BE CONFIRMED AT DETAILED DESIGN. WALLS AND NAILS SHOWN ARE INDICATIVE ONLY

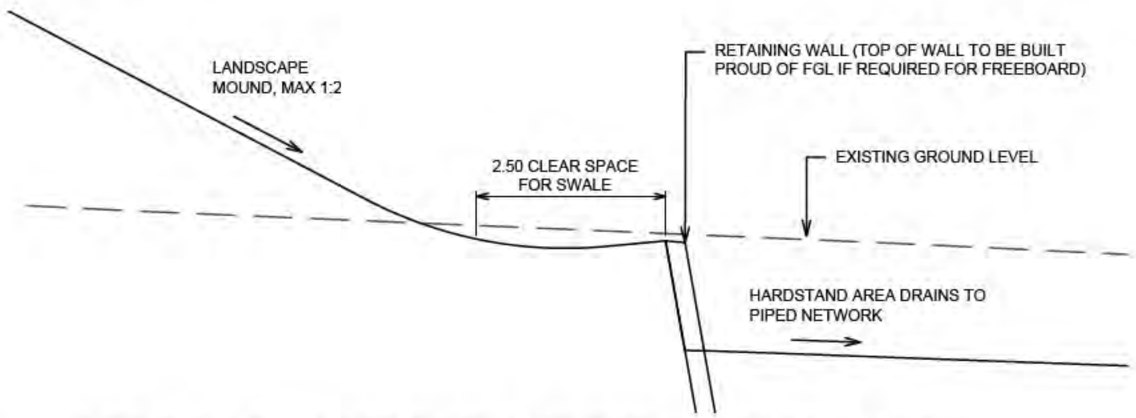
LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- KERB / DISH CHANNEL FLOW
- SW SWALE / TABLE DRAIN
- SLOT DRAIN
- OVERLAND SHEET FLOW DIRECTION
- ENGINEERED POD WETLAND
- TERTIARY TREATMENT POND
- MILL CREEK
- STORMWATER NETWORK
- RAINGARDEN



SECTION B - UPSLOPE CUT OFF CHANNEL

SCALE 1:250



SECTION D - UPSLOPE CUT OFF CHANNEL / SWALE

SCALE 1:100

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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
SECONDARY FLOW DETAIL PLAN

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000
	MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
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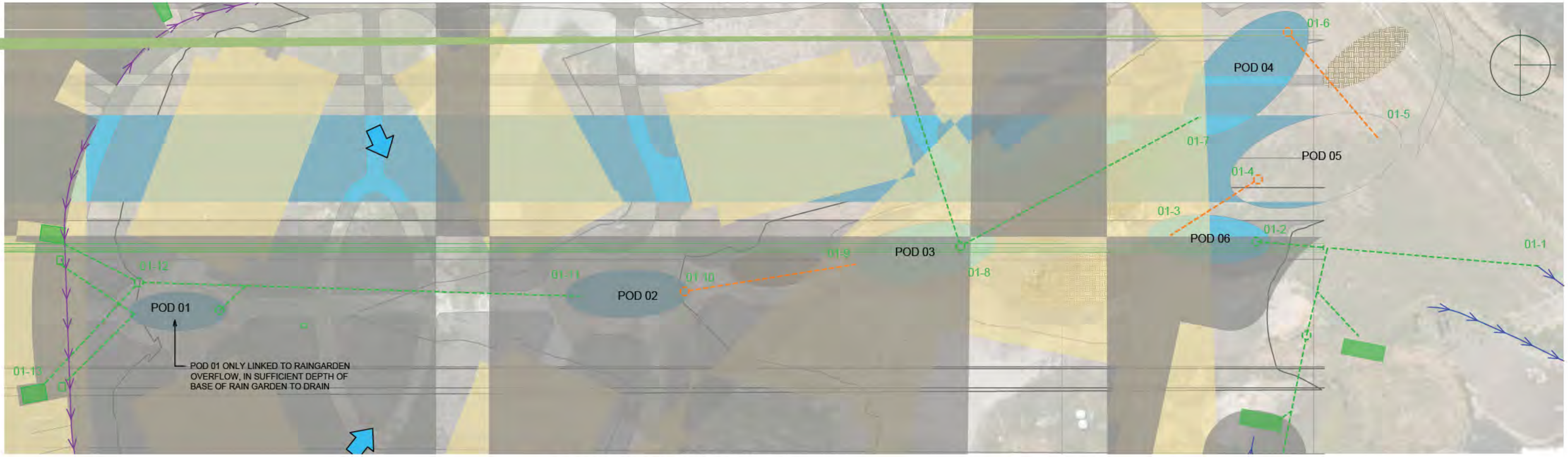
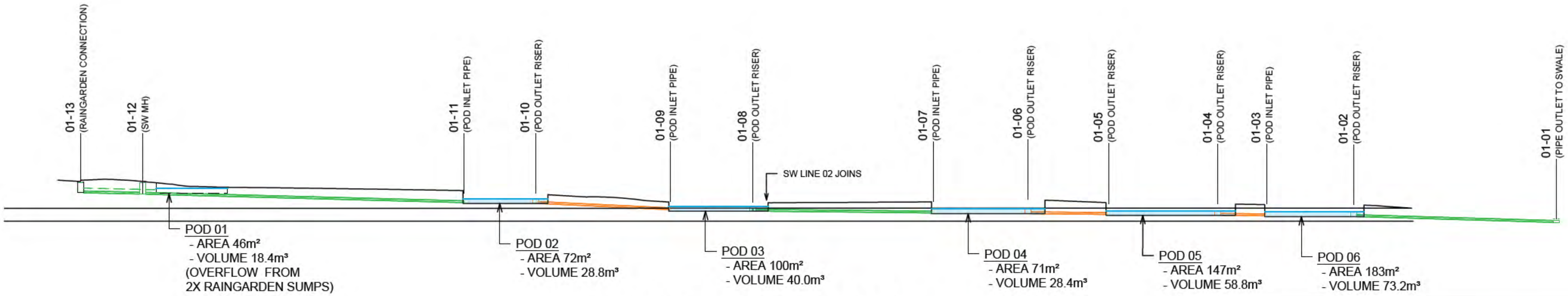
PROJECT	P240664
DRAWING NO	001
SHEET	456
REVISION	B
SCALE (A3)	AS SHOWN



POD WETLAND LAYOUT

SCALE 1:500



POD WETLAND LONG SECTION

SCALE H - 1:750

V - 1:375

LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- PROPOSED BUILDINGS
- PROPOSED ROADING
- SW MH & PIPE NETWORK
- SW OUTLET FROM RAIN GARDENS
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF FLOW DIRECTION

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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER LONG SECTION

DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000
	MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
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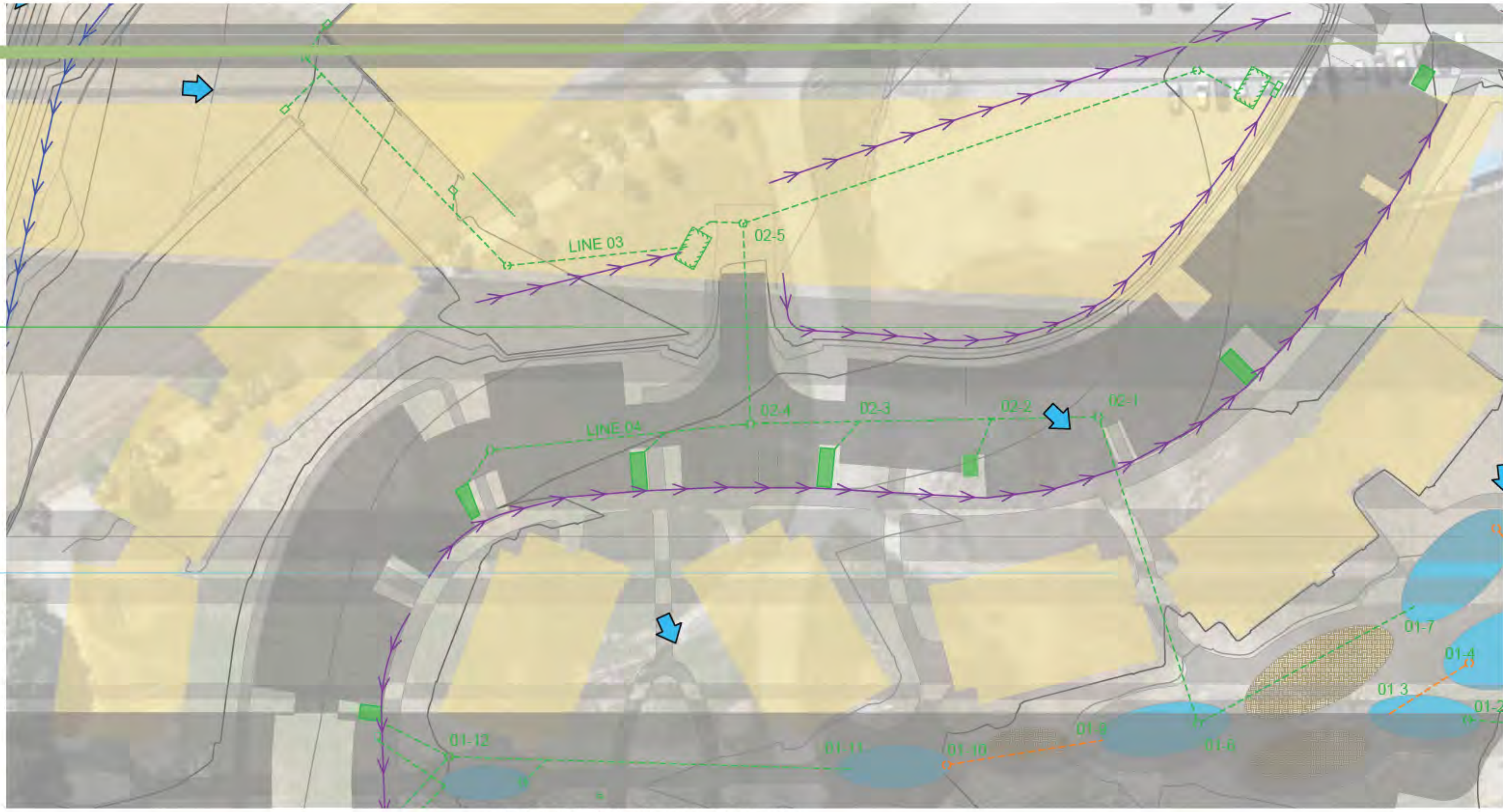
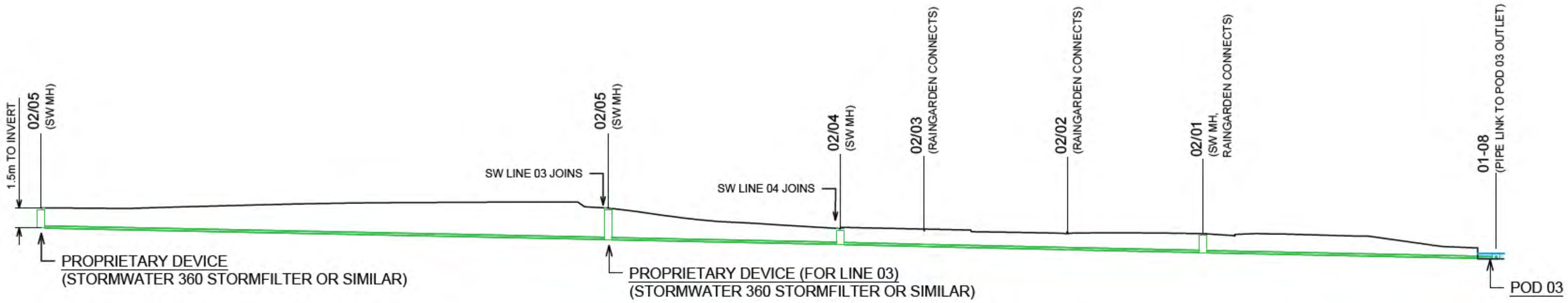
PROJECT	P240664
DRAWING NO	001
SHEET	460
REVISION	B
SCALE (A3)	1:500



LEGEND
- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- PROPOSED BUILDINGS
- PROPOSED ROADING
- SW MH & PIPE NETWORK
- SW OUTLET FROM RAIN GARDENS
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF FLOW DIRECTION

POD WETLAND LAYOUT

SCALE 1:500



PROPRIETARY DEVICE / POD WETLAND LONG SECTION

SCALE 1:750

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WINTON BEST BY DESIGN

DRAWING TITLE	AYRBURN SCREEN HUB - LOT 4 DP 540788 CONSENT DRAWINGS STORMWATER LONG SECTION		
DATUM INFORMATION			
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT		
DATUM	DUNEHT1958		
ORIGIN OF COORDINATES	IT X DP 23038		
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m		

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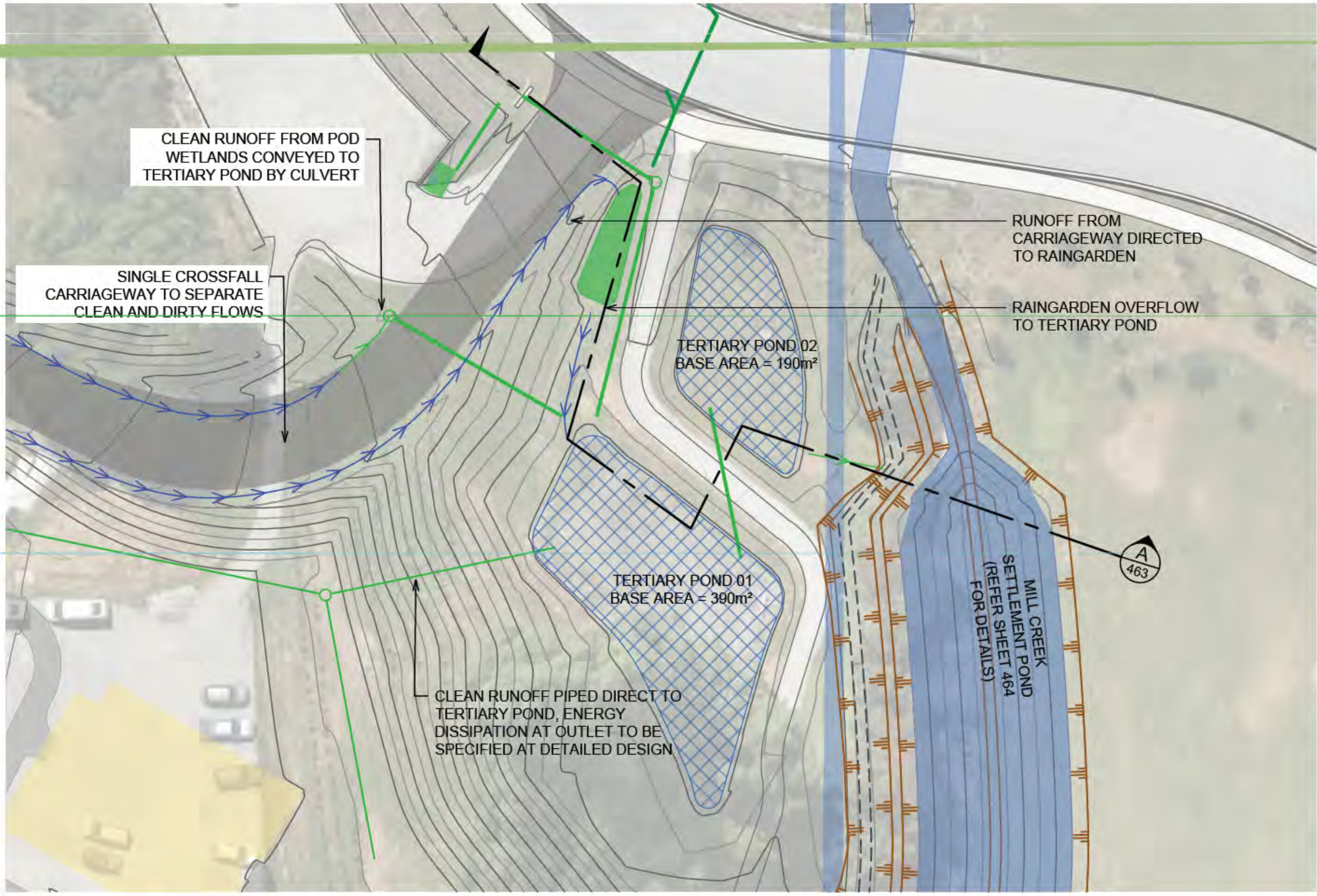
PROJECT	P240664
DRAWING NO	001
SHEET	461
REVISION	B
SCALE (A3)	1:750

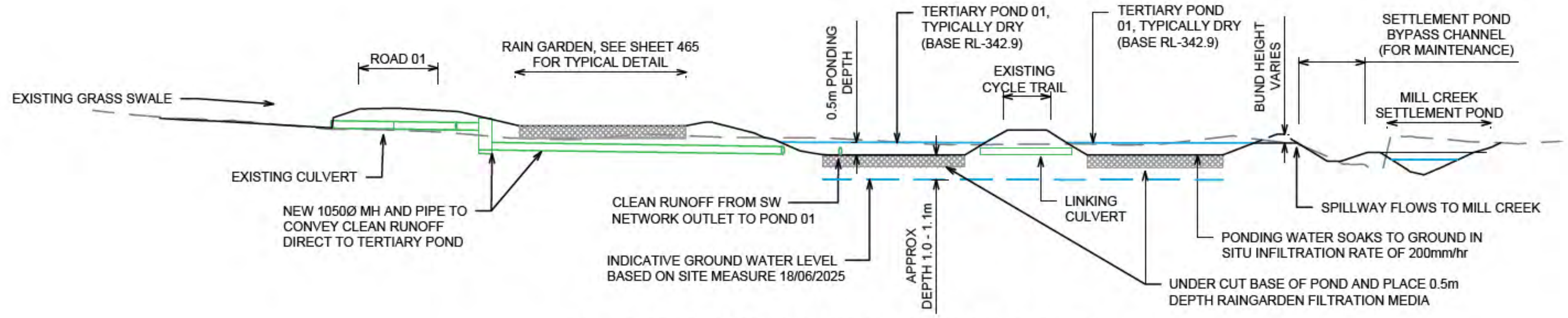


TERTIARY POND LAYOUT

SCALE 1:500

LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- PROPOSED BUILDINGS
- PROPOSED ROADING
- SW MH & PIPE NETWORK
- SW OUTLET FROM RAIN GARDENS
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF FLOW DIRECTION



A - TERTIARY POND LONG SECTION

SCALE 1:500

patersons. Land Professionals

WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER LONG SECTION

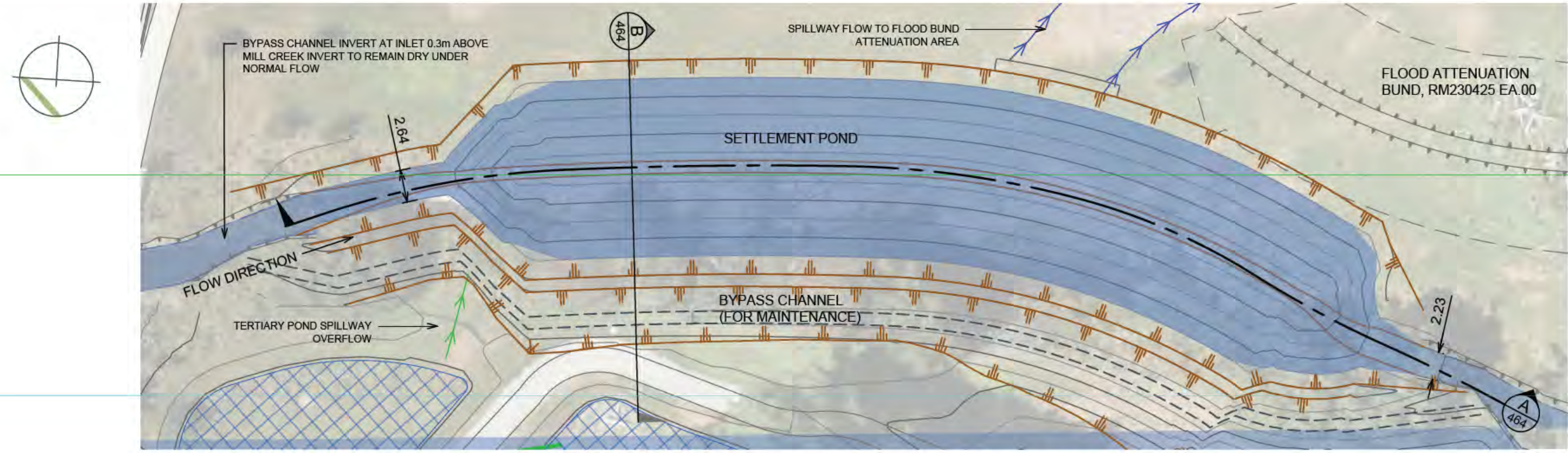
DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000
	MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS FOR CONSENT

SURVEYED	PAT	05.09.2024
DESIGNED	AH	06.11.2024
DRAWN	AH	29.11.2024
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	463
REVISION	B
SCALE (A3)	1:500

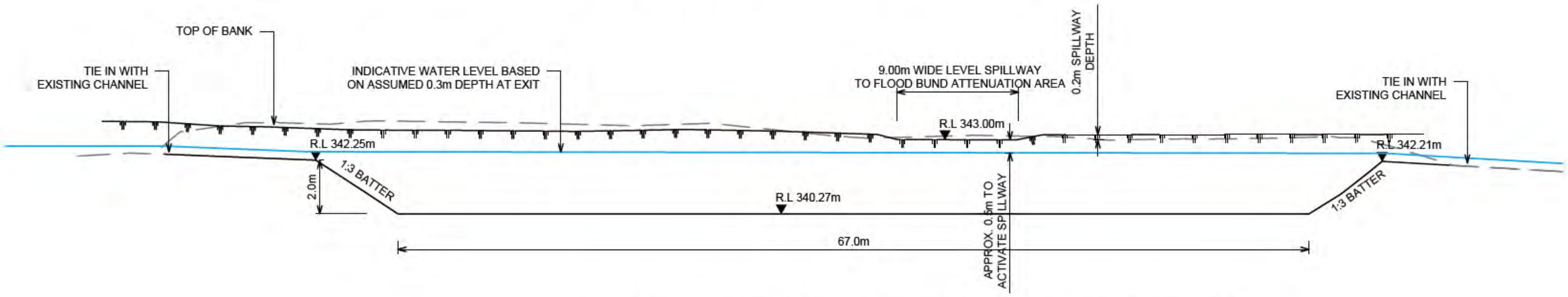


LEGEND

- LEGAL BOUNDARY
- 356.0 PROPOSED CONTOURS (1.0m INTERVAL)
- PROPOSED BUILDINGS
- PROPOSED ROADING
- SW MH & PIPE NETWORK
- SW OUTLET FROM RAIN GARDENS
- KERB / DISH CHANNEL FLOW
- UNDERGROUND CULVERT
- SW SWALE / TABLE DRAIN
- YARD SUMP
- DOUBLE YARD SUMP
- RAIN GARDENS / TREATMENT
- PROPRIETARY DEVICE
- ENGINEERED WETLANDS / TREATMENT
- TERTIARY TREATMENT POND
- MILL CREEK
- RUNOFF FLOW DIRECTION

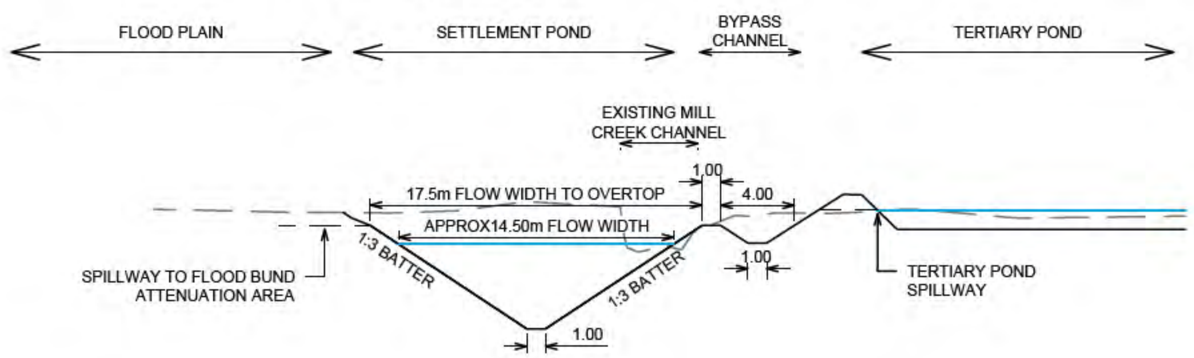
MILL CREEK SETTLEMENT POND LAYOUT

SCALE 1:400



A - MILL CREEK SETTLEMENT POND LONG SECTION

SCALE H - 1:400, V - 1:200



B - MILL CREEK SETTLEMENT POND CROSS SECTION

SCALE H - 1:400, V - 1:200

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WINTON BEST BY DESIGN

DRAWING TITLE
AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER SETTLEMENT POND

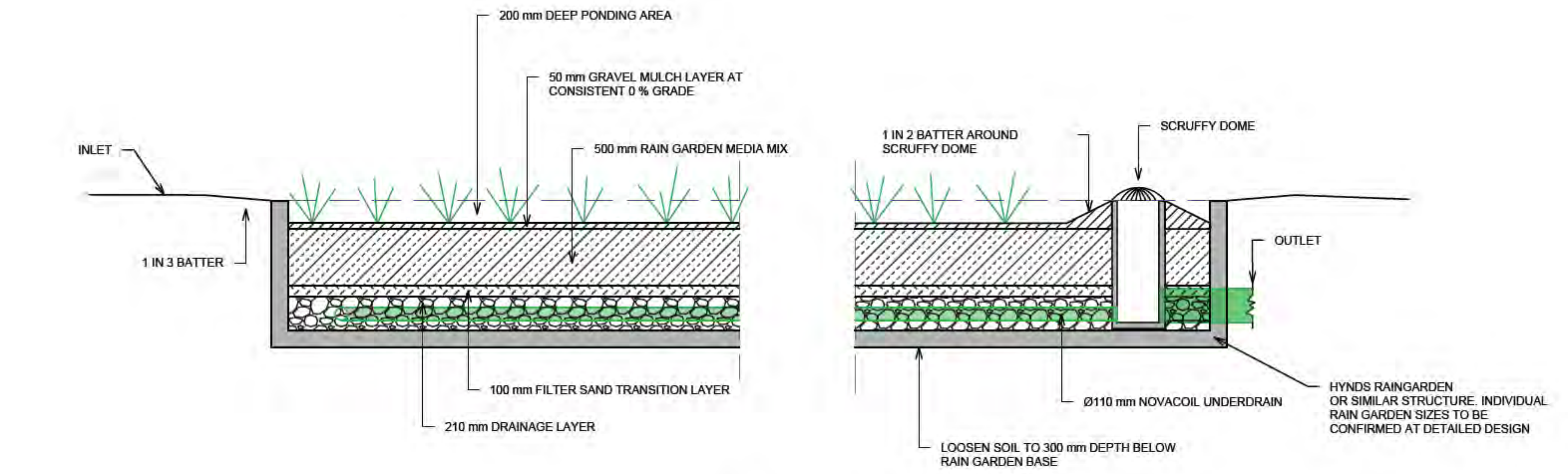
DATUM INFORMATION	
COORDINATE SYSTEM	NZGD2000 MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS **FOR CONSENT**

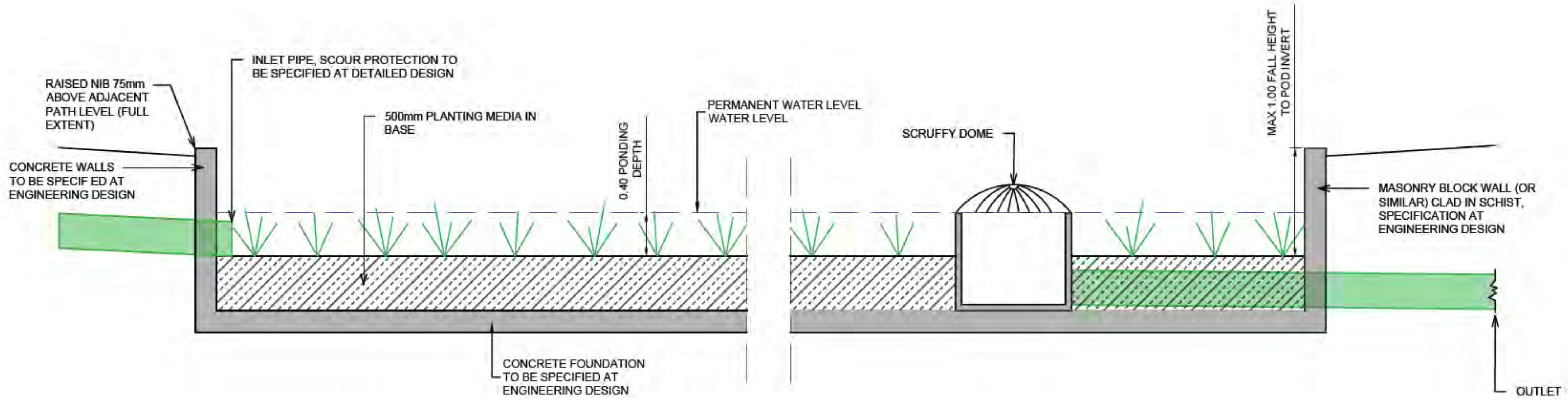
SURVEYED	PAT	05.09.2024
DESIGNED	AH	06.11.2024
DRAWN	AH	29.11.2024
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	**P240664**
DRAWING NO	**001**
SHEET	**464**
REVISION	**B**
SCALE (A3)	**AS SHOWN**



TYPICAL SECTION - RAINGARDEN

SCALE 1:50



TYPICAL SECTION POD WETLAND

SCALE 1:50

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WINTON BEST BY DESIGN

DRAWING TITLE

AYRBURN SCREEN HUB - LOT 4 DP 540788
CONSENT DRAWINGS
STORMWATER TREATMENT TYPICAL DETAILS
SHEET 1 OF 1

DATUM INFORMATION

COORDINATE SYSTEM	NZGD2000
	MOUNT NICHOLAS CIRCUIT
DATUM	DUNEHT1958
ORIGIN OF COORDINATES	IT X DP 23038
ORIGIN OF LEVELS	IT X DP 23038 : 358.566m

REV	DRAWN	DATE	NOTE
A	AH	29.11.2024	-
B	SB	18.07.2025	SUBSTANTIVE APPLICATION

STATUS **FOR CONSENT**

SURVEYED	PAT	05.09.2024
DESIGNED	AH	06.11.2024
DRAWN	AH	29.11.2024
REVIEWED	SP	18.07.2025
APPROVED	SP	18.07.2025

PROJECT	P240664
DRAWING NO	001
SHEET	465
REVISION	B
SCALE (A3)	AS SHOWN

Appendix 2 Calculation Summary

Client :	Waterfall Park
Site address :	Ayr Ave, Arrowtown
Job name :	Screen Hub
Job number :	A20254

Date	5/06/2025	File Name	A20254-EV- -Studio SMP.xlsx
By	FDP	Sheet Name	Tertiary Ponds Soakage E1
Checked	KW		

AIM: To determine soakage trench design and corresponding storage requirements

Design based on Hamilton Infrastructure Technical Specifications Section 4.2.15 and New Zealand Building Code E1/VM1

Design Parameters

Design Storm Event	WQV (1/3 2yr, RCP6.0)	
1 hr duration of rainfall intensity +CC	3.367	mm/hr
Soakage Rate	400	mm/hour
Soakage Rate Reduction	50%	
Design Soakage Rate (S_r)	200	mm/hour

Post-Development Flow

Soakage Flow: $R_C = \frac{CiA}{1000}$ (NZBC E1/VM1)

Contributing Catchment	C	A (m^2)	CA (m^2)	Rc (m^3)
Roof	0.95	0	0	0.0
Driveway	0.90	52639	47375	159.5
Pervious Area	0.30	0	0	0.0
Total		52639	47375.1	159.5

Soakage Trench Design

$$V_{stor} = R_c - V_{soak}$$

where $V_{soak} = (A_{sp} \times S_r)/1000$ (NZBC E1/VM1)

Run-off into soak pit in one hour	159.50	m^3	(R_c)	
Soakage released in one hour	117.00	m^3	(V_{soak})	
Storage Required	42.50	m^3	(V_{stor})	
Number of soakage ponds	1			
Trench Base Area (A_{sp})	585.00	m^2		
Soakage Pond Depth	0.50	m		292.5
Drainage Metal Void Ratio	100%	(NZBC E1/VM1)		
Total Available Trench Volume	292.50	m^3		
Soakage Pit Empties in	0.4	Hrs		

Job Name	Waterfall Park	**File Name**	A20254-EV- -Studio SMP.xlsx
Job No.	A20254	**Sheet Name**	Pod Wetland
Date	7/07/2025		
By	FDP	**Checked**	KW

<u>Catchment 1 Wetland</u>

Volumes:			
Water Quality Rainfall Depth	16.20	mm	
Impervious Area Draining to Wetland	12293.00	m2	Kea and Takahe Catchments (Backlot parking and part of inte
Water Quality Volume	199.15	m3	
Wetland Zone:			
PWV required	199	m3	
Wetland minimum water surface area at PWL			
Depth =	0.40	m	
Permanent water surface area =	498	m2	
Provided Volume in Pods=	229	m3	
Privided Area in pods=	573	m2	

Job Name	Waterfall Park	File Name	A20254-EV- -Studio SMP.xlsx
Job No.	A20254	Sheet Name	Raingarden
Date	7/07/2025		
By	FDP	Checked	KW

Screen Hub Raingarden Sizing

	RG 1	RG2	RG 3	RG 4	RG 5	RG 6	RG 7	RG 8	RG 9	RG 10	RG 11	RG 12	RG 13	RG 14	RG 15	RG 16
Carpark Area (m^2)	**277**	**461**	**263**	**1106**	**516**	**480**	**594**	**538**	**1072**	**631**	**589**	**869**	**703**	**623**	**612**	**827**

Carpark FLow - WQF (10mm)

Area (ha)	0.02770	0.04610	0.02630	0.11060	0.05160	0.04800	0.05940	0.05380	0.10720	0.06310	0.05890	0.08690	0.07030	0.06230	0.06120	0.08270
C No. (Imp)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Int (mm/hr)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Q = 2.78CiA	0.7	1.2	0.7	2.8	1.3	1.2	1.5	1.3	2.7	1.6	1.5	2.2	1.8	1.6	1.5	2.1

Raingarden Sizing

WQF (m^3/hr)	2.5	4.2	2.4	10.0	4.6	4.3	5.4	4.8	9.7	5.7	5.3	7.8	6.3	5.6	5.5	7.4
K m/hr	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Area of RG (m^2)	6.65	11.07	6.32	26.57	12.39	11.53	14.27	12.92	25.75	15.16	14.15	20.87	16.89	14.96	14.70	19.86

Kakapo Catchment (Access Track to south)

Carpark Area (m^2)	**1357**

Flower Farm Carpark FLow - WQF (10mm)

Area (ha)	0.13570
C No. (Imp)	0.90
Int (mm/hr)	10
Q = 2.78CiA	3.4

Raingarden Sizing

WQF (m^3/hr)	12.2
K m/hr	0.75

2) Calculate the minimum area of the bioretention device:

$$A = \frac{WQF}{(0.5 \times K_{(media)})} \quad \text{Equation 13}$$

Where	A	:	Area of bioretention media bed at its narrowest point (m^2)
	WQF	:	Water quality flow (m^3/hr)
	$K_{(media)}$	:	Infiltration rate of bioretention media (m/hr)
	Safety factor for clogging	–	0.5

Job Name	Waterfall Park		File Name	A2025-EV- - SMP
Job No.	A20254		Sheet Name	CLM CarparK
Date	7/07/2025			
By	FDP	Checked	KW	

Contaminant Load Model- Lifestyle to Urban

	Phosporus	Nitrogen	TSS	Zinc	Copper	Units
Farming (Sheep and Beef)	0.198	0.9	152	0.005	0.0011	$g/m^2/yr$
Urban	0.080	0.8				$g/m^2/yr$
Urban (30% reduction- no fertlizer)	0.056	0.56				$g/m^2/yr$
Roads (<1k per day)			21	0.004	0.0015	$g/m^2/yr$
Footpath (adjusted Commercial Paved)			32	0.000	0.0000	$g/m^2/yr$
Roof			5	0.020	0.0016	$g/m^2/yr$
Urban Grasslands and trees			45	0.001	0.0003	$g/m^2/yr$

Existing Contaminants

Total Development Catchment	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Farming (Sheep and Beef)	234000	1	46.33	210.60	35568.00	1.1700	0.2574
Sum	**234000**		**46.33**	**210.60**	**35568.00**	**1.1700**	**0.2574**

Proposed Contaminants

Catchment [Treatment devices]	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff Treated TP (kg/yr)	Runoff TN (kg/yr)	Runoff Treated TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Treated TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Treated Zinc (kg/yr)	Runoff Copper (kg/yr)	Runoff Treated Copper (kg/yr)
Kea Catchment (Raingarden->Pods->Ponds)	3396	1	0.19	0.04	1.90	0.68	71.3	2.14	0.0136	0.0005	0.0051	0.0002
Takahe Catchment (Proprietary->Pods->Ponds)	8897	1	0.50	0.13	4.98	1.82	186.8	7.29	0.0356	0.0058	0.0133	0.0016
Kaka/Kakapo/Weka Catchments (Raingardens->Ponds)	13778	1	0.77	0.12	7.72	1.85	440.9	8.82	0.0000	0.0000	0.0000	0.0000
Footpaths (Infiltration Ponds)	3057	1	0.17	0.07	1.71	0.68	97.8	19.56	0.0000	0.0000	0.0000	0.0000
Roofs (Infiltration Ponds)	15559	1	0.87	0.35	8.71	3.49	77.8	15.56	0.3112	0.0622	0.0249	0.0075
Landscaping (Infiltration Ponds)	189313	1	10.60	4.24	106.02	42.41	8519.1	1703.82	0.1893	0.0379	0.0568	0.0170
Sum	**234000**		**13.10**	**4.95**	**131.04**	**50.94**	**9393.75**	**1757.18**	**0.5497**	**0.1065**	**0.1001**	**0.0263**
			Total TP Reduced	-41.38	**Total TN Reduced**	-159.664	**Total TSS Reduced**	-33810.82	**Total TSS Reduced**	-1.0635	**Total TSS Reduced**	-0.2311
			% TP Reduced	89%	**% TN Reduced**	76%	**% TSS Reduced**	95%	**% TSS Reduced**	91%	**% TSS Reduced**	90%

Options	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device (Up-Flo)	48%	39%	87%	59%	70%
Infiltration Ponds	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention	60%	40%	90%	90%	90%
Total Bioretention + Wetland	80%	64%	97%	96%	96%

R = A + B – [(AxB)/100]

For sediment R = 70 + 90 – [(70x90)/100] = 160 –63 = 97% removal
For nitrogen R = 20 + 40 – [20x40)/100] = 60 – 8 = 52% removal
For phosphorus R = 30 + 50 – [(30x50)/100] = 80 – 15 = 65% removal

Table 2 Land

Landuse
Urban
Exotic
Dairy
Sheep and beef
Lifestyle
Crop and Orchard

Appendix 3 Flood Model Report

Planning | Surveying | Engineering | Environmental

Flood Model Report

Ayrburn Screen Hub

Waterfall Park Development Ltd

Document Information

Client	Waterfall Park Developments Ltd
Site Location	Ayr Avenue, Arrowtown
Legal Description	Lot 4 DP540788
CKL Reference	A20254
Office of Origin	Auckland

Author	Dorcas Adjei-Sasu		
Signed	[redacted]	Date	30/05/2025

Reviewed By	Frances Deamer-Phillips		
Signed	[redacted]	Date	30/05/2025

Authorised By	Bronwyn Rhynd		
Signed	[redacted]	Date	30/05/2025

Revision	Status	Date	Author	Reviewed By	Authorised By
0	Draft	30/05/2025	DAS	FDP	BR
1	Updated for substantive application - Draft	08/07/2025	DAS	BR	BR
2	Issue- substantive application	18/07/2025	DAS	BR	BR

The contributing authors, in their capacity as authors of this report, have read and abide by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses Practice Note 2023. Where this report relies on information provided by other experts, this is outlined within the report.

