

Bannockburn South East Precinct Structure Plan– Stormwater Drainage Design

CONCEPT DESIGN REPORT

September 2025

alluvium



Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This draft report has been prepared by Alluvium Consulting Australia Pty Ltd for Victorian Planning Authority (VPA) under the contract titled 'Bannockburn – Stormwater Drainage Functional Designs and Costings'.

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1 Introduction

Alluvium has been engaged by Victorian Planning Authority (VPA) to prepare concept and functional drainage designs and associated cost estimates for the Bannockburn South East (SE) Precinct Structure Plan (PSP). The VPA is working in partnership with Golden Plain Shire Council (GPSC) to develop the Bannockburn SE PSP.

This report summarises proposed preliminary concepts for the area, including existing conditions and issues as they relate to stormwater management in the project area. The aim of this report is to cover the analysis undertaken to develop stormwater management options to a conceptual design level.

This stormwater drainage strategy sets out the stormwater related infrastructure requirements for the precinct that will inform the Bannockburn South East PSP, which will guide the future development of all land within the precinct; as well as inform the cost the suite of infrastructure required to support development of the land. This report details the designs which have been developed to a detailed concept level.

1.1 Location

The Bannockburn South-East PSP covers approximately 522ha of area and is located 16km north-west of Geelong and to the southeast of the existing Bannockburn township (Figure 1). Bannockburn is the largest urban centre in the Golden Plains Shire. The site has predominantly been used for agricultural purposes. The area of interest is bounded by Charlton Road to the north, the rail line to the south, Bruce Creek to the west and existing property boundaries to the east.

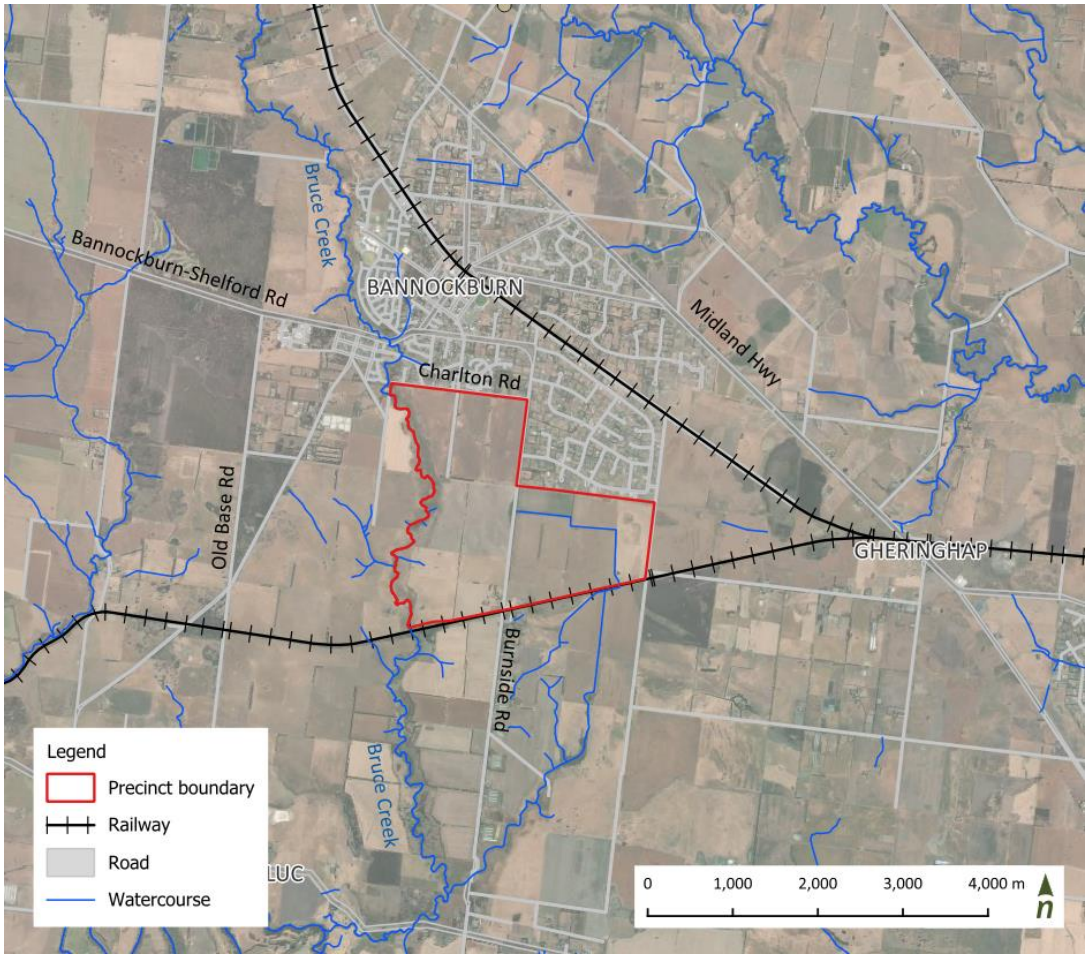


Figure 1. *Bannockburn South East PSP (red outline) within the Western Geelong Growth Area*

1.2 Project background

The Bannockburn Growth Plan has been developed to guide the sustainable development of Bannockburn to the year 2050. Of significance to the development of the drainage strategy the plan identifies several objectives in relation to water and the environment including:

- Interpret and manage areas of cultural significance and embed cultural values into the urban landscape.
- Identify and protect sites of historic heritage significance.
- Understand the extent and ensure the protection of state and federally significant biodiversity.
- Protect existing and identify new open space and waterway corridors to provide habitats for biodiversity.
- Support and provide opportunities for residents to connect with their environment for improved health and wellbeing.
- Ensure the function and quality of existing water assets are not negatively impacted by development.
- Facilitate a sustainable approach to water management by embedding Integrated Water Management (IWM) principles into future growth areas.
- Ensure risks associated with bushfire and flooding are appropriately mitigated.
- Identify buffers to areas of adverse amenity and plan for compatible uses within these.
- Ensure a built environment that is environmentally sustainable and strive for a zero net carbon emissions development.

A co-design plan of the growth area is shown in Figure 2.

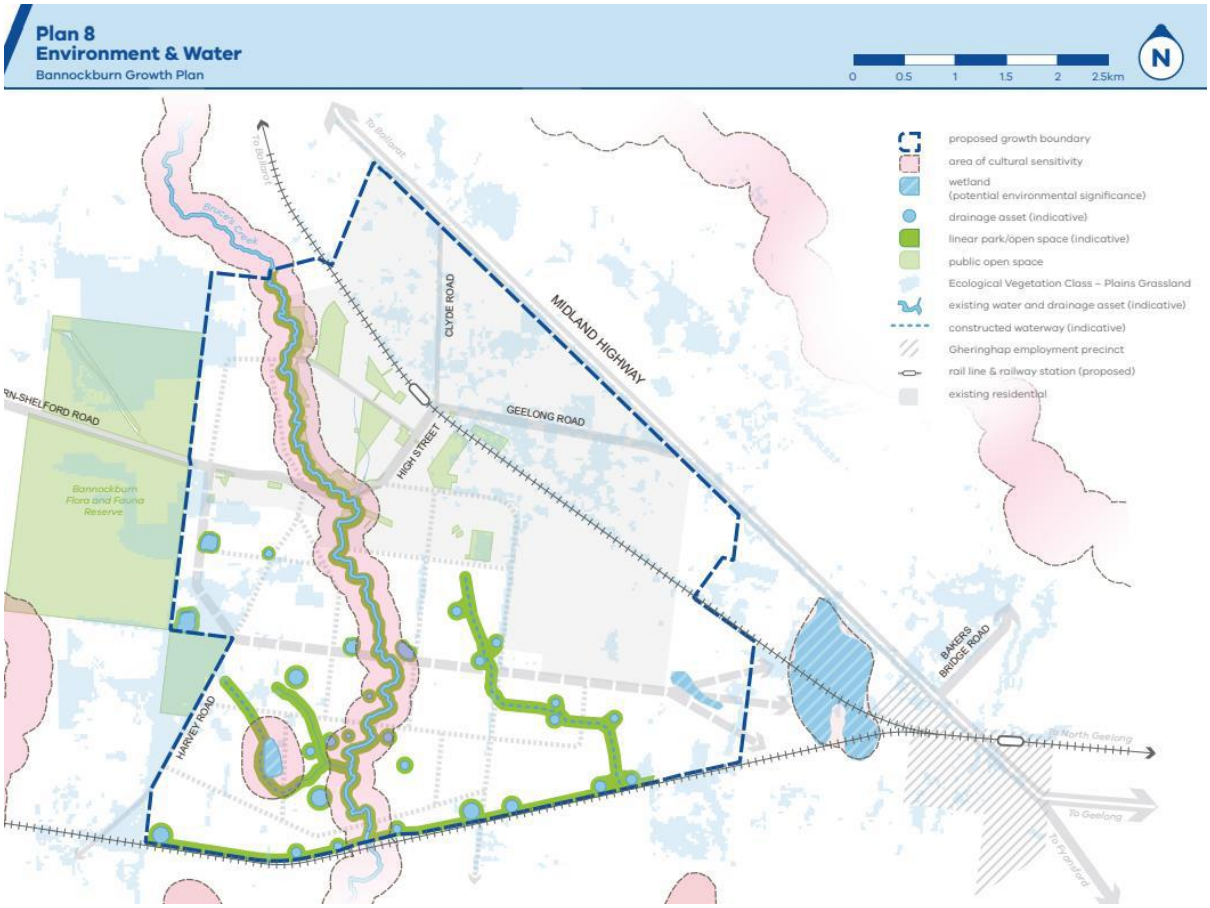


Figure 2. *Bannockburn Growth Plan – Environment and Water (VPA 2021)*

Drainage strategies will need to respond to the unique topography (generally residing on flat plains, with much of the area draining into Bruce's Creek) and drainage patterns of the growth area to manage flood risks, protect waterway environs (including nationally significant fauna species with the potential to occur within the growth area - including the Golden Sun Moth, Striped Legless Lizard and Growling Grass Frog), and to minimise runoff and pollution. The careful planning of drainage assets is critical to support these values and protect environmental assets such as Bruce's Creek and the Bannockburn Flora and Fauna Reserve.

Additionally, the use of recycled water for urban, environmental and agricultural uses has been identified as a key opportunity for Bannockburn. The Bannockburn IWM Strategy (under development by Spiire 2022) outlines IWM initiatives as part of a future IWM strategy for Bannockburn. Key to its success will be the integration into the drainage strategy refinement for the Bannockburn South East PSP (this project).

1.3 Stakeholders

Golden Plains Shire (GPS) is the local drainage authority for all urban land in the region, while the Corangamite Catchment Management Authority (CCMA) is the floodplain manager and Barwon Water the water supply authority. Bannockburn is in Wadawurrung Country, and Wadawurrung culture, heritage and values should be at the centre of the design. VicTrack and the Australian Rail and track Corporation (ARTC) are also important due to the railway line. Together, these are key stakeholders (along with community/landowners) to this project.

1.4 Project scope

The aim of this project is to review the existing stormwater management strategy and develop concept and functional designs of the assets and associated costings, to ultimately inform (and assist) the preparation of a future PSP and Development Contributions Plan (DCP) for the precinct. The overall package of work will provide strategic direction and feasible solutions to guide future development growth for the area including:

- A confirmation of existing and future stormwater drainage needs and challenges in an integrated manner
- Infrastructure solutions that achieve optimised benefits with least impact on land, local values and people
- Preparation of appropriate functional designs (with costings) for all proposed water-related infrastructure solutions that offer:
    - multi-functional / multi-outcome community and council benefits
    - best practice services of the land, its future development, and the wellbeing of the existing and future community.

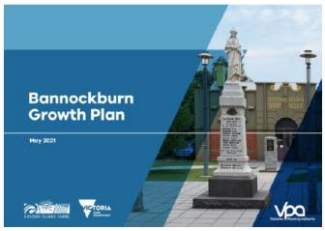
This report details work undertaken up to the conceptual design stage. The functional designs will follow on from final feedback and acceptance of the concept layout by Council and the VPA. The concepts designs presented in this report are relatively detailed concept designs, so to be able to confidently inform land take and cost estimates.

1.5 Strategic context

Planning for growth in Bannockburn has been driven by the Bannockburn Growth Plan (GPS and VPA, 2021). It is recognised that water has been a key influence on the development of this region, through both pioneering irrigation practices that have enabled the towns' growth and the significant flooding that has affected the area in 1916, 1974 and 1993. The sustainable management and use of surface waters (runoff) in the landscape, and the appropriate guidance for urban development adjacent to riverine floodplains, are vital to the continued growth and water resilience of the region.

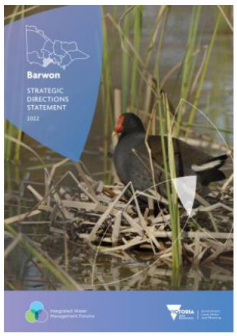
Similarly, the IWM Forum vision for the Barwon has a focus on Working together through sustainable water management to enhance urban landscapes and maximise amenity, environment, and economic outcomes for our communities. In our experience with other IWM plan and PSPs, a clear and shared vision is critical in setting the focus and achieving intended outcomes.

The following summarises key strategic documents that are directly relevant to, will influence, and/or align with key outcomes of this project and the vision for the Bannockburn South East PSP.



Bannockburn Growth Plan (2021)

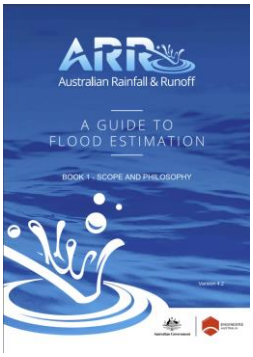
GPS and the VPA developed the Bannockburn Growth Plan to provide a vision and guide the sustainable development of these areas to the year 2050.



IWM Forum – Strategic Directions Statement (SDS) (2018)

The SDS has a region-specific vision, outcomes, objectives, and priority actions. Collaboration between Traditional Owners, Councils, Water Corps, CMAs, and DEWLP, with representatives from a cross section of these institutions has led to shared ideas, buy-in, and momentum. Opportunities identified through this project will demonstrably align with the following outcomes and their associated objectives:

1. Safe secure and affordable supplies
2. Effective and affordable wastewater systems
3. Reduced flood risks
4. Healthy and valued waterways, and Gippsland Lakes
5. Healthy and valued urban landscapes
6. Community values are reflected in place-based planning.
7. Jobs, economic benefits and innovation



Australian Rainfall and Runoff (ARR): A Guide to Flood Estimation – Climate Change Considerations, Chapter 6, Book 1 (Version 4.2 2024)

This chapter has been recently updated to reflect current climate change guidance. As stated in ARR2019, our climate is changing, and therefore unadjusted historical observations are no longer a suitable basis for design flood estimation: they must be adjusted to reflect the impacts of rising global temperatures. This chapter provides guidance on how to do this. This guidance has been adopted for this project.

1.6 Background information and previous studies

For this assessment, the following sources of information have been drawn on:

- Australian Rainfall and Runoff (ARR): A guide to flood estimation (Commonwealth of Australia (Geoscience Australia), 2019) and ARR Data Hub
- Urban Stormwater - Best Practice Environmental Management Guidelines (Victorian Stormwater Committee, 1999)
- Infrastructure Design Manual (version 5.4, September 2022)
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Guideline (Melbourne Water, 2024)
- Wetland Design Manual (Melbourne Water, 2020)

- Constructed Waterway Design Manual (Melbourne Water, 2019)
- Waterway corridors: guidelines for greenfield development areas within the Port Phillip and Westernport Region (Melbourne Water 2013).
- West Region – drainage works reimbursement rates (Melbourne Water 2024).
- Guidelines for Development in Flood Affected Areas (DELWP, 2019).
- Bannockburn Growth Plan – Environment and Water (VPA 2021)
- Placed Based Plan – Post stakeholder consultation working draft (June 2024)
- Provided shapefiles (Cultural sensitivity, Heritage data, Arboriculture data and Ecological Vegetation classes (EVCs) data, council stormwater pipes and pits, contours)
- LiDAR (June 2021 at a 50cm resolution).

Bannockburn South West PSP stormwater design (Alluvium, 2019)

Alluvium undertook a stormwater drainage assessment for the Bannockburn South West precinct in 2019. This assessment identified a drainage plan to the manage site's surface water with future developments and also integrated water management opportunities within the precinct.

The assessment proposed five wetland retarding basins and one sediment basin retarding basing to manage pre and post development stormwater flows and stormwater treatment to meet pollution reduction targets (Figure 3). Assets are not proposed down the bottom of the steep escarpments, adjacent to Bruce's Creek.

IWM opportunities identified through the study:

- Harvesting treated stormwater from the wetlands and using this to irrigate open space
- Rainwater tanks connected to houses to reduce potable water demand, irrigate backyards and provide cooling opportunities
- Passive tree irrigation through gravel trenches at the street-scale (alongside roads)

Of relevance to this project is the catchment area to the east of the precinct (RB/WL6 in Figure 3) is now part of the Bannockburn SE PSP area. Hence the design considerations and constraints discussed in this previous study were considered and revised when proposing stormwater assets for this catchment.

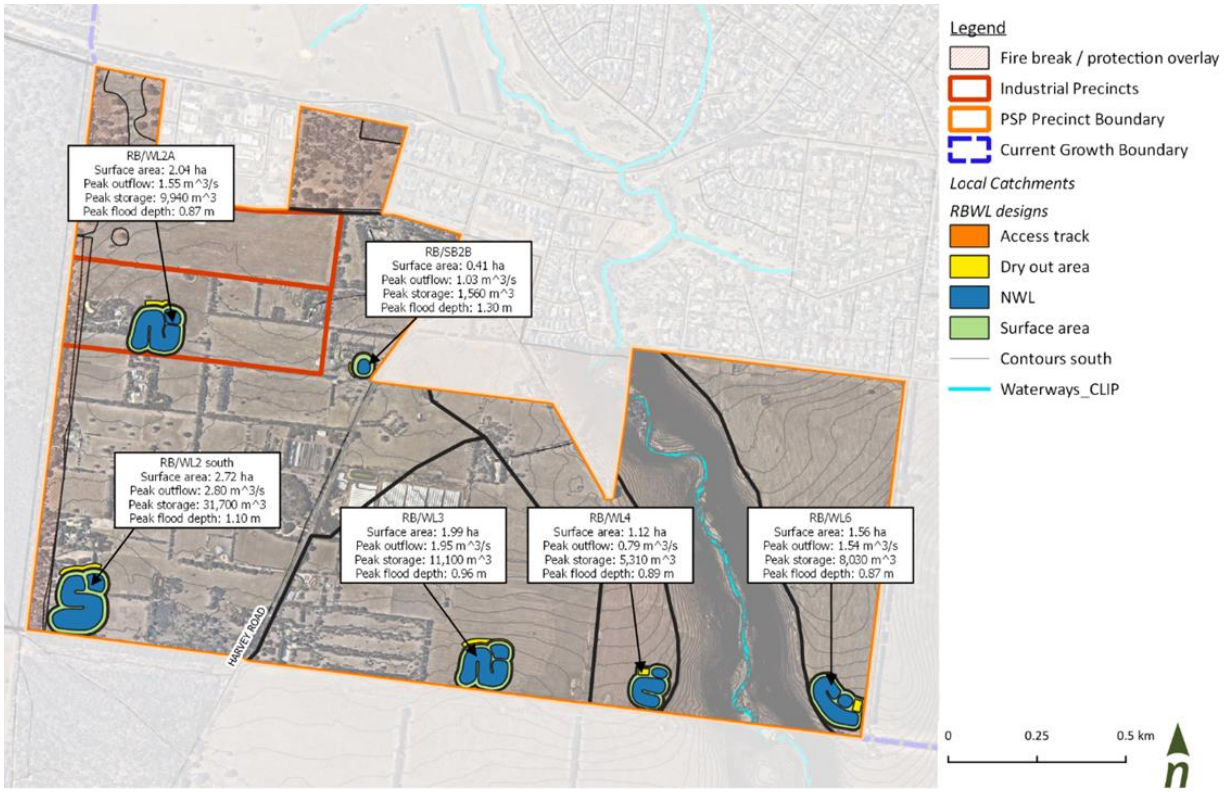


Figure 3. *Bannockburn South West PSP stormwater design (Alluvium, 2019)*

Bannockburn Growth Plan - Bannockburn catchment assessment (Alluvium 2020)

Alluvium conducted a preliminary catchment assessment for the Bannockburn growth plan investigation area in 2020. This assessment built upon the previous work done by Alluvium for the Bannockburn South West Precinct in 2019. The purpose of this initial catchment assessment was to assess the area at a larger scale than was previously done, and to identify opportunities for stormwater management across the growth area. Catchment mapping, high-level treatment modelling, and asset locating was undertaken. No hydrologic modelling was undertaken to size and storage requirements.

The catchment assessment identified many numerous wetlands and waterways to manage pre and post developed surface water from the growth plan area (Figure 4).

This work will be revised as part of this project.

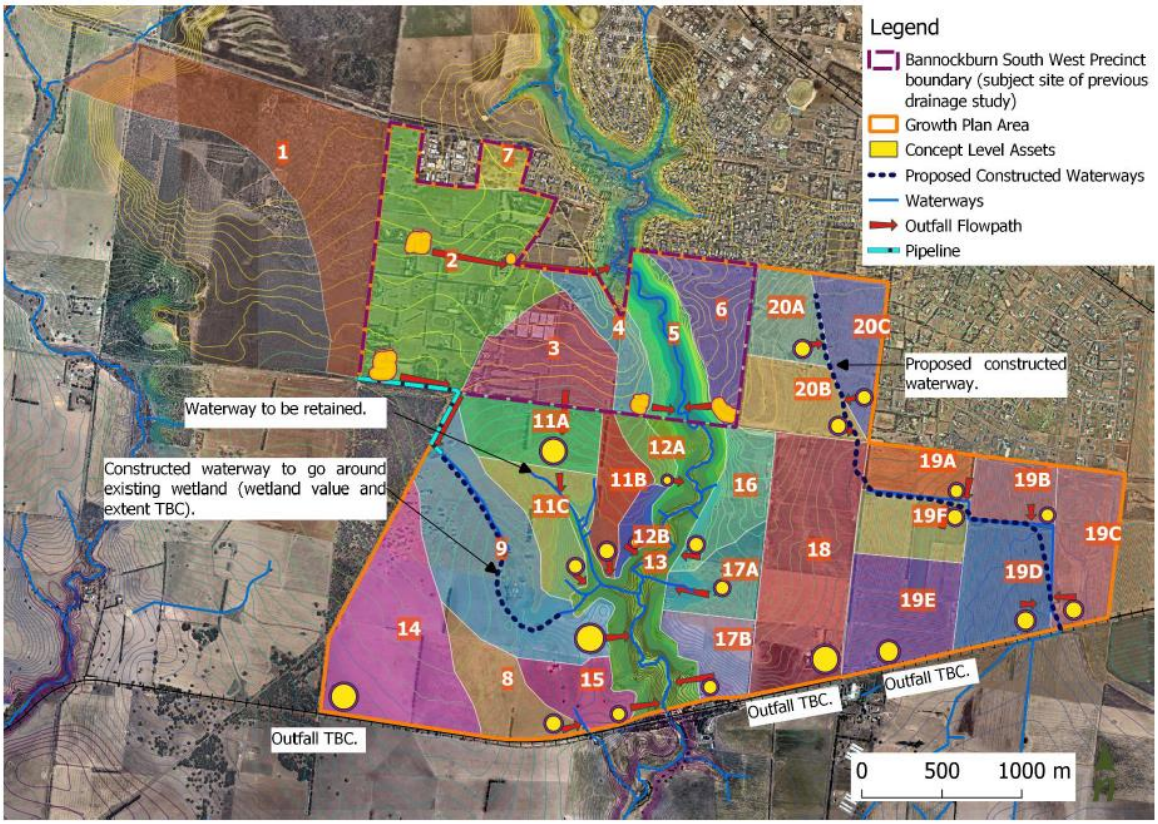


Figure 4. *Bannockburn growth investigation area concept assets (Alluvium, 2020)*

Bannockburn South East PSP Draft Preliminary IWM Issues and Opportunities Report (Spiire, October 2022)

An assessment of Integrated Water Management Issues and Opportunities for Bannockburn South-East Precinct was conducted by Spiire in 2022. This assessment has reviewed previous work undertaken by Alluvium (2020). A summary of the assessment and relevant opportunities for this project are provided below:

- WSUD assets may be located within the high voltage electricity easement. This provides the best use of this empty easement space.
- Stormwater harvesting from constructed wetlands for irrigation of open space.
- There is potential for consolidating wetlands into a smaller number of larger wetlands, subject to detailed assessment. This would reduce the maintenance burden for Council.
- Investigation into the potential role for the eastern waterway to contribute to the stormwater management strategy, open space strategy and transport strategy.
- These is potential for leaky wetlands (baseflow to Bruce Creek).

2 Existing conditions

2.1 Site visit

A site visit was undertaken on Friday 22nd March 2023, attended by Jenny Butcher and Stuart Cleven from Alluvium. The site visit was an opportunity to gain an appreciation of the precinct, identify site values and constraints, identify infrastructure and features not captured in the desktop assessment, and opportunities for stormwater management. Some features identified on site included:

- A small RB on Charlton Rd, which would be controlling flows from existing residential areas entering the precinct (Figure 5, picture 1).

- A small, straight, earthen channel running through the paddock adjacent to Charlton Rd ((Figure 5, picture 2), eventually connecting to the channel in the south-eastern section of the PSP (Figure 6).
- A large wet area to the west of Burnside Rd, in the centre of the PSP. Any existing values associated with this area should be confirmed ((Figure 5, picture 4).
- Many farm dams in valley lines sitting above the Bruce Creek corridor (Figure 5, picture 5). There may be an opportunity to have wetlands in these same locations.
- There are several existing culverts under the railway line. These are small and shallow. These are currently the only outlet for the precinct to the south. These are discussed further in section 2.6, along with photos.
- A channel runs adjacent to the northern boundary in the northeast of the precinct, capturing flows from the residential area to the north (Glen Avon Estate). These flows are then transferred south via another channel (Figure 5, picture 6) to the existing channel which eventually outfalls via the railway. It is unclear what retardation is provided within the development. These flows will need to be catered for in any future designs from a conveyance perspective.



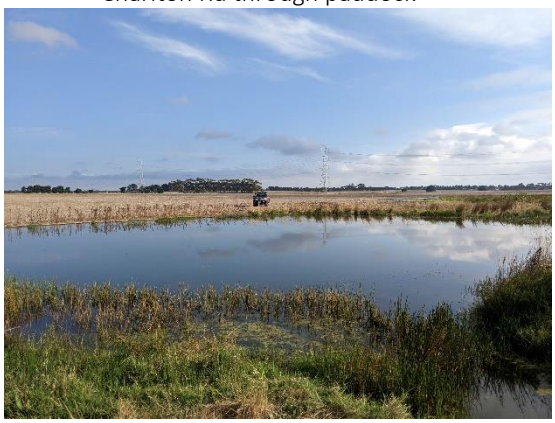
1. Small RB on Charlton Rd, adjacent to cemetery



2. Existing channel flowing north-south from Charlton Rd through paddock



3. Bruce Creek, looking west



4. Low, wet point in the landscape adjacent Burnside Rd



5. Existing perched farm dam



6. Channel taking flows from Glen Avon Estate

Figure 5. *Field photos*

2.2 Land use

An aerial photograph is shown in Figure 6 which covers the existing conditions of the subject site and its surrounds. Current land use is predominately farming with small scale grazing and cropping. The site is dissected by a channel which flows north-south from Charlton Rd, heads east to Burnside Rd, flows south along Burnside to a low and wet area, before flowing eastwards through culverts where it flows along the watercourse shown in the map below. The channel outfalls under the railway line bounding the PSP. The CMA has indicated that the existing channel line to the east of Burnside Rd is a designated waterway.

Other features in the PSP include:

- A rocky outcrop in the south-eastern corner of the PSP.
- Several dams located in low points. These present a potential location for future wetlands/retarding basins.
- A series of minor tributaries flowing into Bruce Creek.
- A chicken farm exists outside of the PSP, to the south of the railway line near Burnside Rd. An amenity buffer assessment will be required to determine the necessary buffer to separate future land uses and manage odour. The Environment Protection Authority (EPA) default buffer is 400m.

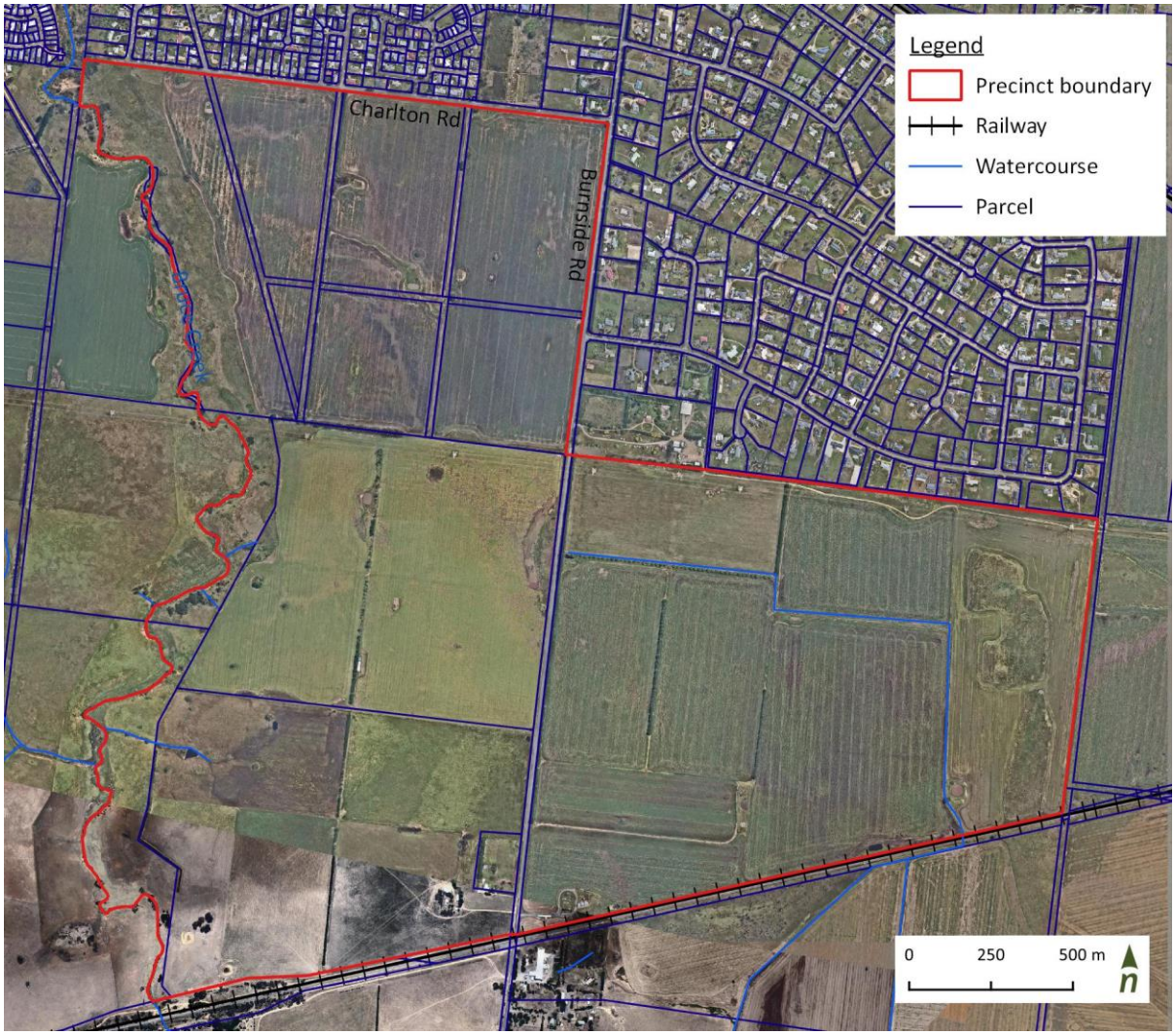


Figure 6. *Current land use*

2.3 Topography

The overall catchment of the site has a general slope in a southerly direction. Figure 7 shows the slope and elevation change across the site.

There is a ridge line that runs through the precinct adjacent to Bruce Creek and splits the flow. Areas to the west of the ridge line flows directly to Bruce Creek. Areas to the east of the ridge line flow south-easterly through an unnamed waterway, and continue south through a culvert at the railway line. There is a smaller catchment which outfalls via separate culverts under the railway.

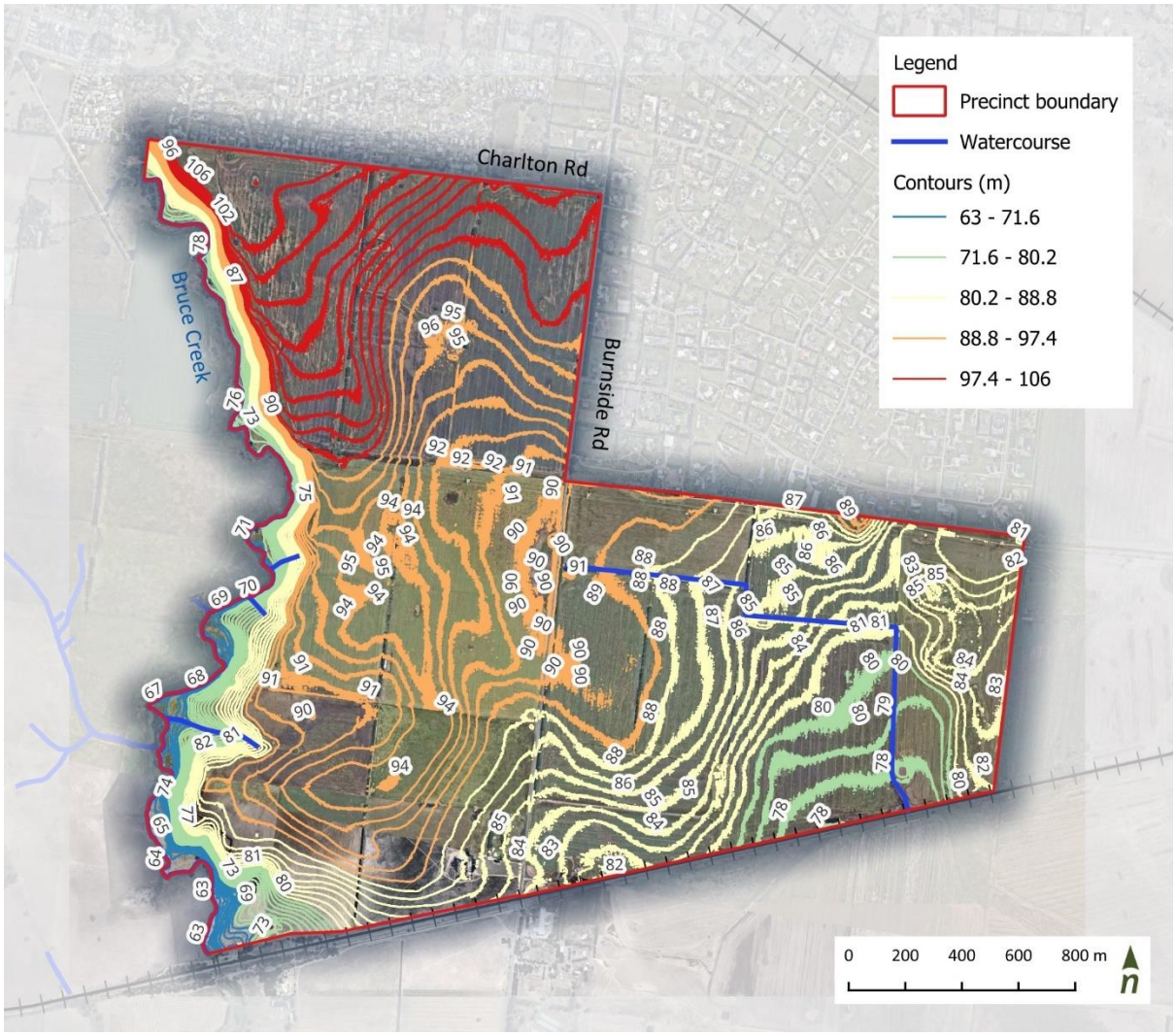


Figure 7. *Site topography*

Figure 8 demonstrates the existing flow directions within the PSP, as well as external flows which will enter the precinct.