Contents

Figures

Tables

Appendices

1 Introduction

CKL has been engaged by Waterfall Park Developments Ltd (WPDL) to develop a Stormwater Management Plan (SMP) for the proposed Ayrburn Screen Hub which includes filming studios with associated accommodation and facilities. The site is located at Ayr Avenue, off Arrowtown-Lake Hayes Road. The site is approximately 2km south of Arrowtown.

To support the SMP development a flood model was built. This flood model included a “rain-on-grid” approach, to support the SMP outcomes and the proposed development. The extent of this rain on grid model reflects the proposed Ayrburn Screen Hub project extents, which lies within the wider site including Ayrburn and Waterfall Park /Northbrook which previous Mill Creek flood modelling reflected. This flood model update to include Ayrburn Screen Hub provides a comprehensive flood assessment. The existing scenario for the flood model includes all consented works within Northbrook/Waterfall Park and Ayrburn to capture the fully developed scenario of the wider site.

This report serves to document the flood modelling process and parameters underpinning the model outcomes.

Figure 1: Site Location (Winton Provided, December 2024)

1.1 Reference Documents

The development of this flood model report is guided by the following key documents, which are referenced throughout this report.

- QLDC Land Development and Subdivision Code of Practice (QLDC COP)
- Ayrburn Screen Hub Resource Consent Drawings by Patersons dated December 2024 – July 2025

2 Existing Site Conditions

The site is located between Lakes Hayes and Arrowtown, on Lot 4 DP 540788, being land currently zoned Wakatipu Basin Rural Amenity Zone (WBRAZ) and subject to the Ayrburn Structure Plan.

The site sits below Northbrook Waterfall Park development where the valley opens up into what is known as Ayrburn Farm. The historic Ayrburn stone farm buildings are located immediately to the east of the site, in the northern extent of Ayrburn Farm in the area known as Ayrburn Domain.

To the west of the site is steep paddocks that extend above the site toward the Millbrook development. Currently, stormwater sheet flows from the paddocks towards the Site and is largely conveyed through an intermittent stream or cut off drains and discharges towards Mill Creek south of the site. The site itself gently sheet flows towards Mill Creek and down the bank adjacent to the creek. Existing site area, and condition, are shown above in Figure 1.

3 Proposed Development

The proposal for the Ayrburn Screen Hub includes the filming studios, offices and workrooms, and accommodation, conference rooms, wellness and reception area for film staff and crew. Figure 2 below shows the proposed site plan.

Figure 2: Proposed Site Plan

4 Existing Northbrook Waterfall Park Flood model

The Northbrook Waterfall Park Flood Model (NWP Flood Model), developed by Fluent Infrastructure Solutions, assessed flood risks and informed mitigation strategies for the wider Ayrburn and Northbrook Waterfall Park site and its surrounding Mill Creek catchment. Using InfoWorks ICM (v2021.9), the model incorporated LiDAR, survey, and design surface data to simulate pre- and post-development scenarios.

Peer reviews from CKL, Stantec, and AWA supported the final flood model and adopted 100-year ARI peak flow of 33 m^3/s at the upstream/northern boundary of the wider site (at the location of the waterfall).

The model concluded that climate change significantly increases flood risk, particularly through overflow of upstream floodplain storages, and that the adopted parameters provide a conservative yet robust basis for development planning. The full report, noted as the Fluent Report, is attached in Appendix 2, for reference.

This model (NWP Flood Model) has been developed and updated through design and consenting process of both Northbrook Waterfall Park Retirement Village and Ayrburn Precinct. As part of the development of these sites, flood mitigation is proposed to limit the peak flow from the wider site to pre-development levels along the southern boundary of site. This flood mitigation relies on the construction of the Haybarn Bund, which is adjacent to the proposed Screen Hub development, and thus this flood bund is included in the updated flood model to enable any effects of future works to be assessed holistically. The Northbrook Retirement Village latest flooding report along with the engineering plan approval (EA) reporting for the Haybarn Bund are included in Appendix 3 for context and reference. The Haybarn Bund EA application is under RM230425.EA00 and at the time of writing this report the construction of this flood bund is anticipated to occur within the next 2-6 months.

Additionally, through updated flood modelling of Northbrook Retirement Village, the southern boundary condition was update in the ICM model as the original flood model by Fluent had incorrect Lidar at the boundary. The memo summarising this boundary change in the model is also included in Appendix 3.

5 Ayrburn Screen Hub - NWP Flood Model Updates

The existing ICM model for Northbrook Waterfall Park (NWP Flood Model) and Ayrburn Domain (Mill Creek 1-D model) has been developed further to support the Ayrburn Screen Hub project and includes a rain-on-grid (2-D) flood model for the Screen Hub site area and surrounding catchment. Figure 3 below shows the existing Mill Creek Peak flow input and the rain-on-gird catchment area assessed.

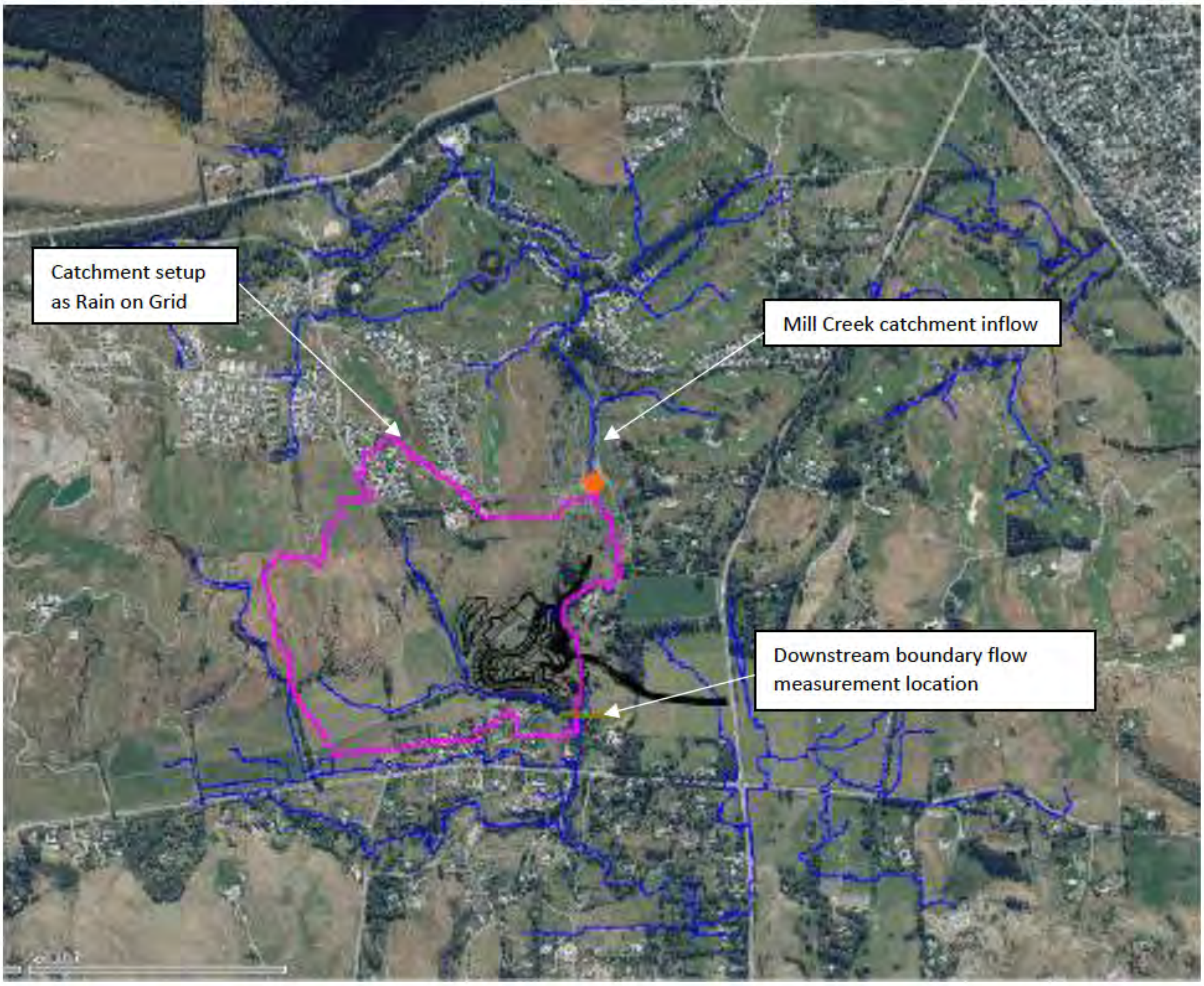


Figure 3: Screen Hub Flood Model Input and Catchment Area

The existing scenario includes the existing development pre all Northbrook & Ayrburn development works.

The latest version of the flood model (Screen hub Model) includes all constructed and consented works within the wider site area including the Northbrook Waterfall Park, Ayrburn, the Haybarn Bund[1] and the rain on grid 2D model for the screen hub. As such the existing scenario for the Screen Hub model is the pre-Screen Hub project (Version 21).

[1] Background to the refence of the Haybarn Bund: the resource consent application for the Haybarn facility which included the surface flow attenuation bund. At the time of writing the bund is has QLDC engineering approval.

5.1 Hydrology Analysis

The hydrological parameters remained the same as used in the previous NWP flood model and summarised below

Parameter	Previous NWP flood Model	Screen Hub Model
Rainfall Hyetograph Type	Triangular rainfall hyetographs were developed for various storm durations.	unchanged
Methodology Reference	Follows Christchurch City Council's "Advanced Analysis" from the Waterways, Wetlands and Drainage Guideline.	unchanged
Rainfall Data Source	NIWA's HIRDS Version 4 was used to generate rainfall data.	unchanged
Pervious Infiltration parameters	Horton infiltration (f_o = 101.6 mm/hr, f_c = 7.6 mm/hr) for other soil types except Hinds 39a (f_o = 63.5 mm/hr, f_c = 7.6 mm/hr)	unchanged
Climate Change Scenario	RCP8.5 scenario (2081–2100) was used to account for climate change.	unchanged
Critical Duration – Main Catchment	9-hour storm duration adopted due to floodplain storage effects in the upper catchment.	Model run with the 2-hour rainfall to capture the maximum levels at the sub catchment level and checked against the 9-hour storm to evaluate any back water effects from the maximum through the mainstream catchment
Critical Duration – Studio Sub-catchments	2-hour storm duration determined as critical for small sub-catchments	

For clarity, the 2 hours storm duration was run for the Screen Hub flood model to ensure that the maximum flow/flood conditions were assessed when the local catchment fully responded to rainfall events without the peak arriving from the Mill Creek catchment. This was also run for 9-hour duration which is the critical duration for the wider Mill Creek catchment.

5.2 Hydraulic Flood Modelling -Parameters & Characteristics

The hydraulic modelling parameters remained the same as used in the previous NWP flood model and summarised below

Parameter	Previous NWP flood model	Screen Hub Model
Manning's Roughness Values	The values used for all roughness areas are derived from the Christchurch City Council "Waterways, Wetlands and Drainage Guide – Part B: Design, Section 22 – Hydraulics". Applied Manning's n values: See Figure 4: Manning's n Roughness Areas – Post-development- NWP Model-Figure 4	Unchanged parameters but areas updated based on land use See Figure 5
Ground Model	• Based on high-resolution LiDAR data (2016) from Aerial Surveys for Otago Regional Council. • Supplemented with survey data and a 3D design surface from Patterson Pitts Group. • Roads and impervious surfaces modelled with a 100% runoff assumption.	• Unchanged, 3D design surface updated to include proposed studio design
Model Extents and Configuration	• Covers entire upstream Mill Creek catchment and Waterfall Park development site. • Mesh resolution: 20 m² max triangle area, refined around Mill Creek.	• Covers the entire studio catchment with point source flow from the Mill Creek catchment. • Mesh resolution: 20 m² max triangle area, refined around Mill Creek and studio development boundary

Figure 4: Manning's n Roughness Areas – Post-development- NWP Model-

Figure 5: Manning's n Roughness Areas – Post-development- Screen Hub Model

5.2.1 Site development characteristics - hydraulic modelling

Much of the Screen Hub site sits well above the Mill Creek catchment and therefore is not at risk from Mill Creek flooding events. However, the rain-on-grid model allows us to assess the overland flow as it passes through the site and the interaction with the upstream flow behind the Screen Hub to assess any flooding risk.

It is proposed to include an in-line sediment retention pond within Mill Creek, to capture and remove sediment that is generated from the upstream catchment prior to discharging into Lake Hayes. This in-line pond effects the flow regime of Mill Creek, at this location, which results in reduced peak flow along southern boundary during smaller storm events. Particular attention is paid to this in-line pond and surrounding environs to ensure velocities are low to encourage sediment deposition into the ponds in smaller storm events.

Adjacent to the in-line pond are proposed treatment infiltration ponds as part of the treatment train approach for the Screen Hub development and to retain runoff from the Screen Hub sub catchment prior to discharging to Mill Creek. These ponds are only inundated from Mill Creek flow in 100yr ARI rainfall event. Flow velocities around these ponds remain low to avoid re-suspending sediment, erosion or affect planting. These ponds are addressed further in the Stormwater Management Plan for Screen Hub[2].

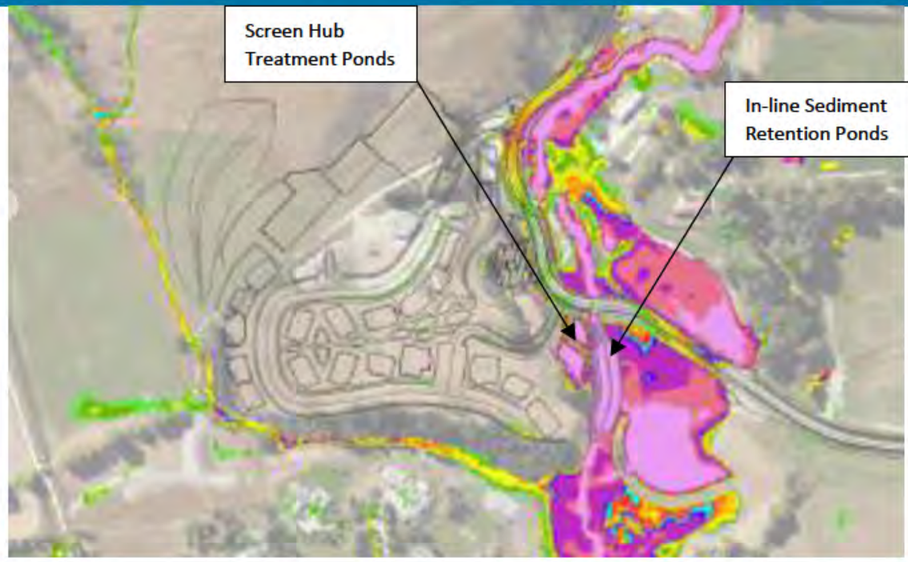
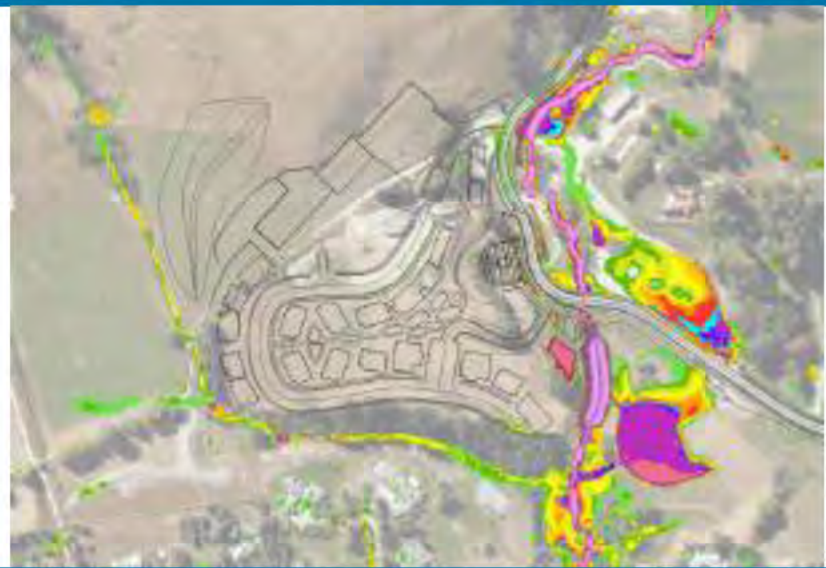
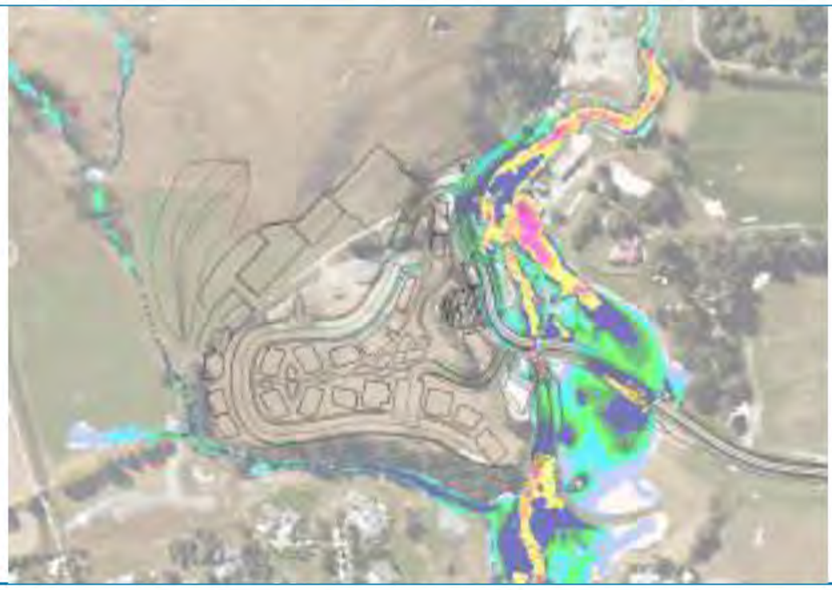
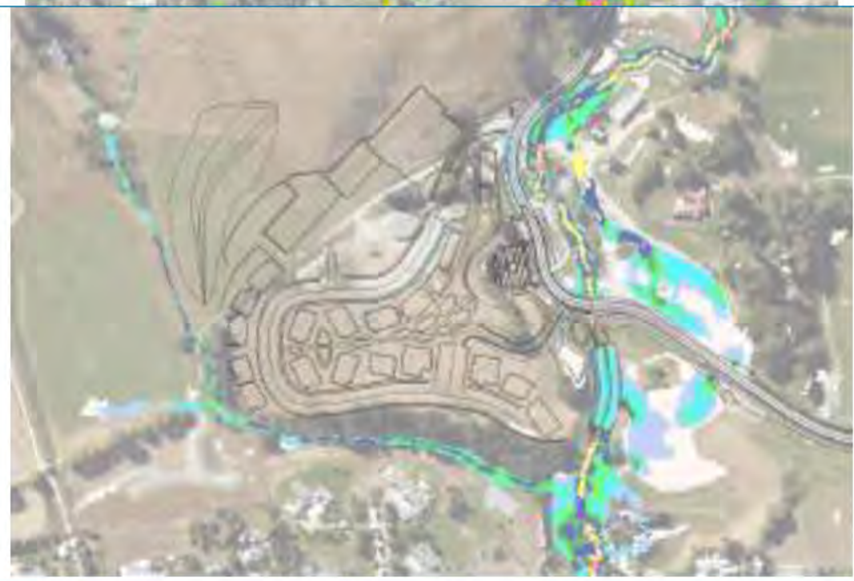
The results from the Screen Hub flood model are included in the following sections.

[2] Stormwater Management Plan, Ayrburn Screen Hub, Waterfall Park Development Ltd, CKL, June 2025

6 Ayrburn Screen Hub Flood Model Results

This section presents the post development flood model results to which the assessment of effects outcomes is based. Larger Maps, for visual clarity, are appended in Appendix 1

6.1 Depth and Velocity and Difference Results

Duration	100year	20 year	2 year
Depth(m) <= 0.05 0.05 - 0.10 0.10 - 0.15 0.15 - 0.20 0.20 - 0.25 0.25 - 0.30 0.30 - 0.35 0.35 - 0.40 0.40 - 0.45 0.45 - 0.50 0.50 - 0.75 0.75 - 1.00 > 1.00			
Velocity(m/s) <= 0.1 0.1 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 0.5 - 1.0 1.0 - 1.5 1.5 - 2.0 2.0 - 2.5 > 4.5			

Duration	100year	20 year	2 year
Depth difference (m) difference(m) <= -1.00 -1.00 - -0.50 -0.50 - -0.10 -0.10 - -0.05 -0.05 - 0.00 0.00 - 0.05 0.05 - 0.10 0.10 - 0.50 0.50 - 1.00 > 1.00 Was Dry now Wet Was Wet now Dry			
Velocity difference (m/s) <= -1.00 -1.00 - -0.75 -0.75 - -0.50 -0.50 - -0.10 -0.10 - 0.00 0.00 - 0.10 0.10 - 0.50 0.50 - 0.75 0.75 - 1.00 > 1.00			

6.2 Results discussion

The peak water level difference maps indicate that no major flood extent changes are observed especially in the 100-year event. No major adverse flood risks are observed downstream or across the broader floodplain; most changes are confined within the new ponds and the haybarn bund. The effects are mainly positive indicating reductions in levels (0.05m to 0.50m), due to creation of more storage capacity with the addition of treatment ponds and the inline sediment pond. Where there is an indication of (post-development) increases in water levels these are indicating newly created flow paths in the development (was dry now wet legend)

The peak velocity difference maps for the 2-year, 20-year, and 100-year events indicate that changes in stream velocity are generally minor and spatially limited. Most of the watercourse shows negligible to moderate changes (within ±0.50 m/s), with only small, isolated areas showing increases greater than 0.75 m/s. The are mainly near the culvert outlets. The inclusion of stormwater treatment measures, particularly the in-line sedimentation pond, moderate velocity changes downstream. The results suggest that changes in flow patterns are minimal and unlikely to result in significant adverse effects on stream erosion or stability.

7 Risk Mitigation

The peak flow assessment at downstream locations provides an understanding as to the mitigation requirements, as well as the protection of proposed buildings through freeboard to top water levels during the large rainfall events.

7.1 Boundary flows and volumes Screen Hub Catchment

An assessment of the flows during various rainfall events have been reviewed in 2 locations shown in Figure 6 below, being:

- Screen hub boundary
- Wider site flow boundary

Figure 6: Flow measurement locations- -

To prevent significant adverse effects, the stormwater management system is required to mitigate any increase in runoff flows up to the 100yr ARI storm frequency back to predevelopment flowrates at the wider site boundary.

The peak flows during various rainfall events at both of the assessment locations are presented in Table 1.

Table 1: Peak flows at downstream locations

Recurrence Interval	Screen hub catchment (2hr duration)		Wider catchment (9hour duration)	
	Predevelopment	Post development	Predevelopment	Post development
100year	2.84	2.20	37.65	35.75
20year	0.36	0.28	10.15	8.92
2year	0	0.03	4.29	4.24

There are increases in the post development peak flows for the 2-year recurrence intervals from the screen hub catchment, prior to discharge to Mill Creek catchment. This responds to the increase in impervious surfaces associated with the proposed screen hub catchment. The increase in flow can be considered as minor as the increases are within 1% of the predevelopment flows that discharge into Mill Creek.

However, at the wider catchment downstream boundary, the post development peak flow at the southern boundary of the site is less in the 2yr, 20yr and 100yr ARI than pre–development scenario.

The total flow volumes were assessed at the downstream boundary and the results are shown in Table 2 and hydrographs are shown in Figure 7.

Table 2: Total flow volumes at wider site downstream boundary

Recurrence Interval	Total Volume (m^3) Wider catchment (9hour duration)	
	Predevelopment (	**Post development**
100year	264121	278400
20year	71857	71996
2year	36036	35636

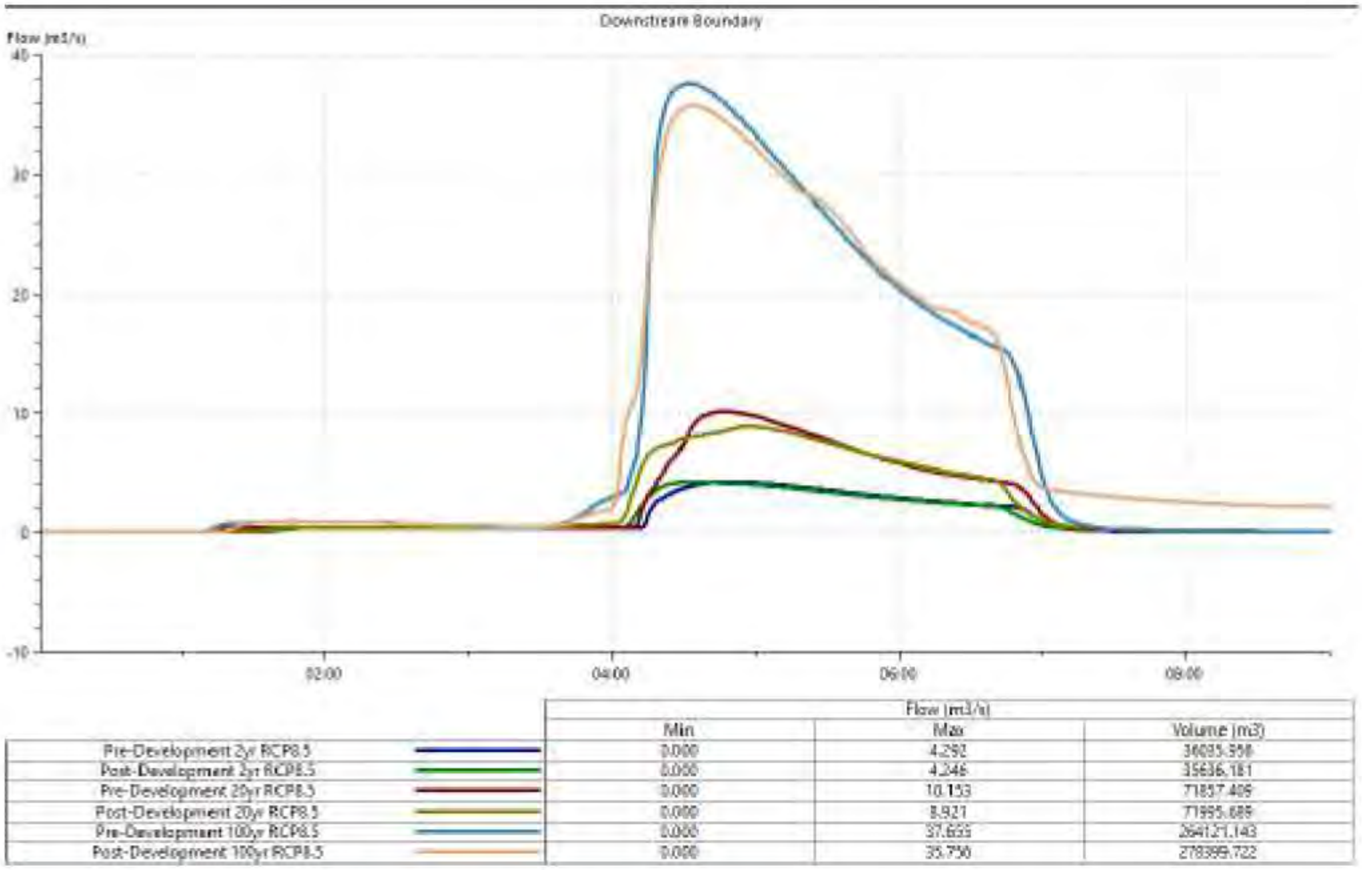


Figure 7: Pre and post development hydrographs at Ayrburn Southern Boundary

The flow volume results show that the proposed development has a negligible impact on total runoff volumes for the assessed events, with differences of less than 1% between pre- and post-development scenarios for the 2- and 20-year event and approximately 5% for the 100-year event.

7.2 Upstream Flow diversions

Upstream catchments located above the film studios present a potential flooding risk if not properly managed, refer to Figure 8. In the current flood modelling, there is no indication of water pooling behind the proposed building, as the model does not block the buildings and allows overland flow across the platforms. While this approach may overlook minor localised flood pockets, these are expected to be minimal and will be addressed in greater detail during the detailed design phase.

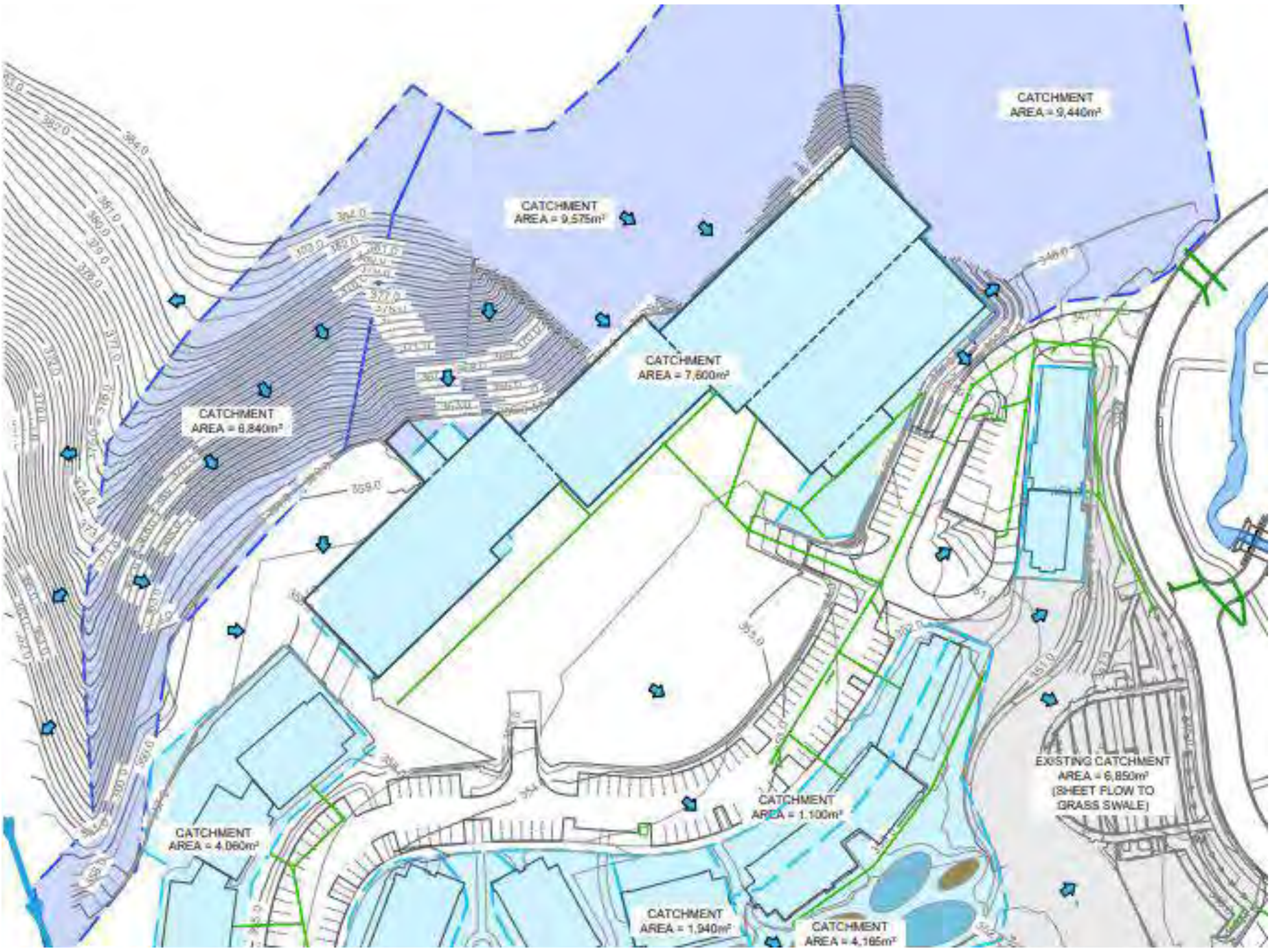


Figure 8: Upstream slope catchments

Details of the surface flow diversion system includes cut-off bunds/swales, ground shaping and utilisation of retaining walls. These diversion systems are presented Figure 9 and Figure 10.

Figure 9: Upstream slope surface flow diversion -Cross section Locations

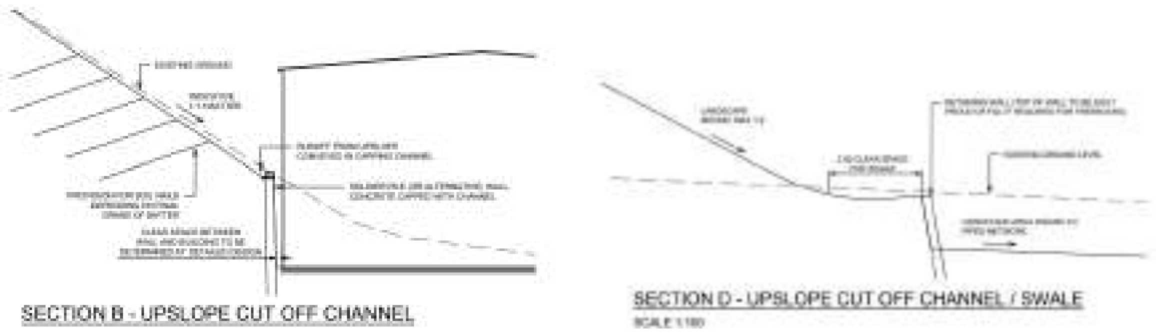


Figure 10: Cross section B and Cross section D

The cut off channels and swales, designed for the 100-year flow, form a key part of the upstream flow management strategy to mitigate flood risk to the development platform and will reduce the risk of surface flooding.

As shown in Section B, the upslope cut-off channel is integrated with a soldier pile wall and concrete-capped conveyance channel, to intercept and redirect overland runoff. The transition to a 2.5 m wide swale located adjacent to a retaining wall, as presented in Section D, will provide runoff conveyance to the other retaining wall structures.

7.3 Freeboard Requirements

The freeboard requirements from the QLDC CoP have been adopted as the minimum freeboard specification for the Screen Hub development. Clause 4.3.5.2, of the QLDC CoP, is copied below:

> The minimum freeboard height additional to the computed top water flood level of the 1% AEP design storm should be as follows or as specified in the district or regional plan:

Freeboard	Minimum height
Habitable dwellings (including attached garages)	0.5 m
Commercial and industrial buildings	0.3 m
Non-habitable residential buildings and detached garages	0.2 m

> The minimum freeboard shall be measured from the top water level to the building platform level or the underside of the floor joists or underside of the floor slab, whichever is applicable.

Please also refer to Figure 11 below which summarises the Finished Floor Levels (FFL). All the buildings meet the recommended freeboard levels except for the Northern building, which is identified in Figure 11.

Figure 11: Finished floor levels compared to flood elevation levels

This northern building is proposed to have a freeboard level of 0.12m, see Figure 12.

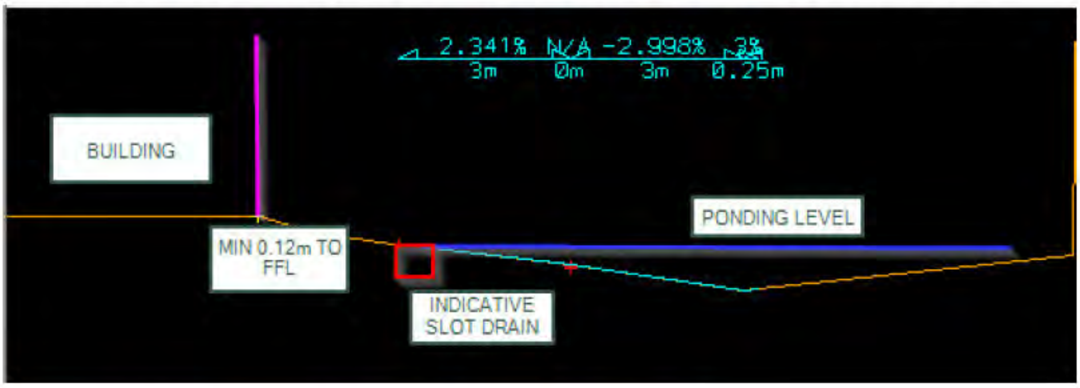


Figure 12: floor level comparison for Northern building and ponding level

It is to be noted that

- That the ponding shown is at a low point in the road and is only present because 100% blockage of the SW network has been assumed.
- To mitigate potential effects for this non-habitable building a slot drain is proposed at the edge of the modelled 100yr top water level.
- The flow calculated during the 100yr ARI demonstrate that thus would be adequately conveyed in a slot drain

8 Summary and Conclusion

This Ayrburn Screen Hub flood report documents the development of a flood model, which includes previous peer reviewed flood models for the Mill Creek catchment and a rain-on-grid flood model to assess the flood risk associated with the proposed Ayrburn Screen Hub development. The modelling builds upon the existing Northbrook Waterfall Park flood model and incorporates updated design data, proposed site layouts, and updated hydraulic parameters relevant to the site.

The results confirm that the proposed Screen Hub development is largely unaffected by overland flow from Mill Creek due to its elevated location. The rain-on-grid (flood model) approach provides a detailed assessment of localised surface runoff, demonstrating that any post-development increases in peak flows from the Screen Hub catchment are minor and will not result insignificant downstream impacts within Mill Creek.

All buildings have been designed to meet QLDC freeboard requirements, with one minor exception identified and mitigation has been documented.

Appendix 1 High Resolution Maps

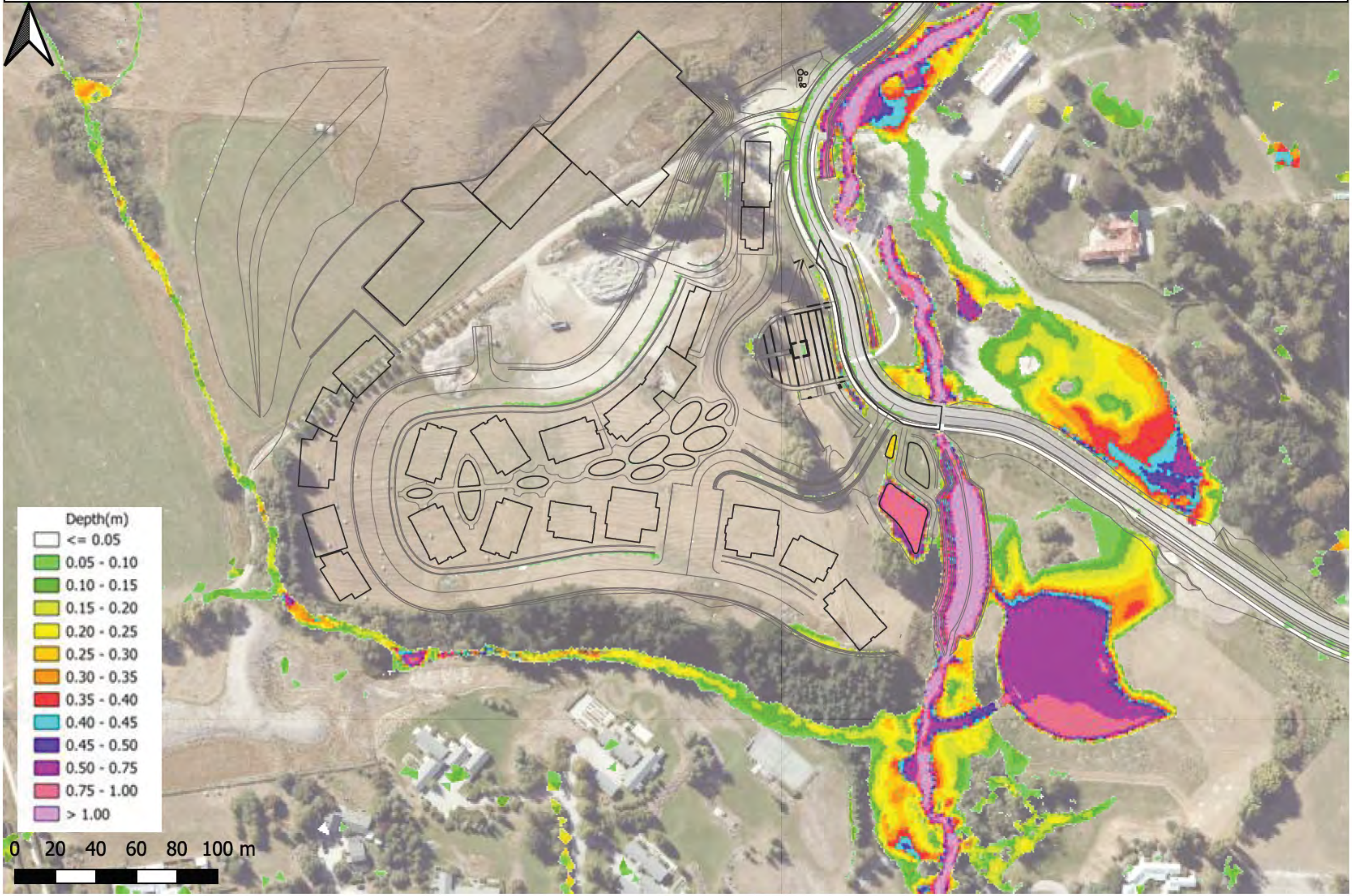
Screen Hub Development - 2 Year Post Development Flood Depths

Screen Hub Development - 2 Year Post Development Flood Level Difference

Screen Hub Development - 2 Year Post Development Flood Velocities

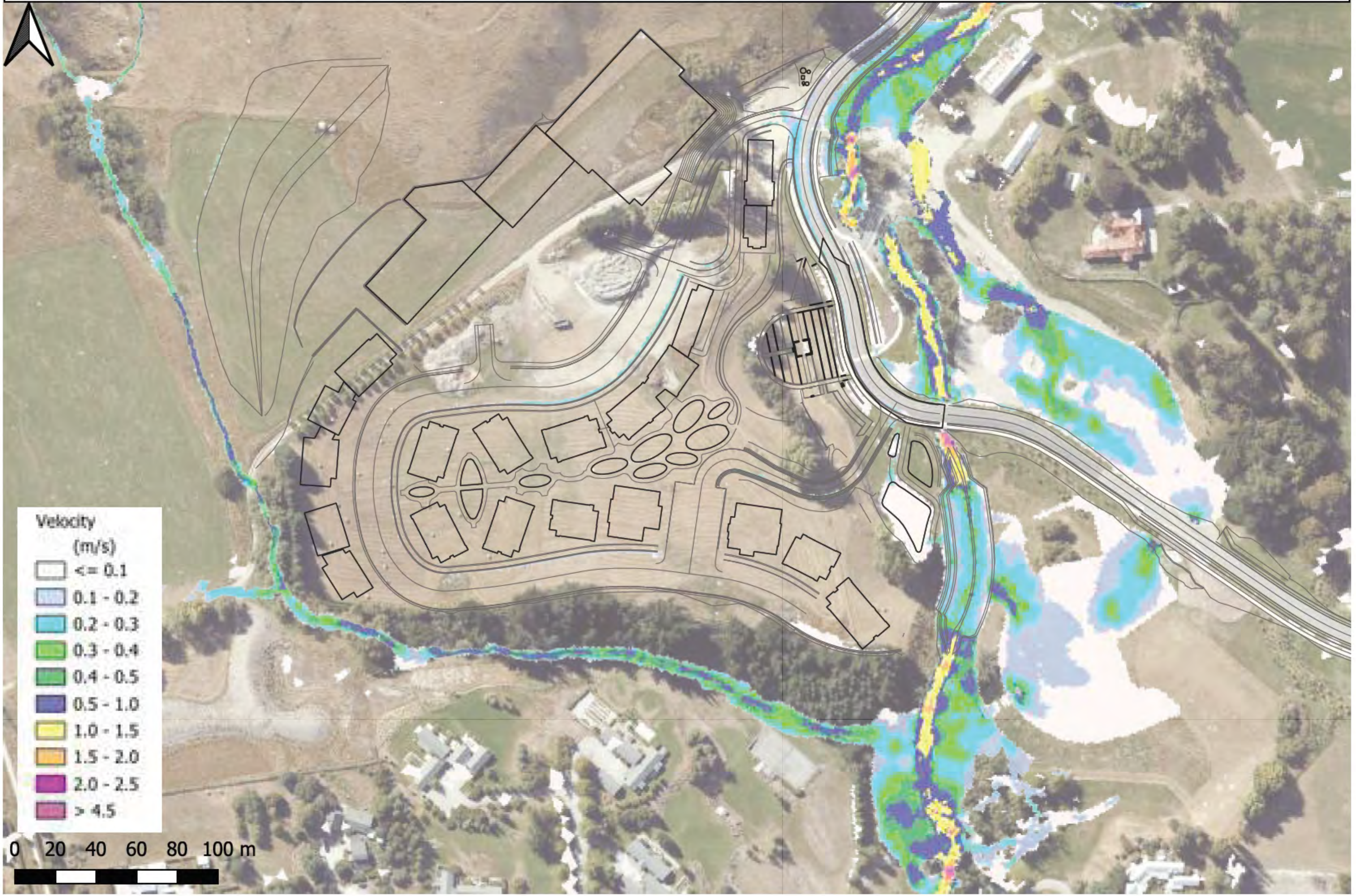
Screen Hub Development - 2 Year Flood Velocity Difference(Post minus Predevelopment)

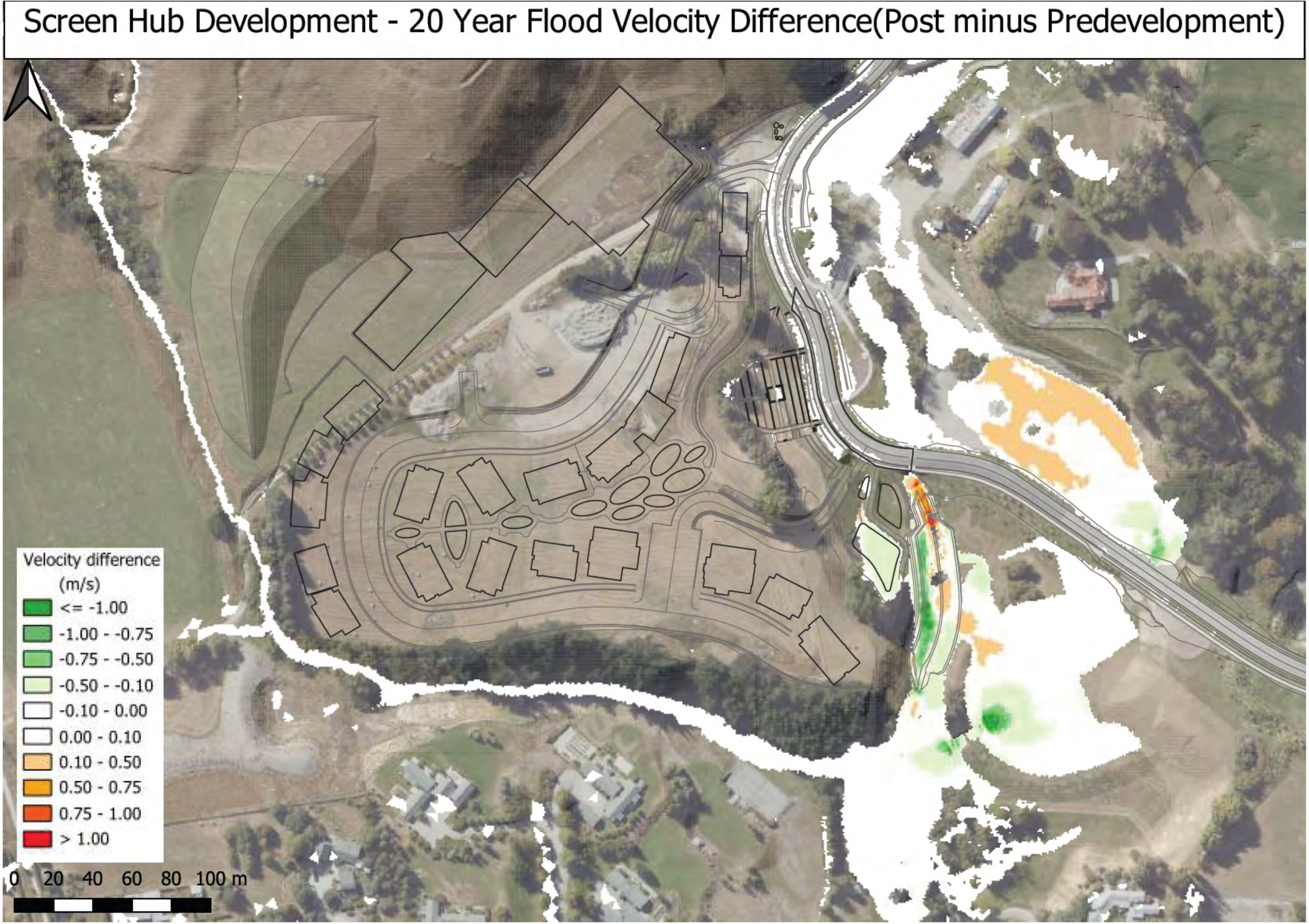
Screen Hub Development - 20 Year Post Development Flood Depths



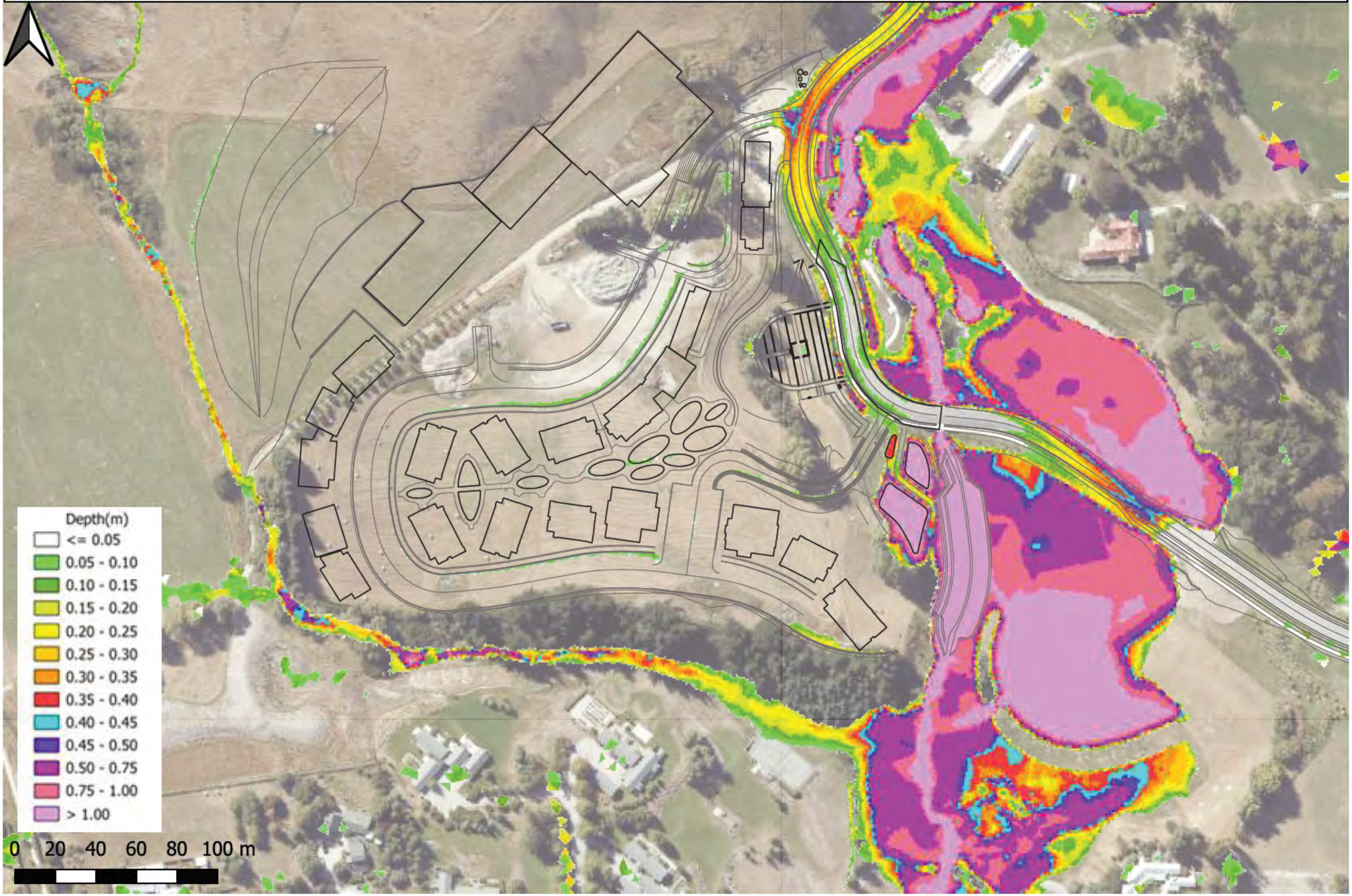
Screen Hub Development - 20 Year Post Development Flood Level Difference

Screen Hub Development - 20 Year Post Development Flood Velocities



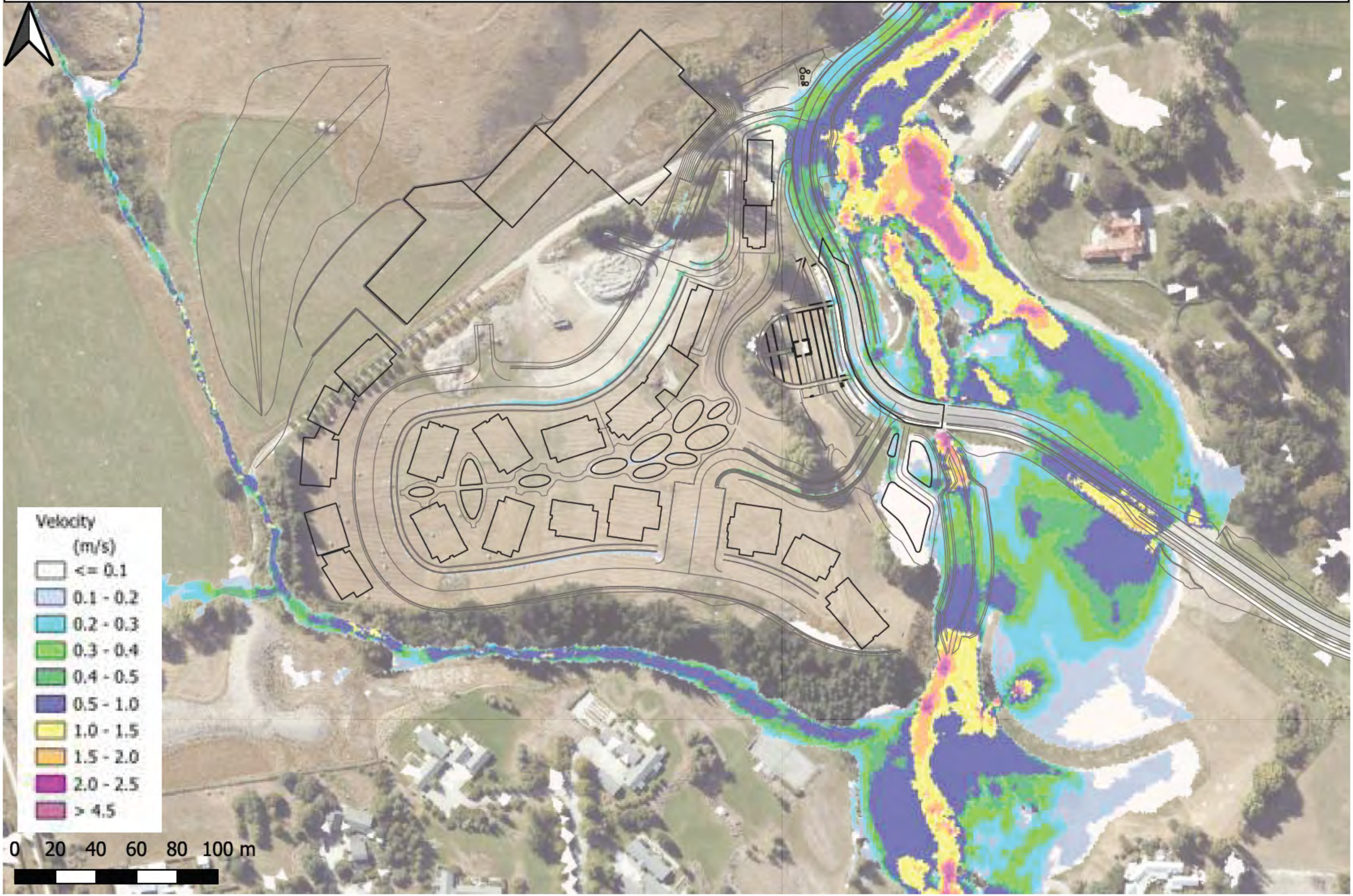

Screen Hub Development - 20 Year Flood Velocity Difference(Post minus Predevelopment)
Velocity difference (m/s)
<= -1.00
-1.00 - -0.75
-0.75 - -0.50
-0.50 - -0.10
-0.10 - 0.00
0.00 - 0.10
0.10 - 0.50
0.50 - 0.75
0.75 - 1.00
> 1.00
0 20 40 60 80 100 m

Screen Hub Development - 100 Year Post Development Flood Depths



Screen Hub Development - 100 Year Post Development Flood Level Difference

Screen Hub Development - 100 Year Post Development Flood Velocities



Screen Hub Development - 100 Year Flood Velocity Difference(Post minus Predevelopment)

Appendix 2 Fluent Report

FILE RECORD

SUBJECT:	Northbrook Waterfall Park Flood Model – Parameters Summary	Job No.:	Q000491
Prepared By:	Fluent Solutions	Date:	03/10/2022
		Page 1 of 16	
		Reference:	*FR-22-10-03 AWF 000491 Parameters Summary.Docx*

1.0 Introduction

This document sets out a summary of flood modeling parameters proposed for use in the design of flood mitigation processes in relation to Mill Creek and the Northbrook Waterfall Park Development area.

The purpose of the flood model is to provide a detailed analysis of pre development vs. post development flows, flood affected developed areas, flood velocities, potential erosion/scour from flooding, flow paths, and flooding extents. The model incorporates data for the entire upstream Mill Creek catchment. The area of focus for the flood assessment model is the Northbrook Waterfall Park Development area. The developed model has been used to inform decisions regarding potential flood impacts affecting the development, as well as proposed design decisions meeting Queenstown Lakes District Councils Land Development and Subdivision Code of Practice (COP) requirements.

2.0 Flood Flow Assessment

2.1 Analysis Methodology

The hydraulic and hydrological modelling software Infoworks ICM (Version 2021.9) (ICM) was used to derive the flood and stormwater flow patterns and estimated flood depths and velocities within the development site and the downstream environment. LiDAR and survey data were used for the pre-development 2D runoff calculations. A combination of LiDAR and a developed design ground model were used for the post-development 2D runoff calculations.

Flow estimates for Mill Creek at the Northbrook Waterfall Park development have been developed using two methods as described in Section 2.2 below.

2.2 Mill Creek Design Flow Estimates

The Northbrook Waterfall Park design flows were developed using two methods, the Generalised Extreme Value method and an ICM 2D catchment model as described in more detail below.

2.2.1 Generalised Extreme Value Flow Estimates

The Mill Creek catchment area at Waterfall Park is approximately 35km^2 while the catchment area at the "Fish Trap" gauging station on Mill Creek is 55km^2. The additional catchment

FILE RECORD

area is largely that of the Speargrass Flat area which includes Mooneys swamp. The Speargrass sub-catchment has a similar catchment shape but shorter time of concentration than Mill Creek at Waterfall Park and therefore the peak flow at the Fish Trap gauging station would generally be marginally higher than the peak flow at Waterfall Park. The flow estimates provided by the Otago Regional Council (ORC) using the Generalised Extreme Value (GEV) analysis of annual maximum flows from the Fish Trap flow records have been used as the basis of the hydraulic analysis of conditions at Waterfall Park.

A 30% increase to the varying ARI flows at the Fish Trap was added to account for climate change.

From these peak flow estimates, flow triangular hydrographs were created with the peak flow occurring at 0.7 times the duration each ARI storm event. The hydrograph was used to represent the storage routing.

The GEV method was used to develop the 2-year through the 50-year ARI design flows reported in Table 2.4 below. The triangular hydrographs were developed from these peak flows and applied to the model at the waterfall located at the top of the Waterfall Park valley.

2.2.2 Mill Creek Upper Catchment Model – 100-year and 500-year ARI Flow Estimates

The 100-year ARI peak flows were developed using a comprehensive ICM model for Mill Creeks "Upstream Catchment" upstream of the Waterfall. A 2D "rain on grid" model assessment was completed to visualise the flow paths through the catchment and assess the potential increases in flood flow magnitude for a range of storm durations and various climatic considerations.

The following sections provide a summary of the model parameters used in developing the Upper Catchment flows ICM model to generate the 100-year ARI design flow.

2.2.2.1 Ground Model Surface

The model is based on LiDAR data captured for Otago Regional Council by Aerial Surveys in March and April 2016.

2.2.2.2 Soil Infiltration Characteristics

The Horton methodology was used for estimating infiltration losses to the soil using a "rain on grid" surface created from the 3D LiDAR data. This document goes into further description regarding the Horton methodology in Section 2.3 below. The specific infiltration values were based on a dry silty loam soil with little to no vegetation, an initial infiltration (f0) of 101.6mm/hr, and ultimate infiltration (fc) of 7.6mm/hr, and a decay rate of 4.1/hr.

As a sensitivity analysis Horton infiltration rates of an initial infiltration (f0) of 50mm/hr, and ultimate infiltration (fc) of 7.6mm/hr, and a decay rate of 2/hr and a further decay rate of 0.05/hr were also trialed. Results from both trials gave similar results.

2.2.2.3 Roughness Considerations

Additional to the soil characteristics, the Manning's roughness of the ground surface was also considered. Figure 2.1 shows the roughness scenario for the hill catchment above the upper Mill Creek flood plain (upstream of the waterfall at Waterfall Park), the upper flood plain and the main Mill Creek flow path within the flood plain considered as part of the analysis.

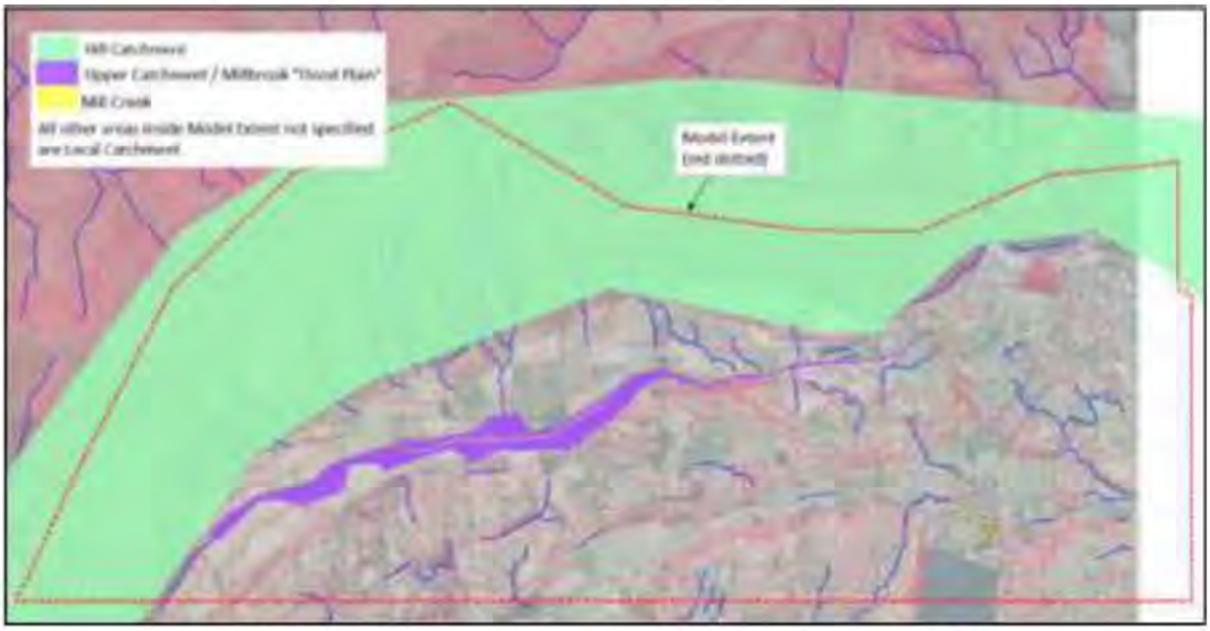


Figure 2.1: Upper Catchment Mannings Roughness Area Map

A variety of roughness allowances were made in the model as part of a sensitivity study. A summary of the varying roughness conditions and the effect on estimated flows at the Fish Trap site are presented below. Note that the information in Table 2.1 only represents the estimated historic flow (no climate change allowance) at the Fish Trap flow station.

Table 2.1: Roughness Area Scenarios

Scenario	Hill Catchment Manning's	Upper Catchment / Millbrook "Flood Plain" Manning's	Mill Creek Manning's	Local Catchment Manning's	100yr ARI Estimated Flow at Fish Trap (Historical Data HIRDS V4, no climate change) – assumed 6hr critical storm – (large scale mesh)	6hr for reference only
1	0.2	0.03	0.03	0.03		6.54
2	0.2	0.1	0.06	0.1		3.49
3	0.16	0.075	0.04	0.075	4.30	4.18
4	0.16	0.075	0.06	0.075		4.14
5	0.16	0.035	0.06	0.075	4.25	4.14

After consideration of the results in Table 2.1 as well as a review of the catchment characteristics, "Scenario 5" was selected as it closely reflected measured flows at the Fish Trap gauging site. "Scenario 5" includes a roughness Manning's n (n) of 0.16 was chosen to represent the sheet and shallow flow, which delays the flow of water through the steep mountainous catchments. A Manning's n of 0.035 was chosen to represent the flow over the "flood plain" in the flat area of the catchment. The Mannings n for the local hill catchments were estimated to be 0.075. Finally, a roughness of 0.06 was allowed for within the Mill Creek margins.

2.2.2.4 Rainfall and Climate Change

A series of triangular rainfall hyetographs (rainfall depth versus time graph) were developed for a range of storm durations and used in the model. The triangular hyetograph methodology, which has been adopted by the Christchurch City Council "Advanced Analysis" method provided in the *"Waterways, Wetlands and Drainage Guideline,"* was applied to this model. The rainfall used in this analysis was taken at a location which represented the upstream catchment area as a whole.

The NIWA High Intensity Rainfall Distribution System (HIRDS) Version 4 was used to generate the rainfall hyetographs. The design rainfall hyetographs utilised in the model included an allowance for an assumed increase in average annual temperature following the RCP8.5 climate change projection scenario for the period 2081-2100 (published by NIWA in HIRDS Version 4) as required by the Queenstown Lakes District Council (QLDC) Land Development and Subdivision Code of Practice (COP).

2.2.2.5 Critical Flow Duration

The initial model was run with triangular rainfall hyetographs for a range of rainfall event durations from 0.5hr to 12hr and the flow at Waterfall Park and at the Fish Trap were reviewed. The purpose of the review was to identify the critical maximum duration 100-year ARI flood flow event at Waterfall Park.

Table 2.2 below shows the maximum peak flows for the various durations for the historical rainfall and the more conservative RCP8.5 climate change allowance. Note that the 6hr duration had the peak inflow from the upper hill catchment, yet the 9hr duration consistently produced the highest flows at the Waterfall and Fish Trap. This is thought to be due to the storage component in the upper catchment area, which is expanded upon in the following sections. Therefore, the 9hr duration event was adopted as the critical design scenario for the flows at Waterfall Park.

Table 2.2: Peak 100-year ARI Critical Duration Analysis

Storm Event	Historic			RCP8.5		
	Peak Flow from Hill (m3/s)	Peak Flow at Waterfall (m3/s)	Peak Flow at Fish Trap (m3/s)	Peak Flow from Hill (m3/s)	Peak Flow at Waterfall (m3/s)	Peak Flow at Fish Trap (m3/s)
100yr, 2hr	2.50	0.02	0.01	34.72	3.17	6.65
100yr, 6hr	20.52	0.33	4.14	48.05	39.63	36.17
100yr, 9hr	17.41	2.97	4.25	35.57	42.08	39.34
100yr, 12hr	11.98	0.18	2.76	25.77	34.90	32.51

2.2.2.6 Model Limitations

- The model is based on LiDAR data as described in the previous sections. From a cross section analysis, the LiDAR data frequently provides a relatively coarse representation of the Mill Creek channel in difference to that available from a detailed survey assessment.
- The mesh size for the initial run iterations has a maximum triangle area of 20m^2. Subsequent runs reduced the mesh size for the area immediately around Mill Creek. Model flow results were similar.
- No culverts have been included in the model to date. It is considered that the culverts would be undersized for the 100-year ARI event and/or may become blocked in large flood events. The exclusion of the culverts from the model would cause additional flooding/overtopping of roads in the model but because culverts carry a small portion of the 100-year ARI flood flow the effect on the results was considered to be relatively minor.
- The model results are based on the HIRDS Version 4 rainfall data from the hills approximately 2km west of the waterfall. Additionally, rainfall data from HIRDS was taken at different points within the catchment to test variations around the upper catchment. Comparisons of the HIRDS rainfall data at points around the catchment showed that spatial variation in the rainfall data is minor and would have minimal affect the magnitude of the flow results from the model.
- In the model, flows around the Fish Trap site show water breaking out from the Mill Creek banks. However, cross sections of the channel taken on site show that there is additional capacity in Mill Creek than what is represented by the LiDAR. To account for this in the model, estimated flows at the Fish Trap included the overspill from the banks.

2.2.2.7 Flow Results

The modelled flow results are presented in Figure 2.2 and Table 2.3 below. Further commentary is provided below.

Figure 2.2: 100-year ARI RCP 8.5 Rainfall Scenario – Flood Map Extents

Table 2.3: 100-year ARI Flood Flow Results – Historic and with Climate Change by Rainfall Duration (2hr to 12hr)

Storm Event	Historic					RCP8.5				
	Rainfall Total Depth (mm)	Peak Flow from Hill (m3/s)	Peak Flow at Waterfall (m3/s)	Peak Flow at WP DS Boundary (m3/s)	Peak Flow at Fish Trap (m3/s)	Rainfall Total Depth (mm)	Peak Flow from Hill (m3/s)	Peak Flow at Waterfall (m3/s)	Peak Flow at WP DS Boundary (m3/s)	Peak Flow at Fish Trap (m3/s)
100yr, 2hr	39	2.50	0.02	0.37	0.01	52.2	34.72	3.17	3.94	6.65
100yr, 6hr	66.3	20.52	0.33	1.89	4.14	86	46.05	39.63	37.71	36.17
100yr, 9hr	80	17.41	2.97	2.31	4.25	102	35.57	47.08	40.29	39.34
100yr, 12hr	89.3	11.98	0.18	0.97	2.76	113	25.77	34.90	33.58	32.51

Figure 2.2 shows an example of the flow paths through the catchment and selected flow measure points for the 100-year ARI RCP8.5 climate change scenario. The yellow highlighted areas signify significant storage areas identified in the upper catchment. In the case of the high flow events with climate change included the storage areas overflow, particularly at Hunter Road/Malaghans Road and in Millbrook, and create an amplified peak flow at Waterfall Park. In the historic rainfall scenario, the storages only experience minimal overflows, which corresponds to the muted observed peak flow for the 100-year ARI event in the case excluding climate change.

The results from the model assessment suggest the following:

- The increase in rainfall depth for climate change produces a major increase in peak flow.
- Modelling of the catchment shows signs consistent with the assumption that flood plain storage modifies flood flows upstream of the Millbrook area. For the historical rainfall data (i.e. no climate change), the storage capacity on the floodplain absorbs the runoff flow from the upper mountain catchments with minimal discharge down Mill Creek.
- The "with climate change" rainfall storms have a greater rainfall depth and higher rainfall intensity. For a 100-year ARI event, the rainfall depths across the range of durations modelled is predicted to increase by 30% on average (based on HIRDS data), with the rainfall intensity, at the peak of the storm, increasing by around 80%.
- The combined effect of the increase in rainfall depth, intensity and saturated soil leads to a much larger response down Mill Creek. **At the waterfall location at Waterfall Park the 100-year ARI flow with climate change based on the model results is estimated to be 42m^3/s.**

2.2.3 Updated Flow Results Peer Reviewed by Multiple Engineering Consultants

After the 100-year ARI flood model assessment described in Section 2.2.2 was completed, the model and results were initially peer reviewed by CKL (Auckland) and Stantec (Dunedin) engineering consultants. Additionally, AWA (Auckland) also undertook a peer review of the flood model assessment. The following points are summaries from the peer reviewer comments:

- The CKL review concluded that the flood estimations presented in the memo (42m^3/s peak flow for the 100-year ARI) seemed reasonable.
- Stantec undertook a review and based on a sensitivity study looking into the infiltration characteristics of the catchment, Stantec found it reasonable to reduce the 100-year ARI peak flow to 33m^3/s. However, even with the reduction in peak flow estimates, the Stantec review concluded that "the future modelled peak flows may be a conservatively high extrapolation."
- Lastly, AWA undertook a peer review and commented as below.