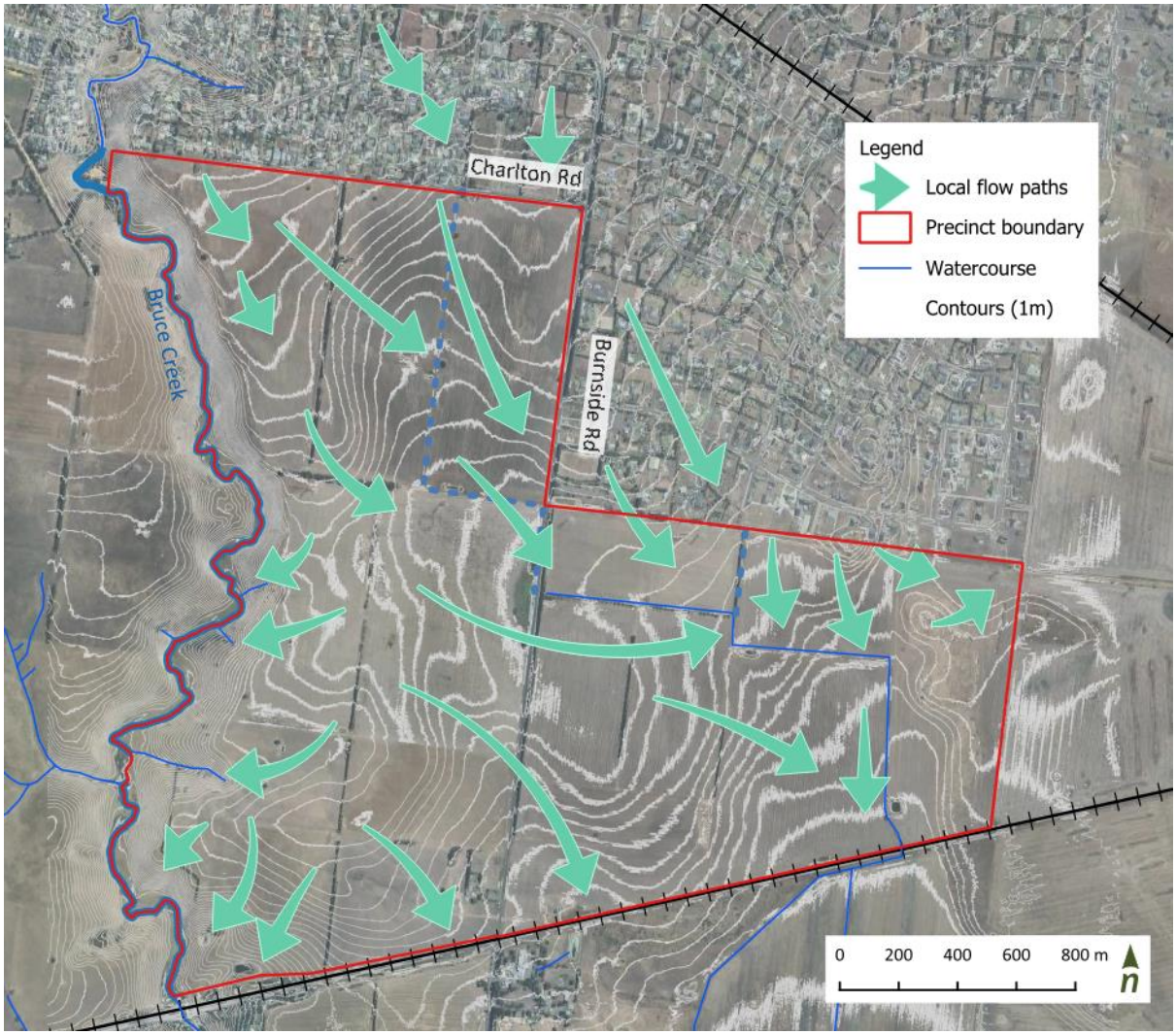


Figure 8. *Site topography and flow direction*

2.4 Catchment context

The site is located within the Barwon River catchment. The unnamed waterway which runs through the site, outfalls via the railway track, and connects with Bruce Creek near the Hamilton Highway. Bruce Creek connects with the Barwon River immediately south of the Hamilton Hwy (Figure 9).

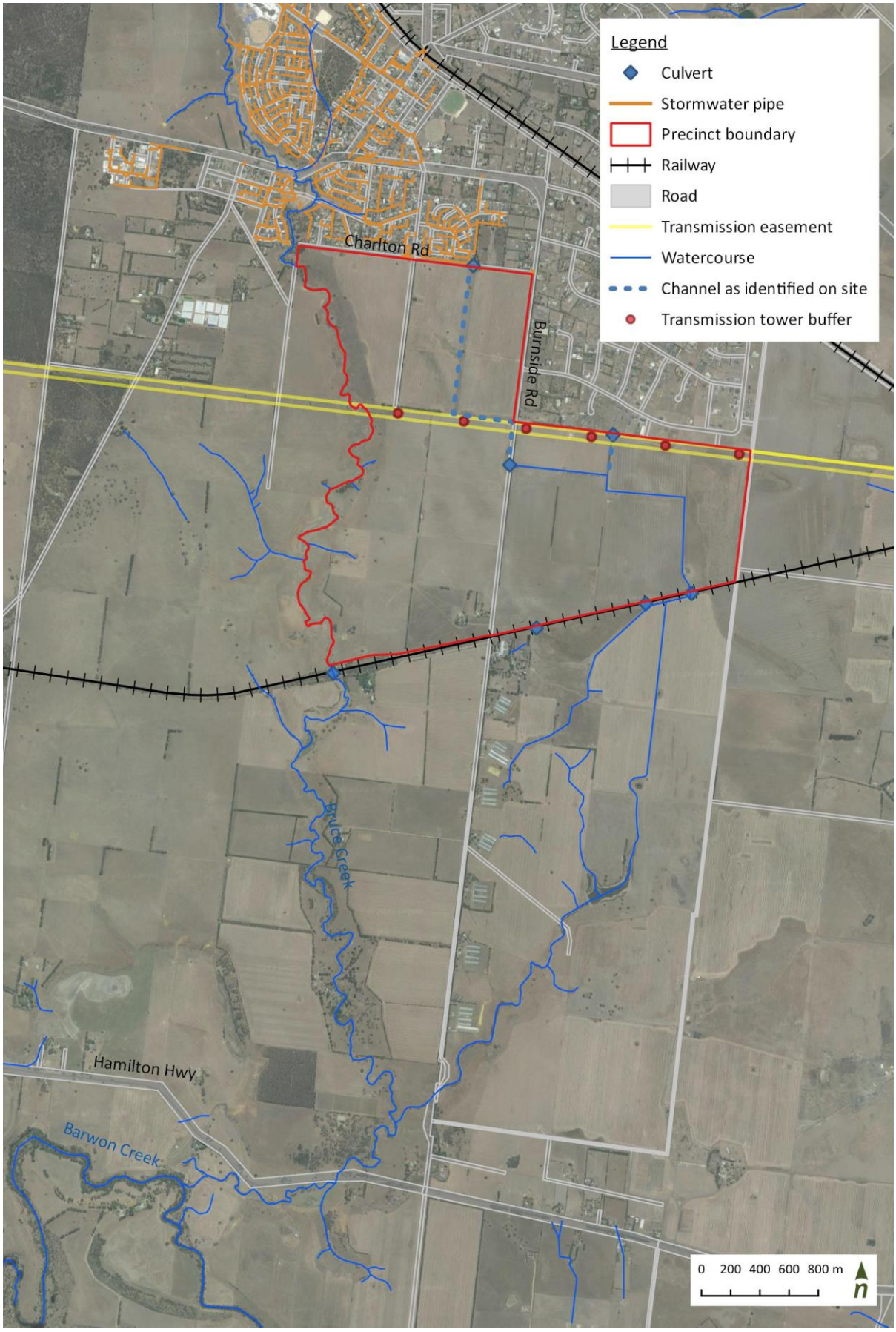


Figure 9. *Catchment context*

2.5 Flooding

Figure 10 shows the 1% Annual Exceedance Probability (AEP) riverine flood extents within the precinct. For the 1% AEP, the flood extent can be shown to be contained within Bruce Creek. This is expected given the steep escarpments on both side of Bruce creek. The Corangamite Catchment Management Authority (CCMA) require all developments to be set outside the 1% AEP flood extend and/ or the 30m buffer zone whichever is the greater.

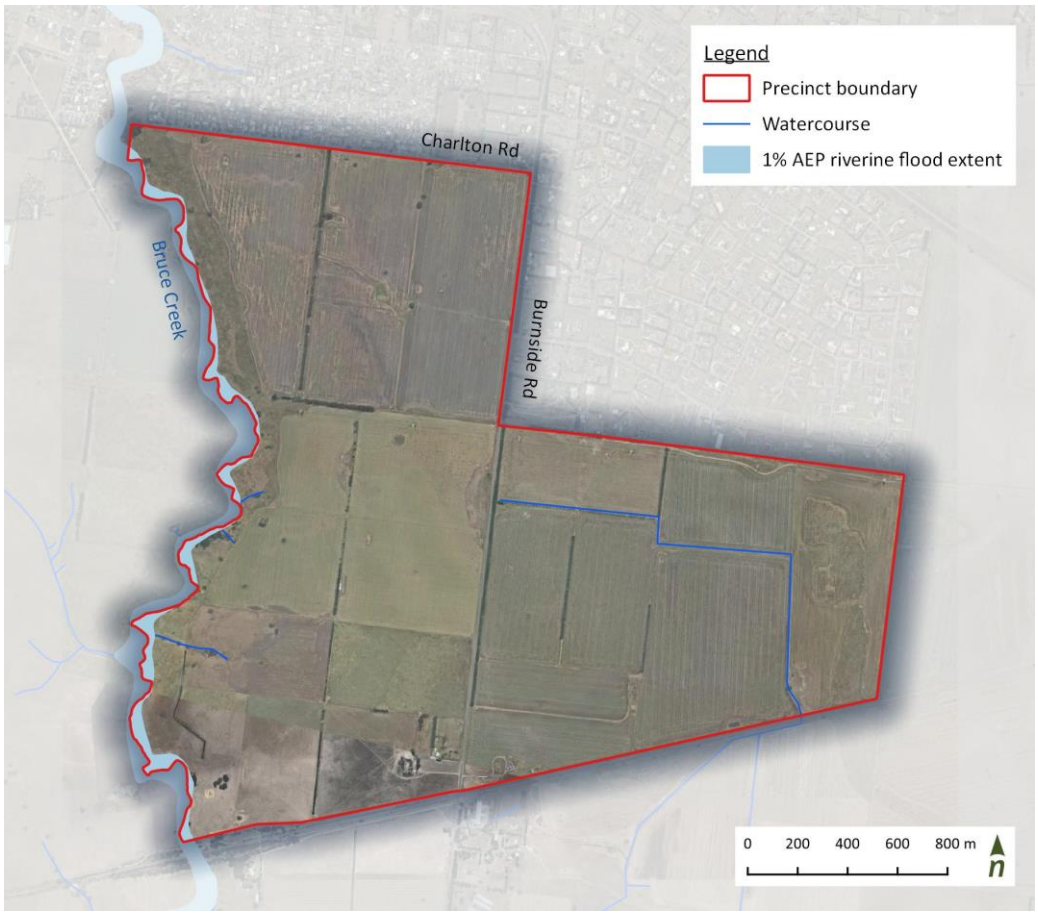


Figure 10. *Existing flood conditions - 1% AEP (1-in-100 year) flood (Source: Regional Floodplain mapping project (Barwon), 2016)*

The CCMA was previously contacted by the VPA for flood information and advice for the proposed Bannockburn Growth Plan Area. Figure 11 shows the 1% AEP flood extent throughout the investigation area, as established from rain on grid and riverine flood modelling from DELWP. Similar to the Barwon 2016 flood extent, flooding is contained within Bruce Creek. This modelling demonstrates overland flow paths within the precinct. There is an overland flow path through the PSP area that aligns with the valley line. Flows from external, existing residential areas can also be seen to enter the PSP at the northern boundaries. The flood risks are very much where expected, having assessed the topography.

Bruce Creek is identified as designated waterway (Water Act 1989) and sits within the Mid Barwon River Landscape Zone. The CMA recognises Bruce Creek as having ecological, cultural and social importance with key threats to this area including encroachment of the waterway within the expanding urban area, degrading water quality, bank erosion and native vegetation degradation.

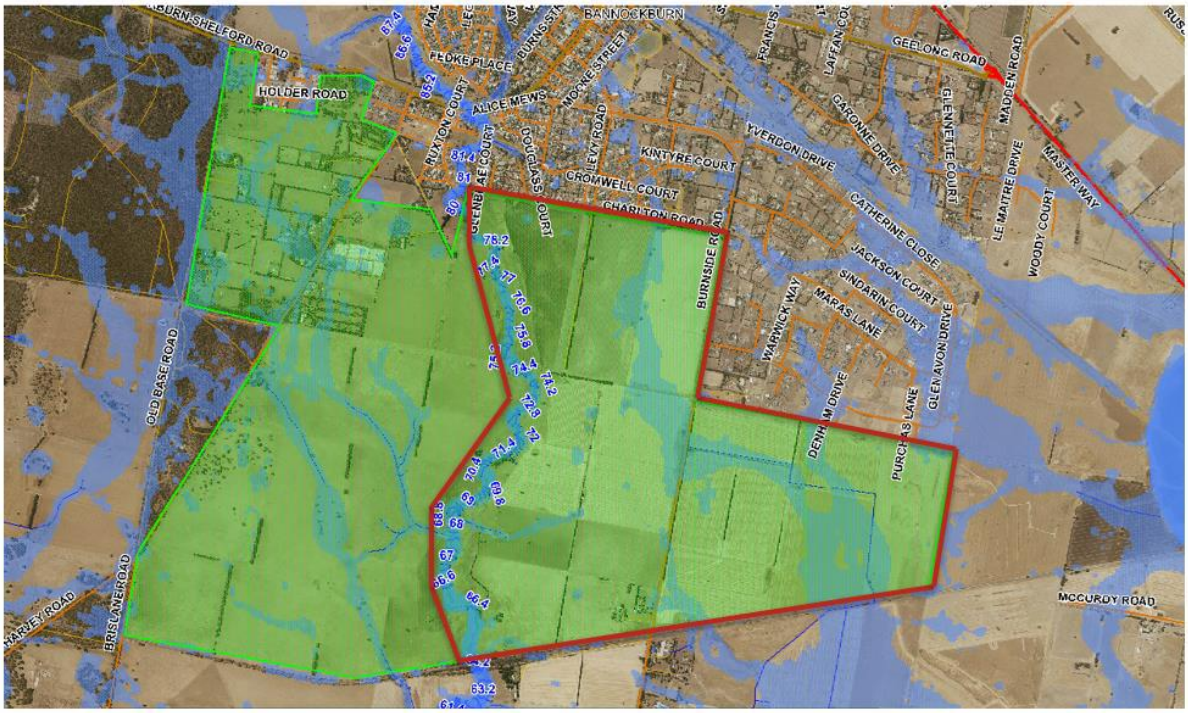


Figure 11. *Rain on grid mapping showing overland flow paths, Regional Floodplain Mapping Project (2016)*

Following a stakeholder workshop in July 2025, Council provided Alluvium with a recent flood study undertaken for existing residential areas to the north of the Bannockburn SEPSP- *Bannockburn Drainage Investigation – Lowndes & Glen Avon Estates* (Water Technology, 2023).

This flood modelling was used to help confirm major overland flow paths, catchment extents external to the precinct, and to establish how the existing storage basins north of Charlton Road operate under major (1% AEP) events. Ultimately this mapping helped refine existing conditions catchment mapping and hydrologic modelling for this project.

A map of the 1% AEP flood depth as extracted from the report is provided in Figure 12 below. Several areas of interest have been highlighted in red by Alluvium, showing major flows paths that ultimately enter the precinct. This mapping in particular demonstrated that the catchment that enters the precinct across Charlton Road extends further north than initially thought, extending beyond Burnside Road and north to Moore Street and Victoria Park.

The mapping also indicates that the existing small storages at Charlton Road and the corner of Dalcruin Dr and Balmaha Ave do not fully retard the 1% AEP flows; that these overtop in this event. It is unclear what event these storages were originally designed for.

The flood report also provided information of the rainfall event which occurred on 14th November 2022 in Bannockburn. This event led to flooding and nuisance inundation throughout the estates assessed in this flood report. The following is an excerpt from the report with regard to analysing this event:

Rainfall records from multiple Wunderground gauges 3 were used to assess the magnitude and distribution of rainfall during the event so that a simulation of the event could be reproduced. Rainfall depth during the 13 and 14 of November indicated that in the order of 40 mm fell within the catchment, with the majority of the rainfall occurring between 11pm on 13th and 6am on 14th. Plotting of the observed rainfall against local Intensity Frequency and Duration information indicates that the storm peak rainfall was close to a 10% AEP event or 1 in 10 Yr ARI.

The assessment also reviewed antecedent catchment conditions, noting that during the spring 2022 the area experienced multiple significant rainfall events. As a result of the antecedent catchment conditions the November event was modelled with significantly lower rainfall losses.

Council approved the inclusion of this flood information in this report, with the following disclaimer: *This report relies, in part, on information and data provided by Council. While that information has been used in good faith, Council does not warrant the completeness or absolute accuracy of such data and accepts no responsibility for any error, omission or inaccuracy contained therein. The findings and conclusions of this report should therefore be read subject to these limitations.*

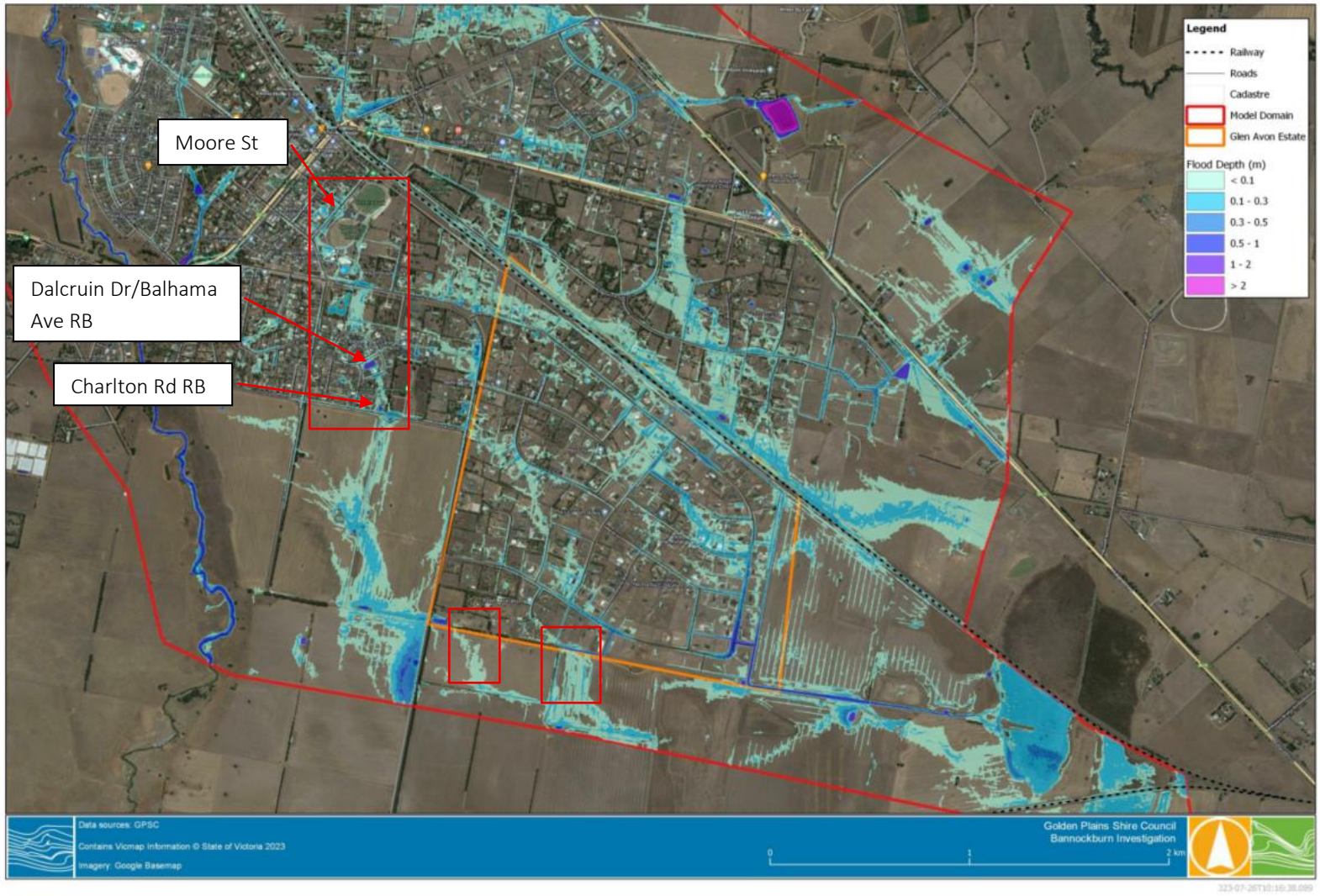


Figure 4-7 1% AEP Flood Depth (m) – Glen Avon Estate

Figure 12. *1% AEP flood depth (m) – Glen Avon Estate (Bannockburn Drainage Investigation – Lowndes & Glen Avon Estates, Water Technology, 2023)*

2.6 Existing services and infrastructure

The site contains several channels as shown in Figure 13. There are two small channels as identified during the field visit that carry flows from northern developments into the PSP area. These drains bringing flows from the northern developed areas will need to have continued service in some form as the site develops. The flows traverse through the site via an unnamed waterway, and ultimately exit the PSP via a culvert under the railway line. Further to this are two more culverts at the railway line that carry flows from the PSP area. These culverts are all relatively small and have shallow invert levels. This pose challenges in terms of limited outflows from the developed precinct, as well as the ability to outfall from any retarding basins. The limited existing culvert capacity is demonstrated in the flood mapping, where water can be seen to pool behind the railway (Figure 11). The culvert capacities and outfall options are further discussed in the hydrology section of the report. Existing precinct culvert details are provided in Figure 14, noting that these have not been captured with feature survey. The culvert sizes have been identified from other reports, and invert levels estimated from LiDAR. Ultimately the sizing and capacities would need to be confirmed and refined in future design stages.

The site also includes approximately 19ha area of transmission easement located at the centre of the PSP (yellow lines in Figure 13). The IWM opportunities assessment undertaken by Spiire (2023) highlights the opportunity to locate wetlands / waterway assets within this high voltage electricity easement. This would improve the amenity value of this corridor and free up developable land. Opportunities to locate assets within this easement will need to be discussed with AusNet. It is likely that there are constraints around buffers to electricity towers, ongoing access requirements, planting densities and allowed plant species.

The railway line abuts the southern boundary of the precinct. VicTrack and ARTC were consulted as part of the development of the concept design.

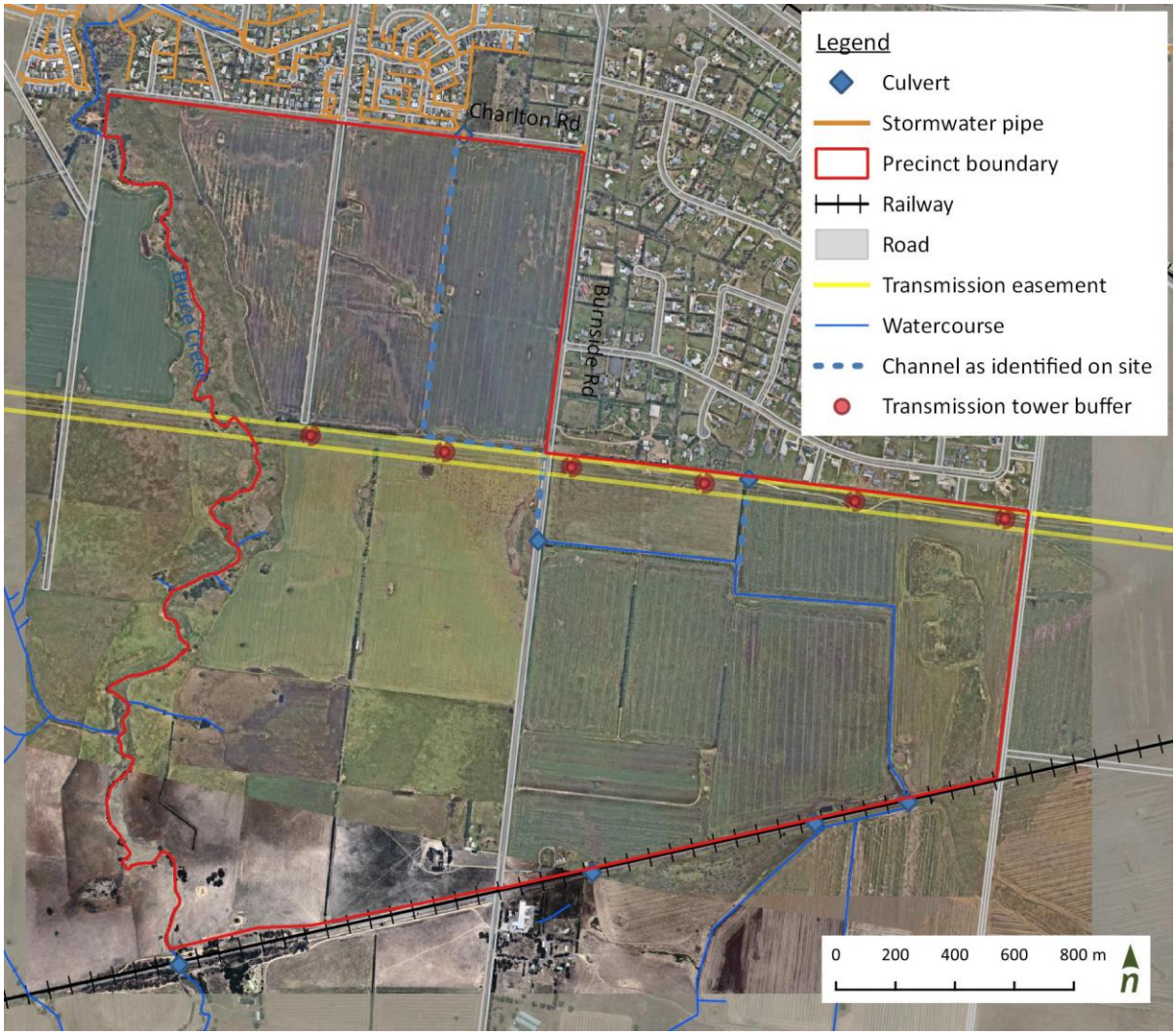


Figure 13. *Existing services and infrastructure*

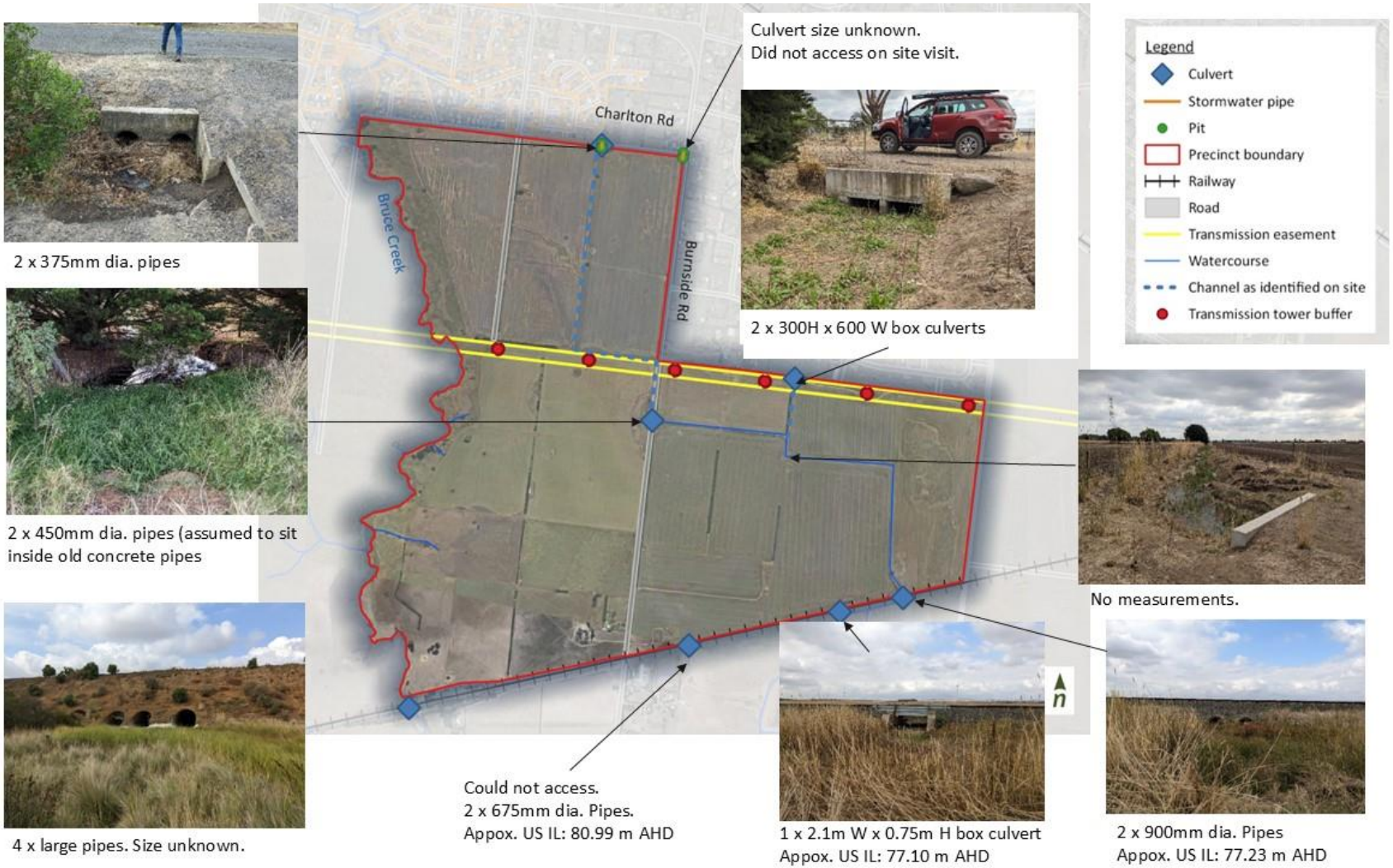


Figure 14. *Culvert details*

2.7 Geology

Geomorphological Management Units (GMU)

Geomorphological Management Units provide a classification of diverse information about the landscape, geology, stratigraphy (rock and soil layering) and geomorphometry (quantitative land surface analysis) of an area. As with the soil type and geology, the site is dominated by one GMU, with others at the edges and towards the creek. The units are shown in Figure 15.

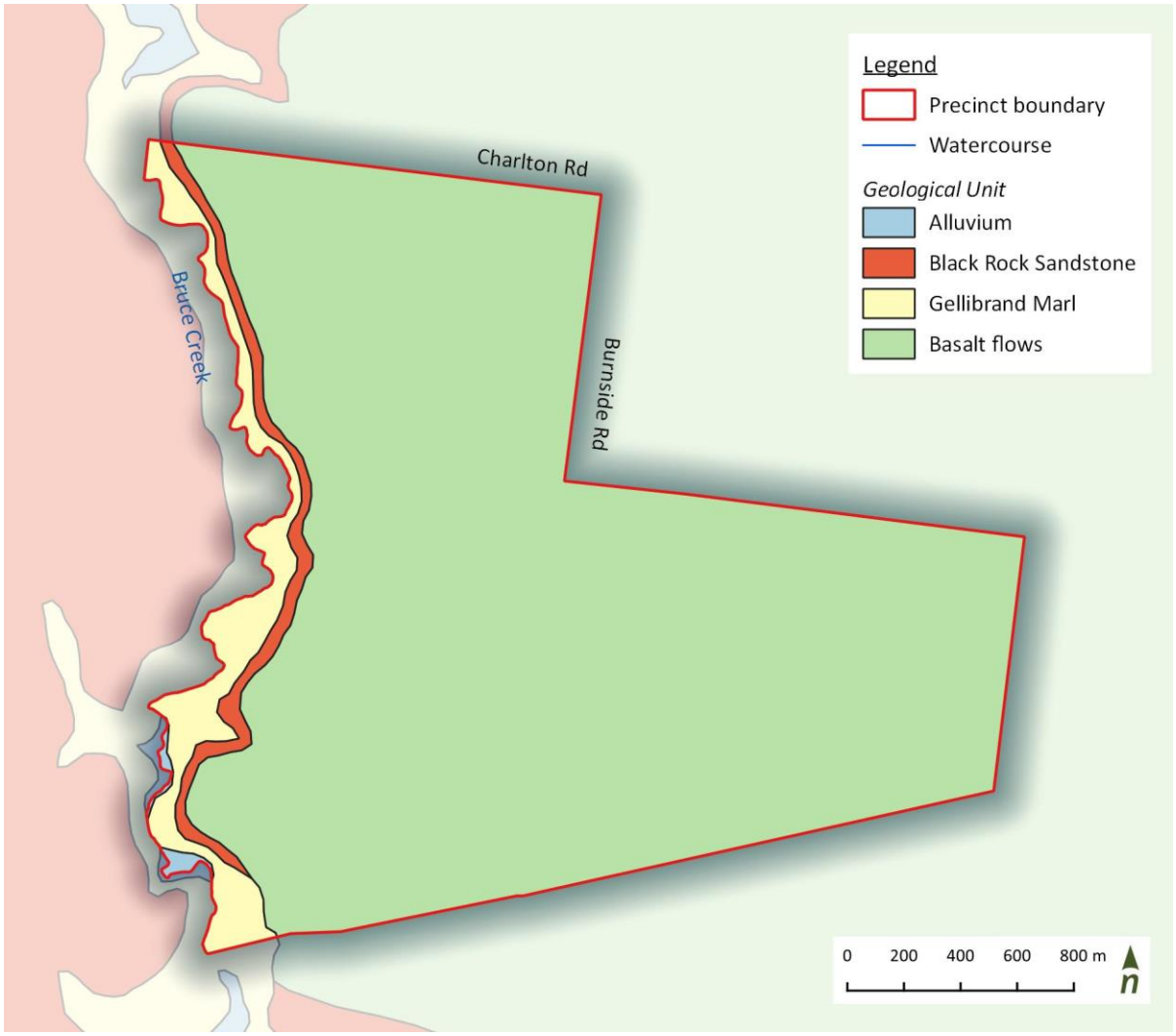


Figure 15. *Geological unit of the project study area (Source: DELWP/Vicmap, 2020)*

There are no sites of geological and geomorphological significance within the study area.

Soils

A desktop assessment of sodic/ dispersive soils within the Bannockburn SE PSP area was conducted by WSP Australia Pty Limited (WSP, 2022). The assessment was informed by a literature review and site visit. The risk rating is considered general in nature. A summary of the study is provided below:

- Sodic soils are clayey soils containing soils with relatively high exchangeable sodium between the clay platelets. When a sodic soil comes into contact with non-saline water or rainwater, water molecules are drawn in-between the clay platelets resulting in swelling of the clay and, often, the detachment of clay platelets into the water making the water cloudy in a process called dispersion. Dispersed clay

particles are readily suspended in the water and can be transported in the water. Dispersion can lead to the development of tunnel, gully and surface erosion.