  "A high-level review of the model was undertaken based on documentation received. AWA is in agreement with previous reviewer comments (Stantec) suggesting the future flow at Waterfall is conservatively high."

After the peer reviewer comments and inputs from a diverse range of engineering consultant firms, a 100-year ARI design flow of 33m^3/s was adopted. Table 2.4 outlines the 100-year ARI design flows for the Northbrook Waterfall Park Development.

The 500-year ARI design flow has been extrapolated from the 100-year ARI design flow, as rainfall records for the 500-year ARI were not available. The extrapolated 500-year ARI design flow is presented in Table 2.4.

2.2.4 Flow Result Summary

Table 2.4 provides a summary of the design input peak flows for the 2-year through the 500-year ARI storm events. The triangular hydrographs were developed from these peak flows and applied to the model at the Waterfall, which is located at the head of the Waterfall Park valley, shown in Figure 2.3.

Table 2.4: Adopted Design Peak Flows for 2-year through 500-year ARI Events

Storm Event	Design Input Peak Flow (m^3/s)
2 Year ARI	4.4
10 Year ARI	7.6
20 Year ARI	8.5
50 Year ARI	9.6
100 Year ARI	33.0
500 Year ARI	86.0

2.2.5 Sensitivity Analysis – Sustained Peak Flow

For the design, the peak flows as referenced the section above were used for the flow hydrograph input at the waterfall. These design flows included a hydrograph shape with a sharp rise and fall.

As a further sensitivity analysis, a long period (12hr) sustained peak flow hydrograph was developed for each ARI storm event and run in the model to assess the effects of a sustained peak flow, which applies a larger volume to the model.

The sustained peak flow hydrograph has an artificial 1-hour ramp up, from $0m^3/s$ to the peak flow value (depending on the ARI), which is maintained for 10 hours, and another 1 hour artificial ramp down.

2.3 Northbrook Waterfall Park Flood Model

An ICM flood model was also developed for the Northbrook Waterfall Park Development area. The design flows developed in Section 2.2 were applied at an inflow point to the developed ICM model. This flood model focused on the proposed development area with the intention of assessing flood flow patterns, flood affected developed areas, flood velocities, potential erosion/scour from flooding, flow paths, and flooding extents for the proposed development site and the downstream environment. Figure 2.3 shows the Northbrook Waterfall Park Development area boundary, the Mill Creek upstream catchment inflow point, and ICM flood model extents.

The entire model had 3D ground surface information available where 2D hydraulic calculation algorithms were utilised to estimate runoff flows and overland flow pathways.

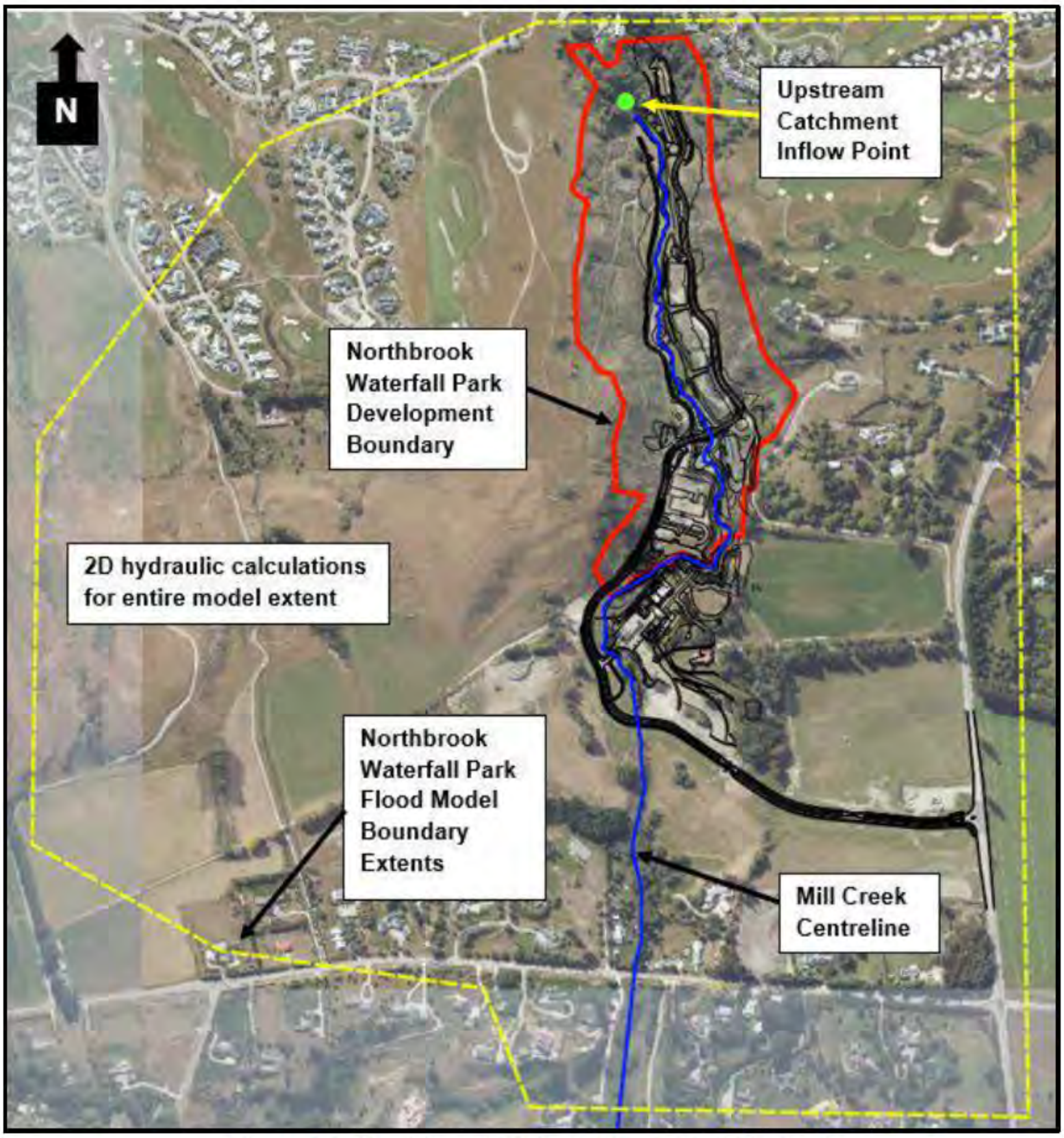


Figure 2.3: Northbrook Waterfall Park Model Extent

2.3.1 Ground Model Data

The model was based on a combination of LiDAR data (circa 2016), survey data, and a design surface for the post-development scenario.

The LiDAR for the area surrounding the Northbrook Waterfall Park development was captured for Otago Regional Council by Aerial Surveys in March and April 2016. The information is available as a 1m Digital Elevation Model (DEM) from Land Information New Zealand (LINZ). The survey and design surface were provided by the Patterson Pitts Group (PPG).

2.3.2 Soil Characteristics

The sections below set out the assumptions for the pre- and post-development soil and land use characteristics. The pre- and post-development scenarios were modelled using different methods as described below. Therefore, it was necessary to use a soil / land use characteristics specific for each area based on land use and available topographical data.

The Horton infiltration methodology was used for estimating infiltration losses to the soil surface created from the ground surface data. The infiltration and decay rate selections are described in more detail in Section 2.3.3.3 below.

2.3.2.1 Pre-development Soil Characteristics

The pre-development flow was modelled using a 2D surface based on 3D LiDAR information. Figure 2.4 below gives the breakdown of soil areas. Table 2.5 provides Horton infiltration rates based on the type of soil present in the area within the model.

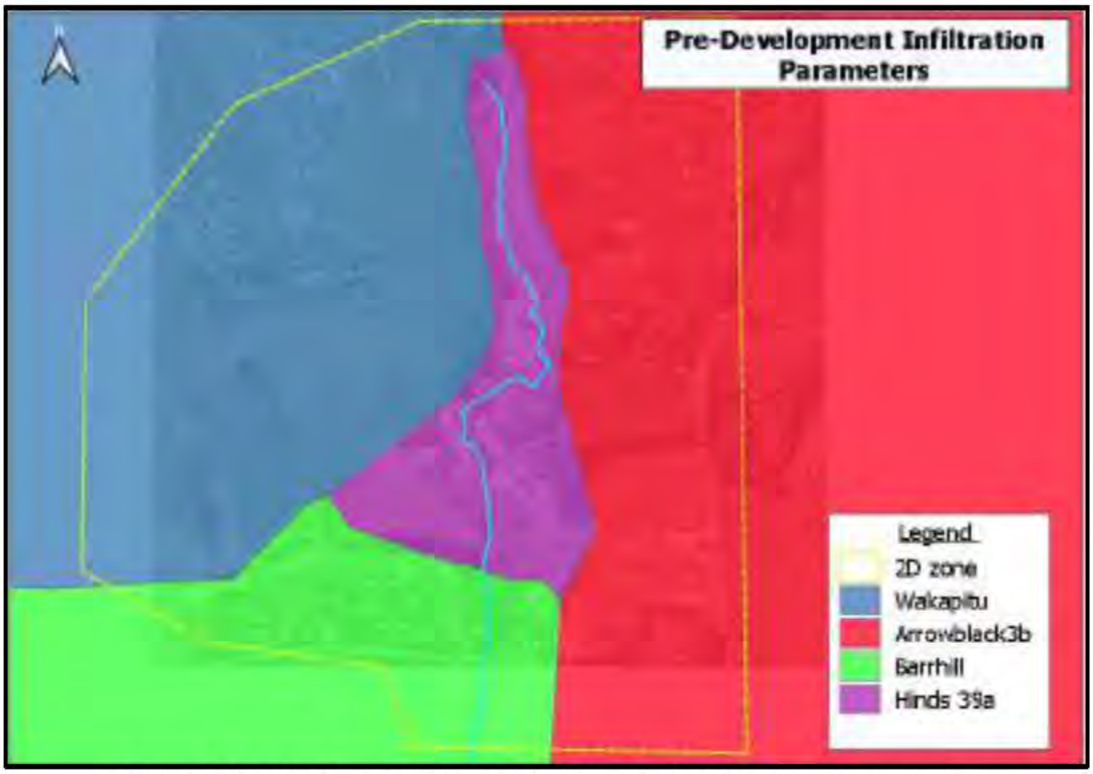


Figure 2.4: Pre-Development Soil Areas and Infiltration Parameters

Table 2.5: Soil Types and Corresponding Infiltration Parameters

S-Map Report	Texture Profile	Permeability Profile	Waterlogging Vulnerability	Initial Infiltration (mm/hr) (F0)	Ultimate Infiltration (mm/hr) (Fc)
Wakapitu 1a	Loam	Moderate over slow	Moderate	101.6	7.6
Barrhill 36a	Silt	Moderate	Very Low	101.6	7.6
ArrowBlack 3b	Loam	Slow	Moderate	101.6	7.6
Hinds 39a	Silt	Moderate	Moderate	63.5	6.0

Note: The selected Horton infiltration values were based on the data available from Akan 1993, which is described in more detail in the section below.

2.3.2.2 Post-development Soil Characteristics

The post-development model incorporates a combination of the 3D LiDAR surface, survey data, and a 3D design surface. The soil characteristics applied for the post-development scenario differed from the pre-development assumptions only with the addition of impervious surfaces in the form of roads and buildings. Figure 2.5 below gives the breakdown of soil areas (similar as the pre-development scenario). Table 2.6 provides Horton infiltration rates based on the type of soil present in the area within the model.

The 3D design surface was used to model the roads and overland flow path features in the development area using fixed runoff and Horton infiltration values on the 2D design surface. For the roads, all flood water was assumed to run off using a fixed 100% runoff allowance.

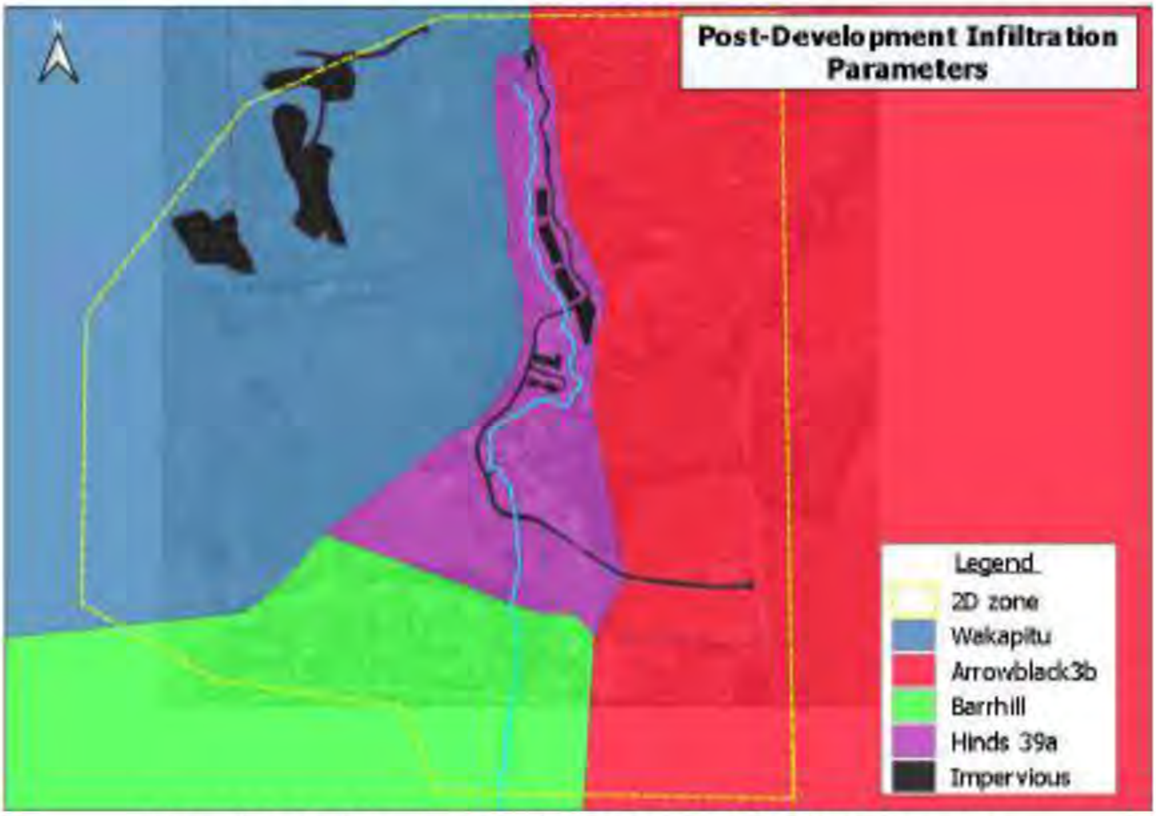


Figure 2.5: Post Development Soil Areas and Infiltration Parameters

2.3.2.3 Horton Infiltration Methodology

<u>Initial Infiltration</u>

The selected Horton infiltration values were based on the data available from Akan 1993 which includes initial infiltration values ranging from 7.6 to 254mm/hr based on differing vegetation covers, soil types, and soil moisture antecedent conditions (based on published scientific study and data) as shown in Figure 2.6.

These values are copied below for reference. The ICM manual also references use of the Akan 1993 data. The assumptions have been based on dry soil conditions considering that the peak flow of the multiple durations was used in the design. Multiple storms in series may occur, but these are likely to be individually less than the 100-year ARI event. The combination of rainstorm on rainstorm on rainstorm, creating wet antecedent conditions, could have a similar effect to the 100-year ARI event, but individual storms would likely be less.

Table 2.6: Akan 1993 Horton Infiltration Values

	Initial infiltration capacity	
Soil Type	in/hr	mm/hr
Dry sandy soils with little to no vegetation	5	127
Dry loam soils with little to no vegetation	3	76.2
Dry clay soils with little to no vegetation	1	25.4
Dry sandy soils with dense vegetation	10	254
Dry loam soils with dense vegetation	6	152.4
Dry clay soils with dense vegetation	2	50.8
Moist sandy soils with little to no vegetation	1.7	43.18
Moist loam soils with little to no vegetation	1	25.4
Moist clay soils with little to no vegetation	0.3	7.62
Moist sandy soils with dense vegetation	3.3	83.82
Moist loam soils with dense vegetation	2	50.8
Moist clay soils with dense vegetation	0.7	17.78

Ultimate Infiltration (Fc)

It should be noted that ultimate infiltration values as determined by infiltrometer studies are highly variable and can show an order of magnitude variation on seemingly similar soil types.

Additionally, the ultimate infiltration rate has been suggested to be driven by the saturated hydraulic conductivity (McLaren, Cameron 1996).

Akan 1993 also provides a table of ultimate infiltration rates based on various soil types, which is shown in Table 2.7. An ultimate infiltration value was selected for the design based on the soil type.

Table 2.7: Horton Ultimate Infiltration Values (Akan 1993)

Soil Type	f_c mm/hr	(in/hr)
Clay loam, silty clay loams	0–1.3	(0–0.05)
Sandy clay loam	1.3–3.8	(0.05–0.15)
Silt loam, loam	3.8–7.6	(0.15–0.30)
Sand, loamy sand, sandy loams	7.6–11.4	(0.30–0.45)

Decay (k)

The rate of decay selected drives how fast the initial or maximum infiltration decreases to the ultimate infiltration rate. A larger decay rate means that the soils become saturated faster and it takes less time to go from the initial to the ultimate infiltration rate. Akan 1993 suggests a decay rate equivalent to 4.14 hr^{-1} ($1.15x10^{-3}$ s^{-1}) for all soil types. The ICM manual also references us of a decay rate of 2.0 hr^{-1} ($5.56x10^{-4}$ s^{-1}).

For this assessment, a decay rate of 4.14 hr^{-1} ($1.15x10^{-3}$ s^{-1}) was utilised for the design.

2.3.3 Pre and Post Development Roughness

Additional to the soil characteristics, the roughness characteristics of the surface for the pre and post development scenarios were analysed. Various Manning's (n) roughness values were applied based on specific ground characteristics for each area, in each scenario.

The Pre and Post Development model roughness values are displayed in Figure 2.6 and Figure 2.7. The polygon values range from 0.0125 to 0.10 which were chosen to represent the roughness based on existing land-use. The values used for all roughness areas are derived from the Christchurch City Council *"Waterways, Wetlands and Drainage Guide – Part B: Design, Section 22 – Hydraulics"*. The roughness values are presented in Figure 2.8. The remaining areas of the 2D model extent have a roughness value of 0.075. These estimates are considered conservative in relation to estimating the flood extent.

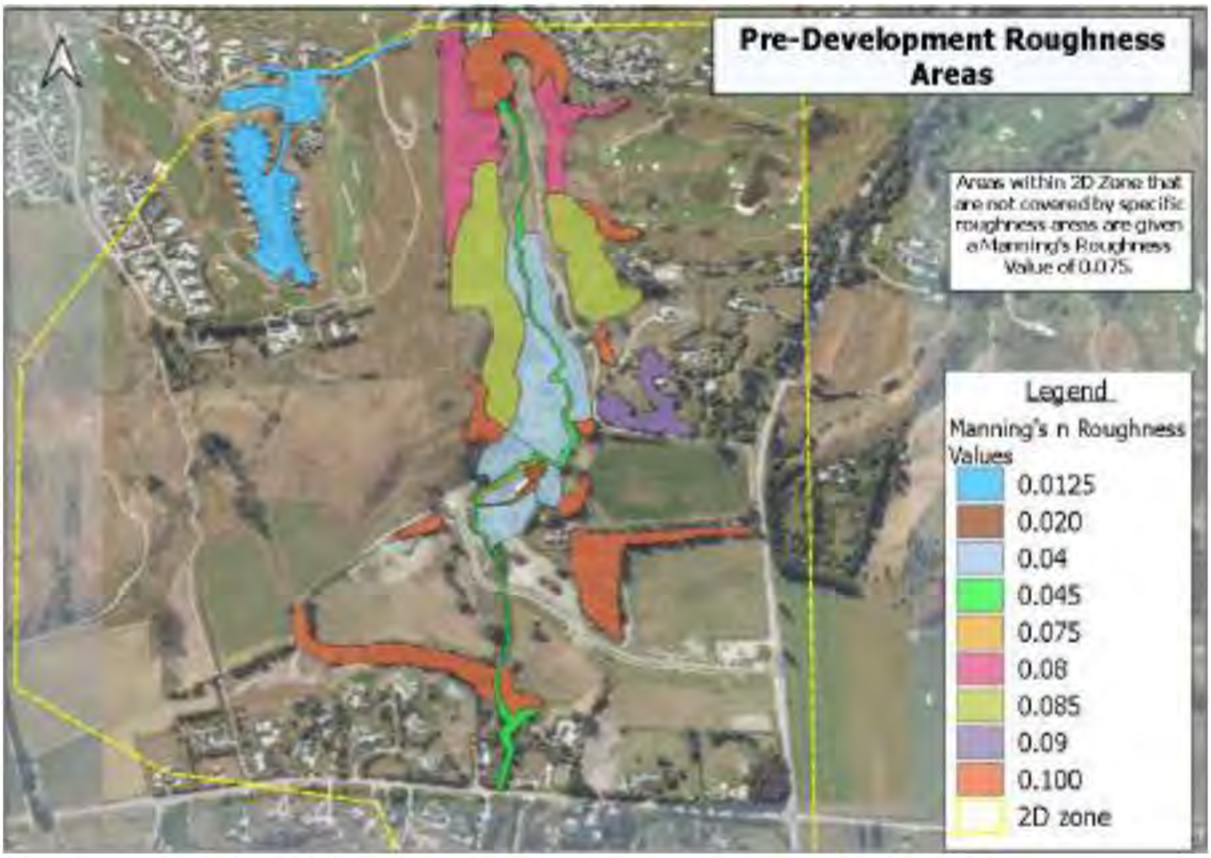


Figure 2.6: Manning's n Roughness Areas – Pre-development

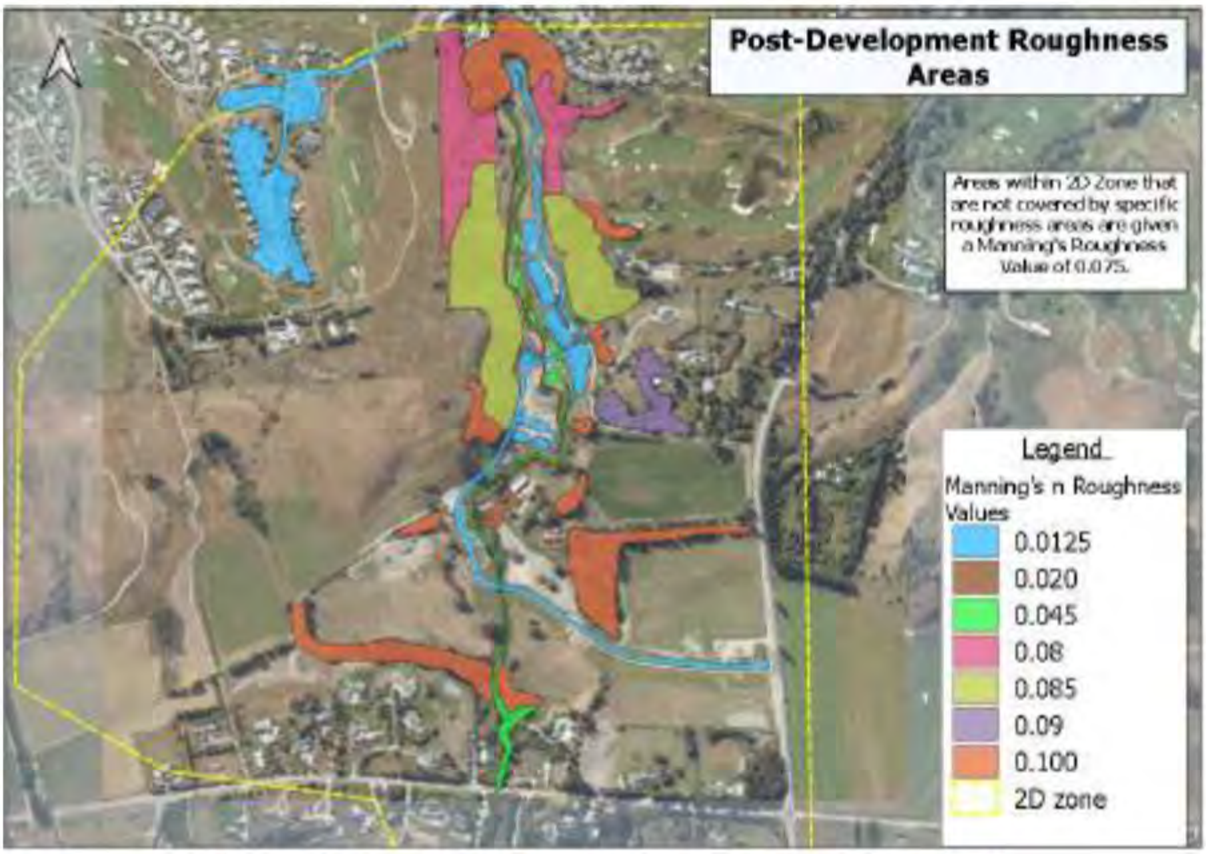


Figure 2.7: Manning's n Roughness Areas – Post-development

Table 22-1: Manning's Roughness Coefficients

Manning's Roughness Coefficients

I. Closed Conduits:

A. Concrete pipe .... 0.011 - 0.013
B. Corrugated metal pipe or pipe arch:
   1. 68 mm by 13 mm corrugation 0.024
   2. 150 mm by 50 mm corrugation (field bolted) 0.030
C. Vitrified clay pipe .... 0.012 - 0.014
D. Cast iron pipe, uncoated 0.013
E. Steel pipe .... 0.009 - 0.011
F. Brick .... 0.014 - 0.017
G. Monolithic concrete:
   1. Wood forms, rough .... 0.015 - 0.017
   2. Wood forms, smooth .... 0.012 - 0.014
   3. Steel forms .... 0.012 - 0.013

II. Open Channels, Lined (straight alignment):

A. Concrete, with surfaces as indicated:
   1. Formed, no finish .... 0.013 - 0.017
   2. Float finish .... 0.013 - 0.015
   3. Float finish, some gravel on bottom .... 0.015 - 0.017
   4. Sprayed concrete, good section .... 0.016 - 0.019
   5. Sprayed concrete, wavy section .... 0.018 - 0.022
B. Concrete, bottom flat finished, sides as indicated:
   1. Random stone in mortar .... 0.017 - 0.020
   2. Dry rubble (riprap) .... 0.020 - 0.030
C. Gravel bottom, sides as indicated:
   1. Formed concrete .... 0.017 - 0.020
   2. Random stone in mortar .... 0.020 - 0.023
   3. Dry rubble (riprap) .... 0.023 - 0.033
D. Brick .... 0.014 - 0.017

III. Open Channels, Excavated (straight alignment, natural lining):

A. Earth, uniform section:
   1. Clean, after weathering .... 0.018 - 0.020
   2. With short grass, few weeds .... 0.022 - 0.027
   3. In gravelly soil, uniform section, clean .... 0.022 - 0.025
B. Earth, fairly uniform section:
   1. No vegetation .... 0.022 - 0.025
   2. Grass, some weeds .... 0.025 - 0.030
   3. Dense aquatic plants in deep channels .... 0.030 - 0.035
   4. Sides clean, gravel bottom .... 0.025 - 0.030
   5. Sides clean, cobble bottom .... 0.030 - 0.040
C. Dragline excavated or dredged:
   1. No vegetation .... 0.028 - 0.033
   2. Light shrubbery on banks .... 0.035 - 0.050
D. Rock:
   1. Smooth and uniform .... 0.035 - 0.040
   2. Jagged and irregular .... 0.040 - 0.045
E. Channels not maintained:
   1. Dense weeds, high as flow depth .... 0.080 - 0.120
   2. Clean bottom, shrubbery on sides .... 0.050 - 0.080
   3. Clean bottom, shrubbery on sides, highest stage of flow .... 0.070 - 0.110
   4. Dense shrubbery, high stage .... 0.100 - 0.140

Note: the value of 'n' for natural channels must be increased to allow for the additional energy loss caused by bends. The increase may be in the range of perhaps 5 to 15 %.

IV. Roadside Channels and Swales with Maintained Vegetation (for velocities of 0.6 m/s to 1.8 m/s):

A. Depth of flow up to 210 mm:
   1. Good stand, any grass:
      a. Mowed to 50 mm .... 0.070 - 0.045
      b. Length 100 mm to 150 mm .... 0.090 - 0.050
   2. Fair stand, any grass:
      a. Length about 300 mm .... 0.140 - 0.080
      b. Length about 600 mm .... 0.250 - 0.120
B. Depth of flow 210 mm to 400 mm:
   1. Good stand, any grass:
      a. Mowed to 50 mm .... 0.120 - 0.070
      b. Length 100 mm to 150 mm .... 0.200 - 0.100
   2. Fair stand, any grass:
      a. Length about 300 mm .... 0.100 - 0.060
      b. Length about 600 mm .... 0.170 - 0.090

V. Roadside Concrete Side-Channels:

A. Concrete channel, trowelled finish 0.012
B. Asphalt pavement:
   1. Smooth texture 0.013
   2. Rough texture 0.016
C. Concrete side-channel with asphalt pavement:
   1. Smooth 0.012
   2. Rough 0.013
D. Concrete pavement:
   1. Float finish 0.014
   2. Broom finish 0.016
E. For side-channels with small slope, where sediment may accumulate, increase above values of n by 0.002

VI. Natural Stream Channels:

A. Streams:
   1. Fairly regular section:
      a. Some grass & weeds, little/no shrubs 0.030 - 0.035
      b. Dense growth of weeds, depth of flow greater than weed height .... 0.035 - 0.050
      c. Light shrubbery on banks .... 0.035 - 0.050
      d. Heavy shrubbery on banks .... 0.050 - 0.070
      e. Some weeds, dense willow on banks .... 0.060 - 0.080
      f. For trees within channel & branches submerged at high stage, increase above values by .... 0.010 - 0.020
   2. Irregular sections, with pools, slight channel meander. Increase values given in 1a. to 1e. by .... 0.010 - 0.020
   3. Mountain streams, no channel vegetation, banks usually steep, trees & shrubs on banks submerged at high stage:
      a. Gravel, cobble, few boulders on bed .... 0.040 - 0.050
      b. Cobbles and large boulders on bed .... 0.050 - 0.070
B. Flood plains, adjacent to natural streams:
   1. Pasture, no shrubs:
      a. Short grass .... 0.030 - 0.035
      b. High grass .... 0.035 - 0.050
   2. Cultivated areas:
      a. No crop .... 0.030 - 0.040
      b. Mature row crops .... 0.035 - 0.045
      c. Mature field crops .... 0.040 - 0.050
   3. Heavy weeds, scattered shrubbery .... 0.050 - 0.070
   4. Light shrubbery and trees:
      a. Winter .... 0.050 - 0.060
      b. Summer .... 0.060 - 0.080
   5. Medium to dense shrubbery:
      a. Winter .... 0.070 - 0.110
      b. Summer .... 0.100 - 0.160
   6. Dense willows .... 0.150 - 0.200

Figure 2.8: Manning's n Roughness Values

Appendix 3 Latest Mill Creek Flood Assessments

- Northbrook Waterfall Park Latest Flood Report
- Haybarn Bund EA Model Report
- Boundary change memo

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Flood Assessment

Northbrook Arrowtown

Variation application

Document Information

Client	**Waterfall Park Developments Ltd**
Site Location	Ayr Avenue, Arrowtown
Legal Description	Lots 1 DP540788
CKL Reference	A20254
Office of Origin	Auckland

Author	Dorcas Adjei-Sasu		
Signed	[redacted]	Date	11/07/2024

Reviewed By	Bronwyn Rhynd & Frances Deamer-Phillips		
Signed	[redacted]	Date	11/07/2024

Authorised By	Bronwyn Rhynd		
Signed	[redacted]	Date	12/07/2024

Revision	Status	Date	Author	Reviewed By	Authorised By
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1	Issued	10/04/2024	DAS	BR/FD-P	BR
2	Issued (updated Variation)	12/07/2024	DAS	BR/FD-P	BR

Contents

Figures

Tables

1 Introduction

CKL has been engaged by Waterfall Park Developments Ltd (WPDL) to revise the technical flood modelling to support a variation application to the approved consents, which are associated with the Northbrook Arrowtown development. The original approved consent is RM220926, with a subsequent approved variation lodged March 2024 being RM240252. This report is with respect to a current variation application to RM240252.

The development comprises the proposed later living development at Waterfall Park (Northbrook Arrowtown). The site is located at Ayr Avenue, accessed from Arrowtown Lake Hayes Road. The site is approximately 2km south of Arrowtown.

The purpose of this updated Flood Assessment (report) is to outline any updates to the flood effects and any mitigation measures required as a result of the changes to the consented development. The original flood report lodged with RM220926 "Northbrook Arrowtown Flood Assessment – Resource Consent", dated March 2023 was prepared by Fluent Solutions.

Figure 1: Site Location (WPDL Provided, November 2021)

1.1 Reference Documents

The development of this flood model update is guided by the following key documents, which are referenced throughout this report.

- QLDC Land Development and Subdivision Code of Practice (QLDC COP)
- Northbrook Arrowtown Resource Consent Variation Drawings by Paterson Pitts Group dated July 2024
- Northbrook Landscape Plans by Winton dated July 2024
- Stormwater Management Plan – Northbrook Arrowtown Variation by CKL July 2024
- Northbrook Arrowtown – Flood Assessment – Resource Consent by Fluent Solutions dated March 2023.

2 Site Existing Features

Please refer to Northbrook Arrowtown – Flood Assessment – Resource Consent by Fluent Solutions dated March 2023 and lodged under RM220926 for detailed background information and existing site characteristics.

3 Proposed Development

As per RM220926 and variation RM240252, the proposed development is accessed by vehicle, via Arrowtown-Lake Hayes Road, along the Ayr Avenue access road and proposed Ayr Avenue extension from Ayrburn Domain to the waterfall at the head of the valley.

The changes proposed under this variation are detailed in Table 1 below, some of which do not affect the flood modelling, and are presented as “consented under RM220926” and “proposed variation July 2024”.

Table 1: Variation between Consented Development and Proposed Development

	Element	Consented under RM220926	Proposed Variation July 2024
Building A	***Height***	• 8.8m	• 9.15m (~350mm increase)
	Building Coverage	• 935m²	• 962.45m² (27.45m² increase)
	Other	• Porte cochere extending 13.5m to south	• Porte cochere removed. • Health club proposed to be open to the general public.
Building B	***Height***	• 18.4m • 4 levels	• 16.456 (1.944mm reduction) • 3 levels + plant in roof gable
	Building Coverage	• 1,106m²	• 1040m2 (66m2 reduction)
	Other	• 23 care units • 12 serviced apartments • 13 residential apartments, • Communal and back-of-house facilities • Mansard roof form	• 27 care units • 12 1-bed residential apartments • Roof form changed to a gable. • Changes to access arrangements and carparking • No office space and storage area in loft •
Building C, D & E	***Height***	• 21.5-21.7m	• No change
	Building Coverage	• 4,396m²	• 5,256m2 (860m2 increase)
	Other	• 148 residential apartments	• 131 residential apartments • Proposed landscape nibs added to achieve freeboard. • An additional 300mm is proposed to be added to each apartment to achieve minimum 4.8m living rooms. • An additional 300mm is proposed to be added to the 2-bed multi rooms. • Proposed lengthening of buildings to the north and slight rotation of Buildings D and E to retain a 7m setback from Mill Creek • Balconies are proposed to be a minimum 2.4 – 2.5m wide. • 3+ bed apartment are proposed on the ground floor as well as sub penthouses and penthouses.
	Access/ Parking	• 94 parking spaces (five accessible) • Entry to basement at Building C and exit at Building E	• Proposed road design amendments and creation of a slow vehicle zone behind apartments • Carpark ratio 1 per 1 and 2-bed; 1 tandem per 3-bed; 2 tandems per penthouse • Basement exit and two-way access now. • Additional carparks for offices • Tandem carparks on ground floor, access from the road proposed at southern end. •
Building F	***Height***	• 12.8m	• 15.25m (~2.45m increase)
	Building Coverage	• 648m²	• 922m2 (2742m increase)
	Other	• 16 hotel rooms • Spa facilities	• 18 hotel rooms • Spa facilities removed. • Function venue proposed. • New parking layout incorporating more carparks and allowing for 8m vehicle turning space
Total	***Residential Units***	196	170 (26-unit reduction)
	Gross Floor Area	28,582m²	29,365m² (783m² increase)
	Site Coverage	5.04% (Waterfall Park Zone excluding Ayrburn Domain extension)	6.08% (extended Waterfall Park Zone)

As part of this variation, an updated ICM flood model was developed. The following table demonstrates the flood modelling runs in ICM for the consented application and this proposed variation.