- The key hazards arising from urban development in areas of sodic and dispersive soils relate to surface erosion, damage to buildings, damage to infrastructure, and negative impacts to waterways.
- Soil erosion risk in the context of soil erosion was assessed as Low – Medium risk under the adopted risk scheme.
- Undisturbed (and cropped land) on the plateau generally showed minimal evidence of surface erosion. Extensive erosion was observed in un-vegetated areas in the southwest corner of the precinct (Sandringham Sandstone).
- The risk to the riparian zone, which is inherently higher than the plateau area due to the presence of more erodible soils coupled with increased slope steepness, should reduce as a result of the development because the escarpment will be fenced, destocked and allowed to revegetate.
- In addition to better informing the risk profile by undertaking intrusive investigations, controls during development may include protection of topsoil, placement of topsoil in scalped areas, and placement of matting to minimise erosion, in addition to maintaining vegetative cover and ensuring revegetation and stabilisation occur in a timely manner throughout the development works.
- Soil erosion risk in the context of buildings and infrastructure was assessed as Low – Medium risk under the adopted risk scheme.
- Soil erosion risk in the context of water quality was assessed as Low – Medium under the adopted risk scheme. In addition to better informing the risk profile by undertaking intrusive investigations, controls may include typical riparian land management (exclusion of stock, establishment and protection of riparian vegetation, weed and pest control), stormwater treatment/settlement to minimise sedimentation, and stormwater retarding to manage peak and total flows within waterways.
- Based on the desk study and site observations, excavations and cuttings in the study area east and west of Bruce's Creek may encounter dispersive soils and this potential should be confirmed with an intrusive investigation including collection and analysis of soil samples. Intrusive investigation is also recommended in the vicinity of Bruce's Creek (500 m buffer), including where mapping indicates presence of Sandringham Sandstone and/or Gellibrand Marl, to confirm the soil type(s) and soil properties.

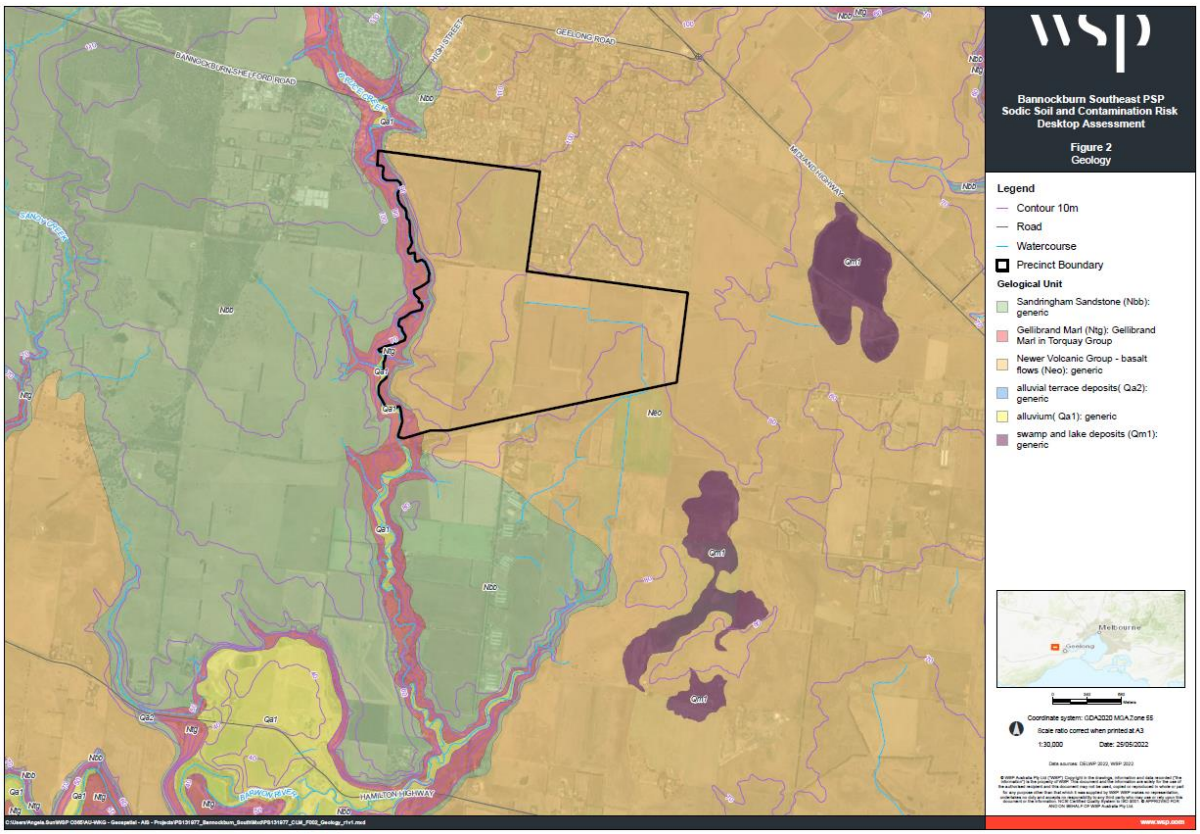


Figure 16. *Soils across the project study area (Source: WSP 2022)*

Contamination

WSP Australia Pty Limited (WSP) were engaged by the VPA in 2022 to complete a Land Capability Assessment along with the soil assessment for selected parcels within the precinct. A historical review of land uses was undertaken, to inform contamination risk and provide recommendations.

The literature review identified predominantly agricultural use in the Precinct, comprising cropping and livestock grazing, with some rural residential use. The site walkover identified some areas of interest where ancillary land uses may be considered to increase the potential for contamination to have occurred.

Areas of interest which have been determined to be “Medium” potential for contamination will require a Preliminary Risk Screen Assessment (PRSA) to be completed in accordance with the requirements of Planning Practice Note 30 (PPN30). PPN30 provides a process to determine suitability of land for a proposed sensitive use based on past land use and its potential for contamination to have occurred. The PRSA will assess the need for an Environmental Audit.

In areas (majority of the precinct) where potential for contamination is assessed as “Low”, PPN30 does not include any recommendations for further assessment. In this case, the General Environment Duty (GED) applies to for any suspected risk to human health or the environment.

VPA may consider two pathways to meeting the requirements of PPN30:

- Strategic Planning approach: Meet the PRSA and/or Environmental Audit requirements prior to the amendment, or
- Statutory Planning approach: Defer meeting the PRSA and/or Environmental Audit requirements until after the amendment via application of an Environmental Audit Overlay

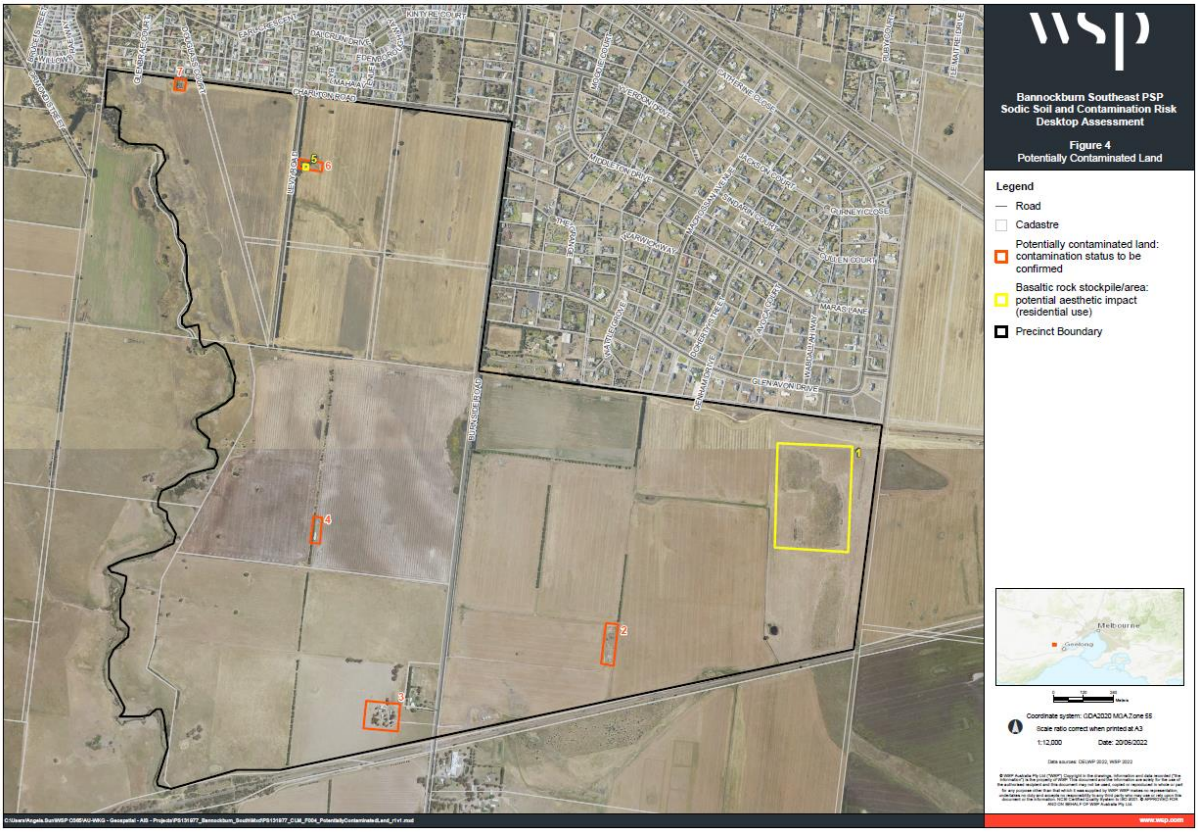


Figure 17. *Potential contaminated land across the project study area (Source: WSP 2022)*

2.8 Cultural heritage

The Bannockburn South East PSP is on the traditional lands of the Wadawurrung people of the Kulin Nation. The shared vision, as set out in the Wadawurrung Healthy Country Plan (2020), is the following:

Our shared Vision

Wurrgurrwilwa gupma bengadak Wadawurrung wurring-wurring baap dja

All people working together to make Wadawurrung Country and Culture strong

Cultural sensitivity data of the precinct was provided by the VPA and is mapped in Figure 18. There is a concentration of areas of cultural heritage sensitivity along Bruce Creek. This matches the sensitivity areas as shown in the Draft Place Based Plan (provided later in the document; Figure 21). Outside of the heritage place extents and locations of artefact scatter, there have been no definite findings to determine that the rest of the precinct is culturally sensitive.

A Cultural Heritage Management Plan (CHMP) is required when a high impact activity is proposed in areas of cultural sensitivity determined by the DELWP mapping. Areas that have been previously subject to significant ground disturbance are no longer areas of cultural heritage sensitivity. CHMPs are likely to be required throughout the precinct depending on the level of historical ground disturbance.

Any proposed stormwater assets will need to remain outside of the Aboriginal place extent as shown in polygons in the map below.

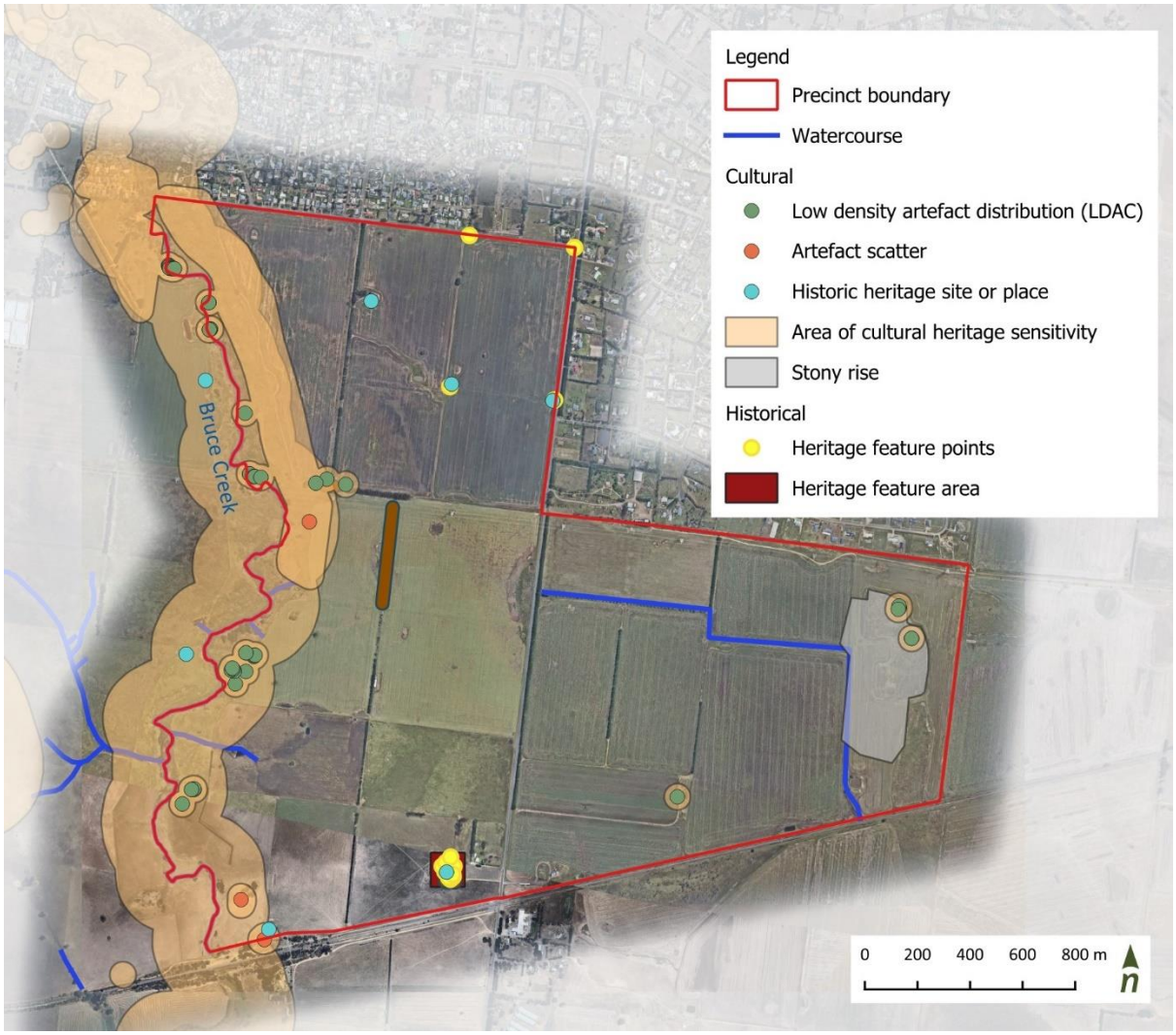


Figure 18. *Bannockburn SE PSP Cultural and historical heritage values*

2.9 Ecology

The Ecological Vegetation Class (EVC) of majority of the prescient can be classed as plains grassland and some areas of grassy woodland plains (Partners' Biodiversity Assessment 2020). Bruce Creek remains a significant value of the site, with steep escarpments and a meandering watercourse.

According to a provided Arborist report (ENSPEC 2021), trees in the project area are typical of western Victorian farming properties in drier areas of the state. The predominantly cleared landscape is defined by cypress windbreaks at the edges of paddocks. These mostly run north-south to provide protection from prevailing westerly winds.

High value trees are present on the site, although they are proportionally few and concentrated along Bruce's Creek on the west of the site. The arboricultural assessment of trees across and around 6 properties within the PSP identified 1456 trees over 150mm in diameter at breast height (DBH) within the properties, or around the properties that potentially impact on the plan. Of these, 78 (5.3%) were rated as Critical for Retention and a further 52 were rated as High for retention.

Eleven major windbreak rows comprised of 882 Hesperocyparis macrocarpa (Monterey Cypress) are all in decline. This represents 60.6% of the total tree population. Further 242 trees (16.6%) are Eucalyptus cladocalyx

(Sugar Gum) in woodlots. These trees have been harvested for firewood, leading to regrowth that has a significantly compromised structure.

The bulk of the higher value trees are remnant or regenerated Eucalyptus camaldulensis (River Red Gum) along Bruce Creek and in the western paddocks adjacent to the creek valley. It is expected that all of the trees in the creek valley will be able to be retained in public open space.

The remainder of the large Eucalyptus camaldulensis are paddock trees. Along with five examples of the protected species Eucalyptus leucoxylon ssp. connata (Melbourne Yellow Gum) in the Levy Road property, these paddock trees are also high value for retention; however, most of these trees have structural factors, or high value habitat in large dead branches, making them inappropriate to retain in residential lots. These trees must be retained in public land with sufficient space around them to allow them to be wholly isolated from the public, preferably by dense complimentary planting under the trees.

A small number of trees around the homesteads at 418 and 430 Burnside Road are rated as High retention value that can be retained in private urban development. For these trees it will be essential to design the sites to provide adequate space to ensure their Structural Root Zones and 90% of the Tree Protection Zones of these trees are adequately protected from development impacts as stipulated by AS4970-2009 Protection of trees on development sites.

As summarised in the arboriculture report, only 130 trees are highly valuable for retention, mainly associated with Bruce Creek. Further trees can be retained, but they have limited value because of their existing size or condition. Further assessment was recommended to confirm the quality and extent of this community.

Significant flora within and surrounding the precinct is provided in Figure 19. Significant fauna mapping is provided in Figure 20. The mapping indicates that along the western side of Bruce Creek is potential Golden Sun Month habitat.



Figure 19. *Significant flora in the study area*



Figure 20. *Significant fauna in the study area*

3 Post development objectives and conditions

The following sets out the aim, objectives and approach of the assessment for the post-development conditions.

3.1 Stormwater drainage requirements

As per Clause 14.02 -1S-2S of the Victorian Planning Provisions (VPP), the catchment planning and management and water quality objectives are to:

- to assist the protection and restoration of catchments, waterways, estuaries, bays, water bodies, groundwater, and the marine environment
- to protect water quality.

As per Clause 53.18 of the Victorian Planning Provisions (VPP), the purpose of stormwater management is:

- to ensure that stormwater in urban development, including retention and reuse, is managed to mitigate the impacts of stormwater on the environment, property and public safety, and to provide cooling, local habitat and amenity benefits.

As per Clause 56.07-4 of the Victorian Planning Provisions (VPP), the stormwater management objectives are to:

- To minimise damage to properties and inconvenience to residents from stormwater.
- To ensure that the street operates adequately during major storm events and provides for public safety.
- To minimise increases in stormwater and protect the environmental values and physical characteristics of receiving waters from degradation by stormwater.
- To encourage stormwater management that maximises the retention and reuse of stormwater.
- To encourage stormwater management that contributes to cooling, local habitat improvements and provision of attractive and enjoyable spaces.

The following are the general stormwater drainage requirements that need to be followed in a stormwater assessment. These have been considered when identifying asset options.

Stormwater quantity management

In order to protect downstream environments from adverse impacts on flood conditions, typically, the fully developed 1% AEP stormwater peak runoff rates are to be retarded back to the equivalent 1% AEP pre-development peak flow rates, prior to discharging downstream. Alternatively, as per the Planning Scheme, the design of the local stormwater drainage network should "ensure stormwater is retarded to a standard required by the responsible drainage authority."

This is typically achieved through the implementation of retention (or detention) systems within the catchment. Ultimately, a stormwater management strategy and design solution should demonstrate no impact on downstream environments, and that increases in stormwater discharges to receiving waters is minimised.

This is achieved through best practice approaches, integrating asset functionality for both quantity and quality management. This further allows consideration of broader community benefits through multi-outcome designs.

Any flood mitigation works must be designed and constructed in accordance with the requirements of the relevant floodplain management authority.

Stormwater conveyance

As per the Infrastructure Design Manual (IDM) and VPP clause 56.07-4, stormwater conveyance is typically designed to a major and minor flow regime where:

- Minor flows – that is, up to and including the 20% AEP storm event (approximately the 1 in 5-year ARI event) are conveyed via the sub-surface stormwater network (for residential areas).
- Major flows – that is, between the 20% AEP and 1% AEP event are typically conveyed on the surface via roadways, overland flow paths, open channels, and waterways.
- In line with the Bannockburn Urban Design Framework (2011), drainage from urban area is to be designed and managed to minimise the volume and speed of runoff entering Bruce's Creek.

Stormwater quality treatment

Stormwater treatment concepts are required to meet the Urban Stormwater Best Practice Environmental Management (BPEM) Guidelines (CSIRO, 1999) pollution reduction targets as set out in the VPPs, before being discharged into stormwater networks and receiving waters. These targets are defined as:

- 70% removal of the Total Gross Pollutant load
- 80% removal of Total Suspended Solids (TSS)
- 45% removal of Total Nitrogen (TN)
- 45% removal of Total Phosphorus (TP).

General Environmental Duty (GED) and EPAV stormwater guidance

The Environmental Protection Act (2017) requires that every development provides a General Environmental Duty (GED). THE GED requires individuals and organisations to eliminate or otherwise reduce risks of harm to human health or the environmental arising from their activities so far as reasonably practicable.

The EPA Publication 1739.1 (June 2021) covers the GED of the PSP with respect to stormwater pollutant reduction performance and stormwater volume reduction.

Stormwater volume reduction requirements are driven by an ecological and physical form response. The EPAV have published an *Urban stormwater management guidelines* (1739.1, 2021) which identifies the need to manage stormwater volumes within landscapes.

The EPA stormwater guidance sets out flow volume reductions for different areas, based on the annual rainfall. These reductions are designed to reduce the impact of increased impermeable surfaces (and decreased vegetation) on the receiving environment by setting out a percentage of impervious runoff to be:

- either infiltrated or filtered to replace the water that would have permeated to the water table to support waterway baseflows, and
- harvested or evapotranspired to make up for water that would have been used by vegetation or evaporated from soils.

As per the guidelines, the performance objectives for the Bannockburn SEPSP are:

- 29% harvest/evapotranspire target of the mean annual impervious runoff
- 7% infiltration target of the mean annual impervious runoff.

Reduction of stormwater volumes has not been investigated in detail as part of this conceptual design development stage. However, stormwater harvesting opportunities, including access to treated stormwater

from PSP wetlands present a way to contribute to volume reduction, reduce potable water consumption, and create urban cooling if the water is used to irrigate nearby sports fields and open space. However, stormwater harvesting from these wetlands alone will not meet the above targets. A suite of harvesting opportunities would be required, as well as maximising demand (i.e. where farm irrigation opportunities may arise, or looking at stormwater for indirect potable supply).

3.2 Future land use

To determine the stormwater quality requirements of the precinct, the post-development conditions of the site are modelled. While it is understood that the layout and proposed land use concepts are subject to change over time (and that the stormwater assessment will inform the proposed layout), a preliminary layout is required for modelling assumptions.

The layout of the precinct, specifically the density of the proposed development and proportion of open space, will impact the volume of stormwater runoff and therefore the treatment and flood mitigation systems required.

The version of the Place Based Plan that has been used in the modelling assumptions has been included in Figure 21. The majority of the site is proposed as general residential. This version (June 2024) has been adopted for all conceptual design modelling in terms of land use and fraction impervious assumptions.

The plan indicates 'sensitive areas.' The VPA initially advised Alluvium to consider the sensitive areas as developable but avoid locating drainage assets in this location. Alluvium advised the VPA that in the case of the Bruce Creek corridor that this is not possible unless drainage is located in the sensitive area due to the topography (i.e. the wetlands/basins need to be located at the low point). A separate stormwater management strategy would be required to manage stormwater within these areas should they be deemed developable. The VPA subsequently advised Alluvium to exclude the Bruce Creek sensitive areas from development assumptions.

The above approach means that developers would need to update their subdivision drainage strategy to consider development in the Bruce Creek sensitive areas, if ultimately deemed appropriate. Stormwater treatment and storage requirements would increase compared to what is presented in this report, as a result of a larger catchment if the Bruce Creek sensitivity areas were deemed developable.

The stony rise sensitive area in the eastern portion of the PSP has been included in development assumptions (i.e. assumed as residential land) as per VPA direction. This area is not the lowest part of the catchments it sits within. Should this not ultimately be developable, treatment and storage requirements would reduce compared to what is presented in this report.

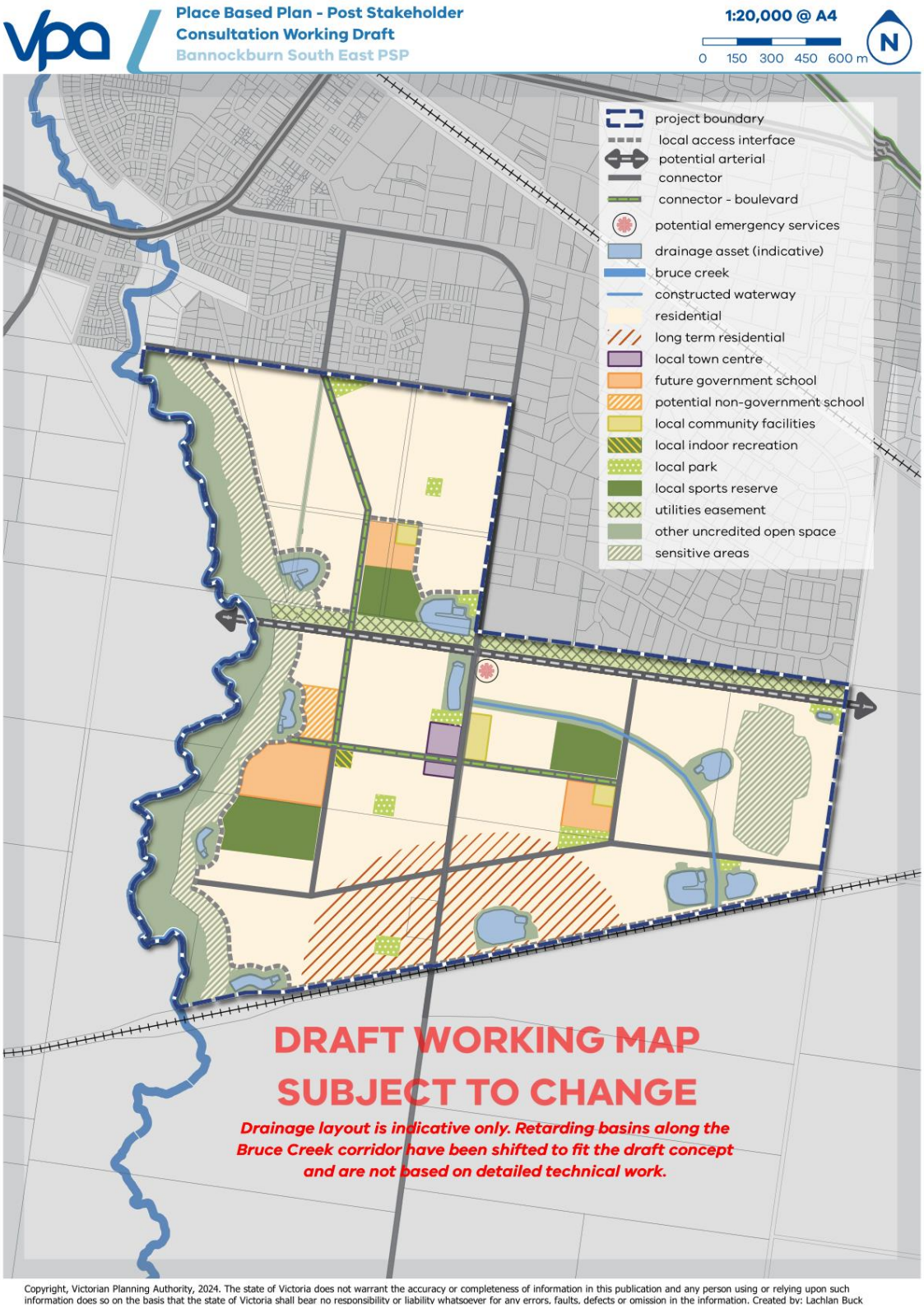


Figure 21. *Draft Bannockburn SE PSP Place Based Plan (June 2024)*

4 Stakeholder input

Preliminary concept designs were provided to stakeholders to enable initial feedback on the concepts. A meeting with ARTC and VicTrack was also undertaken to discuss the potential to upgrade existing railway culverts. A summary of stakeholder feedback and consultation discussions are provided below.

VicTrack and ARTC

- There are three railway drainage culverts in the rail corridor located on the southern boundary of the precinct and this corridor is leased to ARTC. The culverts are not licensed, either to the local Council or to a catchment management authority and accordingly their use is solely for transport purposes.
- Section 221ZI of the Transport (Compliance and Miscellaneous) Act 1983 prohibits drainage to the rail corridor. Consent to drain to or under the rail corridor therefore must be sought from VicTrack via its Service and Utilities department.
- As discussed in the meeting of 18 July 2023, VicTrack's primary interests are in relation to drainage are; a) the size and location of retarding basins adjacent the rail corridor, and b) proposals to drain to existing culverts which are not designed to for large residential subdivisions. Excess water and flooding can damage track infrastructure and in a worst-case scenario, lead to derailment. Therefore, VicTrack has a strong interest in ensuring that drainage adjacent the rail corridor is effective and will not only address flooding but will also decrease the prospect of excess water collecting and sitting on land near the corridor. For this reason, VicTrack strongly supports the proposition discussed at the 18 July meeting to enlarge the rail culverts to ensure there is ample capacity to direct stormwater under and away from the rail tracks. An application can be made via the VicTrack Services and Utilities email address provided above. VicTrack will not support proposals to drain to the existing rail culverts without upgrading their size and capacity, even if supplemented by retarding basins."
- VicTrack and ARTC are comfortable with culvert upgrades, so long as they are at a sufficient depth to meet track clearance and design requirements, extend from the outer edge of the railway corridor, and do not cause additional flooding or excessive soil moisture which can cause the railway to fail. VicTrack and ARTC are comfortable with new culverts, and these do not necessarily have to be in the same location as the existing ones. The existing culverts could remain in place, with the new culverts constructed for the purpose of servicing the precinct development. All proposed culvert locations and designs would need to be approved by VicTrack.
- VICTrack would envisage that any new culverts may be licensed in the future to the Council to maintain.
- VicTrack will not be responsible for costs associated with enlargement of rail corridor culverts.
- Culvert upgrades are likely to improve the existing conditions and risks to the railway due to the existing limited culvert capacities and shallow inverts.
- As Constructed drawings for the existing culverts could not be obtained, so Alluvium will proceed with capacity calculations based on size and invert estimates.
- ARTC is undertaking a detailed hydrological study of its rail corridors and the information to be gathered by this study will most likely be of assistance to the planning of drainage for the Bannockburn South East PSP. At the time of developing the concept designs, the study was not yet available.
- Consideration should be given to the appropriate distance of any retarding basins from the railway corridor.
- It should be noted that the southern rail corridor is a freight corridor and appropriate physical distance buffers for acoustic purposes should be provided.

Wadawurrung Traditional Owners Aboriginal Corporation

- The WTOAC do not wish to have basins located in the creek corridor, as was proposed in the preliminary concept designs. Alluvium had placed the basins within developable land as per the draft Future Urban Structure. The outcome of discussions with the VPA is that the basins will stay outside of the sensitivity areas.
- WTOAC require a Cultural Heritage Management Plan (CHMP) before further information can be provided on locations of assets in the precinct. The VPA discussed this matter with the WTOAC. It is not feasible to undertake CHMPs for every asset prior to the development of where those assets could be located, and what their size is likely to be (this study). CHMPs will be required as the designs progress past the functional design stage.

Barwon Water

- The feedback provided from Barwon Water was largely in reference to the Spiire IWM Plan. It is anticipated that more feedback from Barwon Water will be provided following the delivery of this report, which can then be incorporated into the functional designs.
- In line with the options considered in the Spiire IWM Plan, Class C recycled water from the Bannockburn WRP could be an option for active open space within this precinct.
- The evidence and local experience within the region indicates that in order to protect the ecology of receiving waterbodies that significantly reducing stormwater volumes from new developments is critical.
- At a minimum, this concept report hopes to demonstrate the requirements (e.g. land take and infrastructure) to "keep live" the option of harvesting stormwater at a regional scale to achieve the objectives of the Growth Areas North West of Geelong (GANWG) IWM Plan and the EPA Guidance note. In order to achieve the objectives stated, this stormwater strategy should consider introducing stormwater volume reductions to comply with the EPA guidance note, and specifically at a minimum make allowances for the infrastructure required to "keep live" regional scale stormwater harvesting at a future date.

Corangamite Catchment Management Authority

- The Environment Protection Act has been amended to include a "general environmental duty (GED)". The future planning of the Bannockburn SE PSP area will need to consider the general environmental duty impacts associated with urban stormwater and the impacts addressed early in the planning process.
- It is understood the proposed retarding basins will be designed to retard 1% AEP stormwater peak runoff rates to pre-development levels which is in line with the Infrastructure Design Manual Requirements. However, the CCMA recommend retarding basins be designed to also cater for small events (e.g., 10% AEP and 5% AEP events). If not considered, then the downstream impacts of not retarding more frequent events needs to be assessed and understood.
- The EPA's updated Urban Stormwater Management Guidelines (2021) is intended to help improve the management of urban stormwater in Victoria by recognising current science and the risk of harm from urban stormwater flows. The CCMA recommend that the overall management of stormwater has a focus on minimising risks to property, assets and the environment. In line with the Guidelines, it will need to be demonstrated that everything reasonably practicable has been done to achieve the new recommended targets to eliminate or reduce risk.
- A 30m buffer from the Bruce Creek top of bank should be maintained.
- The existing channel line on the east side of Burnside Road is a designated waterway. Due to its modification into a straight drainage line, the Authority would be unlikely to object to its modification

into a constructed waterway if it can be demonstrated that there will be no adverse downstream impacts as a result of the works or altered flow regime. A Works on Waterways Permit will be required for the works.

- Once drainage and IWM designs are finalised, a Flood Impact Assessment (hydrologic and hydraulic assessment) must be undertaken. The assessment must: a. Be in accordance with Australian Rainfall and Runoff, 2019, methodology. b. Determine the extent, depth, velocity, and hazard of flooding from the 10%, 5% and 1% AEP flood events under existing and developed conditions. c. Complete an assessment of any proposed cut and fill areas within the floodplain, including compensation of filled areas within the floodplain with equal amounts of cut.
- The assessment must demonstrate zero adverse impacts to surrounding areas (i.e., outside the property boundaries) for all flood events up to the 1% AEP event including: a. Protection of adjacent and downstream properties from increases in flood levels and flow velocities. b. No obstruction or redirection of floodwater. c. No reduction in flood storage.

Golden Plains Shire Council

- The proposed location of WLRB1 will interfere with the natural drainage currently sustaining the cluster of River Red Gums, potentially threatening the long-term health of these trees.
- Every effort should be made to ensure infrastructure projects that will be delivered by landowners are contained to one parcel or land owner area.
- The calculation for the pre-development runoff exceeds the current capacity for the railway culverts indicating that there may be an error in the assumptions of site characteristics for the runoff model. Alluvium reiterates that the existing culverts are currently insufficient to drainage existing natural flows, as highlighted by the flood mapping (Figure 11). Any culvert upgrades and basin design should alleviate existing flooding issues.

Landowners

- There was general feedback to review the location of the proposed constructed waterway, following the valley line instead of the existing channel, as was originally presented. Alluvium have refined the waterway alignment to better follow the low point through the precinct.

Railway outfall options

Given the complexities around outfalling through the railway line, Alluvium was directed in February 2025 to develop a high-level railway outfall optioneering memo to assist the VPA and stakeholders with information around potential arrangements. The development of this memo was subsequent to the delivery of concept #2, which proposed using the existing VicTrack culverts. Through consultation with VicTrack it has been confirmed that VicTrack oppose use of their culverts in any way.

The memo looked at the option of installing new culverts or syphons under the railway track. Following the development of the draft memo, Alluvium met with the VPA, VicTrack, ARTC, and Council representatives to discuss the options and understand their preferences (if any).

General outcomes from the meeting were:

- VicTrack and ARTC required further information, modelling and detail to be able to provide a preferred option.

- VicTrack and ARTC reiterated the importance of the provision of lateral track drainage in any future design scenario. This refers to drainage parallel to the railway which prevents the track from being damaged.

- Council have not formalised their position on a preferred approach.

- Despite the above, the discussion indicated that a new culvert option appeared to be the more likely option due to access and maintenance challenges associated with a syphon. It was noted that a syphon would incur on going costs annually for the infrastructure to be in the rail corridor (infrastructure licence).

- Vic Track advised that in their role as rail property owner they avoid requiring the rail operator (in this case ARTC) to maintain rail culverts and this is typically included in a licence agreement with the local Council. Maintenance agreements need to be established. VicTrack and ARTC expectation is that Council maintains any new culverts (or syphon).

- Top of drainage pipes under tracks shall not be less than 1.2m below top of rail level.

- Risk assessments such as ANCOLD assessments would be expected to be undertaken in later design stages by developers, prior to any development.

Following the stakeholder meeting, some additional information and requirements were provided.

- The VPA have indicated that a minimum buffer of 10m from the outer edge of the railway easement to any drainage works should be provided.
- Maintenance access will need to be provided for any downstream channel works associated with the new culverts option. A minimum of 4m either side of the channel has been provided. Any additional access requirements would need to be confirmed by Council.
- Key VPA concerns are:
    - Minimising any outfall works to reduce impacts on the land and any sensitive values.
    - Minimising costs for any outfall work which will be funded by the DCP.
    - Facilitating the drainage treatment within the PSP and under the railway line.

Following the stakeholder meeting, the VPA directed Alluvium to proceed with developing a third concept design option, which adopts news culverts extending across the railway easement to provide outfall for RB4 and RB9. This report presents this option.

Stakeholder workshop (25th July, 2025)

A stakeholder workshop was held in person on 25th July, 2025 to discuss remaining concerns pertaining to the stormwater management strategy. The purpose of the workshop was to reach agreement on as many drainage-related matters as possible. The workshop was attended by representatives from the VPA, Council, the CCMA, landholders, developer groups and representatives, Ramsay Property Group's consultants - Creo and Rain and Alluvium. VicTrack and ARTC could not attend this meeting and therefore another was held to discuss their concerns the following week.

Alluvium presented the existing conditions modelling and updated drainage strategy, and Creo presented an alternative drainage strategy. The strategy that Alluvium presented was a refined strategy (concept #3), which responded to many of the stakeholder concerns and submissions following exhibition of the PSP and DCP.

Key take-away messages from the meeting included:

- <u>Existing conditions hydrologic modelling (Alluvium)</u>
    - General approval of updated existing modelling in terms of inclusion of 'storage' behind the railway track and updated fraction impervious values
    - Acceptance of updating existing conditions model to include climate change (SSP1) scenario
    - General acceptance of updated flow target setting approach (note this is detailed in Section 6 of the report).

- Council still had reservations around the accuracy of the existing conditions modelling given they do not think the railway track overtops. Council noted the significant flood event in November 2022, which did not overtop the railway track.
- Council agreed to share some recent flood modelling undertaken in the developed areas to the north of the precinct, as well as to share details on the existing small retarding basins located north of Charlton Rd. Alluvium agreed to include these existing retarding basins if Council shared the details, noting that these were very small an unlikely to considerably impact the flows.
- Alluvium agreed that some subcatchments could be further refined for the existing conditions model. This would better align with Creo's catchment assumptions.

- Concept designs
  - Alluvium presented an updated concept (compared with exhibited concept #2) which showed the extension of the constructed waterway up to Glen Avon Estate to convey external flows, the removal of WLRB7, inclusion of SBRB7 to manage sediment prior to outfalling into the constructed waterway, refinement of RB4 and RB9 adjacent to the railway in light of updated outflow targets and inclusion of new culverts under railway.
  - The major differences between the Alluvium and alternative (Creo) strategy are:
    - The alternative strategy does not have proposed basins alongside Bruce Creek. Instead the minor flows are piped south and east into basins alongside the railway. The gap flows (1% AEP-20 % AEP) would directly outfall into the creek.
    - The alternative strategy adopted a syphon approach as opposed to culverts for the railway outfall.
  - Alluvium conveyed that they do not have a preference for culverts/syphon under the railway. This would be a decision for the ultimate asset manager.
  - General agreement from Alluvium that the RB3 (in Alluvium strategy) asset could likely be removed and consolidated with RB5. This would align with Creo's strategy and have a beneficial impact on the Net Developable Area.
  - Alluvium generally agreed that the alternative strategy (Creo) would be beneficial in terms of land take and potentially the DCP, however the strategy needed to be supported by modelling and reporting on:
    - Frequent flow impacts given a significant portion of the precinct (~60ha) would have the 20% AEP flows piped east across subcatchments, and into the large basin adjacent to the railway. The risk is that the frequent flows increase significantly, adversely impacting the downstream landholder in terms of frequency of inundation and erosional risks.
    - The post-development gaps flows (1% AEP – 20% AEP) falling directly into Bruce Creek. It would need to be established that these flows were not adversely impacting the creek environ given no retardation is proposed here.
    - Viability of piping such a significant catchment over such a long distance along the Bruce Creek development boundary, and then east into the proposed basin. Pipe longitudinal sections and costing would be useful to confirm feasibility and cost effectiveness of this approach.
    - Velocities going through the large wetland proposed adjacent to the railway track given the asset is proposed to be online.
  - There was general in principle support of the alternative arrangement given the likely positive land take and DCP implications, as well as benefits of removing piped outfall directly into Bruce Creek, however both the CMA and Council indicated that quantitative data would be required in order to confirm no adverse impacts to hydrologic regimes both in Bruce Creek and downstream of the railway track, and to be able to better compare the two strategies.

- General comments were provided by various stakeholders on the financial viability. The current DCP would likely be a significant prohibiting factor for development.
- Council noted that they currently do not have syphons that they manage. Council are generally concerned about ricks, costs and benefits, and would undertake a risk assessment of the various options.

Meeting with VicTrack and ARTC (31st July, 2025)

A meeting was held with VicTrack and ARTC the following week to present the updated modelling and concept options (Creo and Alluvium), focussing on the assets adjacent to the railway track. The key take-away from this meeting was that no development flows can enter the existing railway culverts, regardless of what may be currently occurring. This is as per Clause 221ZI of the Transport Compliance and Miscellaneous Act 1983 which states it is an offense to drain to the rail corridor:

S. 221ZI inserted by No. 9/2006 s. 122.

221ZI Permitting drainage

A person must not cause or permit drainage or sewage to flow or empty from any premises occupied by the person onto land or premises the property of Rail Track.

Alluvium's presented approach does not use the existing culverts at all – these are left as is and the new culverts would take the fully developed and retarded 1% AEP flows, as well as the future year 2100 climate change 1% AEP flows.

VicTrack nor ARTC presented a preference for a syphon or culvert arrangement. The messaging was that Council would be the authority responsible for maintaining the asset, and therefore the decision would be up to them. Regardless of the culvert/syphon arrangement, ARTC would need to be consulted when the time comes to approve the design and ensure all railway track requirements (e.g. clearance) are met.

5 Catchment analysis

Stormwater infrastructure locations are proposed based on existing site conditions, existing flood issues and the proposed urban layout. The site's post-development sub-catchments were defined through a combination of:

- Topography (LiDAR))
- Major roads which may delineate between sub-catchments.

Major catchments can be broken into many sub-catchments, but ultimately it depends on what makes sense in terms of the potential future road layout, and ensuring the overall catchment for an asset is not too big or small (i.e. there is a balance required). Where possible, there is an objective to minimise the number of treatment assets to minimise land take, costs, and ongoing maintenance requirements; without compromising flexibility of development staging, if reliance were placed on a few, larger scale, end of line assets.

For the purposes of surface water modelling, each land use type assumes a fraction impervious. The fraction impervious is the proportion of land that is likely to be sealed or paved (impervious to water infiltration) following development. This impacts the volume of stormwater runoff that is generated in a specific rainfall event, for a specified land size. The impervious fractions (FI) for each planned land use type are included in Table 1. These numbers have been based on the MUSIC Guidelines (Melbourne Water, 2024). The future urban layout does not specify the residential density, but a standard residential has been assumed for modelling). The FI of the existing development to the north of the precinct has been determined by measuring average lot size.

Table 1. Adopted fraction impervious values for each proposed land use type

PSP proposed land use	Description	Fraction imperviousness
Road	Arterial and connector and other major roads	0.60
Parks and open space	Credited open space	0.10
Drainage	Potential drainage asset	0.50
	Waterway	0.50
Town centre	Local government (offices/depots)	0.7
Utility easement	Electricity easement	0.05
School	Future government schools and potential non-government schools	0.70
Community Facility	Local government (Libraries, sports complexes)	0.70
Standard Residential	Residential (allotment size 300m^2 to 600m^2)	0.75
Large residential	Residential (allotment size 601m^2 to 1000m^2)	0.6
Low density residential	Low density residential (allotment size > 1000m^2)	0.2
Investigation area (stony rise)	Potentially fully developed residential area in future	0.75

5.1 Sub-catchments (post-development)

Based on the existing topography and provided urban layout, the precinct was divided into sub-catchments (Figure 22). Sub-catchment delineation was informed by both the slope (natural fall) of the existing topography and the future urban layout (e.g. road alignment). Rationale for sub-catchment delineation is provided below.

- Sub-catchment 1: ridge line eastern extent of catchment, falls southwest towards Bruce Creek. Bounded to the north by proposed road. Development bounded to southwest by proposed road along contour and sensitivity area.
- Sub-catchment 2: ridge line eastern extent of catchment, falls west towards the Bruce Creek. Bounded to south by proposed road, development bounded to west by sensitivity area. Bounded by ridge line to the north.
- Sub-catchment 3: note there is no sub-catchment 3. The existing conditions sub-catchment 3 is a small catchment which outfalls directly into Bruce Creek. Under post-development conditions this small area will be brought into subcatchment 5. See Figure 23 to demonstrate this.
- Sub-catchment 4: Bounded by ridge line to the west, a ridge line to the east, the railway to the south and proposed road to the north. Falls south-easterly and outfalls under the railway (existing culvert there, however this will not be used in post-development scenario).
- Sub-catchment 5: Bound by Charlton Rd to the north, Bruce Creek sensitivity area to the west and Burnside Rd to the east. Falls southeast along existing valleyline. Includes transmission easement.
- Sub-catchment 6: Bounded by proposed road to the north, by Burnside Rd to the east, by ridge line in the west and proposed road to the south. Falls eastwards.
- Sub-catchment 7: Bounded by precinct boundary to the north, by a proposed north-south road to the east, and Burnside Rd to west. Falls in a south-easterly direction.
- Sub-catchment 8: Bounded by ridge line to the west, precinct boundary to north and east, falls north-easterly.
- Sub-catchment 9: Bounded by proposed channel to west/south-west, precinct boundary to the east, railway to the south. Falls south-easterly to existing culvert under railway.
- Sub-catchment 10: Bounded by proposed channel to east, ridge line and Burnside Rd to the west, and railway to the south. Falls south-easterly to existing culvert under railway.

External catchment:

- Sub-catchment 111: Bounded by Victoria Park to the north and precinct boundary to the south. Bounded by ridge lines to the west and to the east. Falls south and outfalls into the precinct via a small retarding basin and culvert at Charlton Road. Flood modelling provided by Council post-exhibition of the PSP has resulted in the refinement of this catchment. Two small retarding basins are located in this catchment, however the provided flood modelling indicates these do not retard the 1% AEP flows – the storage is limited.
- Sub-catchment 222: Bounded by Burnside Road to the north and precinct boundary to the south. Bounded by ridge line to the west and Burnside Road to the east. Falls south and outfalls into the precinct via Burnside Road.
- Sub-catchment 333: Bounded by Burnside Road to the west and ridge line eastern extent of catchment. Falls south towards the precinct before outfalling into a swale running parallel to the transmission easement, before outfalling south to the un-named waterway via a small channel and culvert. No known retardation within this catchment. A small portion of this catchment (in the south-west corner) outfalls directly into sub-catchment 7.

This catchment information was used for the treatment modelling inputs to determine the likely target pollutant loading and the necessary treatment requirements to manage this for the precinct. The sub-catchment information was also used as inputs for the post-development hydrologic modelling.

Figure 22 shows the post-development catchment layout and flow directions. Table 2 shows the total catchment areas and future Fraction Impervious (FI) based on the land use planning for each sub-catchment. The total FI is based on the various land uses within the catchment. Table 3 shows the total loads for each catchment of the target pollutants as obtained in treatment modelling (see section 7.2).

The total impervious areas (TIA) have been calculated based on the proposed land uses in the Place-Based Plan, and associated Fraction Impervious values documented in Melbourne Water's MUSIC Guidelines.

As per Melbourne Water's MUSIC Guidelines, "the TIA must be used for all water quality modelling in MUSIC including sizing of stormwater quality treatment assets and development planning applications. This will help to reduce the potential for under-sizing of stormwater quality assets." The guidelines also state: "As a general principle for new development, the total impervious area should initially be assumed to be directly connected impervious area and modelled as such. This helps ensure that stormwater quality treatment assets are adequately sized to treat all of their likely catchment."

The same approach has been applied for the RORB subcatchment assumptions. This is appropriate at a precinct-scale, for new developments where the property break-down in terms of directly connected/indirectly connected is unknown.

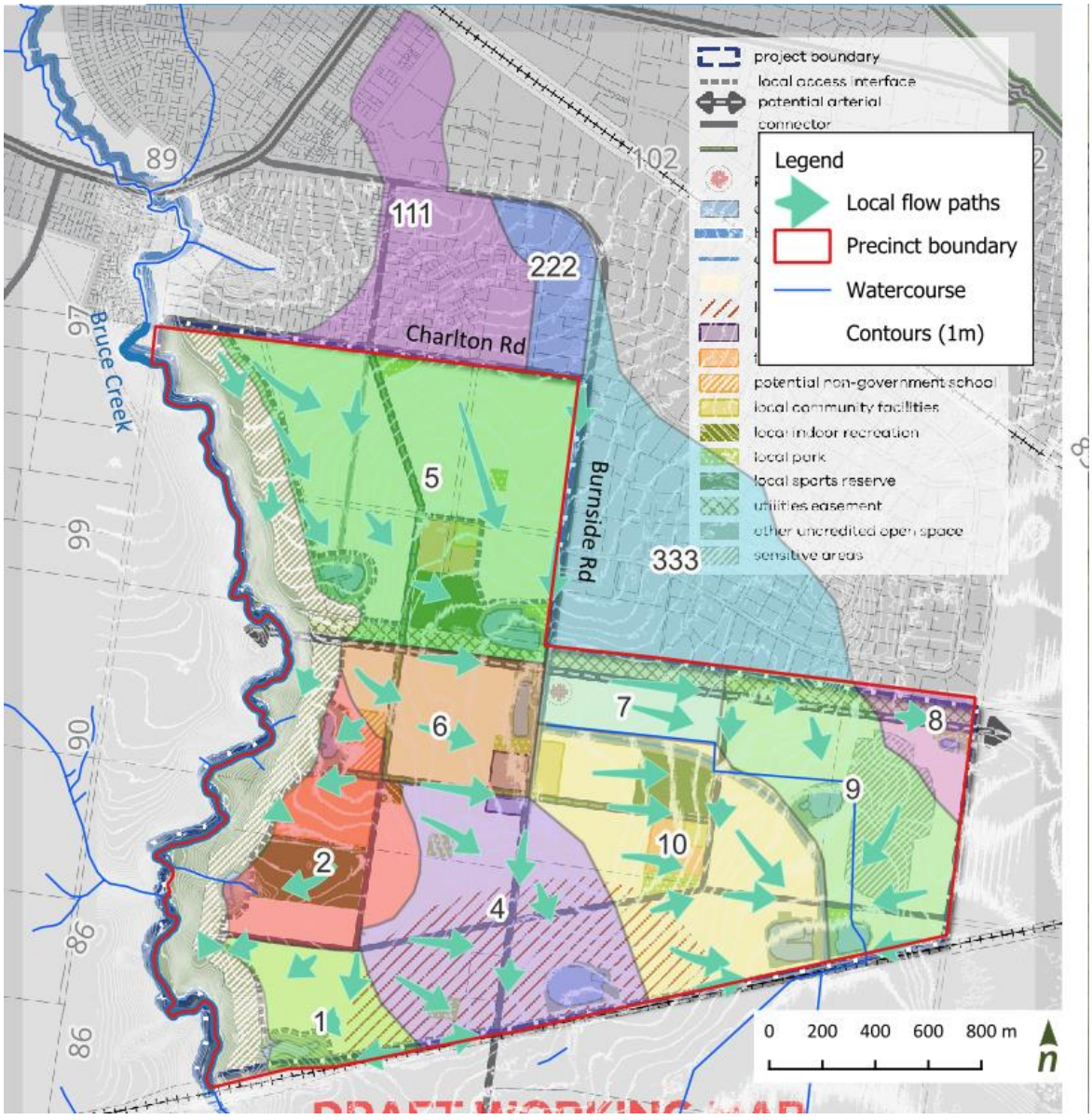


Figure 22. *Post-development sub-catchment layout showing flow direction. A draft urban layout is shown as an underlay.*

Table 2. Post-development conditions effective imperviousness area by sub-catchment

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Catchment 1	21.6	0.72
Catchment 2	41.9	0.58
Catchment 4	71.6	0.72
Catchment 5	111.4	0.65
Catchment 6	34.0	0.7
Catchment 7	20.1	0.62
Catchment 8	12.2	0.45
Catchment 9	56.3	0.67
Catchment 10	76.2	0.65
Total developed area*	**445.3**	**0.66**
External catchments		
111	**58.3**	**0.28**
222	**15.9**	**0.2**
333	**85.2**	**0.2**

***** Investigation area on Bruce Creek waterway corridor excluded as per VPA direction. Investigation area for Stony Rise has been considered fully developed as directed by the VPA.

Table 3. Developed mean annual flow and pollutant loads in each catchment

Subcatchment	Flow (ML/yr)	Total Suspended Solids (kg/yr)	Total Phosphorus (kg/yr)	Total Nitrogen (kg/yr)	Gross Pollutants (kg/yr)
Catchment 1	75.9	150,00	31	218	3020
Catchment 2	124	244,00	48.2	354	5060
Catchment 4	252	507,00	103	719	10000
Catchment 5	361	712,00	144	1010	14600
Catchment 6	117	229,00	46.8	333	4670
Catchment 7	62.7	119,00	25.1	178	2550
Catchment 8	29.9	5390	11.4	83.7	1220
Catchment 9	187	36,600	75.1	527	7510
Catchment 10	247	48,000	99.3	697	9970
Total	1456.5	286,090	583.9	4119.7	58600.0

6 Hydrologic analysis

In general terms, the approach to flood management is to equate post development and pre-development peak flow rates for the 1% AEP event such that the development is not having an adverse impact on downstream flooding. This is typically achieved through the addition of retention (or detention) storage within the relevant catchment. The hydrologic analysis is used to determine the storage capacities of proposed retarding basins required to retard the fully developed peak stormwater runoff rates back to pre-developed conditions. The hydrologic modelling is also used to establish peak flows to size waterways at specific locations.

There is an added constraint of the existing culverts under the railway line, which are the existing discharge points for several of the catchments. These are relatively small culverts, with shallow invert levels.

The outfall constraints have been raised with Council and the VPA and discussed on a number of occasions with stakeholders. To date, three outfalling options have been investigated through the railway culverts. This report covers concept #4 for the stormwater strategy, noting that the outfall approach through the railway is the same for concept #3 and concept #4. A summary of the various approaches that have been investigated is provided below.

Table 4. Summary of concept design outfall approaches for retarding basins outfalling south through railway track

Concept	Outfall infrastructure through railway track	Outflow targets through railway track
Concept #1 (V1 concept report, October 2023)	New culverts, larger and deeper than existing. Channel works to enable outfall from new culverts required.	Pre-development peak 1% AEP flows from the contributing catchment upstream of the railway reserve boundary (i.e. does not account for 'storage' behind the railway and further reduction in flows). Flow targets higher than existing downstream conditions.
Concept #2 (V4 concept report, March 2025)	Utilise existing railway culverts (small and shallow)	Existing culvert capacity (assuming flow does not exceed culvert obvert; no overtopping of railway). No storage behind railway assumed. Flow targets less than existing downstream conditions.
Concept #3 (V5 concept report) Concept #4 (V6 concept report – this report)	New culverts. Culverts will need to ensure 1.2m clearance to track from obvert.	Pre-development peak 1% AEP flow rates exiting the precinct including impact of railway (i.e. immediately downstream of the tracks). Includes existing culvert capacity and overtopping of track, as well as 'storage' behind tracks. Flow targets more in line with actual existing downstream conditions.

6.1 Hydrologic modelling

The hydrologic analysis was undertaken using RORB (v6.31), which is a runoff-routing software designed to simulate attenuation and time of concentrations to produce flood estimates at specified catchment locations.

A RORB model was created for the precinct to determine:

- Existing peak flows
- The impact of development on peak flows
- The reduction in peak flows that is possible using retarding basin storage
- Peak flows to size constructed waterways, pipes and culverts
- The imp[act of climate change on peak flows.

The RORB models were built by delineating the major catchments into sub-areas based on topography and potential road alignments. This section details the peak flows and storage requirements for each catchment.

6.2 Input parameters

Model inputs including temporal patterns and aerial reduction factors were obtained from the ARR2019 data hub and the Bureau of Meteorology's Intensity Frequency Duration (IFD) data. RORB models were built by delineating the area based on flow directions derived from LiDAR data and future preliminary development plans. An overview of the model setup including catchments and reaches is shown in Figure 23.

Key inputs into the RORB modelling include:

- The model used an initial loss/continuing loss model. The initial loss is 13mm and continuing loss is 2.3mm/hr as per the ARR data hub for this location. These were subsequently altered to reflect current climatic conditions (see details further below).
- Pre-burst depths were adjusted as per ARR Guidelines Victoria Loss region 2 (median pre burst), and accordingly initial losses were modelled as variable losses for each duration for the 1% AEP event (see section 6.3 for further details).
- Kc was determined using equation, $k_c = 1.25 \times Dav$ (Pearse et al.,2002, Victoria data). Full details of calibration can be found in Appendix A.
- Intensity Frequency Duration (IFD) data was sourced from the Bureau of Meteorology's (BoM) website, nearest grid cell 38.0689(S), 144.1785(E).
- Temporal patterns were sourced from the AR&R data hub, Southern Slopes.
- For the existing conditions model, storages were included immediately upstream of the railway line to reflect current conditions. This was as per stakeholder feedback. These 'storages' were established by extracting stage storage relationships from LiDAR. The existing culverts were included in the storages, as were 'spillways' at the railway track low points.
- In concept #4 the existing conditions model was updated to include existing storages north of Charlton Road, in the existing residential areas, as per Council feedback. Council provided pipe outlet details for the storages based on a site inspection. There is a small storage on Charlton Rd, next to the cemetery, and another at the corner of Dalcruin Drive and Balmaha Avenue. No As Constructed surveys were provided for these storages, and as such the stage storage was assumed from LiDAR, and the outlets pipe invert levels assumed to be on the base of the basins.
- The existing conditions model was run on a SSP1 climate scenario so to bring the data up to current conditions, which is in line with the latest climate change guidance in ARR2019. This results in a 1.2 degree increase in temperature. Initial loss, continuing loss and IFD data have been scaled accordingly. The SSP1 scenario was also adopted for the developed conditions model for consistency of input data and comparison. Refer to section 6.7 for more details.

- The existing conditions RORB model layout is provided in Figure 23. The catchment delineation is based on the topography and feedback from stakeholders following exhibition of the PSP and stakeholder workshops. Flood mapping provided from Council in July/August 2025 further influenced the external catchment assumptions, which have been refined in this concept #4.
- Post-development catchment areas are as per those presented in the catchment analysis section (section 5). Catchment areas were further divided into sub-catchments to have at least four sub-catchments upstream of a proposed storage node. FI values were updated to proposed land uses for the post-development model (the same as per the treatment modelling assumptions). The RORB layout is provided in Figure 24 and the catchments summarised Table 6.
- Natural reaches (Type 1) were used in the existing conditions model.
- Reaches were updated to 'unlined channel or drain' (Type 2), in the developed scenario to represent overland flow in the 1% AEP.
- The hydrologic modelling considered an ensemble simulation for the 1% Annual Exceedance Probability (AEP) event, for durations 10 minutes to 72 hours. From the ensemble simulation, ten temporal patterns were used to determine peak runoffs for each duration. The median flows (i.e. 6th highest peak flow) for each storm duration was determined, and the peak critical flow with respect to a specific location or storage was calculated.
- Following the modelling of SSP1 post-development conditions, a future climate change scenario – SSP3-7.0 was also undertaken to test freeboard requirements. Initial loss, continuing loss and IFD data have been scaled accordingly. This is discussed in section 6.7.

Table 5. Adopted RORB parameters (SSP1)

Parameter	Existing conditions	Developed conditions
Rainfall Intensity Frequency Duration (IFD)	Obtained from Bureau of Meteorology's IFD tool, scaled for SSP1 climate scenario	Obtained from Bureau of Meteorology's IFD tool, scaled for SSP1 climate scenario
Temporal Pattern details	ARR2019 data hub	ARR2019 data hub
Areal Reduction Factor d	ARR2019 data hub	ARR2019 data hub
Kc (further details in Appendix A)	$k_c = 1.25 \times Dav$ (Pearse et al.,2002, Victoria data)	$k_c = 1.25 \times Dav$ (Pearse et al.,2002, Victoria data)
M	0.80	0.80
Initial loss (IL) (mm)	13.61	13.61
Continuing loss (CL) (mm/hr)	2.54	2.54
Pre-burst	Victoria Loss region 2 (median pre burst)	Victoria Loss region 2 (median pre burst)

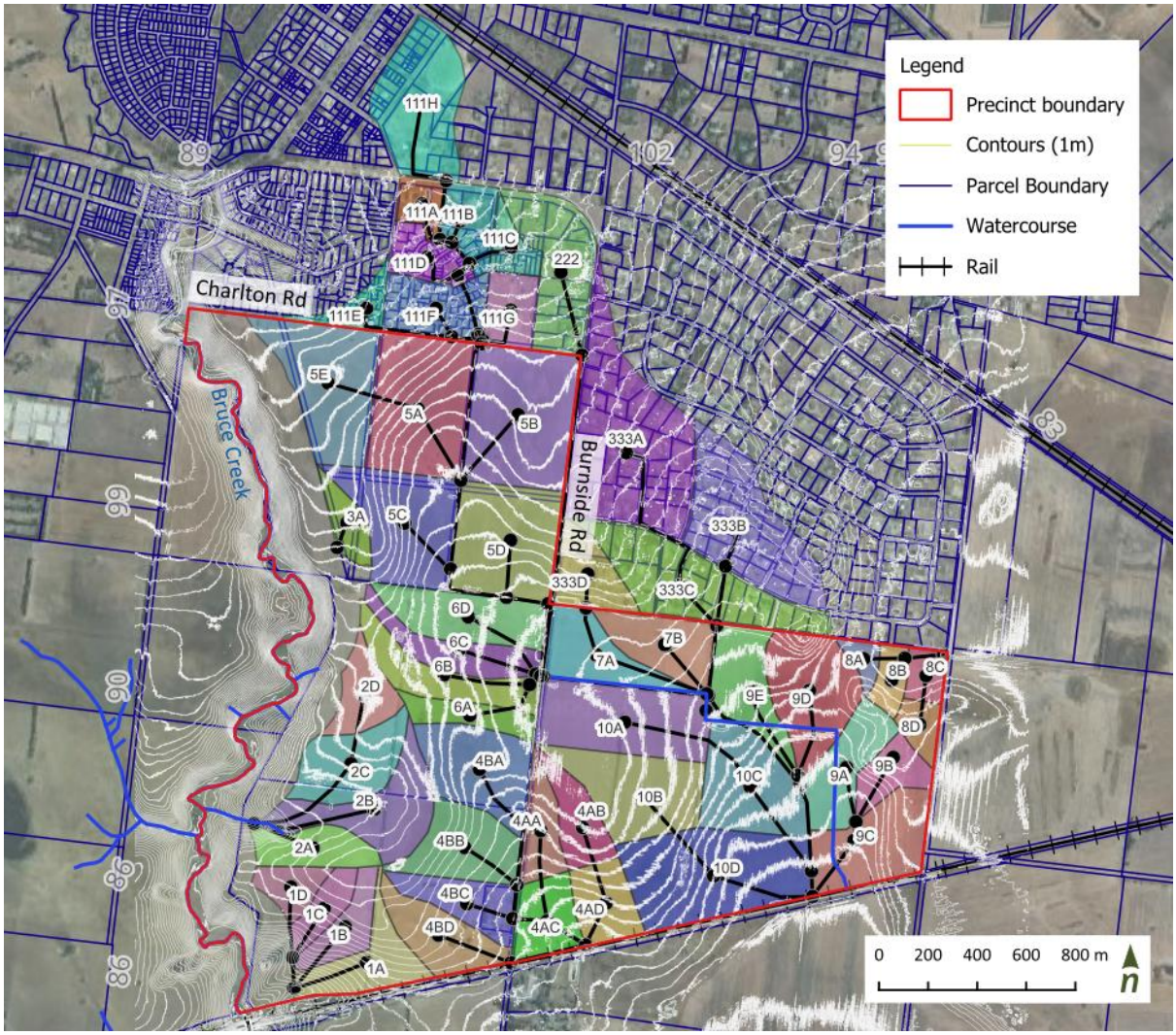


Figure 23. *RORB layout for pre-development conditions*

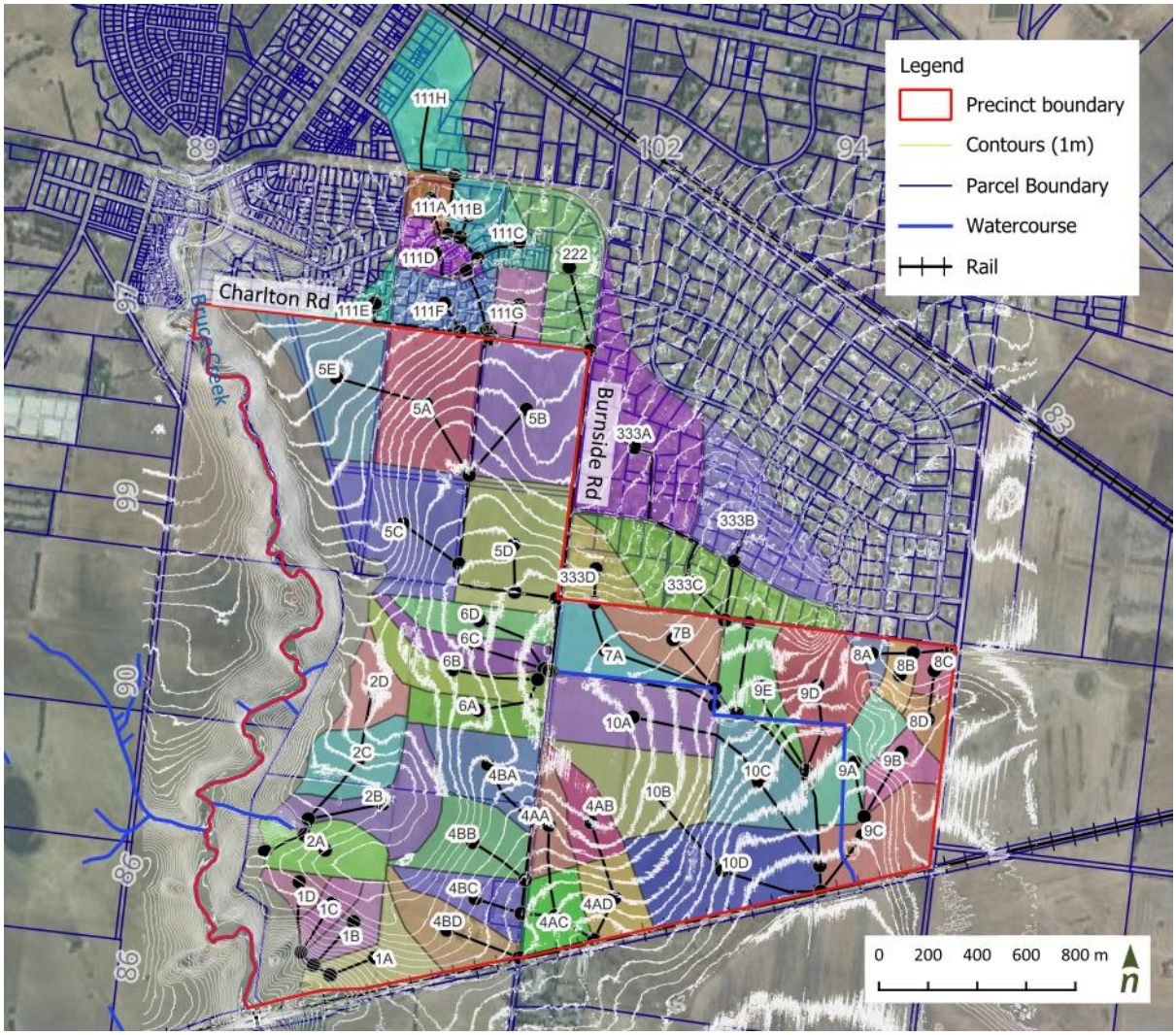


Figure 24. *RORB layout for post-development conditions*

Table 6. Developed conditions effective imperviousness area by sub-catchment

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Sub-catchment 1A	9.4	0.68
Sub-catchment 1B	5.3	0.75
Sub-catchment 1C	3.7	0.75
Sub-catchment 1D	3.2	0.75
Sub-catchment 2A	10.1	0.58
Sub-catchment 2B	14.3	0.49
Sub-catchment 2C	10.5	0.6
Sub-catchment 2D	7.0	0.73
Sub-catchment 4AA	6.4	0.75
Sub-catchment 4AB	6.9	0.75
Sub-catchment 4AC	7.9	0.7
Sub-catchment 4AD	7.6	0.66
Sub-catchment 4BA	12.8	0.72

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Sub-catchment 4BB	12	0.75
Sub-catchment 4BC	8.1	0.75
Sub-catchment 4BD	9.9	0.69
Sub-catchment 5A	22	0.71
Sub-catchment 5B	23.8	0.74
Sub-catchment 5C	24.1	0.53
Sub-catchment 5D	22.2	0.52
Sub-catchment 5E	19.3	0.75
Sub-catchment 6A	7.5	0.74
Sub-catchment 6B	10.3	0.67
Sub-catchment 6C	8.3	0.71
Sub-catchment 6D	7.9	0.69
Sub-catchment 7A	10.2	0.69
Sub-catchment 7B	9.9	0.55
Sub-catchment 8A	2.1	0.38
Sub-catchment 8B	3.4	0.58
Sub-catchment 8C	3.3	0.038
Sub-catchment 8D	3.4	0.75
Sub-catchment 9A	10.2	0.75
Sub-catchment 9B	5.6	0.75
Sub-catchment 9C	14.1	0.69
Sub-catchment 9D	15.6	0.62
Sub-catchment 9E	10.8	0.62
Sub-catchment 10A	19.4	0.5
Sub-catchment 10B	16.2	0.68
Sub-catchment 10C	15.6	0.72
Sub-catchment 10D	25	0.71
Total developed area*	**445.30**	**0.66**

The model extends beyond the precinct to include upstream areas (Catchments 111, 222 and 333) for both current and post-development conditions. The external flows will need to be conveyed through the precinct if they are under current conditions.

In post-development conditions:

- For catchment 111 the flows will be conveyed into the precinct via existing pipes under Charlton Rd. The flows will need to be conveyed via a pipe/road arrangement south through the precinct – further detail is provided later in this section.
- Flows from catchment 222 will continue to flow south down Burnside Road, before heading east.
- Flows from catchment 333 will be conveyed into the proposed waterway in the precinct.
- Collectively, these flows will be conveyed to the railway culverts to the south of the precinct via the proposed constructed waterway.