Table 2: ICM flood model information

ICM Flood Model Version	Date	Resource Consent	Ayrburn Input	Northbrook Input
V17 (by Fluent Solutions)	June 23	Haybarn	Southern Boundary Flood Bund	Consented Northbrook Design (RM220926)
V20 (by CKL)	July 24	Northbrook Variation	Southern Boundary Flood Bund – as per Haybarn Application	Proposed Northbrook Variation Design

Figure 2 demonstrates the proposed variation and previous layout from consent RM220926

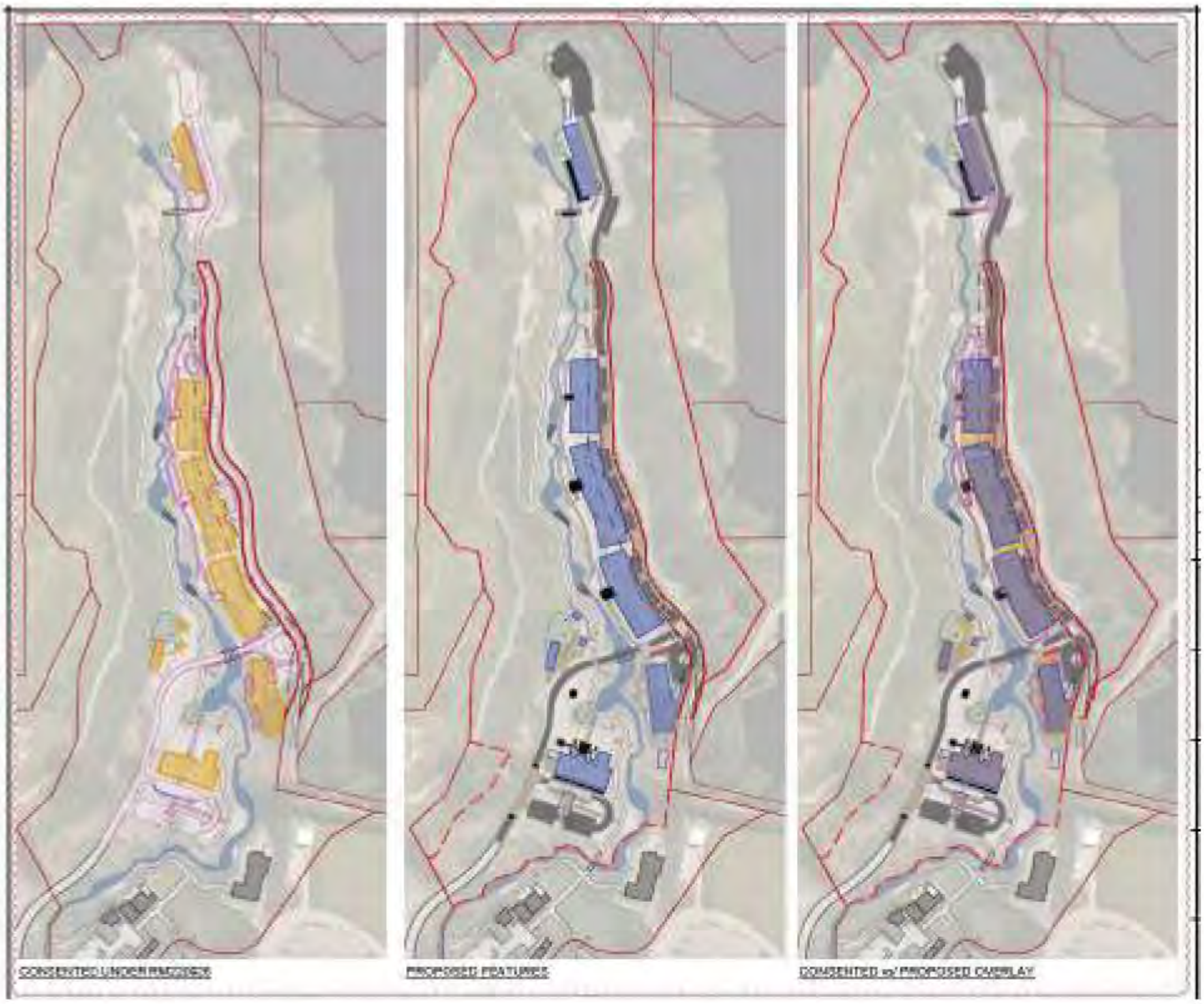


Figure 2: Consented RM220926 layout (LHS), proposed variation(middle), overlay of changes (RHS)[1]

[1] Consented layout, shown in yellow under RM220926, left hand side, and proposed variation layout for this application, middle, shown in Purple. Refer to PPG drawing sheet 101.

4 Flood Flow Assessment

The flood modelling has been updated to include the proposed variation changes, outlined in Section 3, and outcomes are presented in the following sections.

4.1 Pre- and Post-Development Flood Flow Results Summary

An assessment of the pre-development (prior to the RM220926 resource consent application), the consented flows and post-development (this variation application) has been undertaken.

Refer to Figure 3 for the assessment locations where the pre- and post-development flows have been reviewed.

The flood flow assessment has been taken at the following locations:

- Northbrook Arrowtown boundary line (which is the boundary used in RM220926)
- Southern boundary of Ayrburn, which is the boundary of the wider development site (known as Ayrburn Farm and Waterfall Park). This assessment line is known as the “Wider site boundary”.

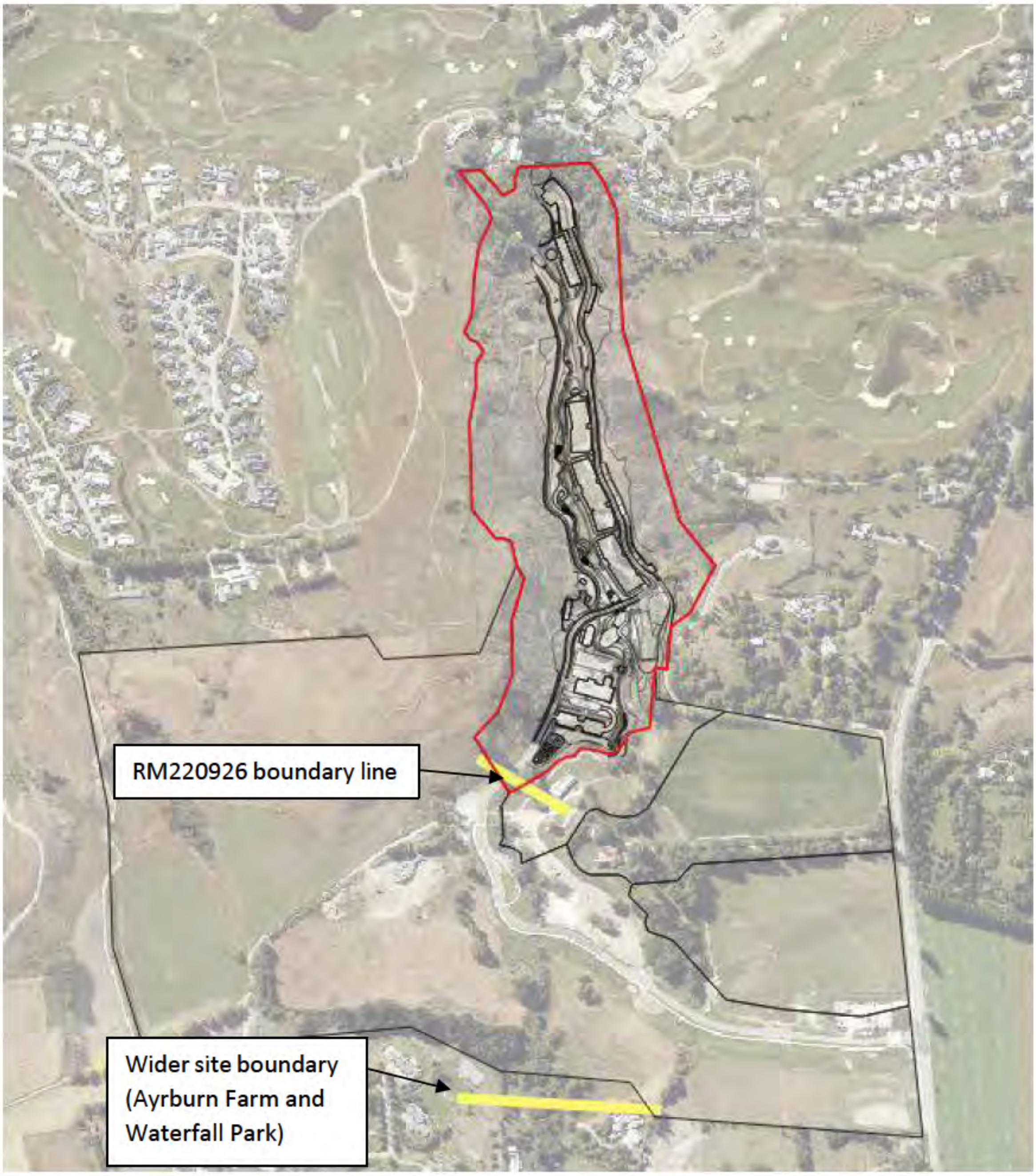


Figure 3: Development boundary and flow measurement locations.

The "wider site boundary" assessment location is considered to be appropriate given it is the ultimate discharge point from the wider site and considers any effects on downstream properties. It is to be noted that the Haybarn consent (RM230425) also included a bund adjacent to Mill Creek upstream of this boundary within the floodplain to manage post-development peak flows at the (wider site) boundary. Therefore, the flows associated with the development of the Northbrook Arrowtown can also be managed within this flood bund downstream, prior to discharging from the wider site to downstream receiving environment. As such the effects of the flows generated within the wider site can be assessed at this downstream boundary location in totality.

The results of the updated flood flows at the Northbrook Arrowtown Boundary are presented in Table 3

Table 3: Summary of Peak flow estimates at Northbrook Arrowtown Boundary

Storm Event	Mill Creek Peak Flow at Northbrook Arrowtown Boundary (m^3/s) Pre-Development*	Consented Development	Variation to Consented Development
2 Year ARI	4.75	4.5	4.71
10 Year ARI	8.12	7.9	8.00
20 Year ARI	9.06	8.8	8.88
50 Year ARI	10.20	10.0	10.02
100 Year ARI	34.11	33.7	33.90

*Predevelopment flows have been revised based on updated LiDAR. The details can be found in CKL Memorandum, A20254-Boundary Flow Assessment also attached in Appendix 1

At the Northbrook Arrowtown boundary, there is no increase in 2-year through to 100yr ARI storm events in post-development scenario, therefore there is no impact on downstream properties.

The results of the updated flood flows at the Wider Site Boundary are presented, presented within Table 4 below.

Table 4: Summary of Peak flow estimates at Wider Site Boundary

Storm Event	Mill Creek Peak Flow at Wider Site Boundary (m^3/s) Pre-Development*	Consented Development	Variation to Consented Development
2 Year ARI	4.64	Not Assessed	4.53
10 Year ARI	7.86	Not Assessed	7.20
20 Year ARI	8.79	Not Assessed	8.13
50 Year ARI	9.91	Not Assessed	9.34
100 Year ARI	33.42	Not Assessed	33.29

*Predevelopment flows have been revised based on updated LiDAR. The details can be found in CKL Memorandum, A20254-Boundary Flow Assessment also attached in Appendix 1

Downstream at the wider site boundary there is no increase in 2-year through to 100yr ARI storm events in post-development scenario, therefore there is no impact on downstream properties.

At the Wider Site Boundary, the 2-year, 10-year, 20-year, 50-year, and 100-year ARI storm events are less than the estimated peak pre-development flows. The proposed bund approved in the Haybarn consent application (RM230425) contributes the greatest peak flow mitigation due to increased storage being provided from the bund with the restricted outflow to Mill Creek.

4.2 Pre- and Post-Development Flow Velocities and Erosion Potential

An assessment of the flow velocity and erosion potential has been undertaken for this variation application against the consented application (under RM220926). The maximum flood flow velocity maps are presented in the following Figure 4 and Figure 5, which show the 100-year ARI pre-development, consented application (RM220926) and latest variation in this application outcomes.

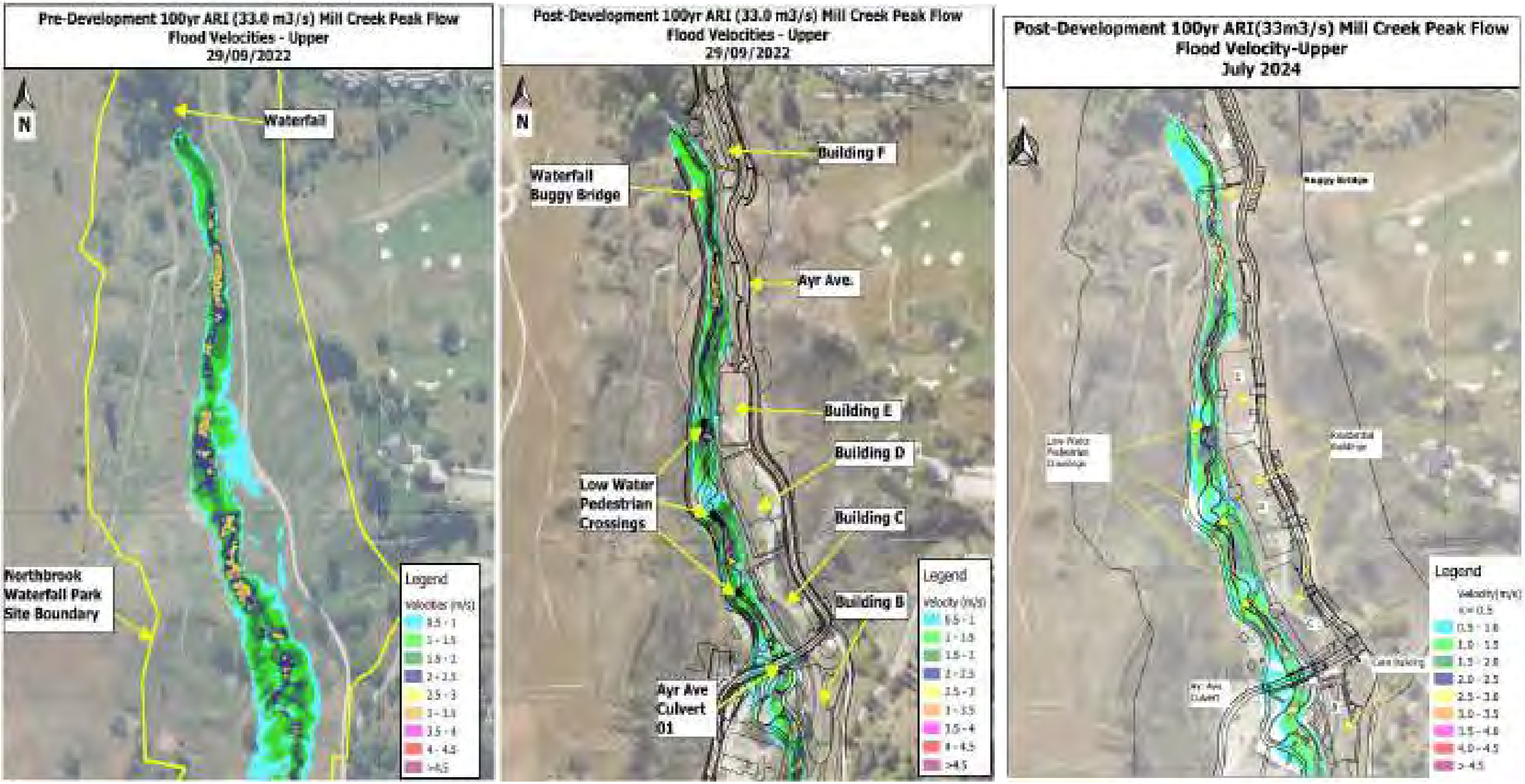


Figure 4: Upper section Velocity Comparison Maps- Pre-Development (LHS), Consented Development (Middle), Variation to Consent (RHS)

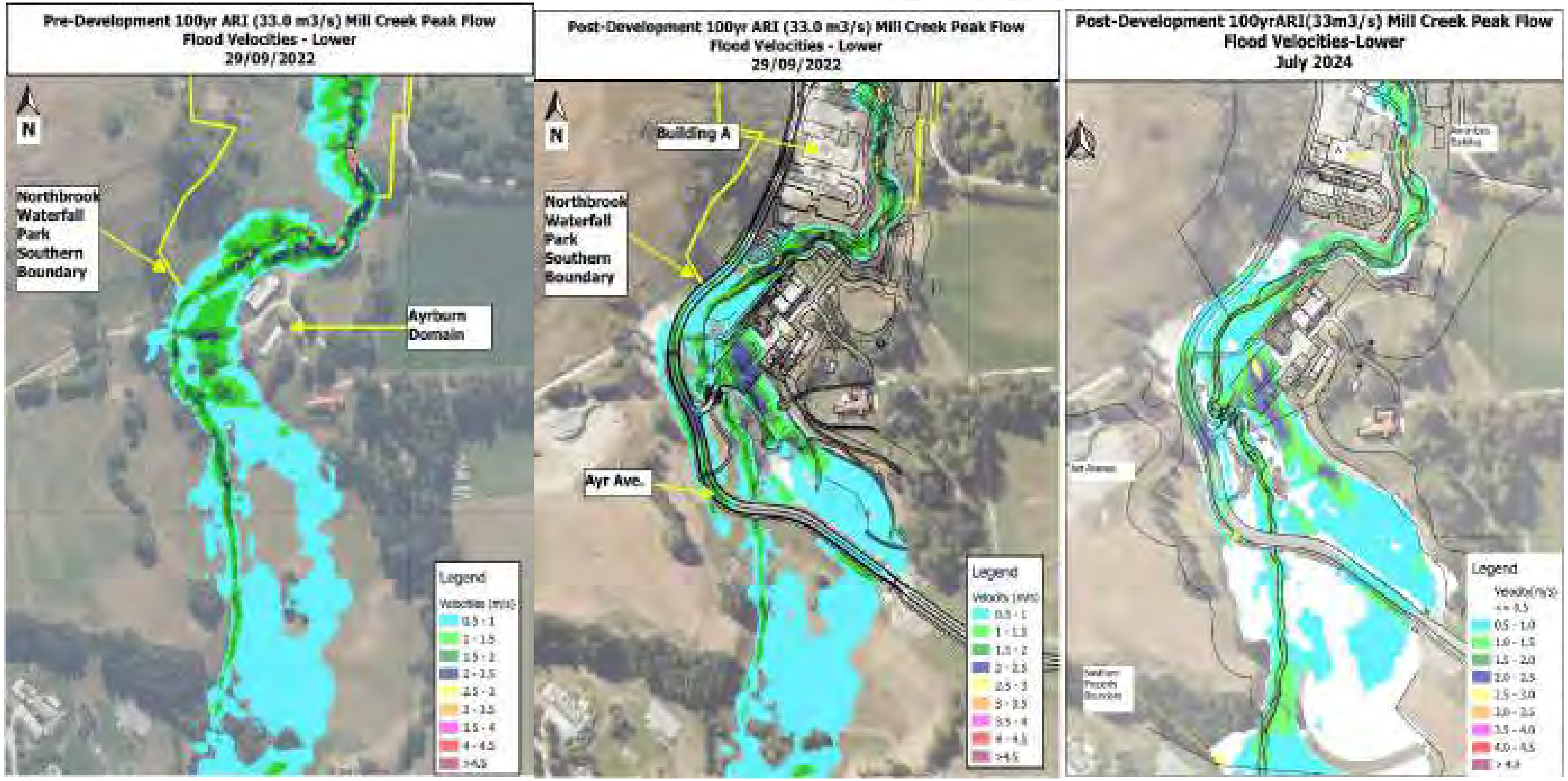


Figure 5: Lower section Velocity Comparison Maps- Pre-Development (LHS), Consented Development (Middle) , Variation to Consent(RHS)

As shown within the above figures, velocities in Mill Creek at certain locations are expected to be in the order of 3-4m/s for the 100-year ARI events for all assessment conditions. This indicates that there is no significant change to the velocity regime of the site due to the variation to the consent. Thus, the previous scour assessment completed for the site is still relevant and the proposed mitigation measures for the consented development still apply to this variation to consent.

Details of the scour assessment can be found in Appendix D of the RM220926 Flood Report. The following bullet points, repeated from consent report, outline the general scour analysis conclusions:

- *General channel scour depth estimations for the 500-year ARI flow event was generated using HEC- RAS at cross-section locations along Mill Creek within the Site.*
- *The scour depth estimates in the HEC-RAS model were used in the design process of erosion/scour protection (channel and bank armouring), as well as structural and geotechnical design plans.*

Given the velocities have not changed significantly in this variation, the scour depth is not expected to change either. The scour assessment will be further updated to support the next stages of design .

Throughout the Site, erosion/scour protection measures have been incorporated into the design of the development (including existing works being undertaken under RM180584).

4.3 Estimated Flood Levels Near Critical Infrastructure

This section provides an update of the estimated flood levels near critical infrastructure and proposed freeboard allowances in Northbrook Arrowtown.

4.3.1 Buildings

An assessment of the finished floor levels and provided freeboard above the 100yr are provided in Table 5.

The top water levels have been assessed at the leading edge (upstream edge). All proposed building finished floor levels meet or exceed the minimum FFL requirements set out by the QLDC COP.

Table 5: Northbrook Arrowtown Building freeboards at leading edge of building

Building	FFL	100yr Consented Water Level	Freeboard Consented	100yr Variation Water Level	Freeboard Variation
F	362.55	361.00	1.55	361.75	0.8
E	358.10	357.00	1.10	357.40	0.70
D	356.30	355.70	0.60	355.77	0.53*
C	354.20	353.30	0.90	353.51	0.69
B	352.60	351.90	0.70	351.24	1.36
A	351.59	350.90	0.69	350.13	1.46

**Building D freeboard is 70mm short of the required 600mm freeboard., however there is a proposed nib wall around the building which provides an effective freeboard of 1053mm. See* Figure 6

To support the freeboard protection of 0.6m (600mm) for building D, it is proposed to provide a nib wall on the leading edge. This is presented in the following cross section, as detailed by PPG.

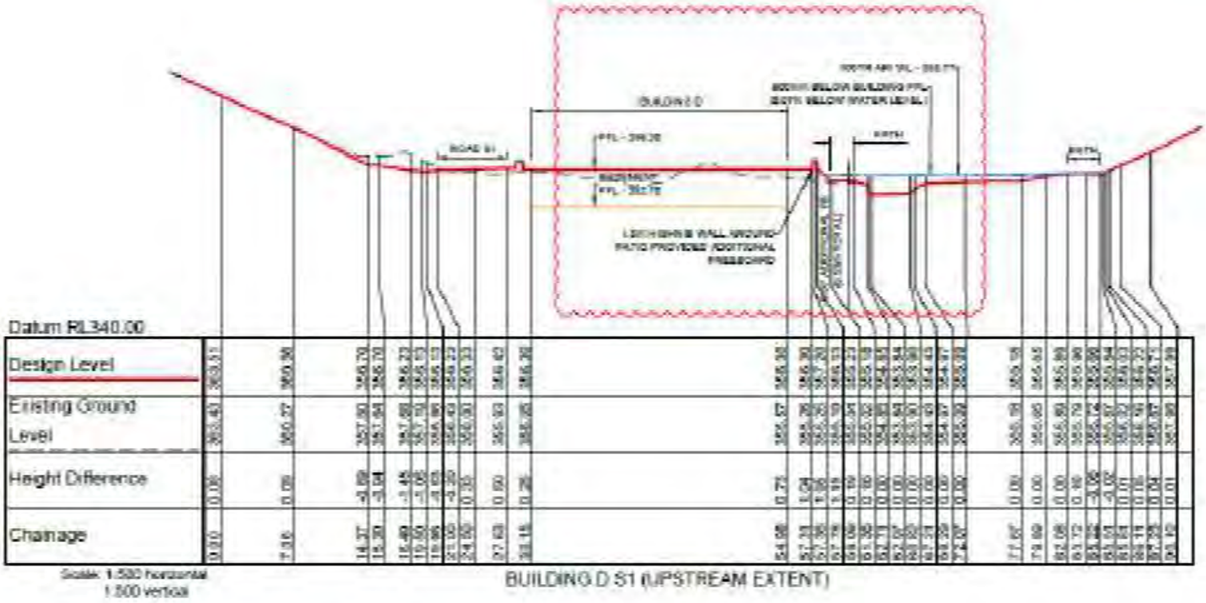


Figure 6: Building D section indicating FFL and Nib wall location

4.3.2 Waterfall Buggy Bridge

For bridges, the COP requires a minimum freeboard of 0.6m above the 50-year ARI maximum water level to the underside of the bridge deck. Table 6 below shows a summary of the buggy bridge levels (located by the waterfall) and freeboards for the buggy bridge for the consented and variation flood levels.

Table 6: Waterfall Buggy Bridge Freeboard

Scenario	Underside of Deck(m)	50-year ARI Max WL (m)	Freeboard from 50-year WL to underside of deck (m)
Consented	361.7	359.8	1.9
Variation to Consented	360.4	359.8	0.6

The Waterfall Buggy Bridge deck levels meet the minimum freeboard requirements set out by the COP for 50-year with the updated model (for the variation to the consent).

4.3.3 Ayr Avenue Culvert 01 Crossing

The COP provides a minimum of 0.5m freeboard above the maximum 50-year ARI event water level to the road level for culverts. As Culvert 01 provides vehicular access (Ayr Avenue), the 100-year flow event has also been assessed (as per RM220926). Table 7, below, shows the freeboard allowance at Ayr Avenue Culvert Crossing for both 50yr ARI event and water depth outcomes for the 100yr ARI event.

Table 7: Ayr Avenue Culvert 01 Crossing - Flow assessment

Bridge	Road Level at sag (western side)	50-year ARI		100-year ARI	
		Top water level (m)	Freeboard (m)	Top water level (m)	Maximum water depth on Road surface (m)
Consented	352.00	351.18	0.82	352.150 - 352.20[1]	0.15-0.20[1]
Variation to Consented	352.00	351.40	0.6	352.2	0.2

[1]The flood depth is shown in Fluent report March 2023, (Appendix A, Figure title: Post development 100yr flow), of between 0.15-0.2m

The Ayr Avenue Culvert meets the minimum freeboard requirements set out by the COP for the 50-year ARI event.

During the 100yr ARI event the Ayr Avenue Culvert 01 crossing is overtopped and flood water flows across the road, which replicates the previously consented scenario. For clarity[3] the 100yr flow crosses the road carriageway at the sag locations which is each side of the culvert crossing (western side is slightly lower than the eastern side). The maximum flow depth is 0.2m which is slightly higher than the CoP. The effect of this flow depth is assessed in relation to the duration of flooding on the road and vehicle passability. The depths are above 100mm for approximately 2 hours. The flows return to the stream channel and continue to flow downstream. During the peak of the 100-year ARI flow event, a small car would be able to drive along Ayr Avenue over the Culvert 01 crossing. Thus, the effect of the slightly higher than COP recommended maximum level above the road is minimal as was determined during the consenting of RM2200926. See Section 6 for further information on safety and operation of site (given the flood levels above 100mm on the road centreline).

Mitigation and management of the secondary overland flow path is detailed in Section 5.5 of the consented Flood Assessment report (Fluent March 2023 report).

For reference, the Culvert 01 crossing is shown in the following image.

Figure 7: Ayr Ave Culvert 01

4.4 Secondary Overland Flow Path and Blockage Assessment

The below sections highlight the secondary overland flow path commentary and blockage assessments undertaken for the Site.

4.4.1 Existing Ayr Avenue Culvert 01 Crossing

As per the results in section 5.2, the flood levels at the Culvert 01 crossing are similar for the consented and this Variation to consent levels. Refer to Table 7.

There are three culvert openings at the existing Ayr Avenue Culvert 01 Crossing: One 3.0m by 1.5m high central culvert and two auxiliary culverts on each side measuring 3.0m by 0.75m high. The soffits of each culvert are at the same elevation with the two auxiliary culverts having inverts 0.75m higher than the centre culvert. The culvert has entry and exit wingwalls.

Under normal flow conditions the culvert conveys the 20-year and 50-year ARI flow events with sufficient freeboard. During the 100-year event, flood flows overtop the road and flow around the sides of the road crossing. Flood water depths at the centreline of the road are above 100mm for approximately 2 hours at the Ayr Avenue Culvert 01 Crossing. The flows return to the stream channel and continue to flow downstream. The road is shaped with a sag point to the west of the road culvert crossing to ensure overland flows are directed downstream, away from developed areas. The road is constructed on engineered fill with vegetated banks on either side of the road. If a full blockage were to occur at this culvert, flood flows from any predicted ARI event would overtop Ayr Avenue at the sag point near the culvert, flow over the road and then flow back into the stream channel and continue downstream.

4.4.2 Waterfall Buggy Bridge

At the upstream extent of the Site is the Waterfall Buggy Bridge. The deck level of this bridge has been lowered compared to previous approved consent. This proposed pedestrian bridge is designed to have an approximate 10m span across Mill Creek and a bridge deck beam 2.1m above the stream invert elevation. The bridge deck is 0.675m thick and equipped with pedestrian barriers spanning the length of the bridge.

In the unlikely event of the opening being fully blocked, flow will overtop the bridge deck and over the pedestrian pathway, returning to the stream channel downstream. The Boutique Hotel and Function Venue is proposed to be built sufficiently above the bridge elevation and the pedestrian path and bridge will be closed to pedestrians during a major flood event.

5 Safety and Operations

The sections below outline the safety and operational considerations for the Site with updated flood levels from this variation.

Considerations are presented in more detail below, but include:

- Flood protection for underground carparks.
- Pedestrian access throughout the Site
- Ayr Avenue access road serviceability for vehicle access

5.1 Basement Carpark Flood Protection

The carpark entrance elevations are above the 100-year ARI flood levels as per RM220926 to prevent flood waters from entering the basement car park.

5.2 Ayr Avenue Road Extension Pedestrian Access

During the 100-year ARI storm event, the modelling for both the consented and variation scenarios predicts flooding on the Ayr Avenue extension road at two localised locations within Northbrook Arrowtown.

In the event of an emergency during a flood event, pedestrian accessibility within the Ayr Avenue extension was assessed based on requirements in the COP as discussed in Section 7.2 of the Consented report (Fluent report March 2023).

Figure 7 below shows the potential pedestrian passability based on maximum depth X maximum velocity (not average) (DxV) for the 100-year ARI Mill Creek flow event as a conservative approach for the consented and variation to consent scenarios.

Note the purple circles in Figure 5 below indicate the areas identified as a potential pedestrian crossing hazard along the road within the site as consented under RM220926 and as proposed by this variation. There is no change as a result of this variation to the consented development under RM220926.

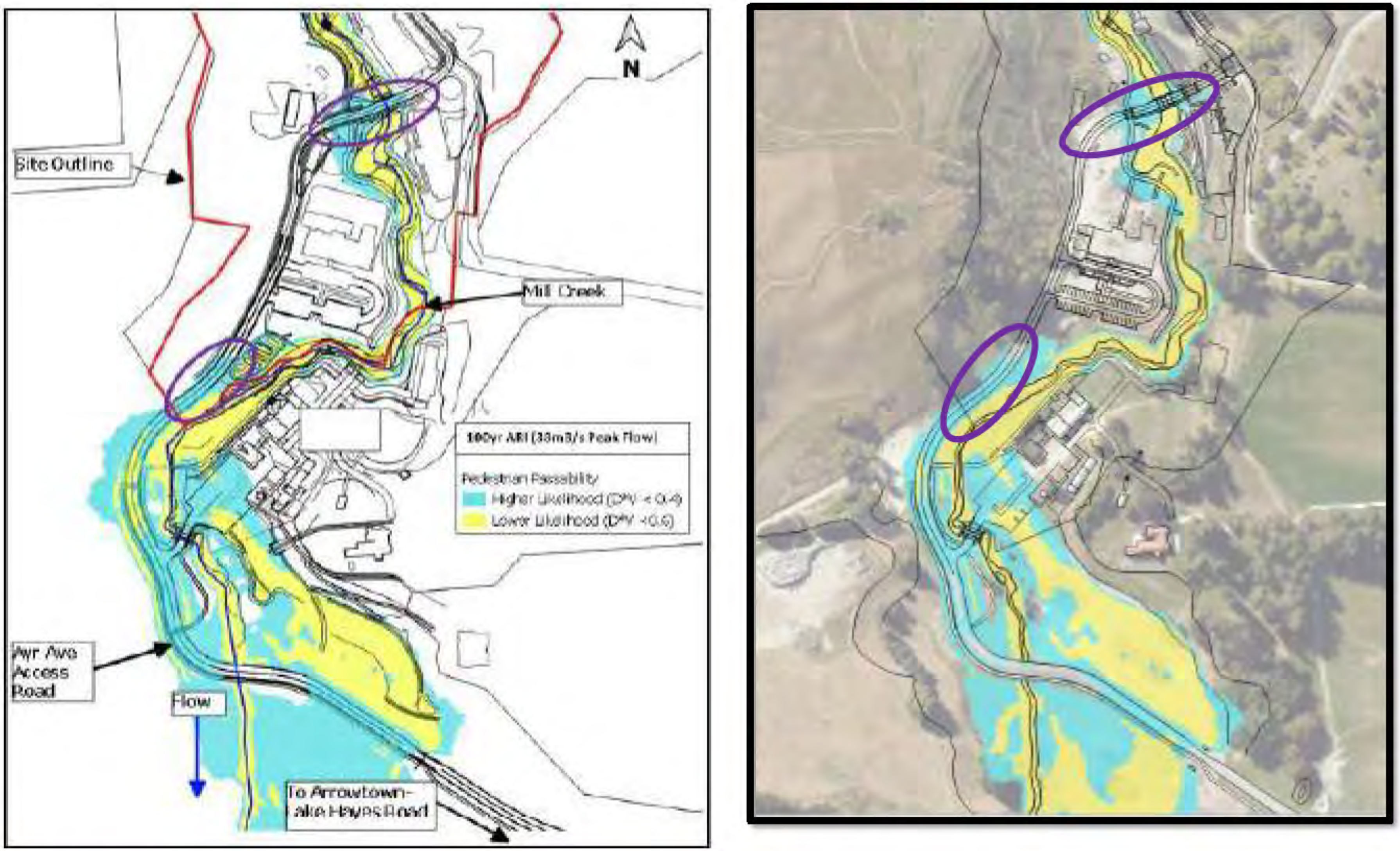


Figure 8: Ayr Avenue Access Road pedestrian access map (DepthxVelocity)- Consented (LHS), Variation to Consented July 2024 (RHS)

5.3 Ayr Avenue Road Vehicle Hazard

Section 4.3.4.2 of the COP (refer to Figure 7.1 in consented report) specifies flooding in secondary flow paths, such as roads, should be limited to 100mm at the centreline for the 100-year ARI event.

Consented Development

For the 100-year ARI flow event and greater, areas along Ayr Avenue are inundated with flood water greater than 100mm depth for a period estimated between 2-4 hours. Flood water depths at the centreline of the road are above 100mm for approximately 2 hours at the Ayr Avenue Culvert 01 crossing and approximately 3-4hours downstream on Ayr Avenue (constructed under RM171280).

Proposed Variation

For the 100-year ARI flow event and greater, areas along Ayr Avenue are inundated with flood water greater than 100mm depth for a period estimated between 1-3 hours. Flood water depths at the centreline of the road are above 100mm for approximately 2 hours at the Ayr Avenue Culvert 01 crossing and approximately 1-3hours downstream on Ayr Avenue (constructed under RM171280). This is a decrease in time compared to consented application (RM220926).

5.3.1 Road Serviceability

Figure 9 shows the road vehicle hazard based on the 100-year ARI peak Mill Creek flood flow event (consented under RM220926 and proposed under this variation) for Ayr Avenue. Note that white areas indicate that there is minimal to no road flooding.

During the peak of the 100-year ARI flow event, a small car would be able to drive along Ayr Avenue extension over the Culvert 01 crossing and Large 4WD vehicles are still able to access Northbrook Arrowtown as per consented under RM220926.

Refer to the Flood Management Plan lodged under RM220926. As the depth of water has not changed and the duration has reduced, there are no changes proposed to this plan.