6.3 Pre burst factors

As per ARR 2019 guidance, pre burst rainfall depths are to be applied for each storm event and duration. The pre burst is applied to the storm event by reducing the Initial Loss by the defined pre burst value (as defined by the ARR Datahub). Based on the ARR Vic specific data (https://data.arr-software.org/vic_specific), a catchment located within Loss Region 2 requires the median (60th percentile) pre burst values to be applied. Figure 25 indicates the loss region of the subject catchment.

The SSP1 climate change scenario was used for both existing and developed conditions. Therefore, median pre burst values were derived from the ARR Datahub and scaled for the SSP1 climate change scenario. Section 6.7 discusses the methods used to derive loss parameters used in the hydrologic modelling for both SSP1 conditions and future climate change scenario SSP3-7. These scaled loss parameters (Table 7) are applied to the RORB model as a variable loss ratio. That is:

Pre burst ratio (for RORB) = $\frac{ILb}{ILs}$

Where

ILb = Initial Loss for rainfall burst (i.e. ILs – Pre burst depth)

ILs = Storm Initial Loss

Table 7 below provides an overview of the proposed pre burst depth rations applied to the RORB model for the 1% AEP event.

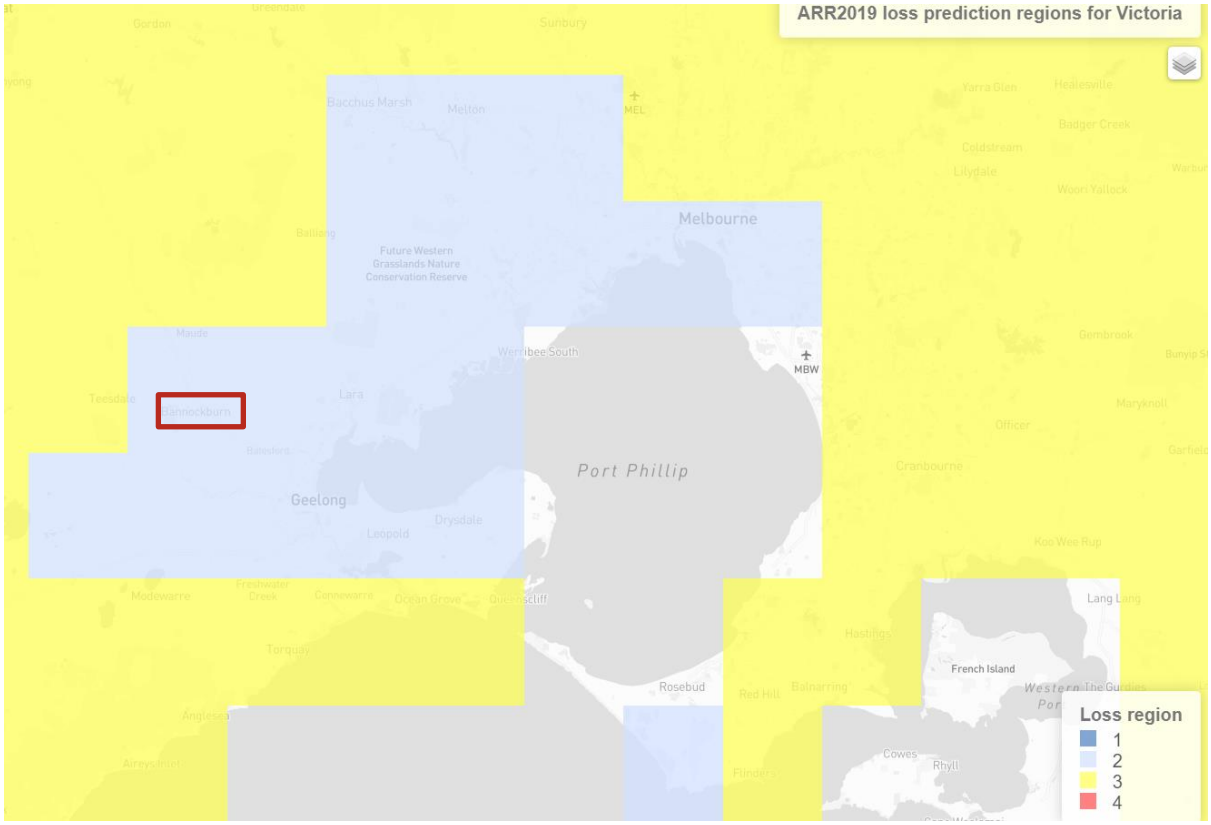


Figure 25. *ARR 2019 loss prediction regions for Victoria (red rectangle indicating precinct location)*

Table 7. Pre burst depth ratios (SSP1)

Duration	Storm Initial Loss (ILs)	Median Pre burst depth	Burst Initial Loss (ILb)	Pre burst ratio
1 hour	13.61	3.3	10.31	0.76
1.5 hour	13.61	2.1	11.51	0.85
2 hour	13.61	2.6	11.01	0.81
3 hour	13.61	1.8	11.81	0.87
4.5 hour	13.61	2.8	10.81	0.79
6 hour	13.61	2.8	10.81	0.79
9 hour	13.61	2.8	12.61	0.93
12 hour	13.61	1	12.61	0.93
18 hour	13.61	1.3	12.31	0.90
24 hour	13.61	0.2	13.41	0.99
30 hour	13.61	0	13.61	1.00
36 hour	13.61	0	13.61	1.00
48 hour	13.61	0	13.61	1.00
72 hour	13.61	0	13.61	1.00

6.4 Results

The RORB model was run for the current and post developed conditions under the 1% AEP flood event with results as shown below. The peak flows are at the locations of the future storage assets to set flow targets for storage sizing. For ease of following this section and Section 7, the concept design overview has been provided in Figure 26.

Table 8. 1% AEP RORB modelling results (SSP1)

Asset	Catchment area	Current conditions	Critical duration	Developed conditions	Critical duration
	Ha	Peak flow m^3/s	(Current)	Peak flow m^3/s	(Developed)
WLRB 1	21.6	2.22	45 min (TP26)	5.53	20min (TP27)
WLRB 2	41.9	3.08	45 min (TP26)	7.67	20min (TP27)
WLRB3	298.0	13.93*	4.5hr (TP27)	21.65^	45mins (TP26)
WLRB 4	71.6	4.11*	1.5hr (TP27)	12.99	20 min (TP30)
WLRB 5	111.4	8.14	1.5hr (TP27)	18.66	45 min (TP26)
WLRB 6	34.0	3.42	45 min (TP26)	7.00	20 min (TP30)
SBRB7	20.1	2.31	45 mins (TP26)	4.73	20 mins (TP27)
SBRB 8	12.2	1.30	45 min (TP26)	2.73	20 min (TP28)

^Note this is the result inclusive of modelled RBs for the developed flow (i.e. inflows to the proposed RB9).

*This is the flow immediately south of the railway line, taking into consideration existing 'storage' behind the railway, existing railway culverts, and potential overtopping of the railway track.

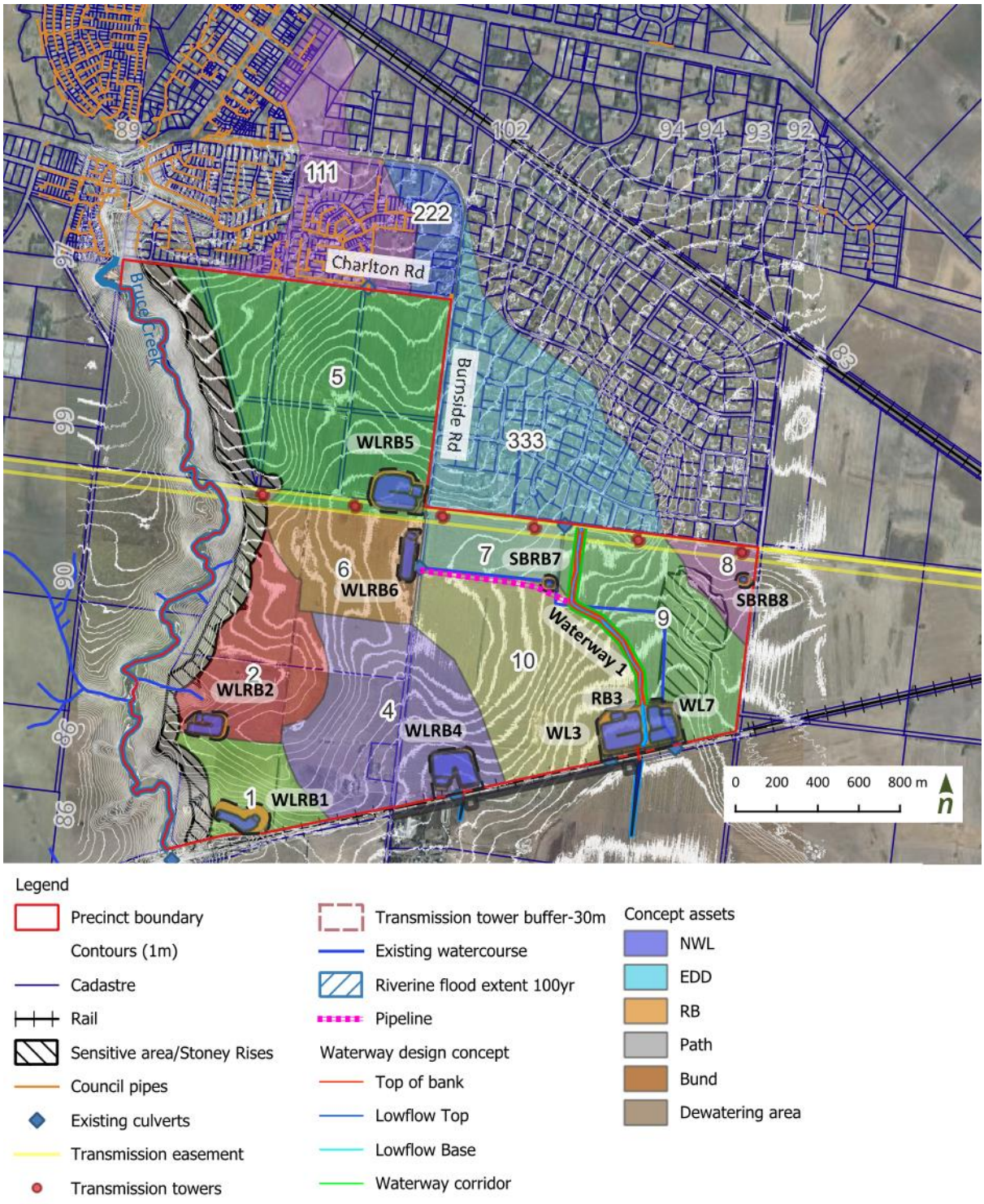


Figure 26. *Concept design overview showing proposed RB locations*

6.5 Retarding basin design

Following the establishment of existing (pre) and post-development peak flows without mitigation, the retarding basins have then been modelled and sized to control the developed 1% AEP peak flow.

The retarding basin sizing was undertaken iteratively with the treatment modelling to ensure the wetland can fit within the RB, and that the required storage was provided in order to meet the discharge criteria. The following discharge criteria has been adopted:

1. Retarding post-development peak 1% AEP flows to a minimum of pre-development 1% AEP conditions- WLRB1, WLRB2, SBRB8, WLRB5, WLRB6, and SBRB7.
2. Retarding post-development peak 1% AEP flows to the current pre-development 1% AEP flows immediately downstream of railway culvert – WLRB4 and WLRB3.

Wetlands are proposed to be located in the base of the RBs. Melbourne Water has published compliance criteria for the design and construction and establishment of constructed wetlands (Melbourne Water, 2020), which has been referred to during design development. The required wetland footprint was established by treatment modelling (detailed in Section 7.2).

- RB *stage storage relationships* were developed using storage volumes obtained from the preliminary modelling undertaken in the earthwork model (12d). During the future functional design stage these will be further refined. The wetland volume has not been included in the basin storage assumptions (i.e. storage above NWL is what is needed to retard flows). This was an iterative process, identifying potential wetland NWLs, RB base levels, RB extents, and testing this with various outfall arrangements in RORB in order to achieve the allowable peak discharge and meet freeboard requirements. Earthworks modelling is not typically undertaken at a concept design stage. This has been done for this project so to more confidently establish stage storage, land take, and excavation volumes for costing purposes.
- The total required area for each asset has been designed in the earthworks model assuming a 1(V):6(H) batter from the RB base to the peak flood level, and an allowance of a minimum of 300mm of freeboard (as per the IDM) on top of the peak 1% AEP flood depth to the existing surface. The systems are designed so they are cut and not in fill. However, two of the basins (WLRB4 and WLRB3) will require embankments given the terrain and outfall level constraints.
- Storage outlet sizes were adjusted until the peak 1% AEP outflows from the RB were equal or less than the pre-development peak flows for assets WLRB1, WLRB2, WLRB5, WLRB6, WLRB7 and SBRB8.
- Storage outlet sizes were adjusted until the peak 1% AEP outflows from the RB were equal or less than the existing flows through/over the railway line for WLRB4 and WLRB3.
- Peak storage volumes and flood heights within the basins were extracted from representative hydrographs runs.

Table 9 provides the required capacities of the retarding basins based on the RORB modelling undertaken. All retarding basins (RB) are integrated assets with a proposed wetland treatment floor to increase functionality, minimise land take and provide a functionally aesthetic asset for the landscape and community.

The results show that some assets have greater than 300 mm freeboard. This can be because the NWLs are being driven by the need for free-draining subdivisional drainage outfall (NWLs are assumed to be a minimum of 2m below existing surface), and/or because the RB base area is being driven by the treatment requirement, resulting in an overall larger storage than the hydrologic modelling indicates is required. Furthermore, the assets will need to still provide a minimum of 300mm freeboard under future climate change conditions (see section 6.7).

Levels would ultimately need to be confirmed once subdivisional road and trunk drainage design is undertaken. Care needs to be undertaken to not intercept groundwater as well.

Given the cumulative flow contribution into WLRB3 (the basin will ultimately receive retarded flows from WLRB5, WLRB6, SBRB7 and external catchments), the use of the available storage has been maximised in

WLRB5 and WLRB6. That is, the RB outflow has been limited far beyond the pre-development peak 1% AEP flows in an effort to utilise the available storage in these upstream assets, whilst still meeting a minimum of 300mm freeboard. To reiterate, this is possible due to the storage being driven by the treatment footprint and minimum 2m NWL depth below surface, creating large storages. This approach minimises the collective flow impact on the downstream WLRB3 in terms of the storage and footprint requirements, as well as reducing outlet sizing for WLRB5 and WLRB6 (i.e. smaller RB outlet pipes). It also reduces flow into downstream pipes and the constructed waterway, which has a positive land take and cost implication. Ultimately this approach can assist with optimising the Net Developable Area for the precinct.

Table 9. Post-development 1% AEP retarding basin requirements (SSP1)

Asset	Existing Peak flow (m^3/s)	Weir length (m)	Peak RB outflow (1% AEP) (m^3/s)	Peak RB storage (1% AEP) (m^3)	Peak RB flood elevation (1% AEP) (m AHD)	Freeboard above peak flood depth (mm)*
WLRB1	2.22	0.35m @ NWL 7.5m @ TED	1.92 (45min, TP22)	5,040	75.40	500
WLRB2	3.08	0.35m @ NWL 6.0m @ TED	2.94 (1hr, TP 29)	9,020	88.75	760
WLRB3	13.93	0.7m @ NWL 5.0m @ TED 30.0m @ 77.8mAHD	13.38 (2hr, TP28)	50,200	78.10	500^ (to 78.6 m AHD)
WLRB4	4.11	0.35m @ NWL 8.0m @ TED	3.95 (1.5hr, TP 28)	18,900	81.76	540^ (to 82.3 m AHD)
WLRB5	8.14	0.35m @ NWL 1.5m @ TED	4.38 (4.5hr, TP26)	49,000	89.53	770
WLRB6	3.42	0.35m @ NWL 1.5m @ TED	1.42 (1.5hr, TP28)	9,670	88.86	840
SBRB7	2.31	0.4m @ NWL	2.29 (1hr, TP27)	4,150	85.27	330
SBRB8	1.30	0.5m @ NWL	1.30 (45min, TP 26)	1,370	81.13	770

*To lowest point of RB top of bank.

^ To embankment crests. Embankment heights established alongside climate change hydrologic modelling – see section 6.7.

6.6 Other peak flow rates

Additional 1% AEP flow rates as established in the developed conditions RORB model are provided in Table 10. Flow locations are shown in Figure 27. These have been used to inform the waterway design (Section 8) and to compare against with existing culvert capacities.

- **Point A –** Retarded outflows from WLRB6 and WLRB5, along with external flows (catchment 111 and 222). The flow point is immediately east of Burnside Road.
- **Point B –** This is the location of the proposed outfall from SBRB7 into the waterway. Flows from external catchment 333 are proposed to outfall into the constructed waterway, as is currently the case with the existing channel. The flow at this location is the combined flow from all upstream, retarded

catchments, plus the flows from the existing residential catchments. These combined flows will inform the waterway design.

- **Point C –**The gap flows (1% AEP minus 20% AEP) will enter the waterway here. These combined flows will inform the waterway design.
- **Point D –** This is the flow exiting the existing residential catchment 333 and entering the precinct. This flow will need to be conveyed via a constructed waterway due to the size of the peak flow.
- **Point E –** This is the existing peak flow from the external catchment north of Charlton Road. It is proposed that these flows are conveyed south through the precinct via a pipe and road arrangement. This is detailed in section 8.7.

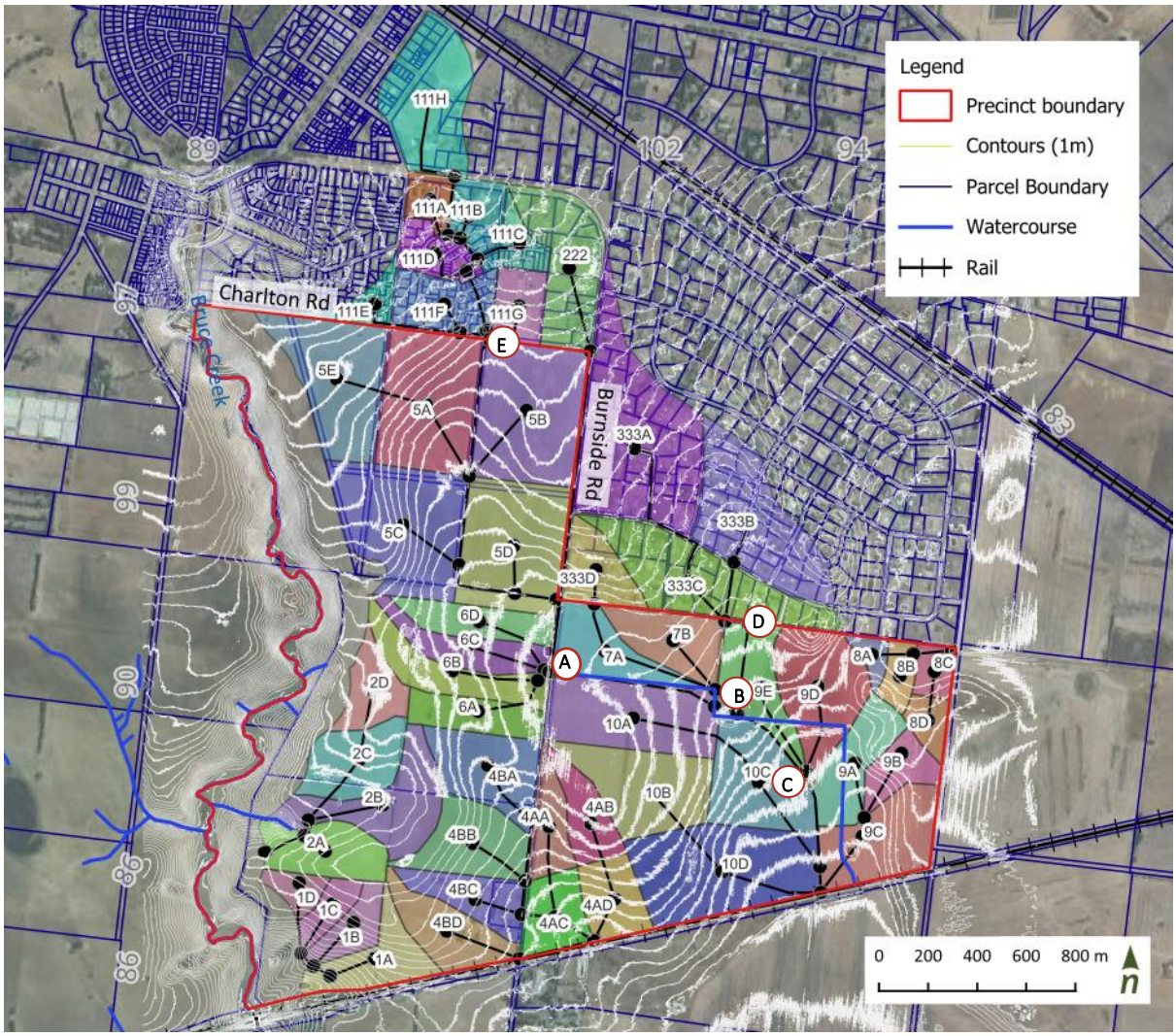


Figure 27. *Constructed waterway flow locations*

Table 10. Calculated 1% AEP flow rates for waterway design and other calculated flow rates (SSP1)

	Developed conditions peak 1% AEP flows (including RBs) (m^3/s)
Point A (To convey flow from WLRB 5, WLRB6 and external catchment 111 and 222)	5.91 (4.5hr, TP22)
Point B (confluence of 333 constructed waterway, SBRB7 outflows and flows from Burnside Rd)	12.05 (45 mins, TP26)
Point C (waterway flows downstream of catchments 9D+9E)	11.37 (1hr, TP27)
Point D (external catchment 333 flows)	12.12 (20mins, TP27)
Point E (external catchment 111 flows)	7.99 (25mins, TP27)

The results indicate that the flows are relatively small at Point A, indicating that a constructed waterway is not necessary at this location. These 1% AEP flows could be conveyed via a pipe to the constructed waterway. However, a simple vegetated swale may be desirable from an IWM perspective from Burnside Road instead of a 1% AEP pipe. A vegetated swale would result in a greater loss of developable land.

The peak flows from external catchment 333 are relatively large at 12.12m^3/s. Therefore, a waterway is proposed to flow south from here, before picking up flows from SBRB7 and the flows coming from Burnside Rd (conveyed in a pipe).

6.7 Climate change considerations

As noted briefly in section 6.2, there is updated climate change considerations guidance (Chapter 6, Book 1), as provided in ARR: A Guide to Flood Estimate (version 4.2). There are now four Shared Socio-economic Pathways (SSP) which have replaced the previous Representative Concentration Pathways (RCP) (Figure 28). RCPs did not consider social change or policies. By adding these societal choices, SSPs enable policy makers to identify efforts required to keep global warming below 2°C. Each SSP outlines ways the world might change in the future, including different types of energy generation, rates of population growth, economic development and land uses (Figure 29). These lead to different levels of greenhouse gas emissions over time.

Climate change factor now impacts both rainfall and losses. The equation for calculating the projected rainfall depth/intensity has changed and is related to the rate of change and the projected global temperature increase. It is generally expected that the conditions will be drier, and therefore there will be an increase in initial loss. Therefore, the initial and continuing losses also need to be updated to account for climate change.

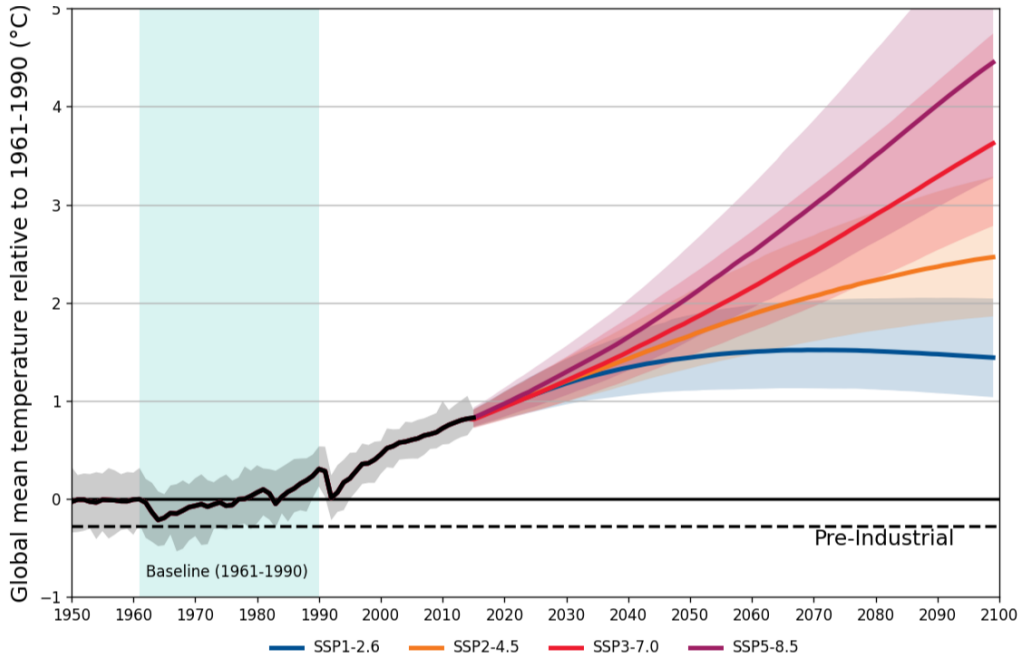


Figure 28. *Projected temperature increase associated with AR6 socioeconomic pathways relative to 1961-1990 and their associated uncertainty (ARR: A Guide to Flood Estimate, version 4.2)*

	SSP1-1.9 "SUSTAINABILITY"	SSP1-2.6 "SUSTAINABILITY"	SSP2-4.5 "MIDDLE OF THE ROAD"	SSP3-7.0 "REGIONAL RIVALRY"	SSP5-8.5 "FOSSIL-FUELLED DEVELOPMENT"
RCP equivalent	No equivalent RCP	RCP2.6	RCP4.5	No equivalent RCP	RCP8.5
THE WAY THE WORLD MIGHT CHANGE IN THE FUTURE					
Emissions reduction	Very high and immediate	High and immediate	Moderate from 2040s	None (minor slowing)	None (accelerating)
Energy sources	Renewables	Renewables and biofuels	Renewables and fossil fuels	Fossil fuels	Increased fossil fuels
Carbon dioxide removal	New technology	New technology	None	None	None
Global socio-economic trends	Gradual move towards sustainability and environmental respect; increasing action towards Sustainable Development Goals (SDGs)	Gradual move towards sustainability and environmental respect; increasing action towards SDGs	Similar to the past; unevenly distributed; slow progress towards SDGs	Slow and increasingly unequal	Rapid growth at the expense of the environment; resource intensive lifestyles and industries; high investment in health and education; dependence on technological solutions
WHAT THE FUTURE CLIMATE MAY LOOK LIKE UNDER EACH SSP					
Global warming by 2100	1.0-1.8°C	1.3-2.4°C	2.1-3.5°C	2.8-4.6°C	3.3-5.7°C
Resulting global warming levels*	Due to past emissions all SSPs reach 1.5°C in the 2030s and then diverge				
	Overshoots 1.5C slightly around 2050 then returns and stabilises near 1.5C by 2100	Reaches 2°C around 2050s and stabilises	Reach 2°C around 2050s 2.7°C by 2100	Reach 2°C around 2050s 3°C around 2070s 4°C possible by 2100	Reach 2°C around 2050s 3°C around 2060s 4°C by around 2080s

Figure 29. *Shared Socio-economic Pathways explainer (Source: Climate Systems, National Environmental Science Program)*

The relevant equation and associated tables for accounting for changes to the IFD curves is provided below, as presented in ARR2019.

$$I_p = I \times \left(1 + \frac{\alpha}{100}\right)^{\Delta T} \quad (1.6.1)$$

where

- I_p the projected (current or future) design rainfall depth or intensity
- α is the rate of change from Table 1.6.1
- I is the historical design rainfall depth or intensity (e.g. from the 2016 IFD portal or historical PMP estimates)
- ΔT is the most up-to-date estimate of global (land and ocean) temperature projection for the design period of interest and selected climate scenario relative to a baseline time period. When used in conjunction with the 2016 IFD curves the baseline is recommended to be the 1961-1990 period (see Table 1.6.2 and text below).

Table 1.6.1. Recommended rates of change (α) and associated uncertainty derived in Wasko et al. (2024), presented per degree global temperature change (%/°C). The factors in this table are applicable for exceedance probabilities from 1EY up to and including the PMP and are designed for application across mainland Australia and Tasmania.

	≤ 1 hr	> 1 hr and < 24 hr	≥ 24 hr
Central (median) estimate (%/°C)	15	Interpolation zone (see Table 1.6.5)	8
'Likely' range (corresponding to ~66%[a] range) (%/°C)	7-28		2-15

[a]Consistent with terminology used by the IPCC the 66% range corresponds to an uncertainty range of +/- 33%.

Table 1.6.2. Global mean surface temperature projections (ΔT) for four socio-economic pathways relative to 1961-1990. The 90% uncertainty interval is provided in parentheses[a]

Climate Scenario	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Current and near-term (2021-2040) (°C)	1.2 (0.9-1.5)	1.2 (0.9-1.5)	1.2 (0.9-1.5)	1.3 (1.0-1.6)
Medium-term (2041-2060) (°C)	1.4 (1.0-1.9)	1.7 (1.3-2.2)	1.8 (1.4-2.3)	2.1 (1.6-2.7)
Long-term (2081-2100) (°C)	1.5 (1.0-2.1)	2.4 (1.8-3.2)	3.3 (2.5-4.3)	4.1 (3.0-5.4)

[a]Projections adapted from the Summary for Policymakers (SPM) of the Working Group I (WGI) Contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)[b]. The projected temperature increases in the table above use a different baseline to the global warming levels referenced in relation to the Paris Agreement which uses a pre-industrial period (represented by the 1850-1900 period). There are approximately 0.3 degrees of global warming between the pre-industrial reference and 1961-1990, and this amount needs to be added to the temperatures in the above if comparing to the 1850-1900 period. The IPCC offers a range of summary projections information including in the assessment reports and the interactive atlas. We have selected the global climate projections from AR6 as they represent a balanced assessment of future global climate based on multiple lines of evidence, rather than a simple average of the global climate model output. This data is only available at the global level, not the regional level.

[ab] Refer to Table SPM.1 from the Summary for Policymakers (SPM) of the Working Group I (WGI) Contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2021)

Figure 30. *Equations and tables to account for change to IFD curves in 2016 IFD portal*

For baseline conditions, the 1960 – 1990 data is used as it is approximately the mid-point of the data used to develop the IFD information. Therefore, to account for the warming that has happened since this time, there is a need to scale the design rainfall intensity to account for the temperature change from when the IFD data was derived. To bring the data to current climatic conditions, a 1.2 degree increase in temperature is applied (SSP1, 2021-2040). To ensure that the same dataset is being used to compare current conditions to developed conditions, the SSP1 was also applied to the developed conditions model.

Table 11. Adopted RORB parameters (SSP1)

Parameter	Developed conditions
Rainfall Intensity Frequency Duration (IFD)	Obtained from Bureau of Meteorology's IFD tool, scaled for SSP1 climate scenario
Temporal Pattern details	ARR2019 data hub
Areal Reduction Factor d	ARR2019 data hub
Kc (further details in Appendix A)	$k_c = 1.25 \times Dav$ (Pearse et al.,2002, Victoria data)
M	0.80
Initial loss (IL) (mm)	13.61
Continuing loss (CL) (mm/hr)	2.54

The CCMA has provided the following advice in relation to climate change scenarios to adopt:

Corangamite CMA recommend planning for flood risk using a climate scenario which is not less than the SSP3-7.0 climate scenario. This means considering climate change impacts on planning decisions by using either the high (SSP3-7.0) and/or very high (SSP5-8.5) climate scenarios when determining flood risk. If the lower is used the sensitivity analysis should be carried out on the very high (SSP5-8.5) climate scenario.

The VPA has indicated that the RBs should be designed such that they still have a minimum of 300mm freeboard provided in the SSP3-7.0 climate change scenario.

Scaled input parameters used for SSP3-7 climate change conditions are summarised in Table 12. Pre-burst depth ratios for SSP3-7 are provided in Table 13.

Table 12. Adopted RORB parameters (SSP3)

Parameter	Developed conditions
Rainfall Intensity Frequency Duration (IFD)	Obtained from Bureau of Meteorology's IFD tool, scaled for SSP3 climate scenario
Temporal Pattern details	ARR2019 data hub
Areal Reduction Factor d	ARR2019 data hub
Kc (further details in Appendix A)	$k_c = 1.25 \times Dav$ (Pearse et al.,2002, Victoria data)
M	0.80
Initial loss (IL) (mm)	14.75
Continuing loss (CL) (mm/hr)	3.01

Table 13. Pre burst depth ratios (SSP3)

Duration	Storm Initial Loss (ILs)	Median Pre burst depth	Burst Initial Loss (ILb)	Pre burst ratio
1 hour	14.75	3.3	11.45	0.78
1.5 hour	14.75	2.1	12.65	0.86
2 hour	14.75	2.6	12.15	0.82
3 hour	14.75	1.8	12.95	0.88
4.5 hour	14.75	2.8	11.95	0.81
6 hour	14.75	2.8	11.95	0.81
9 hour	14.75	2.8	13.75	0.93
12 hour	14.75	1	13.75	0.93
18 hour	14.75	1.3	13.45	0.91
24 hour	14.75	0.2	14.55	0.99
30 hour	14.75	0	14.75	1.00
36 hour	14.75	0	14.75	1.00
48 hour	14.75	0	14.75	1.00
72 hour	14.75	0	14.75	1.00

The results for the SSP3-7.0 climate change modelling are provided in Table 14. The RBs were kept the same as the SSP1 model in terms of stage storage relationships and outlet properties. Results indicate that SBRB7 will require small embankments to ensure the minimum 300mm freeboard is maintained for the SSP3-7 scenario. SBRB7 will also require an additional spillway given the relatively small storage. This could be implemented in the future for adaptive management.

Table 14. Post-development retarding basin requirements (SSP3-7.0)

Asset	Existing Peak flow (m^3/s)	Peak RB outflow (1% AEP) (m^3/s)	Peak RB storage (1% AEP) (m^3)	Peak RB flood elevation (1% AEP) (m AHD)	Freeboard above peak flood depth (mm)*
WLRB1	2.22	3.14 (45mins, TP26)	6,070	75.51	390
WLRB2	3.08	4.62 (45min, TP 26)	11,100	88.90	610
WLRB3	13.93	20.94 (1.5hr, TP 27)	59,600	78.22	380 (embankment crest 78.6m AHD)
WLRB4	4.11	6.03 (1hr, TP 29)	23,100	81.90	400 (embankment crest 82.3m AHD)
WLRB5	8.14	6.66 (2hr, TP 28)	60,300	89.82	480
WLRB6	3.42	2.11 (1.5hr, TP 28)	12,200	89.04	660
SBRB7	2.31	4.58 (45min, TP26)	4,700	85.43	170 – require a small 130mm embankment
SBRB8	1.30	1.79 (25mins, TP 21)	1,960	81.44	460

*To lowest point of RB top of bank.

The 1% AEP flow rates for various flow locations in the SSP3-7 scenario, as well as the SSP1 scenario for comparison, are provided in Table 15. The future climate change flow rates will influence constructed waterway design (see section 8).

Table 15. Calculated 1% AEP flow rates for waterway design and other calculated flow rates – SSP3-7

	Developed conditions peak 1% AEP flows (including RBs) (m^3/s) SSP1	Developed conditions peak 1% AEP flows (including RBs) (m^3/s) SSP3-7
Point A (To convey flow from WLRB 5, WLRB6 and external catchment 111 and 222)	5.91 (4.5hr, TP22)	8.93 (2hr TP28)
Point B (confluence of 333 constructed waterway, SBRB7 outflows and flows from Burnside Rd)	12.05 (45 mins, TP26)	19.48 (45 mins, TP26)
Point C (waterway flows downstream of catchments 9D+9E)	11.37 (1hr, TP27)	18.40 (1hr, TP27)
Point D (external catchment 333 flows)	12.12 (20mins, TP27)	17.80 (20mins, TP27)
Point E (external catchment 111 flows)	7.99 (25mins, TP27)	11.80 (20 mins, TP25)

7 Wetland and sediment basin design

This section details the analysis, modelling, and results for the treatment assets. Seven wetlands (with associated sediment basins) and two stand-alone sediment basin were developed and are discussed in this section.