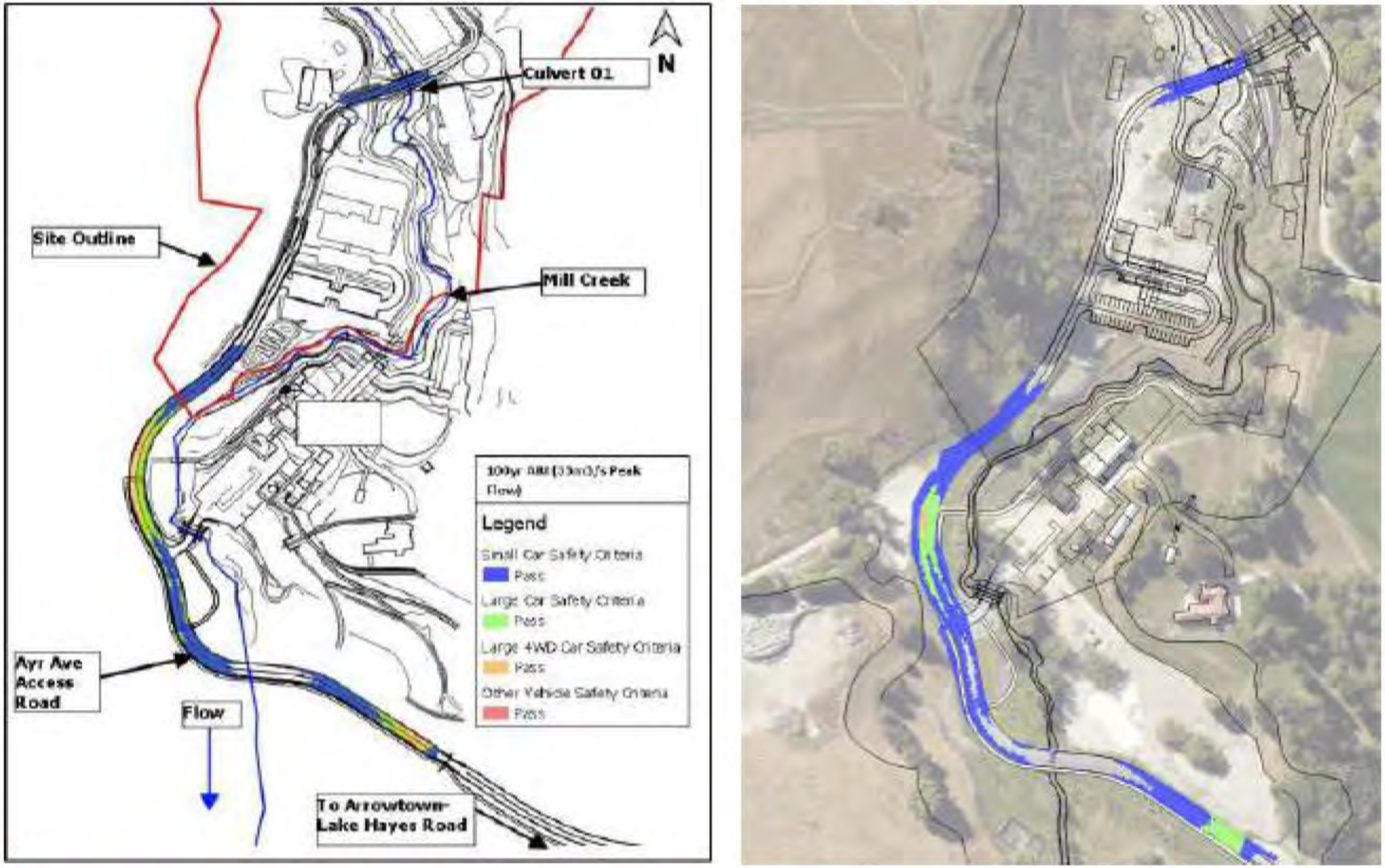


Figure 9: Ayr Avenue Access Road 100-year ARI Hazard Vehicle Serviceability Safety Criteria Map- Consented (LHS), Variation to Consented July 2024(RHS)

6 Summary

The flood modelling has been updated to support the proposed variation to resource consent RM240252, which is a variation to the original resource consent RM220926, as of July 2024 with respect to the Northbrook Arrowtown development.

In summary, as per RM220926, the minimum freeboards have been met for the proposed Buildings (A to F) for this variation to the consent. The freeboards have been detailed in Section 5.3.

Post-development flood flows modelled in this proposed variation are equal to or lower than pre-development flows for the 2-year through the 100-year ARI events at the Northbrook boundary and the new proposed downstream Wider Site boundary location (Ayrburn Farm and Waterfall boundary).

The maximum velocities though the development in the updated model demonstrates that there is no significant change to the velocities through the development, thus the proposed mitigation measures in the consented development still apply for this variation to consent. These mitigation measures will be progressed in detail at the next stage of design.

Road flooding still occurs on Ayr Avenue Road, as per consented, at two localised areas along the road. Flood mitigation measures are incorporated into the design of Culvert 01 and the Ayr Avenue Road extension to reduce flood hazards to both pedestrians and vehicles access, as per the consented proposal.

The overall outcomes from the flood modelling demonstrate that this proposed variation (July 2024) to the consented development (March 2023), have not changed the flood hazards on site (from the consented proposal.) Therefore, the original flood mitigation measures for the consented development remain the same.

7 Limitations

This report has been prepared solely for the benefit of our client with respect to the particular brief and it may not be relied upon in other contexts for any other purpose without the express approval by CKL. Neither CKL nor any employee or sub-consultant accepts any responsibility with respect to its use, either in full or in part, by any other person or entity. This disclaimer shall apply notwithstanding that the memo/report may be made available to other persons including Council for an application for consent, approval or to fulfil a legal requirement.

Appendix 1 CKL Memorandum- Boundary Flow Assessment

MEMO

To:	Nicola Tristram, Winton	**Date:**	12th July 2024
From:	Dorcas Adjei-Sasu- Environmental Engineer	**CC:**	
Reviewed:	Bronwyn Rhynd – Director	**CKL Ref:**	A20254
Re:	Waterfall Park, Queenstown- Boundary Flow Assessment		

1 Introduction

CKL has been engaged by Waterfall Park Developments Ltd (WPDL) to revise the technical flood modelling for various resource consent applications. This memo outlines the outcomes of this flood modelling with respect to the flow assessment at the downstream boundary.

This flood modelling supports:

- a variation to the approved Resource Consent RM230425.
    - The proposed Haybarn Venue and associated accessway and parking.
- a variation to the current Northbrook Arrowtown Resource consent lodged in March 2024 - RM240252

During the review of the flood modelling boundary condition characteristics have been identified which do not match stream conditions.

The purpose of this memorandum is to outline any changes to the flood effects as per the updated boundary conditions and propose the correct boundary LiDAR is used for the project going forward.

1.1 Boundary condition review

In the course of updating the flood modelling, CKL has discovered that the LiDAR at the downstream boundary of the site that was used by Fluent Solutions for the original flood model in 2022 did not reflect the actual 2016 LiDAR boundary (See Figure 1, LHS image).

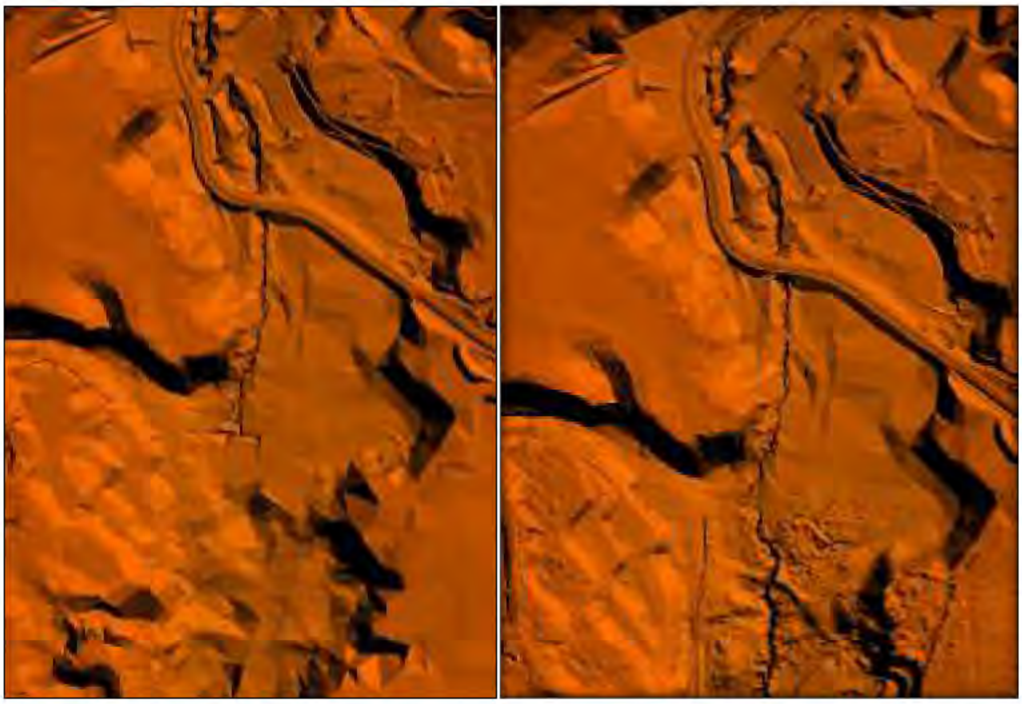
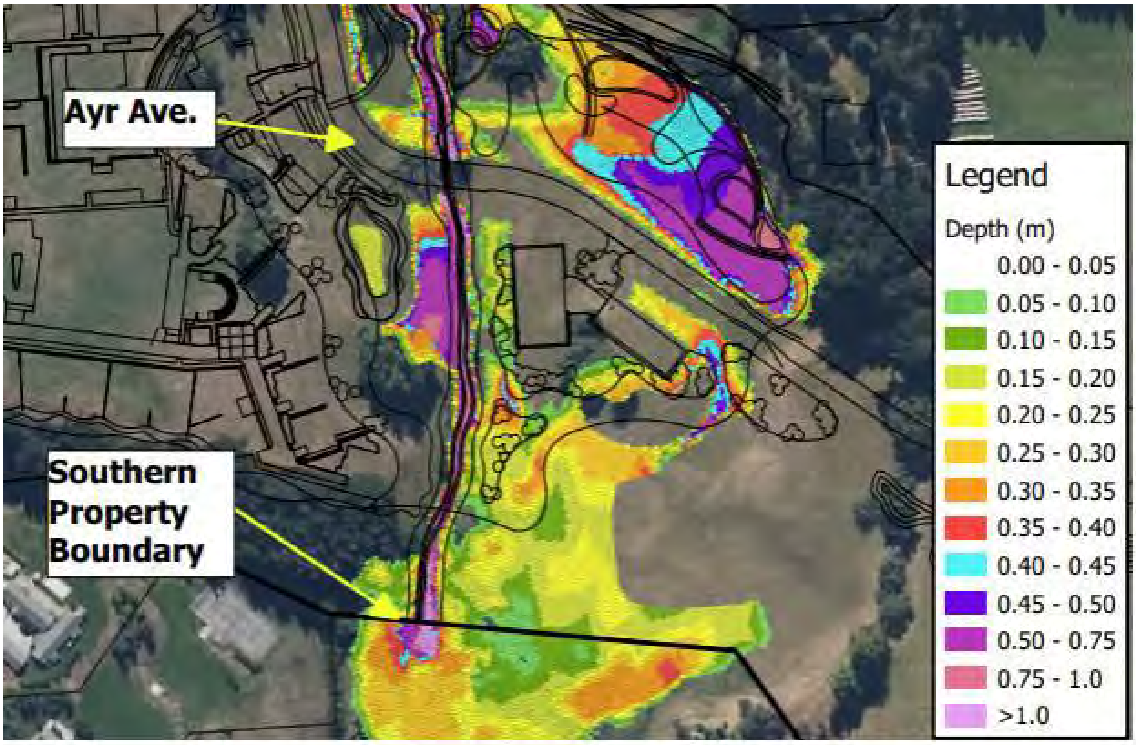


Figure 1: Original (old) LiDAR Fluent 2022 (LHS)S vs Current (new) LiDAR (RHS) CKL 2024

The stream outline seems to end just before downstream boundary with pools after the site (i.e. no defined stream channel).

The published result from the initial Fluent model runs (See Figure 2) and the initial CKL runs indicate the LHS Ground model (figure 1 LHS image) were used as the external (to the subject site) LiDAR. This was identified through critical evaluation of the downstream boundary conditions.



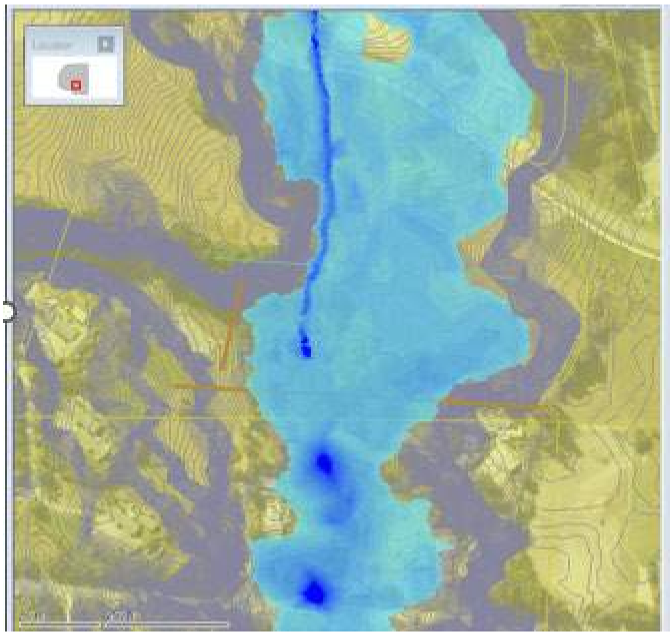


Figure 2: Results showing the anomaly in downstream of the boundary (old) LiDAR

The comparison however between the pre- and post-development for the project, to date, provides an appropriate comparison, as the same boundary LiDAR (ground surface) was used for both runs (previously).

2 Model Runs and outcomes

The pre- and post-development models were re-run with the appropriate downstream LiDAR (ground surface).

The post-development scenario includes the recent changes to the Haybarn bund provided by PPG on 15/05/2024 (EA application) and the latest Northbrook Arrowtown Variation surface (provided by PPG on 04/07/24). The latest post-development model run is referred to as Version 20, completed in July 2024. The post-development scenario with old-LiDAR was run with the EA application Haybarn Bund as well (Version 18 model), in order to compare pre- and post- development with old LiDAR as a baseline. In summary the following model runs were assessed:

- Pre-development with old LiDAR including downstream (old LiDAR)
    - Used for all consent applications to date
- Pre-development with new LiDAR downstream of site (new LiDAR)
- Post-development with Haybarn bund old LiDAR (Model Version 18)
- Post-development with EA Haybarn bund and latest Northbrook Variation new LiDAR (Model Version 20)

2.1 Pre-development Results

The screenshots below show the pre-development peak flow results from using the Current LiDAR (new LiDAR) vs the Previous LiDAR (old LiDAR) at assessment location, Wider Site Boundary.

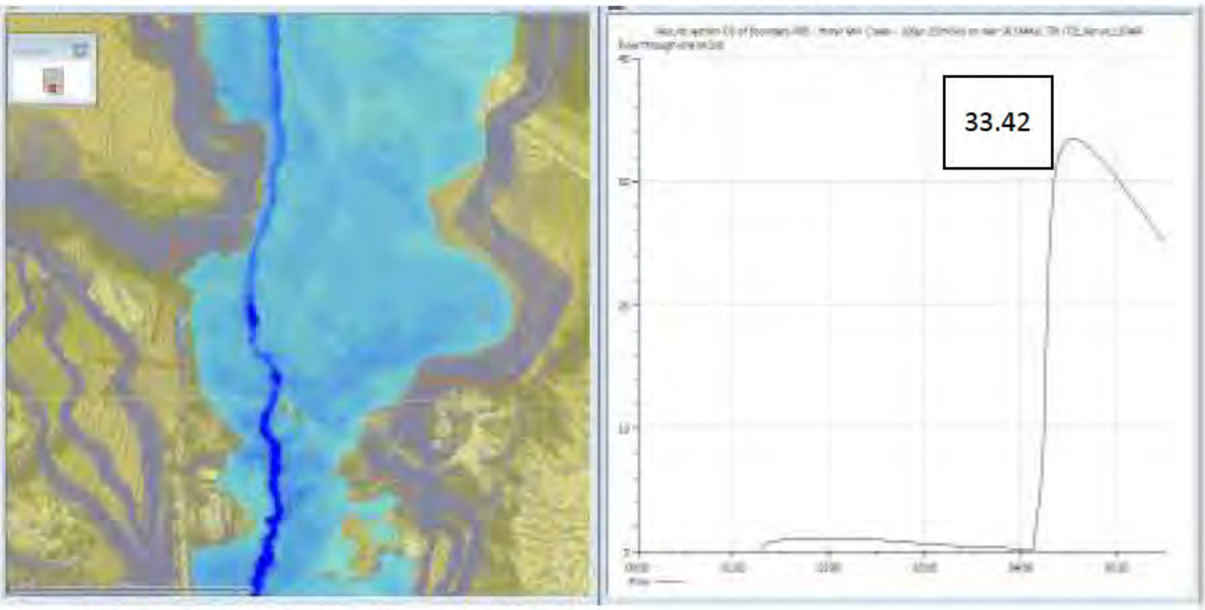


Figure 3: Peak flow and depth results using new LiDAR -100yr

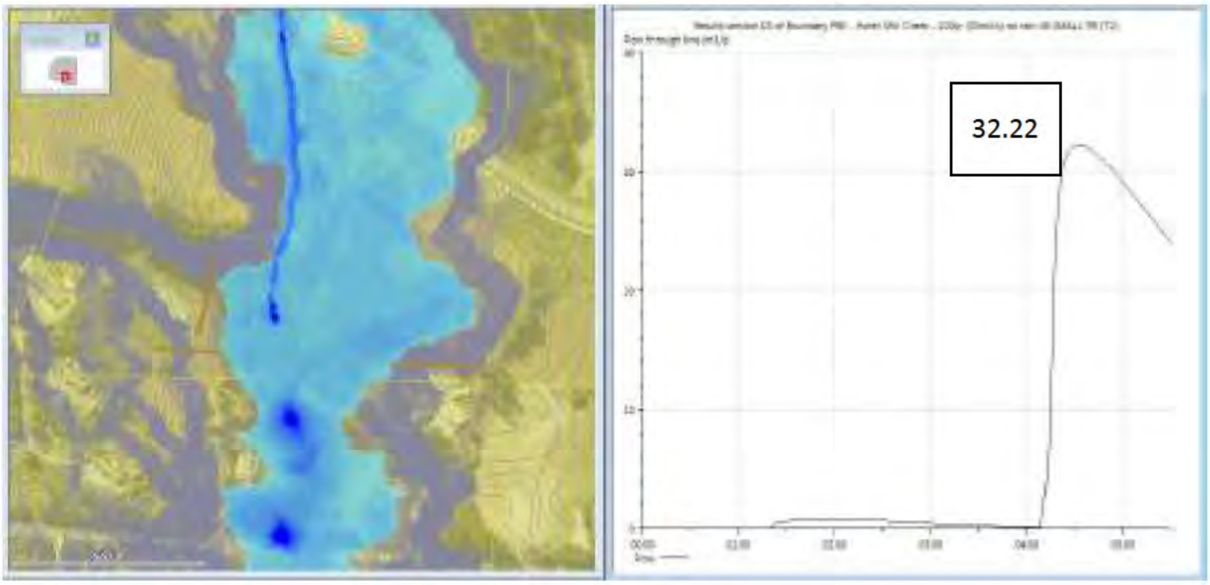


Figure 4: Peak flow and depth results using old LiDAR -100yr

2.2 Post Development Results

The screenshots below show the post-development peak flow results from using the new LiDAR at the assessment location with the Haybarn Bund (from PPG dated 15/05/2024), and Northbrook Variation latest application (From PPG dated 04/07/24), called Version 20.

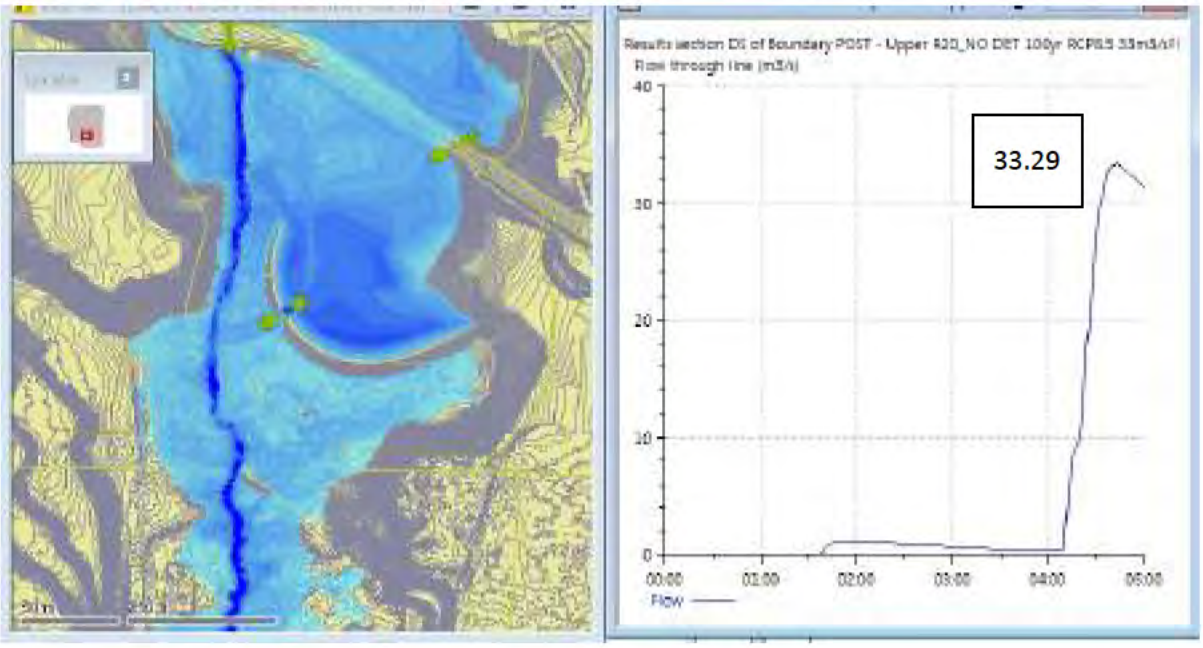


Figure 5: Peak flow and depth results using new LiDAR, V20 model July 2024

2.3 Summary

The table below show the revised pre- and post-development flow rates at the assessment boundary (wider site boundary).

Table 1: Summary of Peak flow estimates at Wider Site Boundary"

	Peak Flow (m^3/s) for return period				
	2 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Pre-Development-Old LiDAR	3.85	7.08	7.95	9.98	32.22
Post Development-Old LiDAR v18 (Haybarn Bund)	3.70	6.05	6.97	8.16	31.46
Difference	***-0.15***	***-1.03***	***-0.98***	***-1.82***	***-0.76***
Pre-Development-New LiDAR	4.64	7.86	8.79	9.91	33.42
Post Development- New LiDAR v20 (Northbrook Variation change and Haybarn bund)	4.53	7.20	8.13	9.34	33.29
Difference	***-0.11***	***-0.66***	***-0.66***	***-0.57***	***-0.13***

The post-development peak flow rates for all LiDAR and rainfall return period scenarios are at or below the pre-development flow rates.

3 Summary and Conclusions

The Waterfall Park and Northbrook Arrowtown developments' flood modelling has been critically reviewed which identified that the previous flood modelling included downstream ground model conditions which did not represent the stream correctly. The current flood modelling has been updated for the appropriate ground conditions downstream of the site with the new LiDAR information including the stream conditions.

The post-development flows with the updated downstream (new) LiDAR, including the proposed Haybarn bund and upstream Northbrook Variation development, was compared to the flows with the pre-development flows utilising the same LiDAR conditions downstream. For all rainfall return periods the post-development peak flow is below the pre-development conditions.

CKL
Planning | Surveying | Engineering | Environmental

MEMO

To:	**Waterfall Park Development Ltd**	**Date:**	**17th December 2024**
From:	**Frances Deamer-Phillips- Environmental Engineer**	**CC:**	
Reviewed:	**Bronwyn Rhynd– Environmental Engineer**	**CKL Ref:**	**A20254**
Re:	**Northbrook Waterfall Park and Ayrburn: Flood Bund - Engineering Approval**		

1 Introduction

This memorandum summarizes the detailed design for the proposed flood bund near the downstream boundary of the wider Northbrook Waterfall Park and Ayrburn sites. The bund has been approved under the Haybarn Venue Resource Consent application (RM230425) submitted by Ayrburn Precinct Limited and included in the Northbrook Waterfall Park Variation Resource Consent (RM240252) as flood management for both applications and the wider upstream site to ensure post-development peak flows are equal or less than pre-development peak flows at the southern boundary.

This memorandum supports the Engineering Approval application for both Northbrook Waterfall Park and Haybarn to Queenstown Lakes District Council (QLDC).

2 Detailed Design Flood Bund

The flood modelling for the wider site has been updated to include the latest surface in the overall development including the (RM240252) Northbrook Variation proposed surface and Haybarn surface (RM230425). Both models extend to the wider southern boundary and the area on the true left bank (east) of Mill Creek, south-west of Ayr Avenue and downstream of the culvert as you enter the hospitality precinct. This area includes the proposed low bund which provides attenuation during various rainfall events for the flow that is passing through the site and discharging on the southern boundary, as shown in Figure 1.

Figure 1: Site layout and location of low bund in southern sector[1]

2.1 Bund Design

The bund is designed and located along the southern portion of the low-lying grassed area to allow flow from Mill Creek, together with overland flow from upstream Ayr Ave culvert and Ayrburn area to collect behind the bund and be slowly released back into Mill Creek as attenuated flows. The bund height varies, max height of 1.4m, with a 300mm pipe to convey low flows to drain through the bund and a battered grassed weir above the pipe to provide slow-release during larger events. The bund features are as follows:

- Bund
  - Top level= 344.2mRL
  - Length= 150m
- Weir
  - Weir base level= 343.70mRL
  - Weir base width=5m
- Pipe
  - Diameter=300mm
  - Invert level=342.40mRL

The site layout and details of the low bund with flow control weir is presented in Paterson's sheets 400 and 401 in Appendix 1.

The following table and graphs include the top water level behind the bund for various storm events and the duration of water (that will remain) behind the bund.

[1] Excerpt from PPG drawing titled Haybarn Venue, Proposed contours overview, sheet 210.

Table 1: Flood Level and Duration Behind Bund for Variation Storm Events

Scenario	DS cross section Bund				
	100yrCC	**50yrCC**	**20yrCC**	**10yrCC**	**2yrCC**
Elevation behind bund	344.13	343.481	343.439	343.398	343.18
Duration of inundation	3-5hrs of inundation greater than 0.5m depth within the bund walls. (See graphs below)				

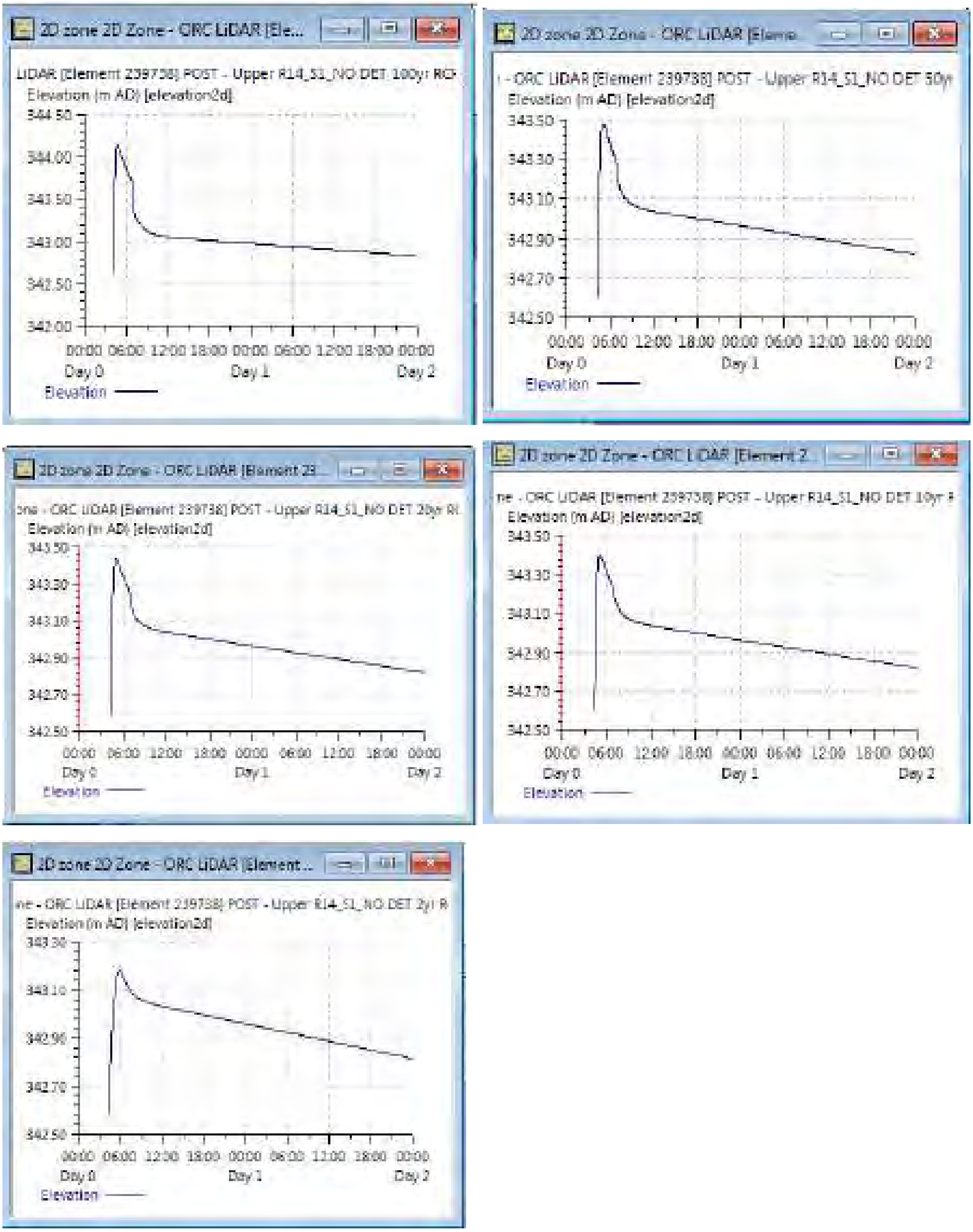


Figure 2: Flood level and duration graphs behind bund for 100yr, 50yr, 20yr, 10yr, and 2yr rainfall events

2.2 Pre- and post-development assessment

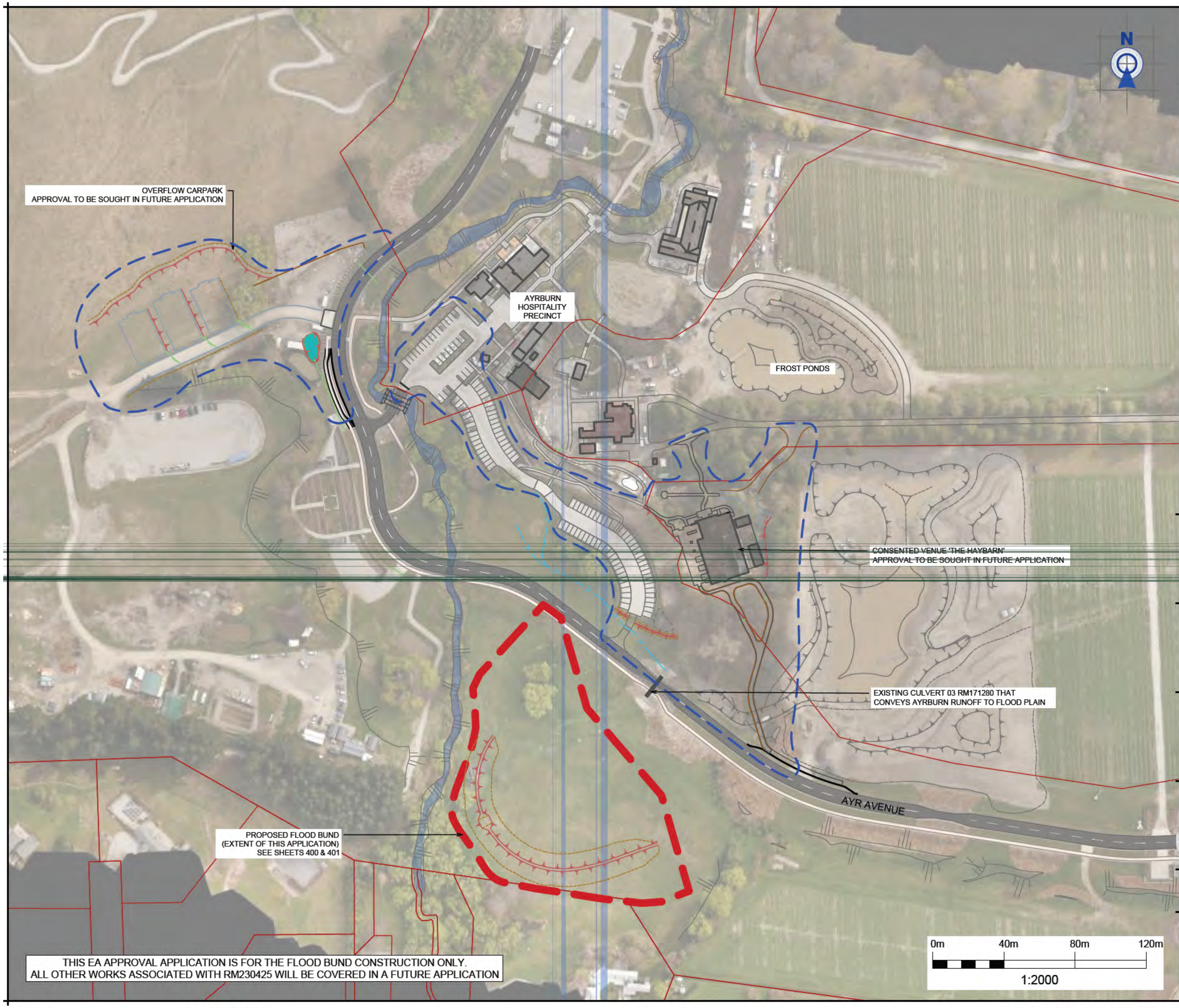
The flood modelling including all upstream consented development (including Northbrook Variation, RM240252, and Haybarn, RM230425) has been interrogated at the location immediately downstream of the boundary, across Mill Creek. This model includes the latest Lidar within Mill Creek downstream of site boundary as addressed in CKL Boundary Flow Assessment Memo (12th July 2024) provided within the Northbrook Stage 1B EA Variation Report. This assessment location is indicated (by the green line) in Figure 1 above.

The resultant flow rates for pre- and post-development are presented in the following table. The post development model run is considered version 21 (including Northbrook Variation Stage 1B EA surface).

Scenario	Peak flow rate (m3/s) –(ARI)				
	100yrCC	50yrCC	20yrCC	10yrCC	2yrCC
Pre-development	33.42	9.91	8.79	7.86	4.64
Post-development	33.29	9.34	8.13	7.20	4.53

The post-development flow at the downstream boundary is no greater than pre-development.

Appendix 1 Drawings



LEGEND

- LEGAL BOUNDARY
- MILL CREEK
- AYR AVENUE CARRIAGEWAY (EXISTING)
- RM230425 CONSENT EXTENTS
- EA APPLICATION EXTENTS
- TOP OF BU D
- TOE OF BU D (BUND EXTENT)
- OVERLAND FLOW PATH

NOTES

1. PARTIAL ENGINEERING APPROVAL IS BEING SOUGHT FOR THE FLOOD BUND IN ISOLATION, IT IS NOT PROPOSED TO CONSTRUCT ANY OTHER FEATURES COVERED BY RM230425 AT THIS TIME.
2. THIS APPLICATION IS TO BE READ IN CONJUNCTION WITH THE PARTIAL EA APPLICATION SUBMITTED FOR NORTHBROOK STAGE 1B UNDER RM220926. THE FLOOD BUND IS REQURIED TO SATISFY PRE V POST DEVELOPMENT RUNOFF CONDITIONS RELATING TO THIS CONSENT.
3. COMPREHENSIVE FLOOD MODELLING HAS BEEN CARRIED OUT BY CKL, REFER TO THE CKL REPORT FOR FURTHER DETAILS.