7.1 Design arrangement overview

The design arrangement of the sediment basins and wetlands has been based off the following design principles:

- The assets are to be fed by the minor drainage network (20% AEP) from the contributing catchments. Bypass requirements should be assessed as part of future design phases.
- The sediment basins have been designed to treat the 4 Exceedances per Year (EY) storm event and to capture 95% of coarse particles ≥ 125µm diameter entering the system. Basins should have sufficient storage for accumulated sediment.
- 4EY flows should be transferred from the sediment basin to the wetland.
- The wetlands have been sized based on achieving best practice treatment targets and a three-day residence time.
- Design should allow for maintenance requirements.
- Designs should aim to avoid fill where possible.
- Design should follow Melbourne Water's Wetland Design Manual Deemed to Comply design criteria (2020).

A design arrangement for the assets was completed based on the design principles and arranged to fit within the existing topography and site constraints.

7.2 Stormwater treatment modelling

A key principle for the strategy is that all stormwater is to be treated to BPEM (Best Practice Environmental Management) Guidelines before being discharged from the study area. As such, the development site will require numerous treatment techniques in order to achieve the targeted reduction in pollutant load concentrations. The following BPEM targets have been adopted:

- 70% removal of the Total Gross Pollutant load
- 80% removal of Total Suspended Solids (TSS)
- 45% removal of Total Nitrogen (TN)
- 45% removal of Total Phosphorus (TP).

A MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model was developed to estimate the pollutant loads generated from the developed conditions scenario. This allowed us to understand the target pollutant load reduction, and therefore test the sizing and treatment capacity of various opportunities required to meet the pollutant reduction targets.

Modelling inputs

The key modelling inputs for the MUSIC model are rainfall and evapotranspiration. Generally, for MUSIC a 10-year rainfall period is selected for a site which is a good representation of the average rainfall. The period adopted should consider a completeness of record, and representation of wet and dry periods.

The 6-min infilled rainfall and evaporation template for Melbourne Airport (station # 086282 from 1971-1980) has been adopted for this modelling as being geographically most appropriate for Bannockburn site (using rainfall template selection map, Melbourne Water MUSIC Guidelines). A comparison was conducted to ensure

the MUSIC template provides similar average rainfall data to local meteorological data sourced from the BoM website (including the 'Bannockburn' rainfall station no. 087147). This template has an annual average rainfall of 575mm, and evaporation rate of 1041 mm/year. BoM website statistics show an average rainfall of 554.5mm for rainfall station #087147.

Wetlands were selected as the preferred water quality assets due to their amenity, ease of maintenance, and ability to deliver a multi-functional asset when co-located within retarding basins (RBs). However, due to the small catchment size, a stand-alone sediment basin retarding basin was proposed for catchment 8. A stand-alone sediment basin/retarding basin was also proposed for catchment 7 before it outfalls into the constructed waterway. Treatment shortfalls for catchment 7 and 8 are offset in wetland 7 and 3 (both within in RB3), but primarily wetland 3 due to it having a larger contributing catchment and therefore a larger treatment capacity. A wetland was not proposed for catchment 7 due to the ability to provide treatment in the large downstream wetland/retarding basin. This is considered a more efficient approach in terms of land take.

When modelling wetlands in MUSIC, an Extended Detention Depth (EDD) of 0.35m is typically adopted and a detention time of 72 hours is aimed for. This allows sufficient contact time with the vegetation, and therefore treatment of the stormwater.

The sediment basin areas for each wetland were sized using the Fair and Geyer equation, where sediment basins are required to meet a minimum 95% sediment capture efficiency of coarse particles ≥ 125 µm diameter for the peak 4EY (4 Exceedances per Year) event. The sediment basins were assumed to have an average depth of 0.8m, and the volume was used in the MUSIC modelling. The details of the sediment basin sizing calculations are provided in Section 7.3.

As is directed in the latest version of the MUSIC Guidelines (Melbourne Water, 2024), a stand-alone sediment basin should not have any nitrogen removal included. This has been updated in the model. Off-setting of catchments 7 and 8 is therefore required by the other assets.

The catchment nodes used in the model have been calculated based on the areas, land use and associated FI values listed in Table 2. The MUSIC model layout is shown in Figure 31.

The treatment assets (wetlands and sediment basins) have been sized to treat the loads being generated from the future developable area to BPEM standards for each catchment. There is no treatment of external catchments.

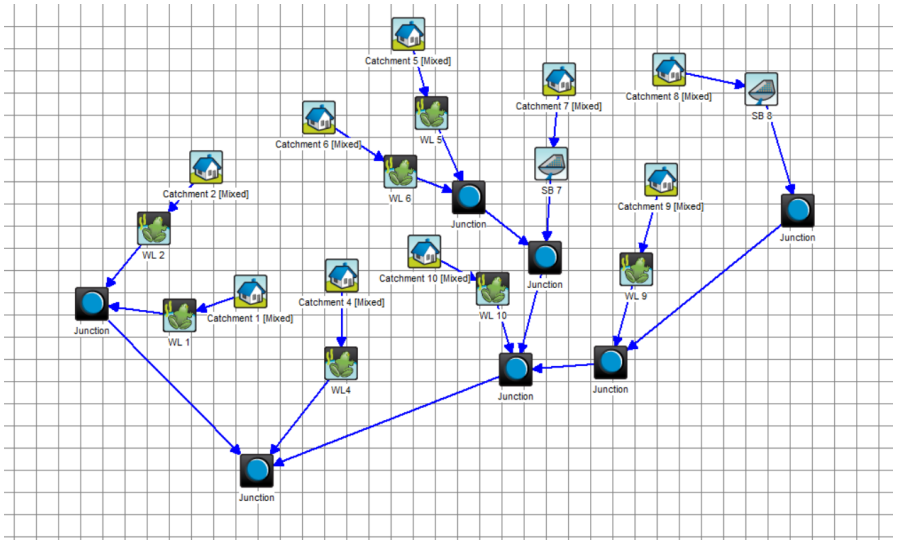


Figure 31. *MUSIC model layout*

The wetland sizing was done in conjunction with velocity checks and sediment capture efficiency calculations.

Asset Performance

The MUSIC modelling determined the sizing required for the wetland assets located at each of the catchment low points. The wetlands have been designed to inform the retarding basin stage-storage relationship presented in the hydrologic modelling section of this report (section 6). The details of the required treatment systems are shown in Table 16.

Table 16. Treatment asset parameters for stormwater treatment assets

	Catchment area	Normal Water Level (NWL) area (m^2)	Inlet pond volume (m^3)	Average depth wetland (m)	Extended detention (m)
Wetland 1 (WLRB1)	21.6	7000	320	0.4m	0.35
Wetland 2 (WLRB2)	41.9	9500	600	0.4m	0.35
Wetland 3 (WL3RB3)	76.2	23,000	1080	0.4m	0.35
Wetland 4 (WLRB4)	71.6	21,500	1080	0.4m	0.35
Wetland 5 (WLRB5)	111.4	25,000	1440	0.4m	0.35
Wetland 6 (WLRB6)	34.0	9000	640	0.4m	0.35
Wetland 7 (WL7RB3)	56.3	15,000	720	0.4m	0.35
SBRB7	20.1	400	320	0.8 (SB)	0.35
SBRB8	12.2	400	320	0.8 (SB)	0.35

The results of the MUSIC modelling analysis demonstrates that BPEM Guidelines / State pollutant reduction targets are met with the performance of those assets, as shown in Table 17. The MUSIC model results for each individual wetland and the stand-alone sediment basins are provided in subsequent tables. Further refinement of the treatment modelling would be expected to occur in the functional design stage, when custom stage storage discharge is included. As discussed previously, there is some level of treatment offsetting occurring in most wetlands so to ensure the precinct can meet the required treatment targets. This is primarily occurring in wetland 3. The modelling indicated that TSS was the pollutant which was the biggest driver for asset sizing (i.e. the limiting pollutant in terms of meeting the targets).

Table 17. Overall PSP MUSIC modelling results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	1,460.0	1,310.0	9.7	
Total Suspended Solids (kg/yr)	286,000.0	57,000.0	80.1	229000
Total Phosphorus (kg/yr)	584.0	181.0	69.0	403
Total Nitrogen (kg/yr)	4,120.0	2,120.0	48.6	2000
Gross Pollutants (kg/yr)	58,600.0	-	100.0	58600

Table 18. Wetland 1 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	75.9	67.0	11.8	
Total Suspended Solids (kg/yr)	15,000.0	2,660.0	82.3	12,340.0
Total Phosphorus (kg/yr)	31.0	8.8	71.6	22.2
Total Nitrogen (kg/yr)	218.0	100.0	53.9	118.0
Gross Pollutants (kg/yr)	3,020.0	-	100.0	3,020.0

Table 19. Wetland 2 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	124.0	112.0	9.8	
Total Suspended Solids (kg/yr)	24,400.0	4,900.0	79.9	19,500.0
Total Phosphorus (kg/yr)	48.2	14.9	69.2	33.3
Total Nitrogen (kg/yr)	354.0	171.0	51.6	183.0
Gross Pollutants (kg/yr)	5,060.0	-	100.0	5,060.0

Table 20. Wetland 3 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	247.0	217.0	11.9	
Total Suspended Solids (kg/yr)	48,000.0	7,450.0	84.5	40,550.0
Total Phosphorus (kg/yr)	99.3	26.0	73.9	73.3
Total Nitrogen (kg/yr)	697.0	315.0	54.8	382.0
Gross Pollutants (kg/yr)	9,970.0	-	100.0	9,970.0

Table 21. Wetland 4 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	252.0	224.0	10.9	
Total Suspended Solids (kg/yr)	50,700.0	9,070.0	82.1	41,630.0
Total Phosphorus (kg/yr)	103.0	28.5	72.2	74.5
Total Nitrogen (kg/yr)	719.0	335.0	53.5	384.0
Gross Pollutants (kg/yr)	10,000.0	-	100.0	10,000.0

Table 22. Wetland 5 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	361.0	329.0	8.9	
Total Suspended Solids (kg/yr)	71,200.0	14,000.0	80.4	57,200.0
Total Phosphorus (kg/yr)	144.0	44.6	69.0	99.4
Total Nitrogen (kg/yr)	1,010.0	514.0	49.0	496.0
Gross Pollutants (kg/yr)	14,600.0	-	100.0	14,600.0

Table 23. Wetland 6 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	117.0	105.0	9.9	
Total Suspended Solids (kg/yr)	22,900.0	4,520.0	80.3	18,380.0
Total Phosphorus (kg/yr)	46.8	14.3	69.5	32.5
Total Nitrogen (kg/yr)	333.0	163.0	50.9	170.0
Gross Pollutants (kg/yr)	4,670.0	-	100.0	4,670.0

Table 24. Wetland 7 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	187.0	168.0	10.3	
Total Suspended Solids (kg/yr)	36,600.0	6,990.0	80.9	29,610.0
Total Phosphorus (kg/yr)	75.1	22.2	70.4	52.9
Total Nitrogen (kg/yr)	527.0	255.0	51.6	272.0
Gross Pollutants (kg/yr)	7,510.0	-	100.0	7,510.0

Table 25. Sediment basin (RB7) treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	62.7	62.4	0.5	
Total Suspended Solids (kg/yr)	11,900.0	5,590.0	53.2	6,310.0
Total Phosphorus (kg/yr)	25.1	15.7	37.7	9.4
Total Nitrogen (kg/yr)	178.0	178.0	0.1	-
Gross Pollutants (kg/yr)	2,550.0	-	100.0	2,550.0

Table 26. Sediment basin (RB8) treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	29.9	29.6	1.0	
Total Suspended Solids (kg/yr)	5,390.0	1,880.0	65.1	3,510.0
Total Phosphorus (kg/yr)	11.4	6.1	46.7	5.3
Total Nitrogen (kg/yr)	83.7	83.6	0.1	0.1
Gross Pollutants (kg/yr)	1,220.0	-	100.0	1,220.0

7.3 Sediment Basin sizing

The wetlands were designed with sediment basins which first receive the minor drainage flows, to allow coarse sediments to drop out before entering the macrophyte zone.

The sediment basins in the treatment modelling have been sized using the Fair and Geyer equation, where sediment basins are required to meet the following criteria - capture 95% of coarse particles ≥ 125 µm diameter for the peak 4EY event. The procedure outlined in *WSUD Engineering Procedures* (2005) has been followed and are based on the typical sediment loading rate of 1.6 m^3/ha/yr for a developed catchment. The sediment basins have been modelled with a pool depth of 1.5 m and a standard cleanout frequency of 5 years. The sediment basin sizing was used for the inlet pond in the wetland nodes (assuming an average depth of 0.8m). The basins all exceed 95% sediment capture efficiency at this design stage. For some basins this is due to a storage requirement for the accumulated sediment. Slightly exceeding the 95% minimum at the concept stage allows for flexibility in the hydraulic efficiency assumptions during the functional design stage.

The sediment basin arrangements have also been informed by the need to meet velocity requirements. That is, that the velocity within the basin needs to be <0.5m/s for the 20% AEP flows. The flows used in these calculations have been obtained from rational method calculations.

The velocity calculations (Table 28) and sediment capture efficiency calculations (Table 27) were performed iteratively to ensure all criteria was met and the sediment basins were sized appropriately.

Table 27. Sediment basin sizing

	Parameter	WLRB 1	WLRB 2	WL3RB 3	WLRB 4	WLRB 5	WLRB 6	WL7RB 3	SBRB 7	SBRB 8
Conditions	Contributing Catchment (ha)	21.60	41.90	76.20	71.60	111.40	34.00	56.30	20.10	12.20
	Area of Basin (m^2)	400	750	1350	1350	1800	800	900	400	400
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11	11	11	11	11	11	11	11	11
	Hydraulic Efficiency (λ)	0.11	0.11	0.11	0.11	0.11	0.26	0.11	0.11	0.11
	Permanent Pool Depth, dp (m)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Extended detention depth, de	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	Number of CTSR's, n	1.1	1.1	1.1	1.1	1.1	1.4	1.1	1.1	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	1	1	1	1	1	1	1	1	1
	Design Discharge (m^3/s) [4EY]	0.39	0.55	0.95	1.00	1.28	0.55	0.83	0.27	0.14
	Capture Efficiency	95%	96%	97%	96%	97%	98%	95%	97%	98%
	Check (>95%)	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
Sediment Storage	Sediment Loading rate, Lo ($m^3/ha/yr$)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Desired clean-out frequency, Fr	5	5	5	5	5	5	5	5	5
	Storage volume required, St	164	323	589	552	860	266	430	155	96
	Available sediment storage volume	200	375	675	675	900	400	450	200	200
	Check (Available storage > required storage)	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
Sediment dewatering	Depth for dewatering area (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Area required for dewatering (m^2)	329	646	1177	1104	1720	532	860	311	192

Table 28. Sediment basin velocity calculations

	Parameter	WLRB 1	WLRB 2	WL3RB 3	WLRB 4	WLRB 5	WLRB 6	WL7RB 3	SBRB 7	SBRB 8
Flow conditions	4EY flow (m^3/s)	0.39	0.55	0.95	1.00	1.28	0.55	0.83	0.27	0.14
	20% AEP flow (m^3/s)	1.95	2.74	4.73	4.99	6.42	2.74	4.14	1.36	0.68
	Flow depth (m)-between NWL and TED	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Sediment basin	Basin area (m^2)	400	750	1350	1350	1800	800	900	400	400
	Width at NWL (m)	16	23	24.5	28	35	16	21	15	15
	SB top width (m)	20.2	27.2	28.7	32.2	39.2	20.2	25.2	19.2	19.2
	Average width (m)	18.1	25.1	26.6	30.1	37.1	18.1	23.1	17.1	17.1
	Flow Area (m^2)	6.3	8.8	9.3	10.5	13.0	6.3	8.1	6.0	6.0
	Flow Velocity (m/s) (20% AEP)	0.26	0.29	0.49	0.50	0.10	0.34	0.10	0.25	0.12
	Check	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK	< 0.5 OK
	Length to width ratio*	1.56	1.42	2.25	1.72	1.47	3.13	2.04	1.78	1.78

*The reduced length to width ratios are reflected in the hydraulic efficiency of the sediment basins

7.4 Wetlands

This section outlines the design calculations that have been undertaken to ensure the performance of the treatment system complies with appropriate guidelines. The sediment basin and macrophyte zone were sized in 12d using LiDAR data to create a surface level Triangulate Irregular Network (TIN). This then allowed for iterative sizing by changing the layout, location, and Normal Water Level (NWL) height in order to integrate into the existing landscape and minimise cut into the site, and avoid requiring fill where possible. The sizing was conducted in conjunction with MUSIC modelling in order to optimise pollutant removal, and the hydrologic modelling to ensure detention requirements were met.

Other factors that influenced the configuration of the asset included:

- The requirement to meet a length to width ratio of at least 4:1 (MZ4 in the constructed wetlands manual), and therefore the associated maximum width, and how this fit in with the surrounding terrain.
- Meeting velocity requirements
- Minimising excavation requirements where possible.

Velocities

The velocities through the wetlands were also checked. A flow depth of 0.35 m, which is the extended detention depth, has been assumed for all flows, which is a conservative approach (as a calculated smaller flow area will result in higher calculated velocities). A manual calculation has been used to check the flow velocities through the assets. This calculates the flow area from the flow depth (between the extended detention depth and normal water level) and the average width in that area. The average width is determined from the narrowest part of the macrophyte zone. Velocities within the macrophyte zone should be under 0.05m/s.

The maximum width of the wetland was determined using the length to width ratio of at least 4:1 (MZ4). The calculations for the velocities through the wetlands, as well as the length to width ratios are shown in Table 29.

Table 29. Velocity calculations

	Parameter	Wetland 1	Wetland 2	Wetland 3	Wetland 4	Wetland 5	Wetland 6	Wetland 7
NWL area	NWL area (m^2)	7000	9500	23,000	21,500	25,000	9000	15,000
Flow conditions	4EY (3 month flow) (m^3/s) (rational calc)	0.32	0.50	0.93	1.05	1.21	0.43	0.58
	Flow depth (m)	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Wetland	Width at NWL (m)	35	40	60	73	72	44	50
	Width at top (m)	39.2	44.2	64.2	77.2	76.2	48.2	54.2
	Average width (m)	37	42	62	75	74	46	52
	Flow Area (m^2)	13	15	22	26	26	16	18
	Flow Velocity (m/s) (4EY)	0.025	0.034	0.04	0.040	0.050	0.03	0.05
	Check	< 0.05 OK	< 0.05 OK	< 0.05 OK	< 0.05 OK	< 0.05 OK	< 0.05 OK	< 0.05 OK
	Length: width ratios	5.71	5.94	6.39	4.03	4.82	4.65	6.00

7.5 Connections

Inflow into sediment basins

The inflow to the sediment basins will be via the minor drainage network. The stormwater main for the catchment will outfall into the sediment basins. Typically, this will be via a rocked endwall.

Sediment basin to wetland transfer

There will be piped connections between the sediment basins and the macrophyte zone to pass the 4EY peak flow. The connections will be an outlet pit, with the top of the pit at the sediment basin NWL to control the water level. A transfer pipe at the bottom of the pit will pass flows through to the wetland. The invert of the pipe on the wetland side should be set 300mm above the base of the pool so to avoid being blocked by accumulated sediment. There are Melbourne Water standard drawings for these connection details (i.e. 7251/12/008 and 7251/12/001).

Bypass pipes

As per the Melbourne Water wetlands manual, where a sediment pond is located within a retarding basin, the bypass must convey at least the peak one year ARI flow. The 1EY bypass from the sediment basin is proposed to be conveyed through a pipe.

Balance pipes

300mm diameter balance pipes connected to submerged offtake pits will be located in the base of the wetland pools, connecting them up. This is important to be able to drain the system for maintenance purposes. This is as per Melbourne Water standard drawings 7251/12/015 and 7251/12/035.

Wetland outfall

The water level in a wetland is controlled by an outlet usually in the macrophyte zone. The macrophyte zone outlet provides the hydrologic control of the water level, and flows in the macrophyte zone, to achieve the design detention time for treatment performance.

Outlet structures should be designed and located so that they can be easily accessed for maintenance. Outlet or overflow pits located within the outlet pool of the macrophyte zone should be accessible from the edge of the wetland, this means that the edge of the pit closest to the wetland margin should be located in no more than 350mm depth.

The wetland outlet configuration consists of a submerged pipe connected to a twin chamber outfall pit (containing the controlled weir outlet) located adjacent to the wetland above TED. The outlet pit should be easily accessible and have a hinged grated lid to enable access to the outlet control structure for maintenance. These pits have been located next to the internal path.

An adjustable weir, such as a side-winding penstock, allows the inundation frequency to be adjusted easily. The control pit has an outlet pipe which will connect with the RB outlet pit.

There is a Melbourne Water standard drawing for this wetland pit detail (i.e. 7251/12/006).

8 Waterway design / flow conveyance

8.1 Constructed waterways

A constructed waterway (Waterway 1) is proposed to take flows from external catchment 333, heading south before going south-east, following the existing valley line. This at times deviates away from the existing channel line which does not always follow the low point of the landscape. The proposed alignment better follows the drainage lines as shown in the flood mapping (Figure 11). The proposed waterway design concept, as informed by the below section, is provided in Section 9.2 along with all asset concepts.

8.2 Design objectives

The design objectives for constructed waterway design are as follows:

- Safely convey large flood events (1% AEP) within the waterway corridor and reduce or maintain current flood extents.
- Integrate drainage outfalls/stormwater connections. The waterway will need to be of a sufficient depth to enable outfall from stormwater basins and existing residential areas.
- Provide an appropriate level of erosion protection to public and private assets using native vegetation as the primary channel boundary material, in preference over rock or other hard engineered materials, subject to the design criteria being achievable.
- Have a naturalistic and variable form with an abundant and diverse native vegetation where possible.
- Create a stable and sustainable waterway asset.
- Be a safe environment for the community to interact with and provide an appropriate level of direct and indirect access to the waterway.
- Provide for the establishment of abundant and diverse native vegetation species within the waterway and provide suitable non-vegetative physical habitat.
- Ensure sufficient access and space for all required maintenance activities that is safe for Council officers and contractors to access and maintain.
- Ensure the waterway has no detrimental impacts on the railway line.

8.3 Design constraints

- There are some mature trees the waterway design should seek to avoid where possible.
- The design must consider how the existing residential development (Glen Avon Estate) stormwater outfall connects into the waterway to ensure future serviceability of this development.
- The waterway ends within RB3, where flows will be transferred out of the precinct via the RB outlet (culverts under the railway track).
- Minimise excavation to reduce costs and land take.

8.4 Waterway design

All designs of the waterways are in accordance with Melbourne Water's Constructed Waterway Design Manual (2019). The waterway will be comprised of a meandering low flow channel within a larger high flow channel. The high flow channel must safely convey the 1% AEP peak flows. The low for channel has been sized for between the 4EY flow and 1EY flow.

The constructed waterway is proposed to begin where the flows from external catchment 333 enter the precinct. There is an existing swale running east-west which captures flows from catchment 333. Some minor regrading of this swale to direct flows into the start of the proposed constructed waterway is likely required.

No constructed waterway is proposed immediately downstream of Burnside Road due to the small flows, as discussed in Section 6.6. The flows from Burnside Road are proposed to be piped into the constructed waterway near SBRB7. The culvert under Burnside Road and the pipe details are provided in Section 8.6. A small vegetated swale could be provided instead of a pipe should there be a desire for more blue-green infrastructure, however, this would be at the expense of the NDA.

The constructed waterway will be aligned to go through RB3. It is proposed that the flow channel will continue through the base of the RB (cut down into the RB base), before outfalling via a pool connected to the RB outlet. There will be no high flow channel within the basin. In larger events, when the RB outlet capacity and low flow channel capacity is exceeded, the basin floor will begin to engage.

Design flows

As presented previously, the following peak flow rates were used to inform the waterway design, as established in the developed conditions RORB model, as well as storage design (Table 30). The low flow channel has been designed to take the 4EY flow and the high flow channel to take the 1% AEP. The flows that are dictating the size of the waterway have been provided below. The maximum 1% AEP peak flow is from the external catchment 333 (15m^3/s). Downstream of this the flows are relatively similar. Therefore, at this stage the maximum flow rate has been used to inform the design. The climate change peak flow has also been included in the table below. This has been used to check the overall depth required to maintain 300mm freeboard to the top of bank.

Table 30. Calculated flow rates for waterway design

Storm event	Flow rate (m^3/s)
1% AEP	12.12
4EY	1.1
1% AEP climate change (SSP3-7) flow check	19.48

Longitudinal slope

One of the key criteria for waterway design is to ensure that shear stress values are within an acceptable range. This is to ensure that the waterway is stable and to minimise the erosion potential. The shear stress threshold value is generally considered to be 80 N/$m^2$for structurally diverse vegetation. Longitudinal grade is one of a few key drivers of shear stresses within a waterway. It is therefore critical to provide a stable, flat longitudinal grade to help manage shear stresses.

The longitudinal slope is dictated by invert controls at the downstream and upstream extents of the constructed waterways, combined with the overall length of the system. Meandering the channel can help lengthen the waterway length, and flatten the grade.

The longitudinal grades were established through iteratively altering the waterway alignments, tie-in locations, and providing grade control structures where necessary. Another key consideration is RB outflows and how these would connect with the waterways. Key RB outfall locations which influenced the waterway invert levels include the 1% AEP pipe from Burnside Road, and SBRB7. A grade control structure is also proposed at the start of the waterway to manage the grade and enable flatter, more stable waterway reaches downstream of the rock chute. Another chute is required approximately in the middle of the overall waterway length. It is expected that chute arrangements would be refined in future design stages.

Table 31 provides the longitudinal slope along the low flow channel, which will be slightly gentler than the high flow channel due to meander in the low flow alignment. These grades are suitable for facilitating stable channel design.

Table 31. Longitudinal slope along low flow channel.

Waterway	Upstream elevation (m AHD)	Downstream elevation (m AHD)	Channel length (low flow channel) (m)	Average slope low flow (1 in x)
CH0-30 (start waterway; chute)	86.8	84.18	30	11
CH30-510	84.18	82.0	480	220
CH510-560 (chute)	82.0	79.0	40	16
CH560-1210	79.0	77.1	650	342

The indicative longitudinal section, as defined in the earthworks model, is provided in Figure 32.

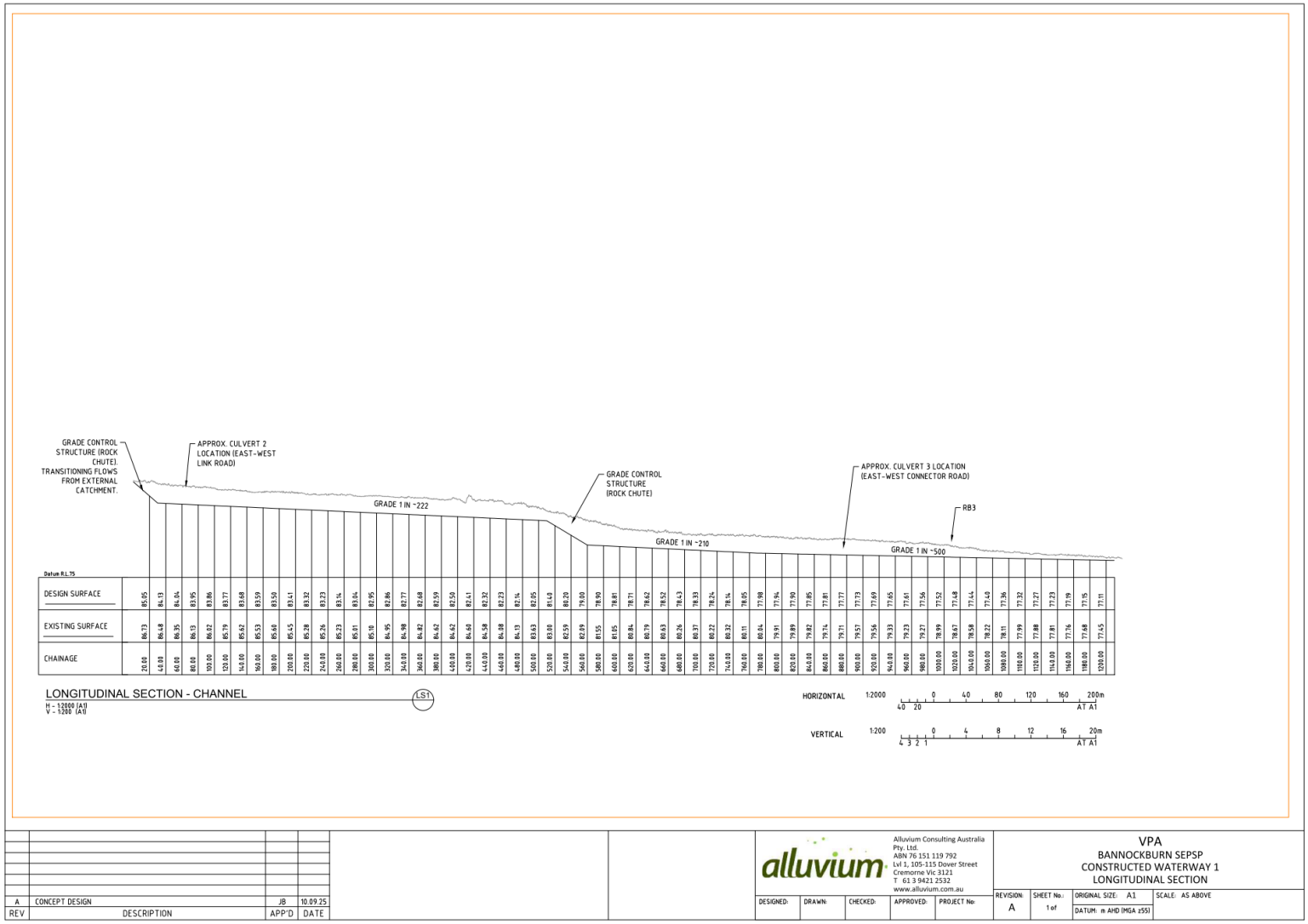


Figure 32. *Indicative constructed waterway longitudinal section*

Cross-section geometry

The cross-sectional geometry should be designed to accommodate between the 4EY to 1EY flows in the low flow channel and the 1% AEP flows in the full compound channel. The 1% AEP flows were determined using RORB modelling as discussed in the hydrologic modelling section. The minimum proposed channel cross section of the waterway is provided in Table 32. The waterway has been designed with a minimum of 300mm freeboard above the 1% AEP peak flow levels, and checked for the climate change flow scenario. The waterway bed depth will also be dictated by the need to enable stormwater outfall. This can sometimes drive depths more than the capacity requirements (i.e. be deeper than the depths required for capacity).

Manning's calculations were undertaken to establish waterway capacities and verify that they would be sufficient to convey the 1% AEP peak flows. The results indicate that an overall channel depth of at least 1.8m is required to enable climate change flows (SSP3-7 for year 2100), and a minimum of 300mm freeboard allowance.

An example cross section (~CH225) is provided in Figure 33.

Table 32. Waterway cross-section geometry and design parameters.

Parameter	Low flow channel	High flow channel
Base width (m)*	3.0	9.0 m (enables benches)
Channel depth minimum (m)	0.5 m	0.7m (or 1m to cater for the climate change SSP3 scenario peak flow)
Side slope	1 in 3	1 in 5
Top width (m)	6.0 m	19.0m
Manning's n (assumed)**	0.05 (vegetated)	0.05 (vegetated)
Capacity	1.6 m^3/s	13.2 m^3/s
Freeboard		300mm
Hydraulic width (m)	-	16 m
Waterway corridor	-	45m^

*Outer edge of benches for the high flow channel

**Parameters informed by Melbourne Water's *Constructed Waterway Design Manual*

^See below discussion on waterway corridor

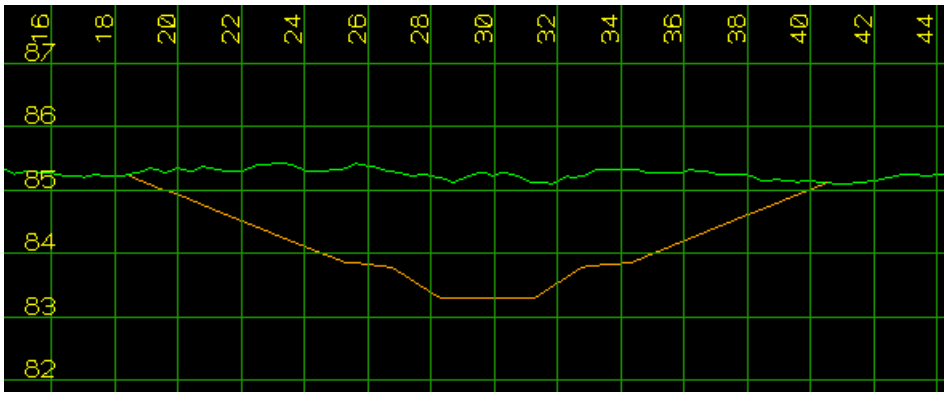


Figure 33. *Example waterway cross section from earthworks model*

8.5 Constructed waterway corridors

Waterways, whether natural or constructed, need to have an appropriate waterway corridor or reserve provided adjacent to development in order to accommodate objectives for flood protection, river health,

biodiversity, safety and amenity. A waterway corridor is defined as the waterway channel and its associated riparian zones. The riparian zones consist of two parts

- the vegetated buffer
- the core riparian zone

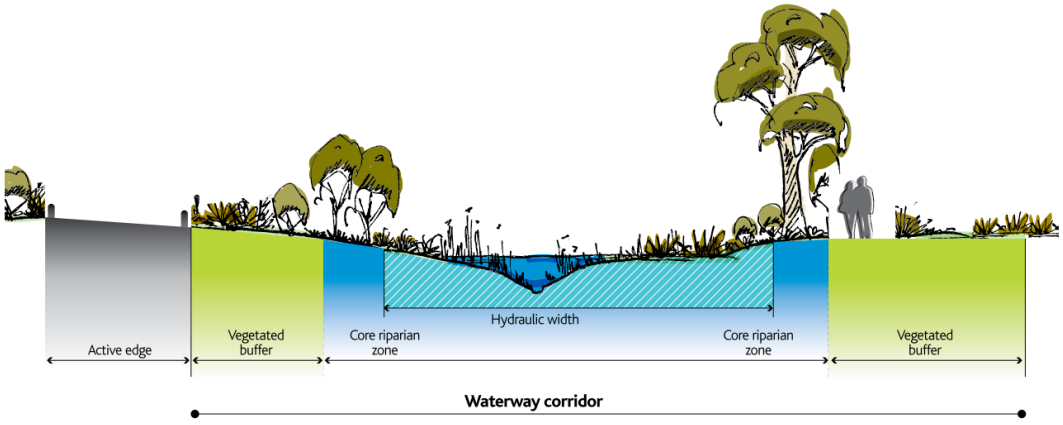


Figure 34. *Waterway corridor (Reference: Melbourne Water's Waterway Corridor Guidelines).*

According to Melbourne Water's Waterway Corridor Guidelines (adopted in lieu of local guidelines), "assigning a waterway corridor preserves areas of the riparian zone that protect or enhance native vegetation, river health and biodiversity in some cases, the waterway corridor may also be able to support a level of passive recreational use or some stormwater treatment elements". Furthermore, the waterway corridor will also be dependent on other site specific factors such as recreation uses or landscape characteristics.

Melbourne Water's Waterway Corridor Guidelines define a minimum width only, and can be increased to reflect site specific factors such as: high value flora, fauna and communities; high value geomorphic features or other characteristics such as escarpments or chain of ponds; habitat connectivity; fuel break; protection of upstream and downstream values; where there is risk of channel migration/erosion; where recreational and stormwater assets are proposed within the corridor; and the protection of cultural heritage values. The CMA should provide input to the proposed waterway corridor width.

A fundamental principle is to provide continuity along the core riparian zone, therefore the strong preference is to locate shared paths and other infrastructure outside of the core riparian zone. However, the Waterway Corridor Guidelines states that "in some instances, stormwater treatment systems such as constructed wetlands and bioretention systems may be located within the core riparian zone – subject to Melbourne Water approval – but should form a relatively small proportion of the area of the core riparian zone so as not to degrade its ecological function or put the asset at undue risk from flooding and/or stream migration". This approval should be sought from the relevant local authority.

Relevant corridor requirements as extracted from Melbourne Water's guidelines are shown in Figure 35. The waterway corridor width, as per the established hydraulic widths, is 45m. This includes allowance for tracks either side of the waterway.

Table 4. Sliding scale for calculating constructed waterway corridor widths – addition of shared trail/maintenance track either side of channel (within vegetated buffer)

HYDRAULIC WIDTH (M)	CRZ WIDTH (M)	VB WIDTH (M)	CORRIDOR WIDTH (M)
5	20	20	40
10	20	20	40
15	20	25	45
20	25	25	50
25	30	25	55
30	30	25	55
35	30	25	55
40	35	25	60
45	35	25	60
50	35	25	60
55	40	25	65
60	40	25	65
65	40	25	65
70	45	25	70

Figure 35. *Minimum Constructed Waterway corridor requirements (Melbourne Water's Waterway Corridor Guidelines).*

8.6 Culvert and pipe design

Proposed culverts

Several culverts are proposed within the PSP where there are major crossings of roads, as per the draft PSP. The proposed culvert arrangement, based on preliminary calculations undertaken in HY-8, is provided in Table 33.

Table 33. Proposed new culvert under Burnside Road

	Upstream invert	Downstream invert	Length	Required capacity	Size
Culvert 1: Under Burnside Rd (flows from WLRB5, WLRB6, 111 and 222)	86.2	86.1*	36m	5.91 m^3/s	1 x 1500mm dia. pipe
Culvert 2: Under east-west link road next to transmission easement (constructed waterway)	84.08	83.9	40m	12.12	4x x1200H x 2400W
Culvert 3: Under connector street near RB3 (constructed waterway)	77.75	77.7	30m	11.37	4x x1200H x 2700W

*Start of new proposed 1% AEP pipe

Proposed pipe

A new pipe is proposed to enable retarded flows from WLRB5, WLRB6 and external catchments 111 and 222 to the constructed waterway. The proposed pipe arrangement, based on preliminary calculations, is provided in Table 34.

Table 34. Proposed new pipe

	Upstream invert	Downstream invert	Length	Required capacity	Size	Pipe capacity
From culvert under Burnside Rd to constructed waterway	86.1	82.9*	755	5.91 m^3/s	1800 mm	5.93 m^3/s

*Into the of the new constructed waterway. Waterway IL is ~82.6 m AHD here. Outfall should be min. 300mm above waterway base.

The proposed culverts and pipe have been included in the cost estimate.

8.7 Flow conveyance from Charlton Road

As previously presented in section 6.6, the peak 1% AEP flow (SSP1) entering the precinct from Charlton Road is 7.99m^3/s. Consideration was given whether a constructed waterway was required to convey these flows through the site, however given the relatively small 1% AEP flows, a traditional pipe and road arrangement has been opted for.

The slope from Charlton Road south towards WLRB5 is approximately 1 in 100. A 20% AEP pipe would need to be able to convey an approximate flow of 3.2m^3/s. A 1200mm diameter pipe would be able to convey these flows.

The gap flow (1% AEP minus the 20% AEP; ~4.8m^3/s) would need to be safely conveyed in the road reserve. Flood depths and velocities along the road must meet the "*Guidelines for Development in Flood Affected Areas*" (*DELWP, 2019*).

Design safety criteria for overland flows along road reserves is covered in DELWP's 2019 document titled "Guidelines for Development in Flood Affected Areas". The technical basis for the DELWP guideline is based on ARR2019, Book 6 – Chapter 7: Safety Design Criteria". The ARR2019 documentation identifies that the two key elements to consider are "human stability" and "vehicle stability". For both situations the metric of velocity and depth is used as the defining criteria.

Human Stability

There are two modes of stability loss associated with people in flood waters, namely "toppling instability" and "sliding instability". There are also two categories of people to consider, with that being adults and children (see Figure 36).

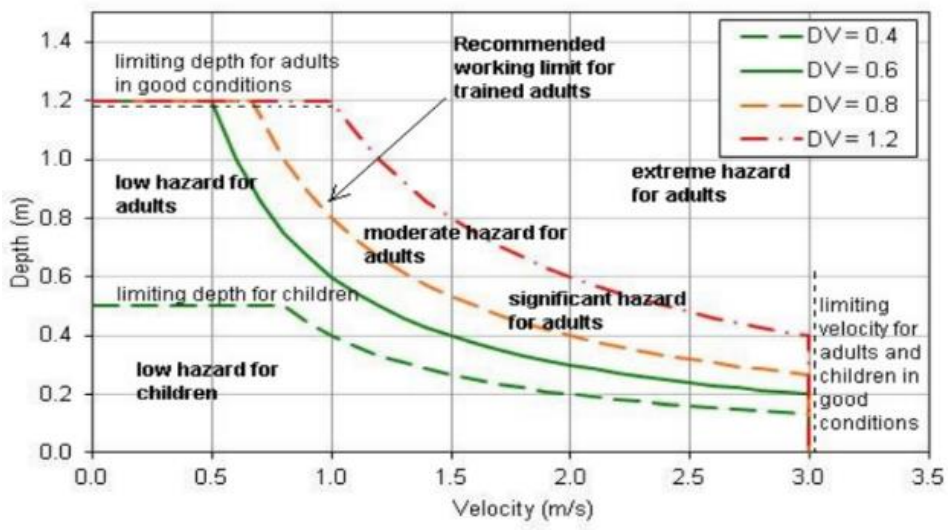


Figure 36. Safety criteria for people in varying flow conditions (source ARR2019)

As shown in Figure 36, the limiting criteria is children. The guidelines recommend that the DxV product is less than 0.4m2/s with a maximum depth stability limit of 0.5m and a maximum velocity stability limit of 3m/s. However as shown below the criteria associated with small vehicle stability is more limiting than the children stability criteria.

Vehicle Stability

There are two modes of stability loss associated with vehicles in flood waters, namely "floating instability" and "sliding instability" (see Figure 37). There are also three categories of vehicles to consider, with that being small cars, large cars and large 4WD vehicles (see Figure 38).

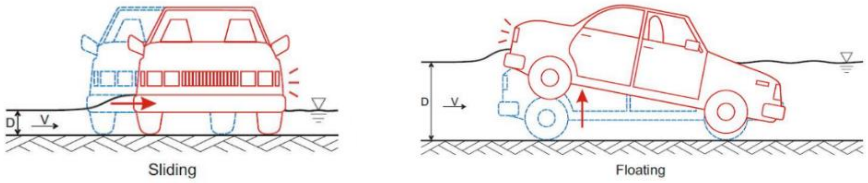


Figure 37. Typical modes of vehicle instability (source ARR)

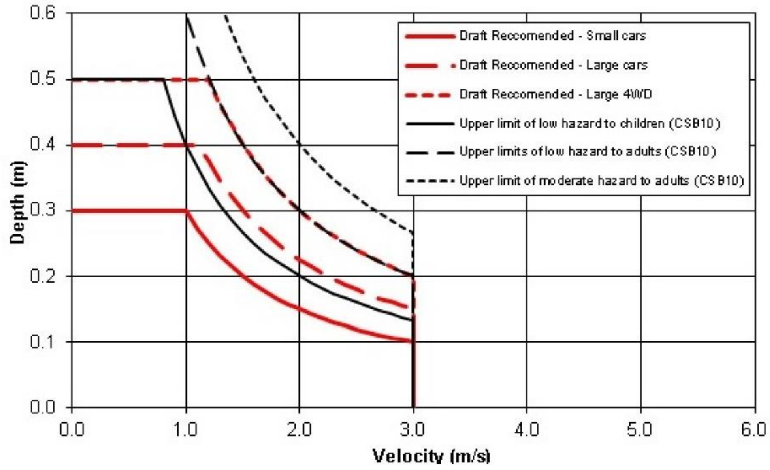


Figure 38. Safety criteria for vehicles in varying flow conditions (source ARR2019)

As shown in Figure 38, the limiting criteria is small cars. The guidelines recommend a limiting DxV product of 0.30m^2/s with a maximum depth stability limit of 0.3m and a maximum velocity stability limit of 3m/s.

Based on the above criteria, two parallel road reserves of 16m width, at 1 in 100 grades would be able to safely convey the gap flows south from Charlton Road (table below).

Table 35. Road reserve safe carrying capacity

Road reserve width	Slope	Road capacity (m^3/s)
16m (two required)	1%	2.4 m^3/s

8.8 Outfall channels

The outfall channels (south of the precinct) for RB3 and RB4 were designed to be able to convey approximately the 20% AEP (retarded) outfall from the retarding basins (i.e. the frequent flow). The upstream invert level of the channels will be as per the culvert invert levels. The downstream tie-in levels have been established so to ensure a reasonable grade. That is, one that minimises the overall channel length, but isn't so flat that the capacity is limited.

The outfall will transition out to existing levels on the downstream end. 4m access buffers around the channels have been allowed for as per VPA direction.

Table 36. Outfall channel details

Parameter	Western outfall channel (RB4)	Eastern outfall channel (RB4)
Base width (m)*	5.0	8.0
Channel depth minimum (m)	0.5 (at deepest point at upstream end)	1.2 (at deepest point at upstream end)
Side slope	1 in 3	1 in 3
Top width (m)	8.0m	15.2
Manning's n (assumed)**	0.05 (vegetated)	0.05 (vegetated)
Capacity	1.6 m^3/s	5.2m^3/s
Upstream channel invert	80.2 m AHD	76.05 m AHD
Downstream channel invert	80.0 m AHD	75.9 m AHD
Length (m)	-97	2453
Slope	1 in 485	1 in 2453

9 Concept designs

The concept design development was an iterative process including:

- Treatment modelling
- Asset calculations
- Hydrologic modelling and storage sizing
- Earthworks modelling
- Stakeholder feedback.

The concepts presented in this section will be used to develop the designs into functional designs following final feedback from the VPA and key stakeholders. Whilst some infrastructure details have not yet been finalised (e.g. wetland bathymetry or internal pipe sizing), the concepts are a good indication of the requirements for treatment and retardation, and the footprint required. These are detailed concept designs given they have been developed in an earthworks model (i.e. captures accurate land take and excavation volumes).

9.1 Concept overview

The concept designs for the options investigated are presented below. Each option includes:

- The sediment basin NWL area as established in sediment capture efficiency calculations.
- The macrophyte treatment area (NWL) as established in MUSIC.
- The storage requirements as established in the hydrologic modelling.
- A Normal Water Level (NWL) identified by assessing the topography of the site, as well as the inclusion of 0.35m EDD, the required 1% AEP flood depth and any freeboard requirements (minimum 300mm).
- Overall footprint based on the selected NWL and battering up to existing surface at a 1-in-6 grade in the earthworks model.
- Indicative inlet pipe, transfer pipe (sediment basin to wetland), bypass, and outlet pipe locations.
- Maintenance access paths (3m internal path, 4m external path).
- Sediment dewatering areas.

Other factors that influenced the configuration of the asset included:

- Subdivisional drainage requirements for the surrounding development
- The ability to outfall
- The requirement to meet a length to width ratio of at least 4:1 [MZ4 in the Constructed Wetlands Manual], and the associated maximum width, and how this fits with the surrounding terrain
- Meeting velocity requirements
- Minimising excavation requirements (where possible)
- Aligning assets along contours to minimise land take (particularly relevant for the assets along Bruce Creek).
- Consideration of proposed land uses and road alignments as per the Draft Place Based Plan.
- Freeboard requirements (minimum of 300mm).
- Climate change modelling considerations (maintaining freeboard requirements).
- A 10m no works buffer from the edge of the railway corridor easement.
- VicTrack requirements for assets outfalling through the railway corridor.
- Maintenance access requirements south of the precinct as directed by the VPA.

An overview of the concept plan for the PSP drainage assets is provided in Figure 39.

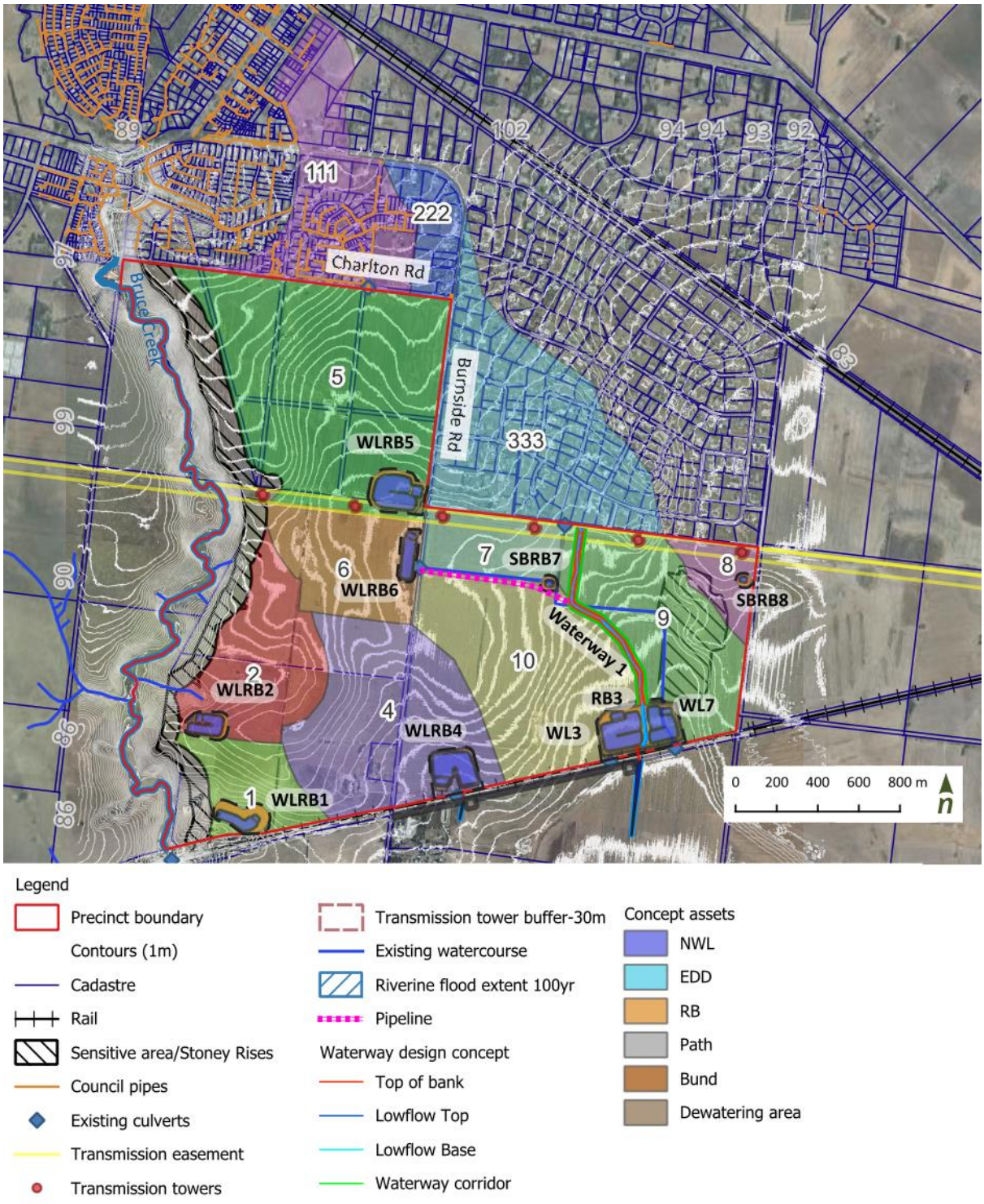


Figure 39. *Concept plan overview for Bannockburn SE PSP stormwater drainage design*

9.2 Asset details

The following pages outline the key parameters and conceptual layouts for each catchment and asset. Some key considerations and rationale for asset locations is provided for each asset below.

WLRB1

- The asset has been located along the contours, in an attempt to minimise excavation.
- Given the steep terrain in this area, the batter extents on the uphill batter are considerable. Consideration could be given in future design to reducing the batter slope in an effort to reduce the overall footprint and excavation requirements.
- There is a small area to the south of the asset which was deemed too steep and challenging to locate the asset in. This area could be well suited to land use such as open space.
- Council indicated in the July stakeholder workshop that they would not accept an embankment or retaining wall for this asset.
- The road built along the sensitivity area boundary would direct overland flows south-east towards the retarding basin.
- A long RB outfall pipe would be required to outfall the retarded 1% AEP flows safely down to Bruce Creek. The future design of this pipeline would need to ensure minimal disturbance to the creek corridor, and that flow velocity into the creek is managed. Drop pits have been allowed for in the cost estimate to manage the velocity.

WLRB2

- The asset has been located in a low area of the catchment, but not the lowest. There is a portion of the catchment to the north-west (a valley with an existing dam) that was deemed too steep to locate the asset on. If an asset was to be located here, an embankment or retaining wall would be required. Council indicated in the July stakeholder workshop that they would not accept an embankment or retaining wall for this asset.
- This valley area could be well suited to land use such as open space.
- The road built along the sensitivity area boundary (up to ~89 m AHD) would direct overland flows south-east towards the retarding basin.
- A long RB outfall pipe would be required to outfall the retarded 1% AEP flows safely down to Bruce Creek. The future design of this pipeline would need to ensure minimal disturbance to the creek corridor, and that flow velocity into the creek is managed. Drop pits have been allowed for in the cost estimate to manage the velocity.

(WL3&WL7)RB3

- This large retarding basin has been located in the existing low point adjacent to the railway track.
- The retarding basin receives flows from the adjacent development areas, retarded flows from WLRB5, WLRB6, SBRB7, and external catchments (existing residential areas).
- Given the constructed waterway flows into the retarding basin, the sediment basins and macrophyte zones will drown out in major events.
- The wetlands have been located either side of the constructed waterway low flow channel so that they are offline to the frequent flows of the upstream catchment. That is, they only receive frequent flows from the adjacent catchment. This avoids double treatment of the stormwater (i.e. treating water in the wetland that have already been treated in upstream wetlands), and also helps manage inundation frequency and velocities through the macrophyte zones. Managing inundation frequency is critical to plant health and the functioning of a treatment wetland.
- An embankment is required on the southern, eastern and western sides of the retarding basin. An embankment could not be avoided given the natural low point here. Council have not objected to an embankment for this asset.
- The embankment design, including an ANCOLD assessment, will be required in future design stages.

WLRB4

- This retarding basin has been located in the existing low point adjacent to the railway track.

- An embankment is required on the southern, eastern and western sides of the retarding basin. An embankment could not be avoided given the natural low point here. Council have not objected to an embankment for this asset.
- The embankment design, including an ANCOLD assessment, will be required in future design stages.

WLRB5

- WLRB5 has been located at the low point of the catchment, bounded by Burnside Road and the proposed east-west link road.
- The asset has been located within the easement in an effort to minimise developable land take.
- Other design considerations include staying outside of the transmission tower buffer zones, and ensuring access is maintained within the electricity easement.

WLRB6

- WLRB6 has been located within an existing low point. This area is currently a wet area.
- The asset has been located adjacent to Burnside Road, and abutting the east-west link road to the north.
- The outfalls from both WLRB5 and WLRB6 will connect via a junction pit on the western side of Burnside Road, before being conveyed under Burnside Road via a pipe.

SBRB7

- A sediment basin has been proposed in this location so that coarse sediment from the catchment minor flows can be dropped out prior to entering the constructed waterway. Minor flows should not directly enter waterways without treatment.

SBRB8

- A small basin has been proposed for the north-east corner of the precinct, where a small catchment naturally falls in this direction.
- The asset has been located to be bounded by the east-west link road to the north, and the precinct boundary to the east.