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Client & Location:

AYRBURN PRECINCT LTD
AYR AVENUE - LOT 4 DP540788

Purpose & Drawing Title:

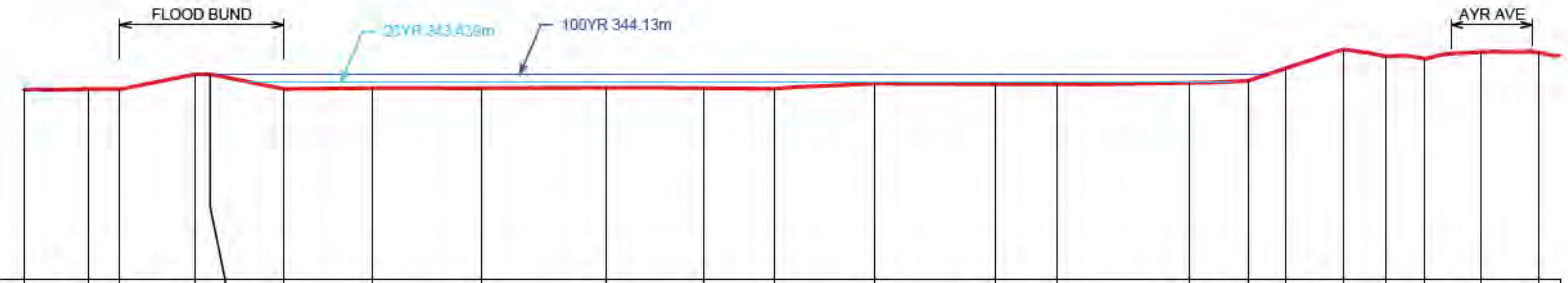
RM230425 HAYBARN VENUE
SITE PLAN OVERVIEW

FOR ENGINEERING ACCEPTANCE

Surveyed by:	PPG	Original Size: A3	Scale: 1:2000
Designed by:	CKL / HT		
Drawn by:	HT		
Checked by:	SB		
Approved by:	SB		DO NOT SCALE

Job No:	Drawing No:	Sheet No:	Revision No:	Date:
Q6388	35 - 15	100	A	11/12/2024

User: sam.ballam Printed: 2024-12-18 10:10:11 Filename: C:\12dS\data\QTSVR01\Q6388D - Ayrburn Domain_79\5 - Drawings\1 - DWG\Haybarn\Q6388-35-15 - Flood Bund - Drawings 400-402.dwg

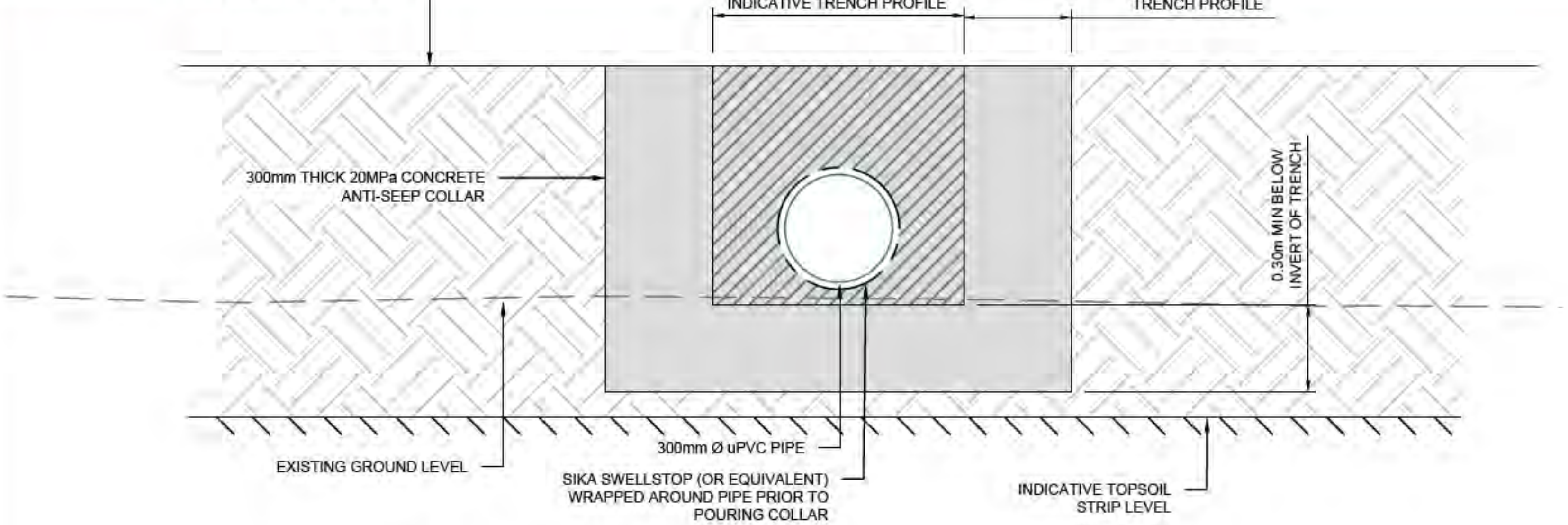


DATUM RL323.00

GROUND LEVEL	342.61	342.66	342.66	344.20	344.20	342.69	342.76	342.75	342.79	342.76	342.70	343.23	343.16	343.16	343.30	343.51	344.82	346.76	346.05	345.81	346.48	346.44
CHAINAGE	0.00	6.64	9.88	17.68	19.18	26.74	35.85	47.11	60.00	70.00	77.34	87.65	100.00	106.41	120.00	126.04	130.00	135.87	140.28	144.25	150.00	156.03

SCALE: 1:750 HORIZONTAL
1:750 VERTICAL

SECTION C - FLOOD PLAIN CROSS SECTION



DETAIL D - ANTI-SEEP COLLAR

SCALE 1:20

LEGEND

- LEGAL BOUNDARY
- MILL CREEK
- PROPOSED CONTOURS (0.25m INTERVAL)
- TOP OF BUND
- TOE OF BUND (BUND EXTENT)
- OVERLAND FLOW PATH

NOTES

1. REFER TO CKL MEMO FOR OUTLET SIZING CALCULATIONS.
2. FLOOD LEVELS SHOWN AS BASED ON CKL FLOOD MODELLING

N

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Client & Location:

AYRBURN PRECINCT LTD
AYR AVENUE - LOT 4 DP540788

Purpose & Drawing Title:

RM230425 HAYBARN VENUE
FLOOD BUND - DETAILS

FOR ENGINEERING ACCEPTANCE

Surveyed by:	PPG	Original Size: A3	Scale: AS SHOWN
Designed by:	PPG / CKL		
Drawn by:	HT		
Checked by:	SB		
Approved by:	SB		DO NOT SCALE

Job No:	Drawing No:	Sheet No:	Revision No:	Date:
Q6388	35 - 15	401	A	11/12/2024

Appendix 4 Soakage Testing

Bronwyn Rhynd

From: Mike Plunket [redacted]
Sent: Friday, 25 October 2024 4:51 pm
To: Frances Deamer-Phillips
Cc: George Watts; Shaun Niven; Andrew Hughson; Bronwyn Rhynd
Subject: RE: [#CKL A20254] [150098.11] Soakage testing

Hi Frances,

I have provided an initial summary related to the soakage testing completed at the Ayrburn Studio development below to allow you to continue with your design.

The site is typically underlain by interbedded layers of alluvial silt, sand and gravel. Existing test pit data was reviewed and additional test pits completed adjacent to soakage testing at SP1 and 2 due to the variable of surrounding test pit observations. The soil profile observed in each test location and associated recorded infiltration rate based on the falling head testing completed is provided below. Each hole was pre-soaked for a minimum of 4 hours prior to recording test values as per the recommendations of the QLDC LDSCoP.


Application Boundary
TP8
TP9
TP3
TP14d
TP11d
Test 2 - 1.5 m cut to FGL
Test 3 - no cut/fill
TP10
TP19a
TP9d
TP21a
TP12d
TP20a
Test 1 - no cut/fill

SP1 – test completed at 1.1 m begl – unfactored infiltration rate of 800 mm/hr/m2 recorded
0-0.2 – Topsoil
0.2-0.4 – sandy GRAVEL
0.4-2.2 – gravelly SAND

SP2 – test completed at 2.9 m begl – unfactored infiltration rate of 30 mm/hr/m2 recorded. Testing was proposed at 2.5 m begl however no more favourable infiltration layer was observed within the adjacent completed test pit (extending to 3.8 m bgl) therefore testing was completed within the sandy SILT layer.
0-0.1 – topsoil
0.1-0.4 – sandy GRAVEL with minor silt
0.4-0.7 – sandy SILT
0.7-1.2 – sandy GRAVEL and gravelly SAND
1.2-2.7 – SILT with minor to trace sand
2.7-3.8 – sandy SILT

SP3 – test completed at 1.2 m begl – unfactored infiltration rate of 400 mm/hr/m2 recorded
0-0.1 topsoil
0.1-0.6 sandy SILT
0.6-1.2 sandy GRAVEL with trace cobbles and interbedded sand lenses – previous test pits surrounding SP3 observed the alluvial gravel layer extending to 3 m and at least 3.6 m.

Let me know if you have any questions in the meantime regarding the above otherwise we will incorporate a more detailed summary of testing and investigation data within our reporting.

Thanks,

Mike Plunket | Geotechnical Engineer, CPEng
GeoSolve Ltd - Engineering Consultants | | [redacted]
25D Gordon Road, Wanaka 9305

From: Mike Plunket
Sent: Tuesday, 22 October 2024 4:07 pm
To: Frances Deamer-Phillips [redacted]; Bronwyn Rhynd [redacted]; Andrew Hughson [redacted]
Cc: George Watts [redacted]; Shaun Niven [redacted]
Subject: RE: [#CKL A20254] [150098.11] Soakage testing

Hi Frances,

Appendix 5 Film Hub SMP Sensitivity Analysis Report

CKL

Planning | Surveying | Engineering | Environmental

SMP – sensitivity analysis

Ayrburn Screen Hub

Waterfall Park Development Ltd

Document Information

Client	**Waterfall Park Developments Ltd**
Site Location	Ayr Avenue, Arrowtown
Legal Description	Lot 4 DP540788
CKL Reference	A20254
Office of Origin	Auckland

Author	Bronwyn Rhynd		
Signed	[redacted]	Date	14/07/2025

Reviewed By	Kellie Whisker		
Signed	[redacted]	Date	14/07/2025

Authorised By	Bronwyn Rhynd		
Signed	[redacted]	Date	14/07/2025

Revision	Status	Date	Author	Reviewed By	Authorised By

Contents

Figures

Tables

Appendices

1 Introduction

This report outlines the sensitivity analysis undertaken which responds to the peer review outcomes of the following aspects:

- Raingarden design utilising infiltration rates of 750mm/day in comparison to 300mm/day
- Contaminant load modelling utilising the existing conditions as lifestyle farming
- Tertiary Infiltration Ponds efficacy

2 Raingarden design

An updated design of the raingardens has been undertaken to utilise an Infiltration rate of the bioretention media (K rate) of 0.3m/day, as per peer review comments, in comparison to the design K rate of 0.75m/day. This updated design will establish the changes to the original design outcomes with respect to the reduction in contaminants post development when compared to the pre-development state.

The raingarden design is based on the WQF associated with the contributing catchment as such the raingarden size in the original design will provide for 40% of the WQF. Conversely if the WQF is used the raingarden with K = 0.3m/hr is 2.5 times larger than the design provided.

To determine the likely contaminant removal efficiency of a raingarden designed with a K value of 0.3 m/hr but sized according to the original K = 0.75 m/hr design, the proportion of the Water Quality Flow (WQF) treated by the raingarden is compared to estimated removal efficiencies, as shown in the table below.

Table 1: Relative levels of treatment efficiency for removal of TSS[1]

Table 3-1
Relative levels of removal efficiency

Practice Volume	Efficiency
150% of WQV	82%
100% of WQV	75%
75% of WQV	70%
50% of WQV	60%
25% of WQV	50%
10% of WQV	40%
5% of WQV	30%

It is to be noted that the Contaminant Load Model (CLM) applied standard raingarden designs typically achieve TSS contaminant removal rates of 90%. In contrast, the table referenced above indicates a 75% removal rate when treating 100% of the WQF. For this comparison we are assessing the removal rate as per the above table, as such in reality the smaller raingarden design is likely to achieve higher removal rates.

The TSS treatment efficiency of raingardens designed to handle 40% of the Water Quality Flow (WQF) is estimated at 56%.

[1] Auckland Regional Council TP10 2003, Table 3-1

A comparison, and assuming a reduced removal efficiency, the table below sets out both the previously assessed and the smaller raingarden removal rates from runoff (WQF) for each contributing catchment.

Table 2: Contaminant removal rates - Raingarden K=0.3/hr

Treatment device	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Bioretention % removal rates	60%	40%	90%	90%	90%
Bioretention % removal rates @ 56% removal efficiency	34%	22%	50%	50%	50%

3 Contaminant Load Modelling

CKL assessed contaminant loading for the site in existing (lifestyle block) and proposed conditions in order to determine if the proposed stormwater treatment approach would improve the water quality of the stormwater discharging from site. Given nutrient loading is an issue in Lake Hayes, the focus was on Phosphorus, Nitrogen and TSS, however heavy metals are also considered.

Auckland Council Contaminant Load modelling methodology is used in the assessment. Although this methodology is applicable to a different climate and geology it is currently the main methodology used across the country and also adopted by the Christchurch City Council.

3.1 Total Phosphorus and Total Nitrogen Yields

The Ministry for the Environment conducted contaminant loading for different land uses in New Zealand for Total Nitrogen (TN) and Total Phosphorus (TS). Table 3 below demonstrates the contaminant yield for each type of land use.

Table 3: Land use specific yields for Total Nitrogen and Total Phosphorus

Landuse	LCDB4 category	TN specific yield (kg/ha/year)	TP specific yield (kg/ha/year)	Reference-land use type
Urban	Built-up Area (settlement)	8.0	0.8	MfE (2002) -Urban
Exotic	Exotic Forest	2.8	0.35	MfE (2002) -Exotic
Dairy	High Producing Exotic Grassland	25.0	1.00	MfE (2002) -Dairy
Sheep and beef	High Producing Exotic Grassland	9.0	1.98	MfE (2002) -Hill
Lifestyle	High Producing Exotic Grassland	5.2	0.46	MfE (2002) -low intensity pasture
Crop and Orchard	Orchard, Vineyard or Other Perennial Crop	15	No Data	Plant & Food

The existing grass areas within the site are considered to be assessed as Lifestyle in light of its current zoning and potential use.

The proposed land use is considered urban given this section of site is being converted to a commercial like area. This is considered a conservative assumption given the daily use of the proposed carparks and accessways will be significantly lower than an urban road. However, most nutrient loading in an urban environment comes from pet waste, fertilizer of garden, and atmospheric depositions. It is not expected that the Ayrburn Screen Hub will have much, if any pet waste and the use of fertilizers on site will be limited. Atmospheric deposition cannot be controlled. Therefore, the actual nutrient loading in the post-development scenario is expected to be lower than what is presented above. Given the use of fertilizer can be limited for this development proposal, it is assumed that post-development nutrient loading will be reduced by 30% compared to above table levels.

3.2 Total Suspended Solids and Heavy Metal Yields

Total Suspended Solids (TSS) and heavy metals loading was assessed based on the contaminant yields applied within the Auckland Council's contaminant load model (CLM). TPH below stands for Total Petroleum hydrocarbons, not considered here given the low vehicle traffic. Table 4 below demonstrates TSS yields for different and uses.

Table 4: Auckland Council's Land Use Specific Contaminant Yields

	AREA	Contaminant yield g m-2 year-1			
		TSS	Total zinc	Total copper	TPH
Roofs	galvanised steel unpainted	5	2.24	0.0003	0
	galvanised steel poor paint	5	1.34	0.0003	0
	galvanised steel well painted	5	0.20	0.0003	0
	galvanised steel coated	12	0.28	0.0017	0
	zinc/aluminium surfaced steel	5	0.20	0.0009	0
	zinc/aluminium surfaced steel coated long run and tiles	5	0.02	0.0016	0
	concrete	16	0.02	0.0033	0
	copper	5	0.00	2.1200	0
	other materials	10	0.02	0.0020	0
Roads	<1k vpd	21	0.004	0.0015	0.033
	1k-5k vpd	28	0.026	0.0089	0.201
	5k-20k vpd	53	0.110	0.0369	0.838
	20K-50K	96	0.257	0.0858	1.947
	50k-100k vpd	158	0.471	0.1570	3.564
	>100K vpd	234	0.729	0.2431	5.519
Paved	Residential paved	32	0.195	0.0360	0
	Industrial paved	22	0.590	0.1070	0
	Commercial paved	32	0.000	0.0294	0
Perviou	Urban grasslands and trees	45	0.001	0.0003	0
		92	0.002	0.0006	0
		185	0.008	0.0013	0
	Urban stream channels (length x	6,000	0.210	0.0420	0
	Construction sites	2,500	0.086	0.0180	0
	Slope	5,600	0.106	0.0390	0
		106,0	0.371	0.0740	0
Rural	Exotic production forest	35	0.001	0.0002	0
	Slope	104	0.003	0.0007	0
		208	0.007	0.0015	0
	Stable forest	14	0.000	0.0001	0
	Slope	42	0.001	0.0003	0
		83	0.002	0.0006	0
	Farmed pasture	152	[illegible]	0.0011	0
	Slope	456	0.016	0.0032	0
		923	0.032	0.0065	0
	Retired pasture	21	0.000	0.0001	0
	Slope	63	0.002	0.0004	0
		125	[illegible]	0.0009	0

Based on the above contaminant yields, the existing lifestyle scenario has the following contaminant yields, these have been assumed to be an average of the Rural Farmed Pasture and Retired Pasture: TSS is

86.5g/m^2/yr, Zinc as 0.0025g/m^2/yr and Copper as 0.0006g/m^2/yr, given it would be considered lifestyle type pasture on flatter land.

For the proposed scenario, different land uses were used for each surface type. The following were used: Zinc, aluminium surfaced steel for roofs, <1k vehicle per day for roads, urban grasslands and trees for pervious area, and Commercial paved for footpaths. However, the commercial paved area has significant levels for copper which is not expected in foot paths for this site development. The Auckland CLM yield levels for paved areas considers carparks and footpaths[2]. Carparks are expected to have high heavy metals due to car brakes, but footpaths should have next to no levels (very low levels). Additionally, heavy metals in paved areas in the studies supporting the Auckland CLM were found to come from adjacent building facades that had copper cladding or downpipes. The buildings proposed for this development will use low contaminant generating facades and downpipes. TSS on footpaths are from adjacent grassed areas. The concrete footpaths themselves produce little to no contaminants. Therefore, the paved commercial copper yields in the Auckland CLM are assumed to be much higher than what is generated from footpaths within this proposed development and the copper yield is assumed to be zero here.

The filming studios 'backlot' parking area is assumed to be the same as road contaminant given the paved commercial levels are skewed for areas with copper cladding or signs or large landscape areas adjacent to these areas, which this specific area would not have. The roads yield with vpd<1000 seems to be a more appropriate estimate.

[2] Urban Sources of Copper, Lead, and Zinc, Auckland Regional Council, Oct 2009

3.3 Pre- and Post-Contaminant Yields

Using the above assessment for contaminant yields, Table 5 and

Table 6 below identifies the contaminant loading for the pre- and post-development scenario for just the area of the existing and proposed carparks, which is the area where contaminants may be generated in relation to this application.

*Table 5: Pre-Development Contaminant Loading **(Lifestyle)***

	Area (m^2)	TP Loading (g/m^2/yr)	Runoff TP (kg/yr)	TN Loading (g/m^2/yr)	Runoff TN (kg/yr)	TSS Loading (g/m^2/yr)	Runoff TSS (kg/yr)	Zinc Loading (g/m^2/yr)	Runoff Zinc (kg/yr)	Copper Loading (g/m^2/yr)	Runoff Copper (kg/yr)
Lifestyle	234000	0.046	10.76	0.52	121.68	86.5	20241	0.0025	0.585	0.0006	0.1404
Sum	**234000**		**10.76**		**121.68**		**20241**		**0.585**		**0.1404**

Table 6: Post-Development Contaminant Loading (untreated)

	Area (m^2)	TP Loading (g/m^2/yr)	Runoff TP (kg/yr)	TN Loading (g/m^2/yr)	Runoff TN (kg/yr)	TSS Loading (g/m^2/yr)	Runoff TSS (kg/yr)	Zinc Loading (g/m^2/yr)	Runoff Zinc (kg/yr)	Copper Loading (g/m^2/yr)	Runoff Copper (kg/yr)
Catchment A	3396	0.056	0.19	0.56	1.90	86.5	71.3	0.004	0.0136	0.0015	0.0051
Catchment B	8897	0.056	0.50	0.56	4.98	21	186.8	0.004	0.0356	0.0015	0.0133
Catchment D/ Catchment E/Catchment C	13778	0.056	0.77	0.56	7.72	21	289.3	0.004	0.0551	0.0015	0.0207
Foot paths	3057	0.056	0.17	0.56	1.71	32	97.8	0.000	0.0000	0.000	0.0000
Roofs	15559	0.056	0.87	0.56	8.71	5	77.8	0.020	0.3112	0.0016	0.0249
Land-scaping	189313	0.056	10.60	0.56	106.02	45	8519.1	0.001	0.1893	0.0003	0.0568
Sum	**234000**		**13.10**		**131.04**		**9393.75**		**0.5497**		**0.1001**

3.4 Contaminant Removal Rates from Treatment Devices

(To provide the background to the removal rates, the following is included for completeness and is the same information as the Ayrburn Screen Hub SMP.)

Estimated removal rates of each contaminant for different stormwater management practices are assumed using NZTA's rates[3]. NZTA removal rates are considered best practice for wider NZ. Christchurch City Council[4] (CCC) also have assumed removal rates for various devices and these rates were also considered when choosing removal rates for each device. The CCC rates include a range or removal efficiencies for each device, many of the NZTA rates are within the middle of the range provided in CCC. Table 7 below shows NZTA's removal rates for various stormwater practices.

Table 7: NZTA Removal Rates for Various Stormwater Devices

[3] Stormwater Treatment Standard for State Highway Infrastructure, NZTA, May 2010

[4] Waterways, Wetlands, and Drainage Guide, Chapter 6 Stormwater Treatment Systems, CCC

Table 8-1
Removal Rates for Various Stormwater Practices for TSS and Nutrients

Practice	Removal rates (%)				
	TSS	Nitrogen	Phosphorus	Zinc	Copper
Swales	70	20	30	75	60
Filter Strips	80	20	20	75	60
Sand Filters	80	35	45	90	90
Rain Gardens (normal)	90	40	60	90	90
Rain Gardens (w/anaerobic zone)	90	50	80		
Infiltration Practices	80	30	60	80	70
Wet Ponds	75	25	40	50	40
Wetlands	90	40	50	80	80
Oil Water Separators	15	0	5	5	5

The removal rates are relatively low for Phosphorus and Nitrogen in some stormwater treatment devices and given these nutrients are of particular interest in the catchment, a treatment train approach is suggested as the best practical option to treat runoff from the site.

Phosphorus and Nitrogen are removed from stormwater within raingardens as stormwater filters into/through the media and clings to the sediments and soil's structure. The nutrients are then absorbed by the roots of the plants within the devices and removed from the stormwater. Treated (Stormwater) water then drains from the bottom of the device.

Heavy metals partially cling to TSS which, when stormwater is slowed down through devices, this settles out. It is filtered through media in the raingarden where it fills the void space in the topsoil and media overtime. The devices usually need to be dug up and fresh soil media replaced given the build-up of TSS and heavy metals in the soil. This typically happens every 25 years.

Similar nutrients in wetlands are removed through sedimentation and through plant uptake. Given the proposed pod wetlands are not designed as a traditional wetland, many of the removal efficiency rates used in this assessment are on the lower end of the range provided in CCC reporting, and lower than the NZTA rates provided above.

Ponds are less efficient at removing nutrients, however, given the water quality event can be infiltration through ground, the tertiary infiltration ponds are assumed to have similar removal rates to infiltration practices. The removal efficiency rate range for nitrogen in infiltration practices in CCC is higher than NZTA rates. Given the infiltration ponds are proposed to be planted as well which will include nutrient uptake, a removal rate in middle of CCC value range, but higher than NZTA value was chosen. All other rates use the above NZTA value and relate to the CCC values.

3.5 Treatment Train Approach

(The following is included for completeness and is the same information as the Ayrburn Screen Hub SMP.)

A treatment train approach is suggested to treat the proposed carpark in order to achieve high removal rates of TP, TN, TSS and heavy metals.

NZTA uses a simplified equation for the total removal of a given contaminant for two stormwater treatment devices in a series. The equation is as follows:

$$R = A + B - [(A \times B)/100]$$

Where:
R = total removal rate
A = Removal rate of the first or upstream practice
B = Removal rate of the second or downstream practice

This equation was used to determine the total removal rate of contaminants from the catchment. It should be noted that it was applied for two devices, while the Catchment A and Catchment B receive three levels of treatment, for this assessment only the first two devices are assessed, and the tertiary infiltration ponds are not included in removal rates for these catchments in the CLM model. These catchments will receive tertiary treatment acting as polishing treatment and this adds robustness to the design in case of upstream devices have reduced efficiency.

Table 8 below indicated the total removal rates for each contaminant in question.

Table 8: Total Removal Rates of Contaminants for Treatment Train Approach

Options	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device[5]	48%	39%	87%	59%	70%
Infiltration Pond	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention	60%	40%	90%	90%	90%
Total Bioretention + Wetland	**80%**	**64%**	**97%**	**96%**	**96%**
Total Proprietary Device and Pond	**74%**	**63%**	**96%**	**84%**	**88%**
Total Bioretention and Pond	**84%**	**76%**	**98%**	**98%**	**97%**

As seen above, it is difficult to achieve (relatively) high rates of TN removal rates in comparison to TP, TSS and heavy metals which have relatively high rates of removal based on this treatment train approach. Additionally, nitrogen and phosphorus often bind to TSS, so the high levels of TSS removal will ensure elevated levels of TN and TP removal are achievable.

[5] Data on removal rates from Hynds Up-Flo researchhttps://ccc.govt.nz/assets/Documents/Environment/Water/waterways-guide/WaterwayswetlandsandDrainageGuideWWDGchapter6StormwatertreatmentsystemsMay2012.pdf

3.6 CLM assessment - update to treatment train:

For the purposes of the CLM it is proposed to assess the efficacy of the system without the inclusion of the Tertiary infiltration pond as part of the contaminant removal. The efficacy of the ponds, which have infiltration bases, for the catchments C, D & E as a contaminant reducer is influenced by the runoff from Catchments A & B. Therefore, inclusion of these ponds as part of the treatment train is not truly reflective of the runoff arriving at different times. Therefore, for the CLM the following system has been assessed:

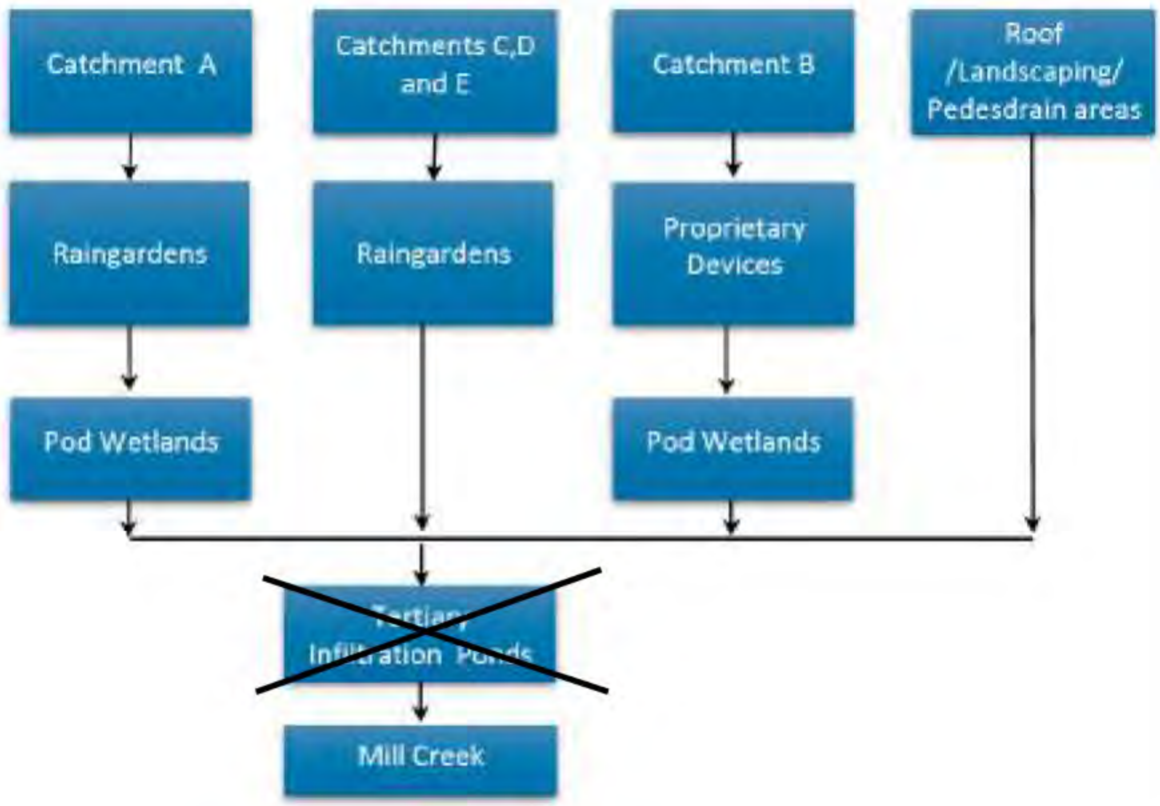


Figure 1: Diagram of the CLM assessed proposed stormwater treatment system

3.7 Treated Stormwater Contaminant Yields

The treatment efficacy has been updated based on the following scenarios:

- Reduced raingarden efficacy
- Reduced raingarden efficacy and no Tertiary infiltration ponds

3.7.1 Reduce raingarden only

Due to reduced raingarden sizes, removal rates were assessed for a treatment train approach, accounting for lower efficiency from not treating the full WQF. The contaminant yield after treating runoff from the site, including the existing carpark and less efficient raingardens, was evaluated. The table below compares pre and post development runoff contaminant yields following treatment.

Table 9: Pre-Development **(Lifestyle)** and Post-Development Contaminant Yield After Treatment (w reduce raingarden efficiency)

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Pre-Development	10.76	121.68	20241	0.585	0.1404
Post-Development (Treated)	4.24	51.68	1785.46	0.1141	0.0302
Reduced Yield	**-5.71**	**-70.0**	**-18455.46**	**-0.4709**	**-0.1102**
% Reduced	**53%**	**58%**	**91%**	**80%**	**78%**

Thes results were compared with the full rain garden treatment under the previous K=0.75 outcome in the following table

Table 10: Reduction in contaminant – compare Raingarden K values

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
K=0.75 % Reduced	54%	58%	91%	82%	81%
K=0.3 % Reduced	53%	58%	91%	80%	78%

Although the K factor is reduced and subsequent treatment efficiency of the raingarden affected the outcome is that all contaminants of interest are reduced by a similar (if not the same) quantum as the original design assumptions.

3.7.2 Reduce raingarden & no tertiary infiltration ponds

In addition to the reduced raingarden treatment efficiency the removal of the tertiary infiltration ponds from the treatment train has been assessed,

Table 11: Contaminant Yield After Treatment reduced raingarden efficiency & no tertiary ponds

	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Pre-Development (Lifestyle)	10.76	121.68	20241	0.585	0.1404
Post-Development (Treated)	5.36	55.27	1900.2	0.1360	0.0374
Reduced Yield	**-5.40**	**-66.408**	**-18340.65**	**-0.490**	**-0.1030**
% Reduced	**50%**	**55%**	**91%**	**77%**	**73%**

As seen above, all contaminants of interest are reduced in the runoff from the proposed site compared to the existing situation. TSS and heavy metals have been greatly reduced, and nutrients are reduced by at least half from the existing situation.

4 Summary

Based on the sensitivity analysis for both the reduced raingarden sizes, due to eth infiltration rate reduction, and the removal of the tertiary pond infiltration as part of the treatment train the outcomes indicates a substantial improvement in water quality at the proposed Ayrburn Fillm Hub site. Key contaminants such as total suspended solids (TSS), heavy metals, and nutrients have all demonstrated significant reductions in runoff compared to current conditions. In particular, nutrients were decreased by at least 50%, while TSS and heavy metals showed even greater reductions, highlighting the effectiveness of the mitigation measures implemented.

These results confirm that the proposed changes will lead to a marked enhancement in the environmental performance of the site.

Appendix 1 Calculation Summary

- CLM Raingarden reduction
- CLM Raingarden reduction and no Tertiary Pond
- Raingarden treatment size assessment

CKL

Job Name	**Waterfall Park**		**File Name**	**A2025-EV- Studio SMP**
Job No.	**A20254**		**Sheet Name**	**CLM(Lifest- post) RG re NO C**
Date	**11/07/2024**			
By	**BR**	**Checked**	**KW**	

Contaminant Load Model- Lifestyle to Urban -Raingarden WQF reduced

	Phosporus	Nitrogen	TSS	Zinc	Copper	Units
Lifestyle (mix between farmed & retired pasture)	0.046	0.52	86.5	0.0025	0.0006	$g/m^2/yr$
Urban	0.080	0.8				$g/m^2/yr$
Urban (30% reduction- no fertlizer)	0.056	0.56				$g/m^2/yr$
Roads (<1k per day)			21	0.004	0.0015	$g/m^2/yr$
Footpath (adjusted Commercial Paved)			32	0.000	0.0000	$g/m^2/yr$
Roof			5	0.020	0.0016	$g/m^2/yr$
Urban Grasslands and trees			45	0.001	0.0003	$g/m^2/yr$

Existing Contaminants

Total Development Catchment	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Lifestyle (mix between farmed & retired pasture)	234000	1	10.76	121.68	20241.00	0.5850	0.1404
Sum	234000		10.76	121.68	20241.00	0.5850	0.1404

Proposed Contaminants

Catchment [Treatment devices]	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff Treated TP (kg/yr)	Runoff TN (kg/yr)	Runoff Treated TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Treated TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Treated Zinc (kg/yr)	Runoff Copper (kg/yr)	Runoff Treated Copper (kg/yr)
Catchment A (Raingarden->Pods->Ponds)	3396	1	0.19	0.06	1.90	0.89	71.3	10.61	0.0136	0.0027	0.0051	0.0010
B Catchment (Proprietary->Pods->Ponds)	8897	1	0.50	0.13	4.98	1.82	186.8	7.29	0.0356	0.0058	0.0133	0.0016
C/D/E Catchments (Raingardens->Ponds)	13778	1	0.77	0.20	7.72	2.39	289.3	28.70	0.0551	0.0055	0.0207	0.0031
Footpaths (Infiltration Ponds)	3057	1	0.17	0.07	1.71	0.68	97.8	19.56	0.0000	0.0000	0.0000	0.0000
Roofs (Infiltration Ponds)	15559	1	0.87	0.35	8.71	3.49	77.8	15.56	0.3112	0.0622	0.0249	0.0075
Landscaping (Infiltration Ponds)	189313	1	10.60	4.24	106.02	42.41	8519.1	1703.82	0.1893	0.0379	0.0568	0.0170
Sum	234000		13.10	5.06	131.04	51.68	9242.20	1785.54	0.6048	0.1141	0.1208	0.0302
			Total TP Reduced	-5.71	Total TN Reduced	-70.000	Total TSS Reduced	-18455.46	Total TSS Reduced	-0.4709	Total TSS Reduced	-0.1102
			% TP Reduced	53%	% TN Reduced	58%	% TSS Reduced	91%	% TSS Reduced	80%	% TSS Reduced	78%

Options	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device (Up-Flo)	48%	39%	87%	59%	70%
Infiltration Ponds	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention @ 56% of removal effeciency as per Table 8-1	34%	22%	50%	50%	50%
Total Bioretention + Wetland	67%	53%	85%	80%	80%
Total Proprietary Device + Wetland	74%	63%	96%	84%	88%
Total Bioretention + Infiltration Ponds	73%	69%	90%	90%	85%

R = A + B – [(AxB)/100]

For sediment R = 70 + 90 – [(70x90)/100] = 160 – 63 = 97% removal
For nitrogen R = 20 + 40 – [(20x40)/100] = 60 – 8 = 52% removal
For phosphorus R = 30 + 50 – [(30x50)/100] = 80 – 15 = 65% removal

Job Name	Waterfall Park	File Name	A2025-EV- Studio SMP
Job No.	A20254	Sheet Name	CLM(Lifest- post) RG TP re NO C
Date	11/07/2025		
By	BR	Checked	KW

Contaminant Load Model- Lifestyle to Urban -Raingarden WQF reduced & No Tertiary Pond treatment allowance

	Phosporus	Nitrogen	TSS	Zinc	Copper	Units
Lifestyle (mix between farmed & retired pasture)	0.046	0.52	86.5	0.0025	0.0006	$g/m^2/yr$
Urban	0.080	0.8				$g/m^2/yr$
Urban (30% reduction- no fertlizer)	0.056	0.56				$g/m^2/yr$
Roads (<1k per day)			21	0.004	0.0015	$g/m^2/yr$
Footpath (adjusted Commercial Paved)			32	0.000	0.0000	$g/m^2/yr$
Roof			5	0.020	0.0016	$g/m^2/yr$
Urban Grasslands and trees			45	0.001	0.0003	$g/m^2/yr$

Existing Contaminants

Total Development Catchment	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Lifestyle (mix between farmed & retired pasture)	234000	1	10.76	121.68	20241.00	0.5850	0.1404
Sum	234000		10.76	121.68	20241.00	0.5850	0.1404

Proposed Contaminants

Catchment [Treatment devices]	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff Treated TP (kg/yr)	Runoff TN (kg/yr)	Runoff Treated TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Treated TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Treated Zinc (kg/yr)	Runoff Copper (kg/yr)	Runoff Treated Copper (kg/yr)
Catchment A (Raingarden->Pods->Ponds)	3396	1	0.19	0.06	1.90	0.89	71.3	10.61	0.0136	0.0027	0.0051	0.0010
B Catchment (Proprietary->Pods->Ponds)	8897	1	0.50	0.13	4.98	1.82	186.8	7.29	0.0356	0.0058	0.0133	0.0016
C/D/E Catchments (Raingardens->~~Ponds~~)	13778	1	0.77	0.51	7.72	5.99	289.3	143.51	0.0551	0.0273	0.0207	0.0103
Footpaths (Infiltration Ponds)	3057	1	0.17	0.07	1.71	0.68	97.8	19.56	0.0000	0.0000	0.0000	0.0000
Roofs (Infiltration Ponds)	15559	1	0.87	0.35	8.71	3.49	77.8	15.56	0.3112	0.0622	0.0249	0.0075
Landscaping (Infiltration Ponds)	189313	1	10.60	4.24	106.02	42.41	8519.1	1703.82	0.1893	0.0379	0.0568	0.0170
Sum	234000		13.10	5.36	131.04	55.27	9242.20	1900.35	0.6048	0.1360	0.1208	0.0374
			Total TP Reduced	-5.40	Total TN Reduced	-66.408	Total TSS Reduced	-18340.65	Total TSS Reduced	-0.4490	Total TSS Reduced	-0.1030
	44687		% TP Reduced	50%	% TN Reduced	55%	% TSS Reduced	91%	% TSS Reduced	77%	% TSS Reduced	73%

Options	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device (Up-Flo)	48%	39%	87%	59%	70%
Infiltration Ponds	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention @ 56% of removal effeciency as per Table 8-1	34%	22%	50%	50%	50%
Total Bioretention + Wetland	67%	53%	85%	80%	80%
Total Proprietary Device + Wetland	74%	63%	96%	84%	88%
Total Bioretention + Infiltration Ponds	73%	69%	90%	90%	85%

Catchment C/D/E

$R = A + B - [(AxB)/100]$

For sediment $R = 70 + 90 - [(70x90)/100] = 160 - 63 = 97\%$ removal
For nitrogen $R = 20 + 40 - [(20x40)/100] = 60 - 8 = 52\%$ removal
For phosphorus $R = 30 + 50 - [(30x50)/100] = 80 - 15 = 65\%$ removal

Table 2 [illegible]

Landuse
Urban
[illegible]
[illegible]
[illegible]
Lifestyle
[illegible]

Job Name	Waterfall Park	File Name	A2025-EV- Studio SMP
Job No.	A20254	Sheet Name	CLM(Lifest-post)noC K0.75
Date	11/07/2025		
By	BR	Checked	KW

Table 2 Land

Contaminant Load Model- Lifestyle to Urban Raingarden K=0.75m/day

	Phosporus	Nitrogen	TSS	Zinc	Copper	Units
Lifestyle (mix between farmed & retired pasture)	0.046	0.52	86.5	0.0025	0.0006	$g/m^2/yr$
Urban	0.080	0.8				$g/m^2/yr$
Urban (30% reduction- no fertlizer)	0.056	0.56				$g/m^2/yr$
Roads (<1k per day)			21	0.004	0.0015	$g/m^2/yr$
Footpath (adjusted Commercial Paved)			32	0.000	0.0000	$g/m^2/yr$
Roof			5	0.020	0.0016	$g/m^2/yr$
Urban Grasslands and trees			45	0.001	0.0003	$g/m^2/yr$

Existing Contaminants

Total Development Catchment	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Copper (kg/yr)
Lifestyle (mix between farmed & retired pasture)	234000	1	10.76	121.68	20241.00	0.5850	0.1404
Sum	**234000**		**10.76**	**121.68**	**20241.00**	**0.5850**	**0.1404**

Proposed Contaminants

Catchment [Treatment devices]	Area (m^2)	Runoff Coefficient (C)	Runoff TP (kg/yr)	Runoff Treated TP (kg/yr)	Runoff TN (kg/yr)	Runoff Treated TN (kg/yr)	Runoff TSS (kg/yr)	Runoff Treated TSS (kg/yr)	Runoff Zinc (kg/yr)	Runoff Treated Zinc (kg/yr)	Runoff Copper (kg/yr)	Runoff Treated Copper (kg/yr)
Catchment A (Raingarden->Pods->Ponds)	3396	1	0.19	0.04	1.90	0.68	71.3	2.14	0.0136	0.0005	0.0051	0.0002
B Catchment (Proprietary->Pods->Ponds)	8897	1	0.50	0.13	4.98	1.82	186.8	7.29	0.0356	0.0058	0.0133	0.0016
C/D/E Catchments (Raingardens->Ponds)	13778	1	0.77	0.12	7.72	1.85	289.3	5.79	0.0551	0.0011	0.0207	0.0006
Footpaths (Infiltration Ponds)	3057	1	0.17	0.07	1.71	0.68	97.8	19.56	0.0000	0.0000	0.0000	0.0000
Roofs (Infiltration Ponds)	15559	1	0.87	0.35	8.71	3.49	77.8	15.56	0.3112	0.0622	0.0249	0.0075
Landscaping (Infiltration Ponds)	189313	1	10.60	4.24	106.02	42.41	8519.1	1703.82	0.1893	0.0379	0.0568	0.0170
Sum	**234000**		**13.10**	**4.95**	**131.04**	**50.94**	**9242.20**	**1754.15**	**0.6048**	**0.1076**	**0.1208**	**0.0269**
			Total TP Reduced	-5.82	**Total TN Reduced**	-70.744	**Total TSS Reduced**	-18486.85	**Total TSS Reduced**	-0.4774	**Total TSS Reduced**	-0.1135
			% TP Reduced	54%	**% TN Reduced**	58%	**% TSS Reduced**	91%	**% TSS Reduced**	82%	**% TSS Reduced**	81%

Options	% P removal	% N removal	% TSS removal	% Zinc removal	% Copper removal
Proprietary Device (Up-Flo)	48%	39%	87%	59%	70%
Infiltration Ponds	60%	60%	80%	80%	70%
Wetland	50%	40%	70%	60%	60%
Bioretention	60%	40%	90%	90%	90%
Total Bioretention + Wetland	80%	64%	97%	96%	96%
Total Proprietary Device + Wetland	74%	63%	96%	84%	88%
Total Bioretention + Infiltration Ponds	84%	76%	98%	98%	97%

R = A + B – [(AxB)/100]

For sediment R = 70 + 90 – [(70x90)/100] = 160 – 63 = 97% removal
For nitrogen R = 20 + 40 – [(20x40)/100] = 60 – 8 = 52% removal
For phosphorus R = 30 + 50 – [(30x50)/100] = 80 – 15 = 65% removal

Appendix 6 Mill Creek Example Measures, Winton Report

7 November 2024

To whom it may concern,

My name is George Watts, I am an employee of Winton Advisory Limited which is the parent company of the Applicant for the Ayrburn Fim Hub fast track application. I am a Landscape Architect with the role of Senior design manager. I have worked on the Ayrburn site since 2017 where I have been responsible for landscape advice, design and implementation. I have prepared the Ayrburn Film Hub Design report.

The purpose of this letter is to explain and set out the measures that the applicant has taken to improve water quality within the Wai Whakaata catchment and comment on how those measures are performing through monitoring. Measures have taken place alongside the development of the land into a hospitality precinct (Ayrburn) and a retirement facility (Northbrook Waterfall Park).

Measures taken to protect and improve stream health.

Catchment remediation is the key element of the Strategy being implemented by the Wai Whakaata Strategy Group. It is well documented that sediment load arriving at the lake is the main contributor to poor lake health. This is through the introduction of nutrient directly into the water column and indirectly when nutrient in the form of sediment is deposited on the lake bottom. When the lake stratifies nutrient detaches from the sediment to which it is bound making it available to algae tipping the lake towards a eutrophic state.

The applicants land contains 1.2km of the main tributary (Mill Creek) that flows to Wai Whakaata (Lake Hayes). Winton have undertaken significant catchment remediation since the land was purchased in 2016. They have also taken measures to ensure that development of the site has been done in such a way that it positively contributes to the health of Wai Whakaata.

There are two main ways to reduce sediment loads reaching Wai Whakaata. Firstly, defensive measures to stop the sediment mobilising into the creek and secondly trapping / containing sediment that has mobilised and is within the creek. Examples of these measures are below.

Defensive Measures
- Stabilising areas of erosion with vegetation cover
- Stabilising creek edges with vegetation and armouring (especially in fast flowing steep catchment areas)

Trapping / Containment Measures
- Sediment traps (within the creek)
- Sediment ponds (before water meets the creek)
- Wetlands
- Bioretention swales and raingardens

It is worth noting that when the applicant purchased the land it was part of a working farm (Ayrburn). The waterways were not fenced from stock, there were large areas of badly eroding banks (some pictured) and there was no riparian planting and margins. There were also large areas of wilding species which needed to be removed which can have temporary adverse effects between the time of deforestation and revegetation.

Since purchasing the land the applicant has taken steps to improve creek health alongside the development of the site into a hospitality precinct and retirement facility.

To date the applicant has:

1. Carried out native riparian planting to the creek margins that runs through the site 1.2Km (C.15,000 plants)
2. Planted C.30,000 native plants to stabilise the eroding banks, mainly within the Waterfall Park area of the site. (this includes the removal of 15 Ha of wilding pines, sycamores and other banned species.)
3. Created 3 sediment traps within the creek and gained consent to remove the sediment and volunteered consent conditions to remove the sediment periodically. This was carried out in close consultation with Friends of Lake Hayes, Hokonui Rūnanga and ORC.
4. Excluded stock from waterways
5. Introduced several bioretention ponds and swales to trap sediment and remove vehicle contaminants
6. Created an engineered wetland to trap sediment and remove vehicle contaminants
7. Carried out and continues to carry out predator trapping along the riparian margins.
8. Armoured C.600m of steep and fast flowing creek area, which includes the creation of habitat for the native Koaro (Native Galaxid) and separate habitat for trout as they are predators of the Koaro.
9. Created 2 x large ponds which intercept water from a large sediment laden catchment allowing it to slow and settle out. The ponds create a Koura (Native Freshwater crayfish) habitat, the applicant has obtained a fish farming licence from MPI with help and consultation from Hokonui Rūnanga and ORC.
10. Volunteered consent conditions to limit fertiliser use within the site to non-compound organic fertilisers.
11. Remediated and removed large volumes of Arsenic and lead contaminated land.

Although the wilding tree removal, predator, trapping and Habitat creation it is not directly related to water quality it has other environmental and conservation benefits. Similarly, the applicant has granted esplanade strips / public trail easements along the Mill Creek corridor to the waterfall, constructed cycle trails and opened a previously private stretch of creek to the public including creating playgrounds and an event space.

Much of work the applicant has completed has been in consultation and collaboration with, Friends of Lake Hayes, Hokonui Rūnanga, Otago Regional council, Fish and Game, and with design carried out using several expert hydrology, environmental, ecological, geotechnical and structural consultants.

Graphic examples of the work undertaken to date can be found in the Attached document: *Examples and analysis of construction and operational measures to protect stream health*
This is not a conclusive list, however it shows a pattern of water sensitive design and implementation using best practice design principals.

Monitoring Water quality within the site.

The applicant has installed data loggers that sample the creek water and measure turbidity on the upstream and downstream boundary of the site to establish if the water quality is improving or declining through their site.

These were installed in 2019. This is before construction began of the first stage of civil works, being the construction of Ayr Avenue. These data loggers are managed and calibrated by NIWA, they are telemetry and take samples of the water every 5 minutes. They give a reading in Nephelometric Turbidity unit (NTU).

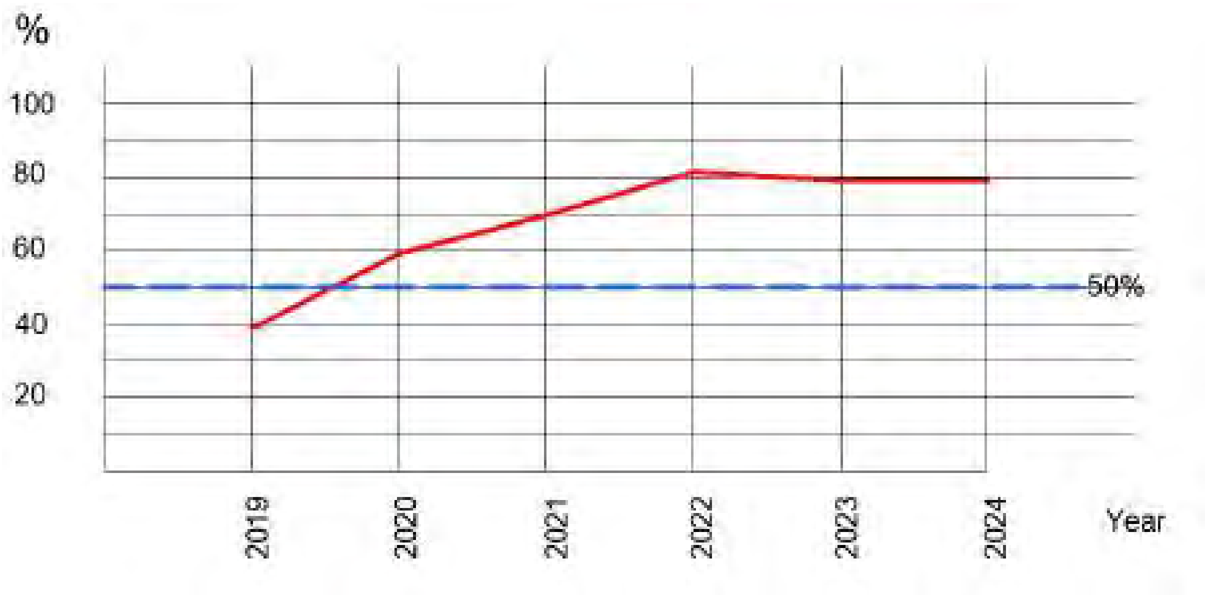
There is a consistent relationship between clarity NTU and sediment in the creek which is measured in total suspended solids (TSS). This has been established through the analysis of laboratory samples and reports.

Below is a table and 2 graphs which summarise 6 years of turbidity data from within the applicant's site. The table and first graph show the % of instances that the turbidity was better or worse downstream. The second graph shows a yearly average turbidity at the upstream and downstream turbidity monitors. A lower NTU number constitutes a less sediment.

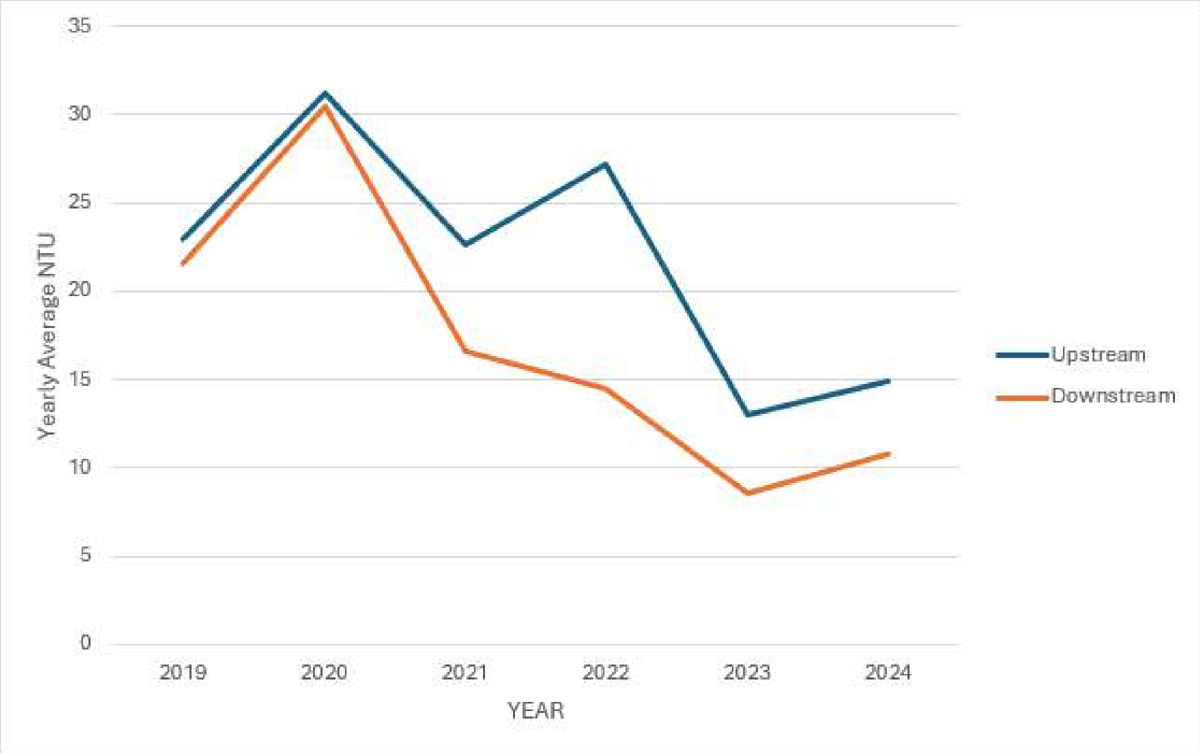
Year	Data Points	Percentage of times Turbidity worse downstream	Percentage of times Turbidity better downstream
2019	70,313	62%	38%
2020	105,408	42%	58%
2021	105,120	31%	69%
2022	85,276	16%	84%
2023	101,277	22%	78%
2024	88,611	23%	77%

(Table Source CKL Environmental)

Graph showing Percentage of times Turbidity better downstream



Graph showing difference between upstream and downstream turbidity. (yearly average) (A higher NTU number represents greater TSS therefore lower water quality)



(Graph Source CKL environmental)

Note the gap between the lines illustrates the difference in water quality (NTU). In recent times this gap is around 30% improvement though the applicant's site. This is a significant improvement when considering its scale compared to the entire catchment.

In summary, the monitoring results show that the measures taken by the applicant have improved water quality within the site which has significant benefits for the Wai Whakaata catchment. It is important to consider that this monitoring has been undertaken throughout an intensive period of development, with large areas of land open at a time. Generally, development releases sediment. In this case the applicant's work has not only mitigated the adverse effects of development on water quality, but improved it and the site has become an example of best practice in regard to water sensitive design.

Appendix 7 Author Bio's

Curriculum Vitae

Frances Deamer-Phillips – Environmental Engineer

CKL
Planning | Surveying | Engineering | Environmental

Professional Profile:

9 years' experience as a MEngSt qualified Stormwater Engineer, with experience in integrated stormwater design and management including water sensitive design, flow control, flood analysis, stream restoration and conveyance. I have experience in both public and private sector in New Zealand and the United States.

Qualifications:

- MEngSt (hons) Environmental Engineering
- BA (hons) Environmental Science

Professional Affiliations:

- Engineering NZ Member

Areas of Expertise:

- Water sensitive design
- Hydrological and hydraulic modelling
- Flood management
- Contaminant loading in stormwater runoff
- Engineering design of hydraulic structures
- Stream and wetland assessments and restoration

Employment History:

2019-Present	CKL
2018-2019	Parametrix, USA
2015-2017	Auckland Council
2014-2015	Tonkin & Taylor

Experience:

Stormwater Management Plan – Southern Gateway Consortium Development, Manukau, Auckland

Stormwater management plan for the development of large industrial park on Puhinui Road. Designed to meet SMAF 1 controls including detail design of several large wetlands and bioretention devices and at source stormwater treatment recommendations. Design includes the restoration and mitigation of several tributary streams running through the site.

15, 29 and 33 Galbraith Street Residential Development, Ngāruawāhia

Lead stormwater engineer on ongoing multistage residential development. The site is flat and prone to flooding which lead to development with council for a public stormwater line to convey 100yr ARI event to Waikato River. Navigated changing NES-FW rules on wetlands as a farm wetland was found on site and required new masterplan to protect and enhance wetland while maintaining baseflow to it.

Stormwater Management Plan & Contaminant Load Model – Ayrburn Domain Extension & Northbrook Retirement Village, Arrowtown

Development of Stormwater management plan for retirement village, vineyard, commercial buildings and associated parking in the Lake Hayes catchment suspectable to high contaminant loading. Robust treatment train designed to filter contaminants from site and supported by contaminant loading research.

Stormwater Management Plan – Northlake Residential Development, Wanaka

Stormwater Management Plan for final Stages of Northlake large scale residential development. Working alongside the civil engineers, flood modeller, urban designers and client to develop the final stages of the development including large stormwater management and attenuation devices and complex network to mitigate effects of development on downstream development and protect stream against erosion.

Forlong Rise Residential Development, Helensville

Lead the stormwater team on design of conveyance, treatment and floo modelling for 49 lot residential development. The site is steep dischargir to a stream/wetland system and undersized culvert under Awaroa Driv A system of both on-lot attenuation and communal raingarden f treatment and detention for stream protection was designed. On-l(tanks sized for flood attenuation. Consideration of downstream floodir and stream protection and restoration was integral to a sustainab development.

29 Prole Road, Residential Subdivision, Omokoroa
Lead Stormwater designer on a residential project in Omokoroa with various options for stormwater management on site or communal device shared with council projects. Working alongside WBOPDC to receive discharge consent for the site and potential communal device from BOPRC as WBOPDC discharge consents for Omokoroa had expired and new CMP has not been approved yet.

Festival Way Road Design, Ngāruawāhia
Through the initial assessment and design process for 15, 29 ad 33 Galbraith, the existing stormwater system of farm drains and intermittent pipes was found to be undersized and degraded. Best practical option for development in the catchment was a pipe network sized for 100yr ARI event to discharge residential area to Waikato River. It also included an upgrade and extension of Festival Way Road and Galbratigh Street. Lead stormwater engineer on the design of the conveyance, treatment of the new road, a large outfall to Waikato Rieve that was visually discrete from the river, and managing the flood modelling team.

Prices Road Extension and Upgrade, Manukau, Auckland
Designing stormwater network, bioretention and wetland device, and overland flow paths of extension of Prices Road over Puhinui Stream to connect the newly zones light industrial area of Southern Gateway to existing industrial area to the south of Puhinui Stream. Included scour design and stream restoration around bridge abutments and designing bridge to standards with sufficient freeboard above stream.

Stormwater Management Plan – Outdoor Boating Club, Auckland
Design of innovative water sensitive design and stormwater recycling system for renovation of boat parking/launch at the Marina. Environmental Management Plan for the treatment and management of hazardous materials found on site due to being in an Industrial Trade Activity area. Delivery of design to meet the needs client, community, and Auckland Council water quality controls to limit impact of site on the health of Hobson Bay.

Curriculum Vitae

Bronwyn Rhynd – Director | Environmental Engineer

Professional Profile:

Bronwyn has over 20 years' experience as an environmental engineer and has been involved with many of New Zealand's environmental and civil engineering projects. Beginning her career as a civil engineer, Bronwyn has gained a reputation as one of New Zealand's leading experts in the water resource area, with a focus on stormwater treatment, disposal and management. Her approach to land development projects is realistic to ensure that the client's aspirations and environmental outcomes go hand in hand.

Professional Affiliations:

- CPEng. – Engineering NZ
- IntPE – Engineering NZ
- FEng. – Fellow Engineering NZ
- Member of Water NZ

Areas of Expertise:

- Project Management
- Stormwater Management
- Design
- Environmental Management
- Flood Risk Assessment
- Expert Witness
- Climate adaptation and resilience

Employment History:

2015–Present CKL
2004-2015 Stormwater Solutions Consulting Ltd
2001-2004 Environmental Engineering Consultant
1998-2001 Pattle Delamore Partners

Experience:

Expert Witness

Provision of expert witness for several environmental court and high court hearings involving multiple disciplines, defendants and plaintiffs. Focus areas of expertise: Water Resources, Stormwater management, stormwater design and construction, flood management and mitigation.

Iona Stormwater Management Plan, Havelock North

Stormwater and flood management strategy entailed designing green spaces around the urban environment, integrating natural land contours, and avoiding unnecessary earth movement which could disrupt the natural water pathways. Bronwyn lead the team to develop flood and integrated stormwater conveyance models to identify optimal locations for stormwater facilities, ensuring they fit seamlessly into the urban landscape. This integration prevented urban disruption and maintained the natural flow of water, creating a harmonious environment for residents. The design philosophy aimed to avoid intrusive elements like large retaining walls, instead fostering a sense of cohesion and natural beauty. Bronwyn's involvement included liaison with other consultancy disciplines, HDC and HBRC to ensure the SMP was well understood.

Mission Hills, Napier

The 246ha development has progressed from the initial scheme plan through to current construction of the first stages since 2021, with the stormwater and overland flow path management being integrated into the urban design and landscape outcomes. This project is unique with respect to the topographical changes that create the plateau above the receiving environment. This provides an opportunity to focus on environmental outcomes that truly integrate with recreational and green infrastructure. CKL provides the low impact design influence to honor Te Mana o te Wai with great success with a treatment train approach which mitigates detrimental effects of this urban outcome for the greenfield development.

Bronwyn led the team , working collaboratively with other consultants to ensure that NCC and HBRC requirements are fulfilled whilst not forgoing the essence of the projects delivery has been the cornerstone of the design. Working side-by-side with NCC and HBRC to provide technical expertise to minimize Councils' review process.

Experience:

Morrinsville Stream Catchment Management Plan, Morrinsville

Stormwater management strategy to support the Morrinsville Stream catchment to enable delivery of the full district plan urban form and mitigate effects of development in brownfields and greenfields areas. Options for mitigation of effects and consultation with team leaders of council. Stormwater and flood modelling lead. Presentation to both stakeholders and councillors to inform the outcomes of the project as these progresses. Engagement by Matamata Piako District Council (MPDC).

T11 Growth Cell, Te Awamutu – Private Developer

Development of an integrated approach to the stormwater management of the growth Cell T11 at Te Awamutu. Close liaison with local and regional authorities to meet the district and regional plan as well as enhance environmental outcomes. Focus on flood modelling that will benefit the assessment of effects process and guide urban form to deliver a new suburb of circa 1000 lots including local town centre. Water sensitive and low impact techniques integrated into the stormwater strategy for this growth cell.

Te Awa Lakes, Hamilton – Private Developer

Development of stormwater management strategy to support plan change for the proposed multi land use development at the northern entrance to Hamilton. Stormwater management including the integration of recreational lakes and commercially operated adventure park into the overall water sensitive aspects of the development. Water balance assessment of the viability of water re-use for both commercial and residential aspects of the project. Preparation of evidence for and attendance at hearings involving several consultants with individual expertise to provide a successful outcome for the client. Causing and expert conferencing to assist in the hearing process.

Rotokauri Development, Hamilton

ICMP stormwater management for the catchment wide ICMP requirements. Stormwater and ecological delivered in a staged approach to the large residential development of circa 100ha. Raingardens and centralised wetland for treatment of phosphorus removal. Greenway channel to manage the overall ICMP catchment. Temporary stormwater pumpstation, a syphon system and large open top manholes supporting fish passage.

Whenuapai Residential Development, SMP, North Auckland

Stormwater management options assessment to understand the best practical option of management of stormwater for this new residential development. Consultation with key stakeholders from the property developer, council, building company and ultimate property owners ensured that the successful long-term solution was applied for this area of Auckland. Delivery of the stormwater management plan under the newly formed Auckland Council and the Auckland Unitary Plan. Expert witness at hearings for plan change.

Water, Sanitation, Hygiene services (WaSH) project, Vanuatu

Working collaboratively with UNICEF to create a Bill of Quantities Toolkit which will help facilitators and DWSSP participates create a plan for improvements to water and sanitation facilities for schools, communities and healthcare providers. The toolkit bridges the gap between risk assessment and implementation. This toolkit paves the way for improvements to the access of drinking water and sanitation for Vanuatu.

Keepa Road, Whakatane - Lysaght Developments Ltd

Industrial and residential development options explored for a subdivision in Keepa Road, Whakatane. Stormwater Management, Flood risk assessment and Hydrological and hydraulic modelling for multipurpose development scenarios of circa 10ha. Consultation with local and regional authorities to ensure flood mitigation requirements were addressed. Adjoining landholdings incorporated complex flood management through canal and pump station operations.

Ranulf Street, Rotorua – Private Developer

A residential development project that required multi consultant team to implement a robust solution to land development. Integration of a stormwater management system in the private realm to meet the requirements of Rotorua District Council. Extensive option analysis to maximize the at source discharge whilst managing risks to the public system downstream.

SH16 & 20 Waterview Connection

Review of the stormwater management design for the Waterview connection during the Board of Inquiry hearing to decide the resource consent application. Participated in expert witness caucusing and provided recommendations to the Board of Inquiry through the hearing process.

Curriculum Vitae

Dorcas Adjei-Sasu – Senior Engineer – Environmental

CKL
Planning | Surveying | Engineering | Environmental

Professional Profile:

Dorcas is a civil engineer with 16 years of experience. Dorcas has worked and gained experience in 3 different countries. She has previously been involved in mine water management for different mines including, coal, gold, and diamond mines. In this role, she become proficient in the use of risk modelling software GoldSIM. She also gained experience early in her career as a geotechnical engineer specialising in slope stability assessments and modelling using SLIDE 2D software, dam design and on-site construction supervision. She gained experience in Civil 3D software in this role.

Qualifications:

- BSc. Civil Engineering

Professional Affiliations:

- CMENG. – Engineering NZ
- PR. Eng. – Engineering Council of South Africa

Areas of Expertise:

- Catchment planning
- Flood risk assessments
- 1D-2D hydraulic modelling using ICM, TUFLOW, DHI (Mike Urban, +) and HEC-RAS software
- Stormwater management
- QGIS software

Employment History:

2023-Present	CKL
2022-2023	WSP Auckland
2018-2022	WSP Hamilton
2014-2017	Golder Associates (SA)

Experience:

Various Land Development projects , Environmental Engineer

Dorcas managed and oversaw the execution of land development projects Her responsibilities included conducting comprehensive flood risk assessments, implementing stormwater management strategies, and liaising with councils (QLDC, AC, TCC, HCC, BPoRC etc) to secure resource consent and EPA approvals, ensuring all projects adhered to environmental regulations and standards

iReX Terminal Design Services – KiwiRail Waitohi Picton Terminal, Stormwater Modeller and Reviewer

Involved in the design of the terminal infrastructure in both Picton and Wellington that need to be redeveloped and configured to support the larger dimensions and capacity of new ships with rail capacity that will replace the current Interislander fleet. Dorcas is part of the team developing and reviewing the stormwater model for the Picton Terminal to assess flood risk to current and future infrastructure.

NZUP SH6 upgrades – Wakatipu Transport Programme Alliance, (QLDC and Waka Kotahi) Principal Stormwater Modeller

Principal modeller for the NZ Upgrade Programme (NZUP) being a significant investment for public transport and walking and cycling upgrades on state highway 6 and 6a funded through the NZUP. This involves supporting design team through optioneering and design confirmation and feasibility.

Wairoa Model Conversion – Tauranga City Council, Reviewer

Internal reviewer of the DHI to TUFLOW conversion on the Wairoa model. This was necessary to create an up-to-date consented base model of the Wairoa catchment that can be used in TCC planning/ hazard identification and understand the level of risk associated with the proposed rezoning and subsequent landform alterations regarding flood hazards and any change in risk to other land within the Wairoa River catchment.

Cambridge to Piarere Stormwater Model (2021-2022) – Waka Kotahi, Stormwater Models Reviewer

Supported the stormwater model development for the Cambridge to Piarere State Highway 1 Improvement Project. This involved leading the model development, reviewing models and hydrological calculations for the infrastructure.

Grey Street Stormwater Model (2023) – Timaru District Council, Stormwater Models Reviewer

Kainga Ora proposed a development in the land available between Grey Road and Theodosia Street and required information from TDC to confirm finished habitable floor levels for the development. Dorcas was the reviewer for the model build for Timaru District Council (TDC) as part of their future works programme to complete hydraulic model builds for the various catchments in Timaru.

Experience:

Waikato District Subdivisions consenting- Waikato District Council, Project Manager

Dorcas led a team to help Waikato District Council to fill a deficit they had in Engineers assessing subdivision consenting. She pulled together a national team of 6 to integrate with councils' engineers to assess subdivisions for transport, geotechnical and stormwater assessments. Based on its success and feedback the team secure a further $150,000 in fees to provide more support until 2023

Wellington Water Stormwater Modelling Peer Reviews – Wellington Water Limited, Reviewer

Wellington Water (WWL) has engaged several consultants to build stormwater models (ICM) of all the catchments in the Greater Wellington region (consisting of Porirua, Wellington, Lower Hutt and Upper Hutt). Dorcas is a part of the team that challenge and review these models on behalf of WWL. As part of this role, she draws on her experience to assess whether the outputs are defendable. This includes following a formal Quality Assurance process and providing challenge to assumptions, inputs, and data suitability.

Ōpōtiki township model conversion (2021) – Ōpōtiki District Council, Stormwater Model Reviewer

Dorcas reviewed the conversion of the 2019 TUFLOW stormwater model for Ōpōtiki township to Infoworks ICM. This involved building the model based on the TUFLOW set up and verifying compatibility of results. Once the comparison was confirmed to be reproducing the same results as expected. The model was updated with the latest infrastructure upgrades. The Infoworks model was a 1D- 2D rain on grid coupled model including river boundary conditions, river reaches and 1D ponds.

Bethlehem East Stormwater Management Plan (2020) Tauranga City Council, Project Manager/ Stormwater Engineer

Dorcas was project manager for the team that helped create two stormwater management concepts, one based on conventional stormwater management, and one based on Low Impact Design. She assisted in comparing these options using the 'More than Water' tool and cost comparisons. As part of this project Dorcas presented the outcomes of the project at the Stormwater conference in 2021

Bethlehem West Carmichael Road Flood Management Options Assessment (2020) Tauranga City Council, Stormwater Engineer/ Project Manager

Dorcas was project manager for the conceptual design of three stormwater management options to reduce upstream flooding and direct flow to the Wairoa River. The concept design required hydrologic and hydraulic calculations and modelling options in Mike DHI to size pipes and inlet structures.

Chartwell Stormwater Management Plan. Chartwell Investments Ltd, Stormwater Modeller

This project involved developing stormwater management plans to support stormwater discharge permit being sought from Waikato Regional Council and demonstrate that a solution can be delivered to provide the necessary stormwater infrastructure. This project involved assessment of the different stormwater solutions for flood management and treatment due to the unique nature of the terrain.

Tauhara Ridge Master planning- Taupō District Council – Water Modeller

Experience:

Water supply modelling and master planning for the new developments for the 2025 to 2050 future developments. This project involved the assessment of future developments. Analysing best supply options and modelling the effects of 10 future development areas on existing infrastructure. As part of the project, the modelling was used to determine asset acquisition and renewal timelines.

Curriculum Vitae

Kellie Whisker – Environmental Team Leader

CKL
Planning | Surveying | Engineering | Environmental

Professional Profile

Kellie is an Environmental Consultant for CKL, working within the Environmental Team for 19 years. She has experience in the design of stormwater management systems and ecological assessments for medium to large infrastructure and land development projects in the Auckland, Waikato and Canterbury areas. Her varied portfolio of work has also included industrial and trade assessments and associated environmental management plans, along with detailed design of low impact bioretention and proprietary stormwater treatment systems.

Qualifications

- BSc – Biological & Earth Sciences - UoW
- Post Graduate Diploma - Environmental Science - University of Auckland

Professional Affiliations

- Member of EIANZ

Areas of Expertise

Stormwater Management and Design for:

- Residential properties
- Green and Brown Field developments
- Building and Resource Consents
- Engineering Plan Approval applications

Environmental Assessments:

- Industrial and Trade Assessments
- Environmental Management Plans
- Environmental Assessments (Fresh Water)
- Stream Ecological Assessments (SEV)
- Infrastructure Assessments
- 1D Flood Risk Assessments

Employment History

2005–Present Stormwater Solutions / CKL

Experience

Green Gorilla Drury South

Green Field waste transfer facility/ resource recovery - design of stormwater and wastewater (Trade Waste) treatment systems and harvesting tanks.

Green Gorilla Riverhead

Greenfield development of resource recovery site in Riverhead including design of stormwater and wastewater infrastructure for conveyance, storage and treatment of water in line with subdivision resource consent conditions.

Green Gorilla Onehunga

Design and upgrades of extensive stormwater treatment devices (both bioretention and proprietary systems) and associated alterations to original ITA and Stormwater Discharge consents. Trade Waste permit applications. Surface design and stormwater treatment for new carpark located on a landfill and within the strict constraints required for this.

Wetland/Spring Planting Plan – Haultain Street, Kihikihi

Create a planting plan for a wetland to service the subdivision development at Haultain St, Kihikihi. This is a challenging plan and construction due to the need to retain and naturalise a natural spring.

Stream Ecological Evaluations (SEV) Boundary Road

An SEV assessment was performed for an urban stream within a tributary of the Slippery Creek, Pukekohe. Onsite mitigation and planting plans were produced for the stream as well as for an offline wetland to be utilised for treatment of the site stormwater runoff.

Precious Metal Recycling Environmental Management Plan – 350 Neilson Street

Creating an environmental management plan for the extensive site processes to ensure maximum recovery of precious metals and ensuring maximum treatment for wastewater from the various recovery processes including chemical and furnace-based extractions. Trade Waste Permit applications and updated air quality management plan.

Saint Patricks Catholic School Te Awamutu

Design stormwater management system including new soakage devices for stormwater disposal from a new administration building.

Appendix 8 Peer Review response

MEMO

Planning | Surveying | Engineering | Environmental

To:	Lauren Christie, Waterfall Park Developments Ltd	Date:	6th August 2025
From:	Bronwyn Rhynd, Environmental Engineer	CC:	
Reviewed:	Dorcas Adjei-Sasu, Environmental Engineer	CKL Ref:	A20254
Re:	Ayrburn Screen Hub – Stormwater Management Plan – Peer review response		

The Stormwater Management Plan (SMP) for the Ayrburn Screen Hub sets out how stormwater will be managed to ensure the fully operational site does not have any adverse effects on the environment.

Peter Christensen from Storm Environmental conducted a peer review of the SMP, working collaboratively with CKL to enhance the stormwater management strategy where improvements were identified. The peer review report, addressed to Waterfall Park Developments Ltd and dated 23 July, outlines areas where additional assessment could be beneficial.

A summary the Peer Review findings and an overview of the SMP responses are as follows:

- Flooding effects:
  - Peer reviewer findings consider:
    - the flood modelling methodology adopted is appropriate
    - flood modelling undertaken is appropriate for the assessment of effects of the *proposed* development.
  - No further refinement required by CKL
- Stormwater Quality:
  - Peer reviewer findings:
    - Design rainfall;
      - Water Quality Flow (WQF) is conservative at 10mm/hr
      - Water Quality Volume (WQV) from 1/3 of the 2yr rainfall is standard approach
      - No further refinement required by CKL
    - Treatment train approach
      - Roofs are low contaminant generating surfaces
      - Treatment through infiltration basin is appropriate
      - No further refinement required by CKL
    - Treatment device design
      - Raingarden infiltration rate is too high
      - CKL response –
        - Infiltration rate for water quality used = GD01 as per QLDC CoP
        - Sensitivity assessment conducted for smaller design footprint and compared to the treatment quality
        - Outcome is reduction in contaminants and overall water quality improvements
      - Infiltration basin ground water table separation acceptable
    - Contaminant load assessment
      - Baseline load of Sheep and beef farming not representative of the current status.

ISO 9001 certified Equal Assurance

- Removal rates for devices could be more up to date
- CKL response –
    - Sensitivity assessment for changes in baseline to lifestyle and reduction in treatment rates undertaken
    - Outcome is there is water quality improvement from existing status