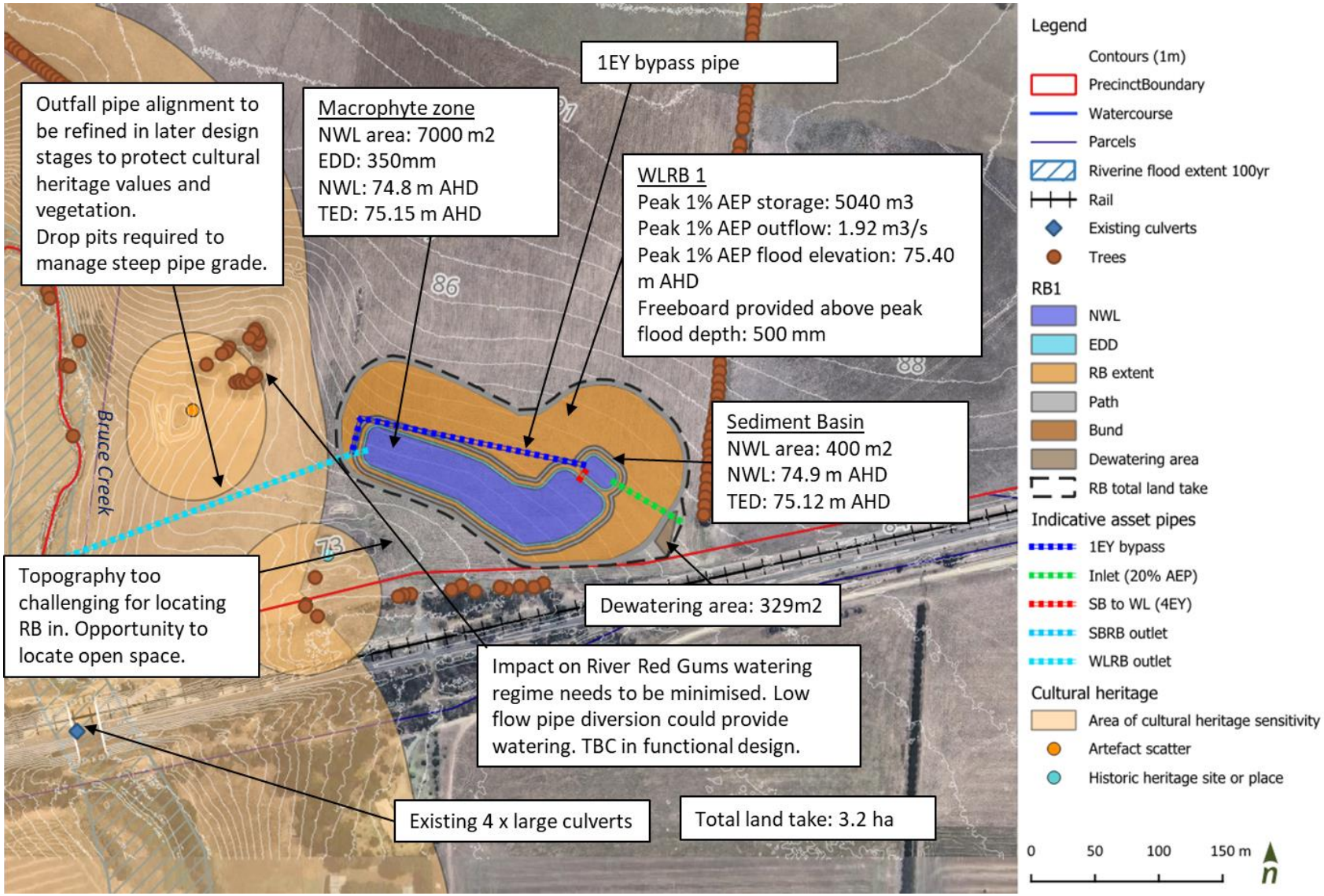


Figure 40. *WLRB 1 Concept Design*

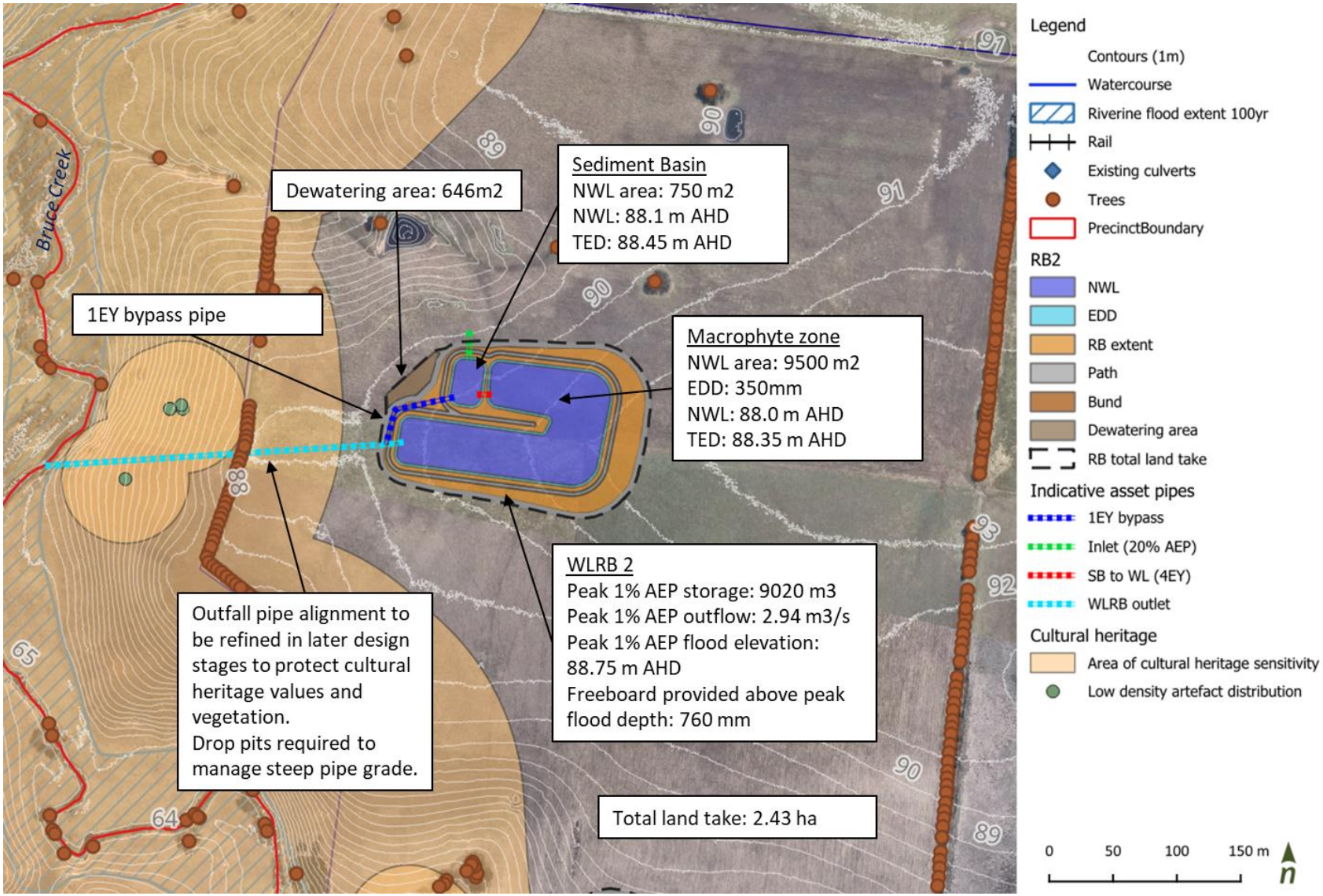


Figure 41. *WLRB 2 Concept Design*

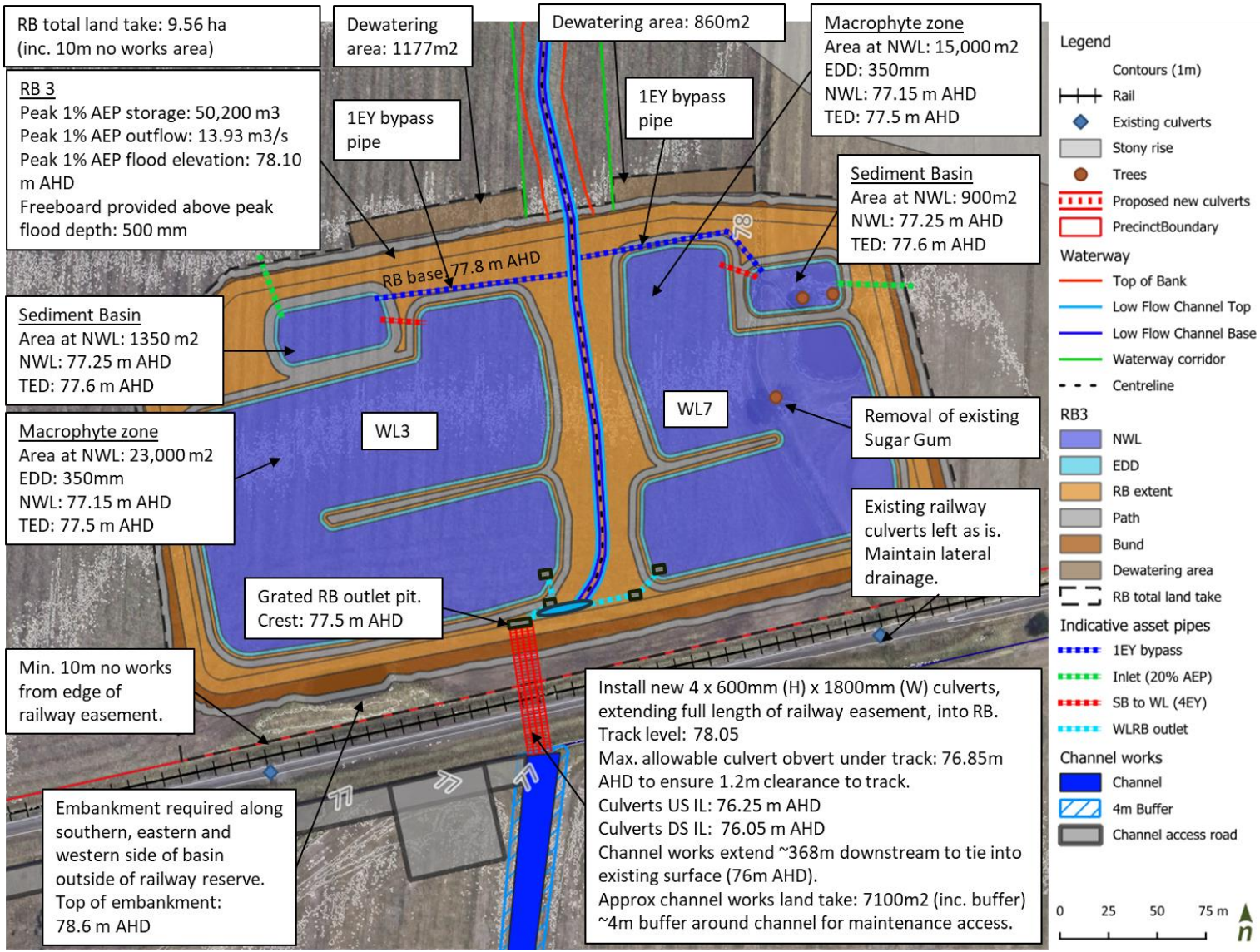


Figure 42. *WL 3, WL 7 and RB 3 Concept Design*

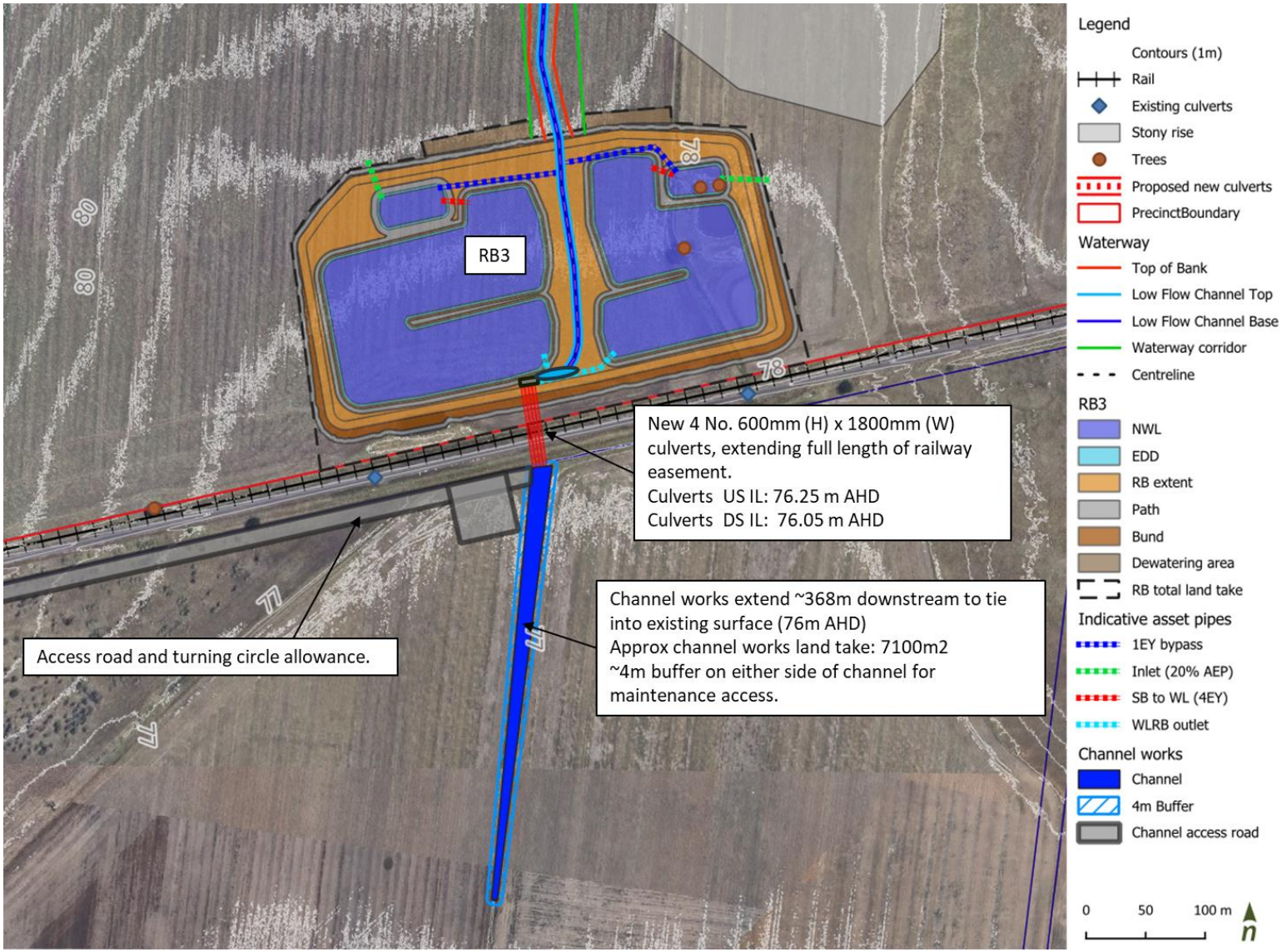


Figure 43. *WL 3, WL 7 and RB 3 Concept Design outfall*

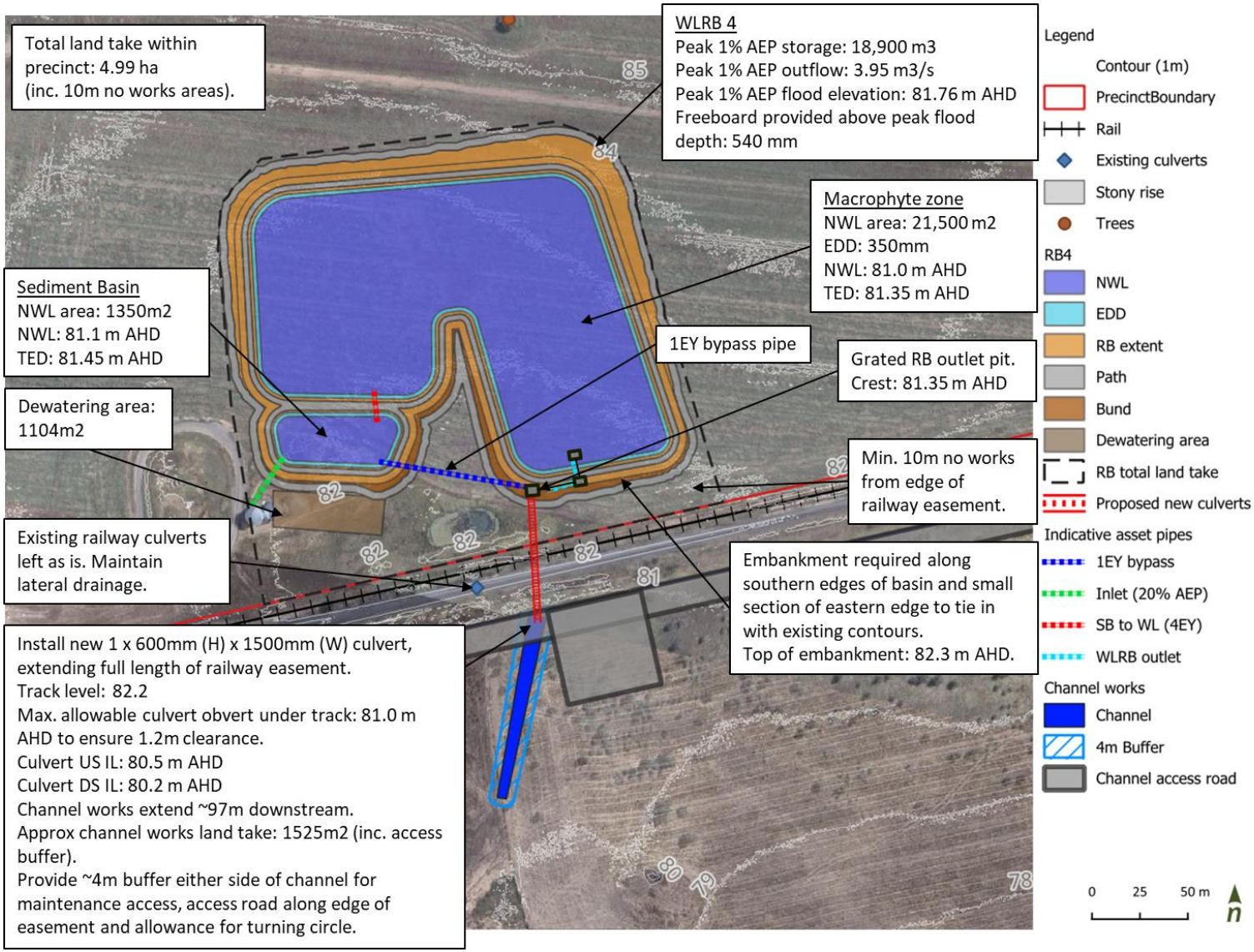


Figure 44. *WLRB 4 Concept Design*

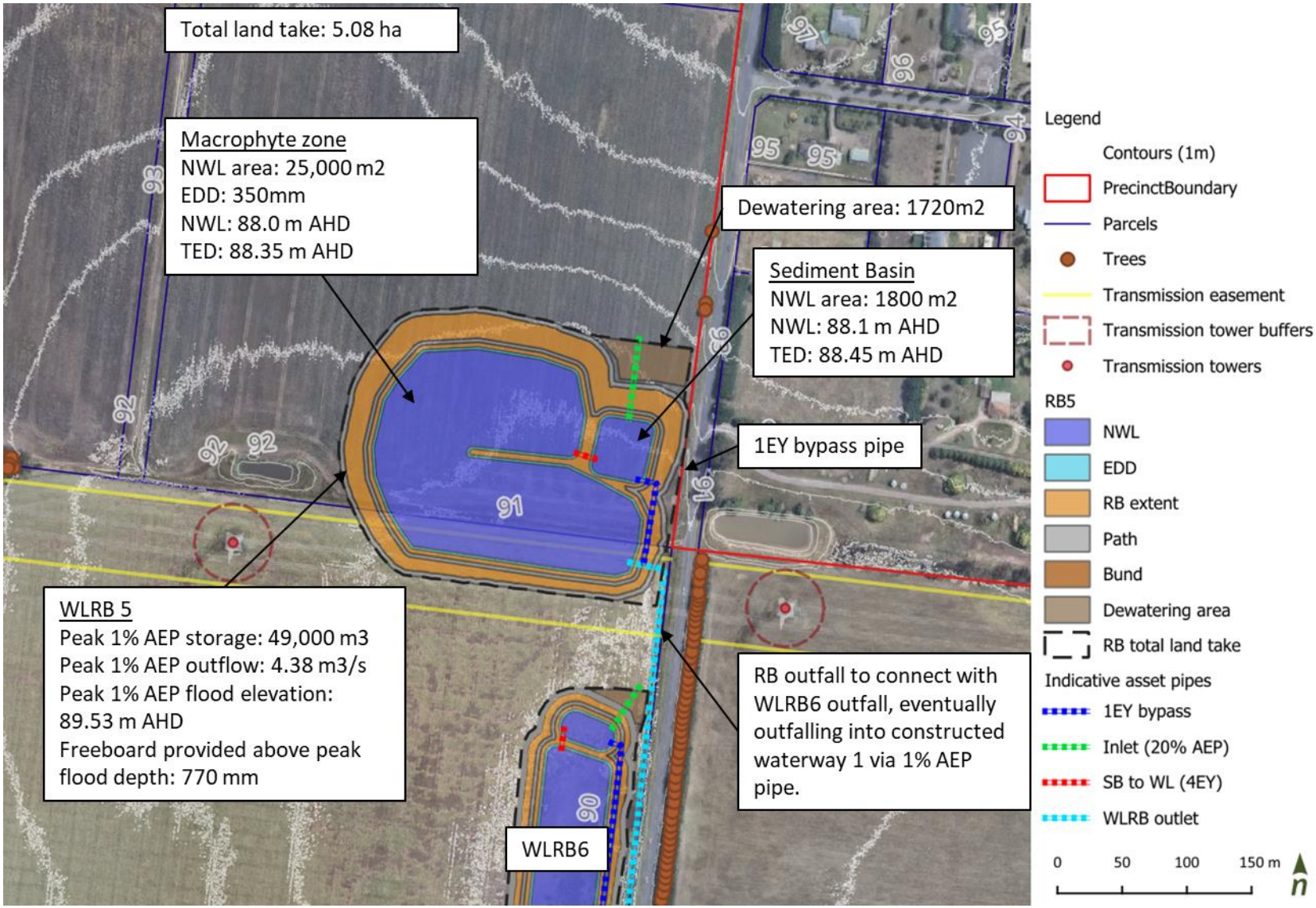


Figure 45. *WLRB 5 Concept Design*

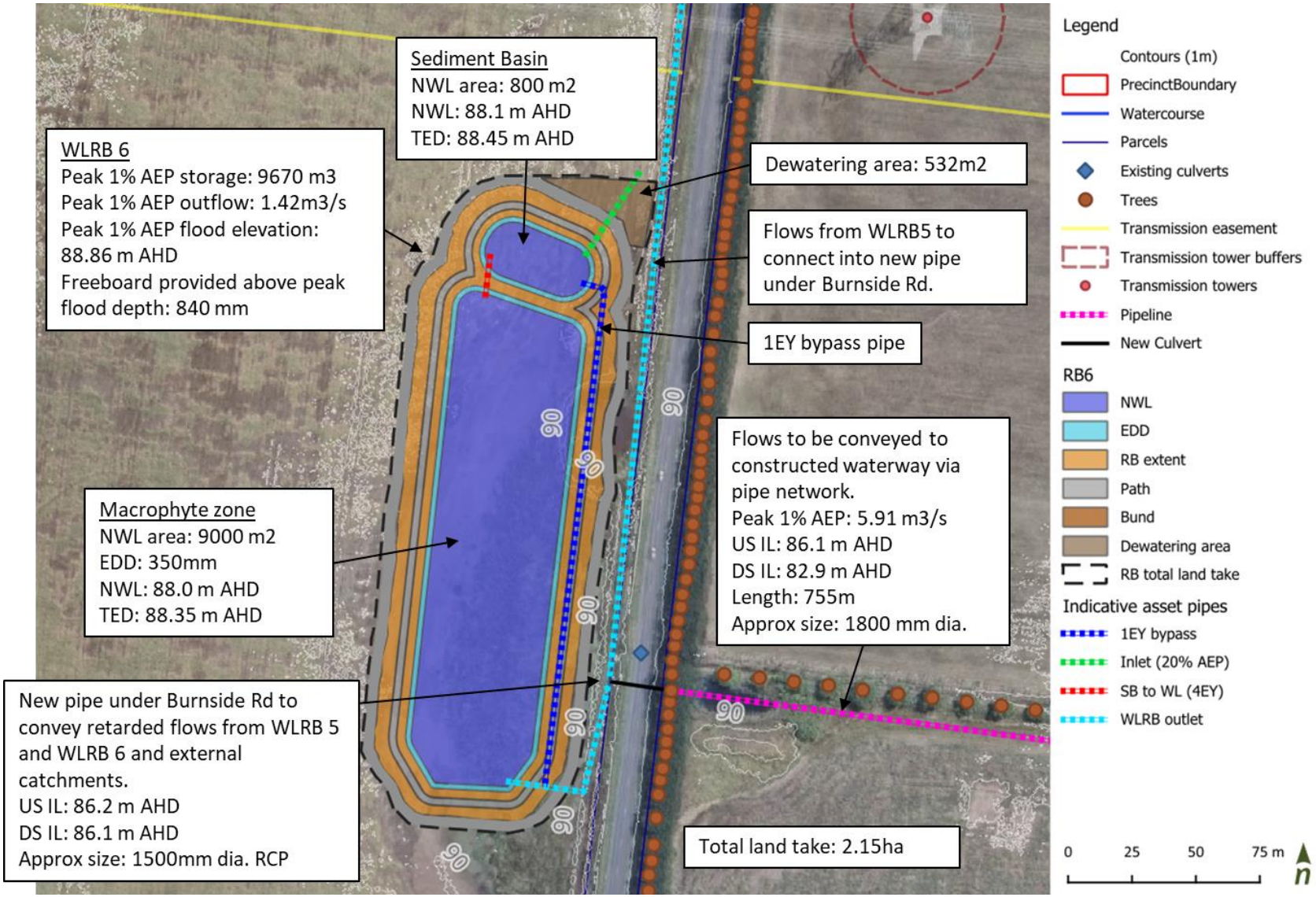


Figure 46. *WLRB 6 Concept Design*

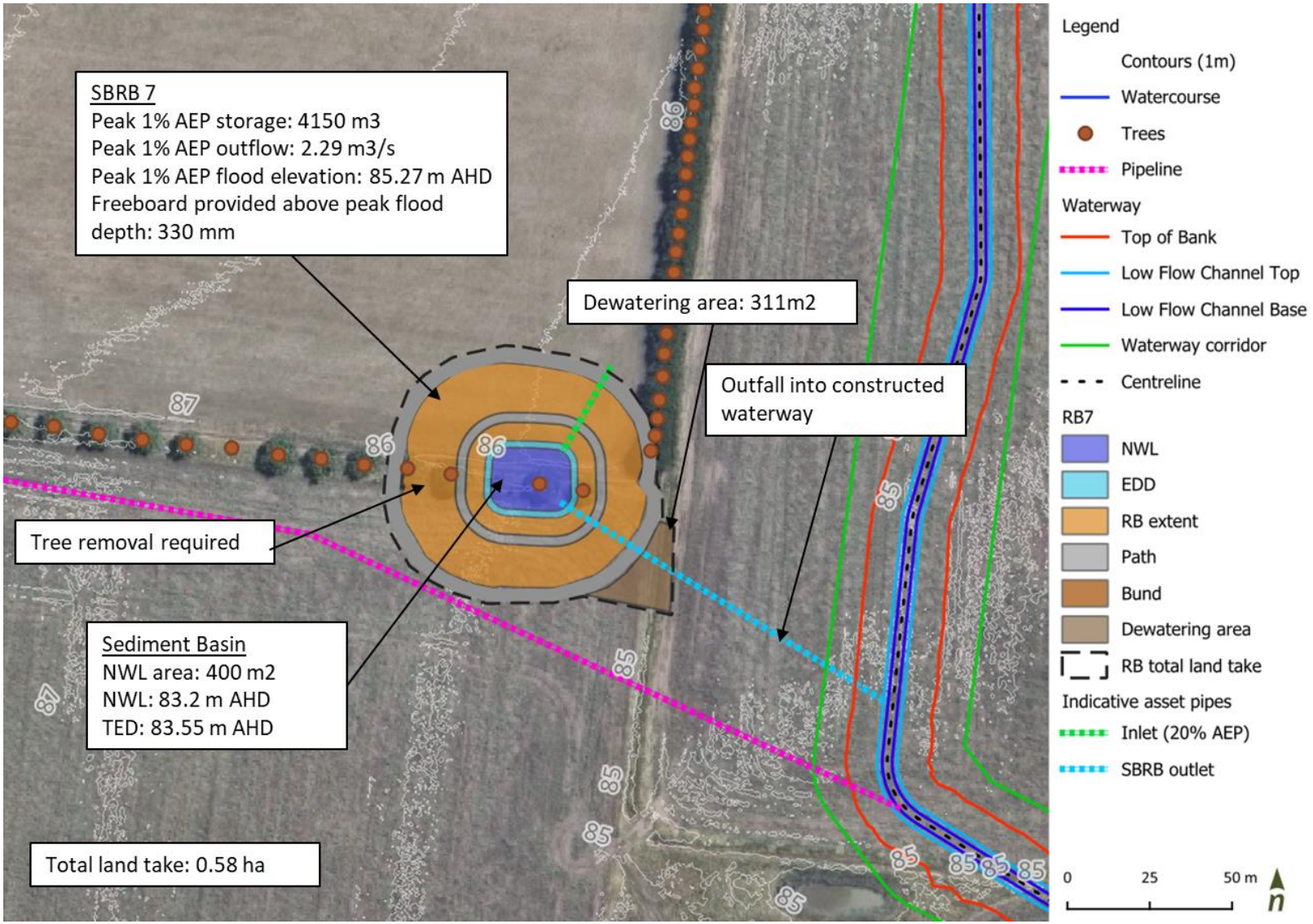


Figure 47. *SBRB 7 Concept Design*

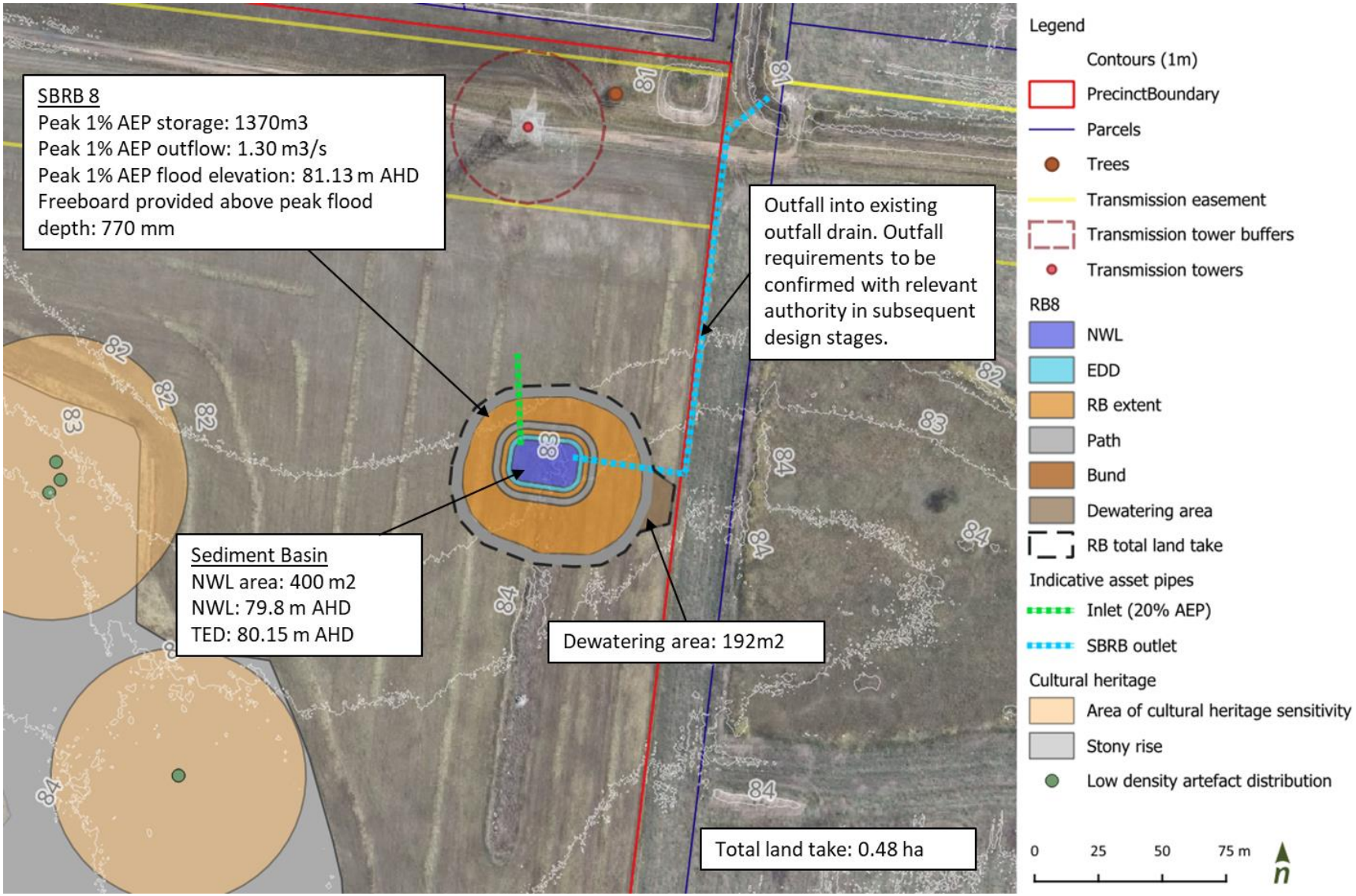


Figure 48. *WLRB 8 Concept Design*

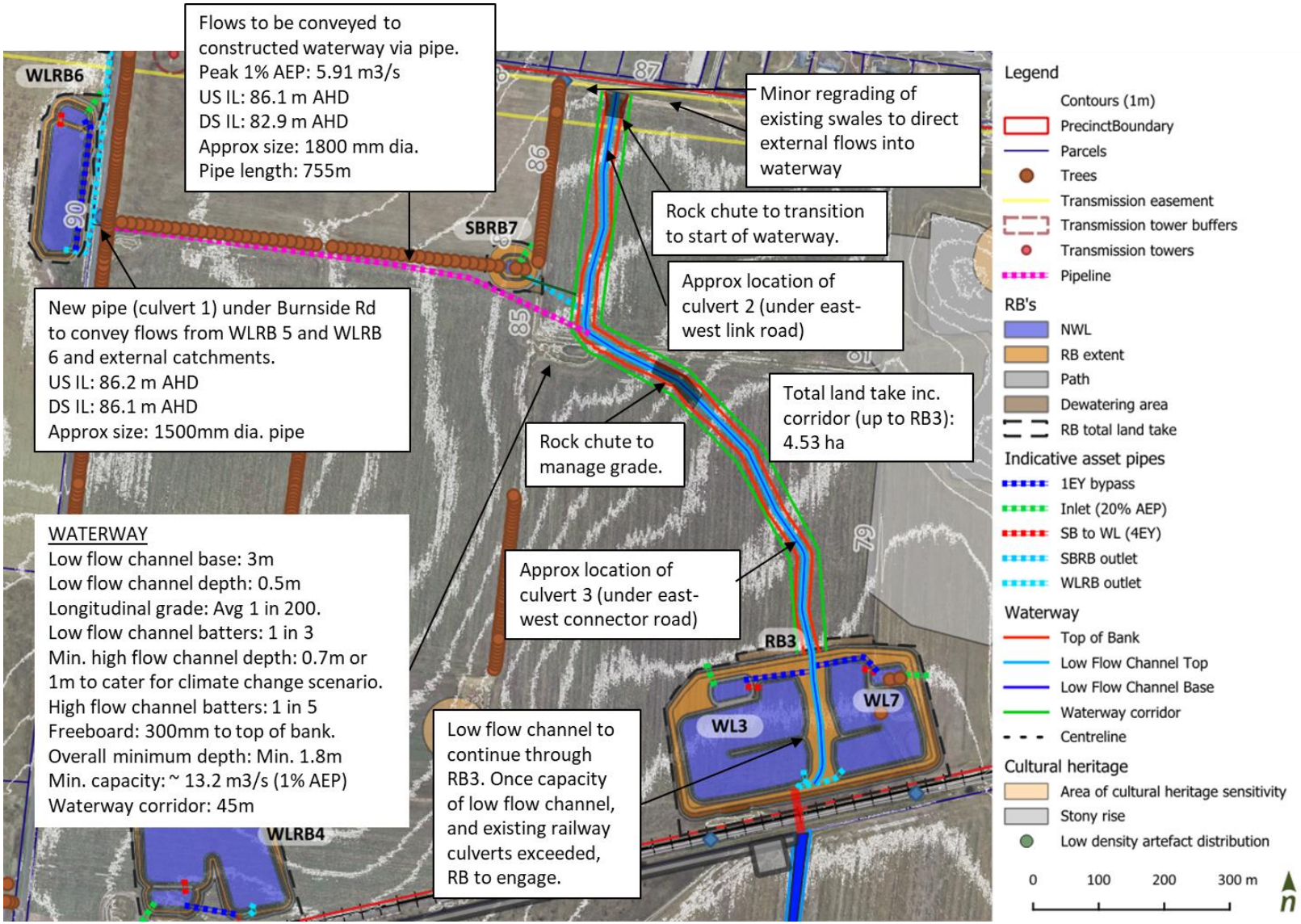


Figure 49. *Waterway concept design*

10 Cost estimate

Cost estimate summaries for each asset are provided in Table 37 below. The values provided are high-level estimates only – concept level. The rates are based on the current Australian Construction Handbook, Melbourne Water's reimbursement rates for the West (August 2024), as well as our experience with similar projects (PSPs/DCPs). More detailed cost breakdowns for the proposed assets are provided in the separate Concept Design Cost Estimate spreadsheet. This includes all quantities, assumed rates and cost assumptions. The costs provided are exclusive of GST.

It should be noted that the cost estimate tables for each asset are more itemised and detailed than would normally be expected at a concept design stage. This has been done in an effort to provide more accurate cost estimates. These figures would be further refined at functional design stages when further modelling and asset refinement is undertaken to provide more detailed cost estimations.

Details regarding pit and pipe sizing are not included due to the concept level design, however nominal pipe sizes and/or rates have been adopted for these line items as appropriate. Internal wetland and sediment basin bathymetry design has not been undertaken. A contingency of 35% has been adopted, which allows for uncertainty around some of the nominal items and assumptions, and uncertainty around geotechnical conditions. It is expected this will drop as further modelling and functional design detail is undertaken in future stages. The pipeline cost for the pipe extending from Burnside Road to the start of the constructed waterway is included, as are the culverts.

Table 37. Cost estimate summary for the proposed works

Item	Description	WLRB1	WLRB2	WLRB4	WLRB5	WLRB6	SBRB7	SBRB8	WL7&3/RB3	Waterway 1	1% AEP pipe	Culvert 1	Culvert 2	Culvert 3	ALL ASSETS
1	SITEWORKS AND EARTHWORKS	$ 3,472,586.9	$2,111,068.7	$2,392,501.8	$5,035,452.7	$1,279,276.9	$ 293,718.5	$ 30,716.1	$3,077,640.2	$1,121,313.3	$ 122,998.0	$ 11,477.5	$ 5,692.0	$ 7,288.0	$18,961,730.6
2	DRAINAGE	$ 701,535.0	$ 814,193.2	$ 857,830.7	$1,426,024.9	$ 698,659.5	$ 385,400.0	$ 218,358.0	$1,716,230.8	$ -	$ 1,143,726.7	$ 138,904.6	$ 663,158.1	$ 575,725.3	$ 9,339,746.9
3	ROCK WORKS	$ 36,600.0	$ 36,600.0	$ 51,100.0	$ 16,600.0	$ 16,600.0	$ 5,100.0	$ 5,100.0	$ 86,700.0	$ 145,440.0	$ 2,000.0	$ -	$ 15,000.0	$ 15,000.0	$ 431,840.0
4	CLAY LINER	$ 202,123.5	$ 275,960.5	$ 581,460.5	$ 678,562.5	$ 259,205.0	$ 14,100.0	$ 13,512.5	$1,041,731.5	$ -	$ -	$ -	$ -	$ -	$ 3,066,656.0
5	TOPSOIL	$ 102,905.9	$ 73,332.8	$ 123,957.9	$ 154,721.9	$ 61,105.5	$ 14,573.0	$ 12,289.2	$ 289,366.2	$ 172,197.0	$ -	$ -	$ -	$ -	$ 1,004,449.4
6	PLANTING	$ 537,123.2	$ 385,363.7	$ 631,247.2	$ 771,149.4	$ 321,855.8	$ 77,218.0	$ 65,239.4	$1,537,668.9	$ 825,085.8	$ -	$ -	$ -	$ -	$ 5,151,951.3
7	PUMPING	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
8	LANDSCAPE	$ 269,485.2	$ 226,854.4	$ 613,019.6	$ 321,135.6	$ 241,058.2	$ 86,867.8	$ 73,247.4	$1,019,542.4	$ 217,814.1	$ -	$ -	$ -	$ -	$ 3,069,024.7
9	MISCELLANEOUS	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 60,900.0	$ 60,900.0	$ 141,800.0	$ 64,800.0	$ 60,000.0	$ 30,000.0	$ 30,000.0	$ 30,000.0	$ 832,900.0
10	OTHER	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUB-TOTAL WORKS	**$ 5,393,259.8**	**$3,994,273.2**	**$5,322,017.7**	**$8,474,547.1**	**$2,948,660.9**	**$ 937,877.3**	**$ 479,362.6**	**$8,910,680.0**	**$2,546,650.2**	**$ 1,328,724.7**	**$ 180,382.1**	**$ 713,850.1**	**$ 628,013.3**	**$41,858,299.0**
11	DELIVERY (inc. 35% contingency)	$ 3,303,371.6	$2,446,492.3	$3,259,735.9	$5,190,660.1	$1,806,054.8	$ 574,449.8	$ 479,362.6	$5,457,791.5	$1,559,823.3	$ 813,843.9	$ 110,484.1	$ 437,233.2	$ 384,658.2	$25,823,961.1
12	TOTAL ESTIMATED COST	$ 8,696,631	$ 6,440,766	$ 8,581,754	$ 13,665,207	$ 4,754,716	$ 1,512,327	$ 772,972	$ 14,368,471	$ 4,106,473	$ 2,142,569	$ 290,866	$ 1,151,083	$ 1,012,671	$67,496,507.1

The costings do not include costs associated with the complexity of constructing an outfall across the railway track, nor does it include railway closure costs. This is outside the area of expertise of the team developing this strategy, and therefore these costs should be obtained from other specialists. Provided below are some considerations and high-level cost estimates provided by the VPA based on a previous project:

a. Siteworks/ earthworks, open cut construction through railway embankment (if culverts are adopted)

b. Construction occupation fees (~$1.5M per crossing)

c. Signalling adjustments (~$1M)

d. Railway track modifications/reinstatement (~$1M)

e. Any service relocation and associated risks

f. Increase in head contractor preliminaries, to allow for complexity

g. Access track and boundary fencing, adjacent railway

    i. Unsealed pavement plus table drains and nature strip on both sides (assumed 10m wide)

    ii. Full length of railway embankment for access.

Provision for the outfall channel works (excavation, rockwork and planting) are included with RB3 and RB4. Provision for gravel access tracks to the outfall channels and turning circle areas are provided within the RB3 and RB4 cost estimates.

WLRB1 and WLRB2 are relatively high cost assets due to the significant amount of excavation as a result of the surrounding steep topography.

11 Conclusion

Alluvium Consulting has been engaged by Victorian Planning Authority to prepare concept and functional drainage designs for the Bannockburn SE Precinct Structure Plan.

Building on previous strategies for the Bannockburn growth area plan and in consultation with the VPA and other broader stakeholders, the stormwater management assets for the precinct were developed as concept designs. Once the preferred concept arrangement is agreed on, the assets will be developed into functional designs.

The design process included:

- Review of previous strategies
- Review of background studies and data
- Treatment modelling to ensure best practice treatment targets were met
- Hydrologic modelling to ensure post-development flows are retarded back to pre-development flows
- Velocity and sediment capture efficiency calculations
- Earthworks modelling
- Stakeholder feedback on previous concept designs options.

Seven wetland/retarding basin assets, one waterway, and two sediment basin/retarding basins were developed up:

- WLRB1, outfalling into the Bruce Creek
- WLRB2, outfalling into the Bruce Creek
- WL3 (within RB3), outfalling into the waterway
- WLRB4, outfalling via new railway culverts
- WLRB5, outfalling into the constructed waterway via pipe network
- WLRB6, outfalling into the constructed waterway via pipe network
- WL7 (within RB3), outfalling into the waterway
- WL7&3/RB3, outfalling via new railway culverts.
- SBRB7, outfalling into the constructed waterway
- SBRB8, outfalling into the existing drainage channel
- Constructed waterway, outfalling via RB3.

A summary of the assets, land take and cost estimates are provided in Table 38.

Table 38. Summary of assets, land take and cost estimates

Asset	Cost (inc. 35% contingency)	Land take (ha)^
WLRB1	$8,696,631	3.20
WLRB2	$6,440,766	2.43
WLRB4	$8,581,754	4.99 # (+0.15 for outfall channel)
WLRB5	$13,665,207	5.08
WLRB6	$4,754,716	2.15
SBRB7	$1,512,327	0.58
SBRB8	$772,972	0.48
WL3&7/RB3	$14,368,471	9.56# (+0.71 for outfall channel)
Constructed waterway*	$4,106,473	4.53
Culvert 1	$290,866	-
Culvert 2	$1,151,083	-
Culvert 3	$1,012,671	-
1% AEP pipe	$2,142,569	-

* Corridor area, up to RB3.
^Includes perimeter paths and sediment dewatering areas.
#Includes 10m no works buffer from railway easement.

12 References

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Appendix A
Hydrologic modelling

Kc calibration

In line with the Australian Rainfall & Runoff (2019), calibration of the hydrologic model (i.e. RORB model) is required in order to determine the estimation of rainfall intensities for a specific site.

The Australian Rainfall & Runoff 2019 guidelines suggests that the model is calibrated in line with the Regional Flood Frequency Estimation model (RFFE), whilst using Initial Loss (IL) & Continuing Loss (CL) values provided from the ARR datahub. However, when running the RFFE model, there appears no data points of relative catchment size to the study area. Therefore, this suggest the flow from RFFE is not directly relatable.

Several calibration approaches were consequently investigated. Noting the average annual rainfall for Bannockburn according to the BoM website is less than 800mm. The following formulas investigated were:

• Kc = 1.25 × Dav (for Victorian catchments Pearse et al. 2002)

• Kc = 0.49 × A^0.65 (for regions with mean annual rainfall less than 800mm)

The Kc values very varied by interstation area across the site. A check was also performed using the rational method.

Following the analysis, the Pearse et al formula for Victorian catchments (i.e. 1.25 * dav), correlated the most with the rural rational method flows. These results are included in Figure 50.

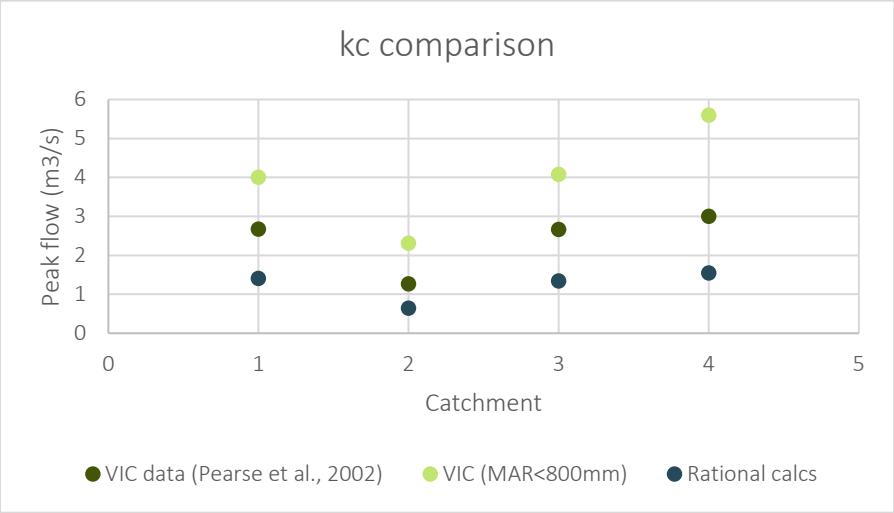


Figure 50. *Results of RORB model with various kc, compared to rational method calculation*

The Pearse et al. formula for Victorian catchments was adopted for the Kc, and flows were determined using RORB.

RORB models

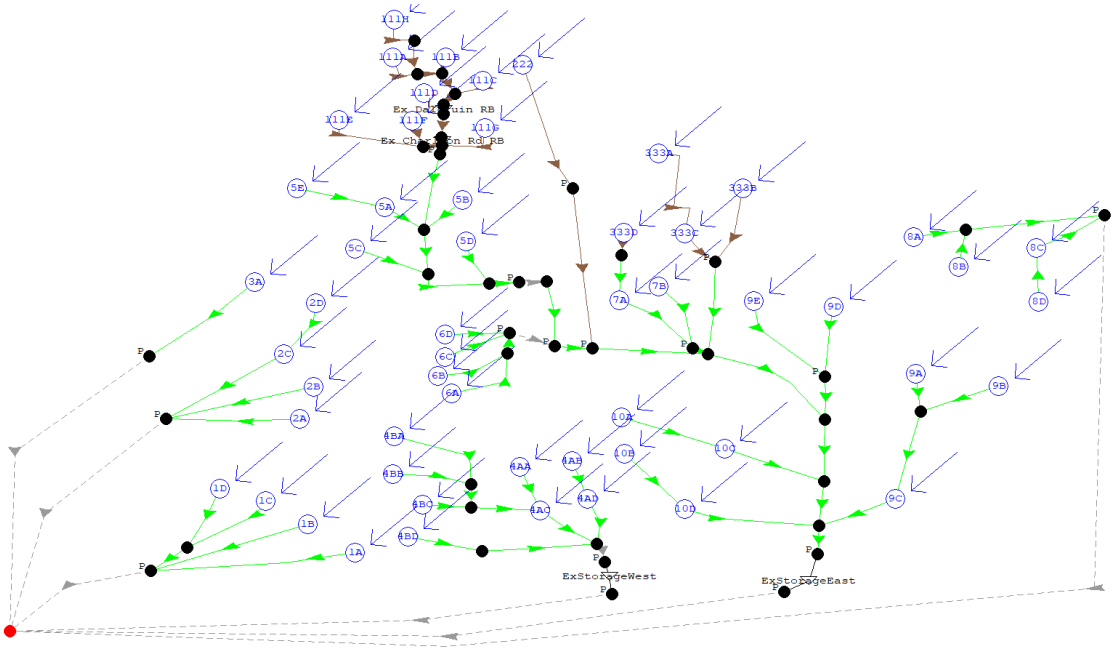


Figure 51. *Existing conditions RORB model*

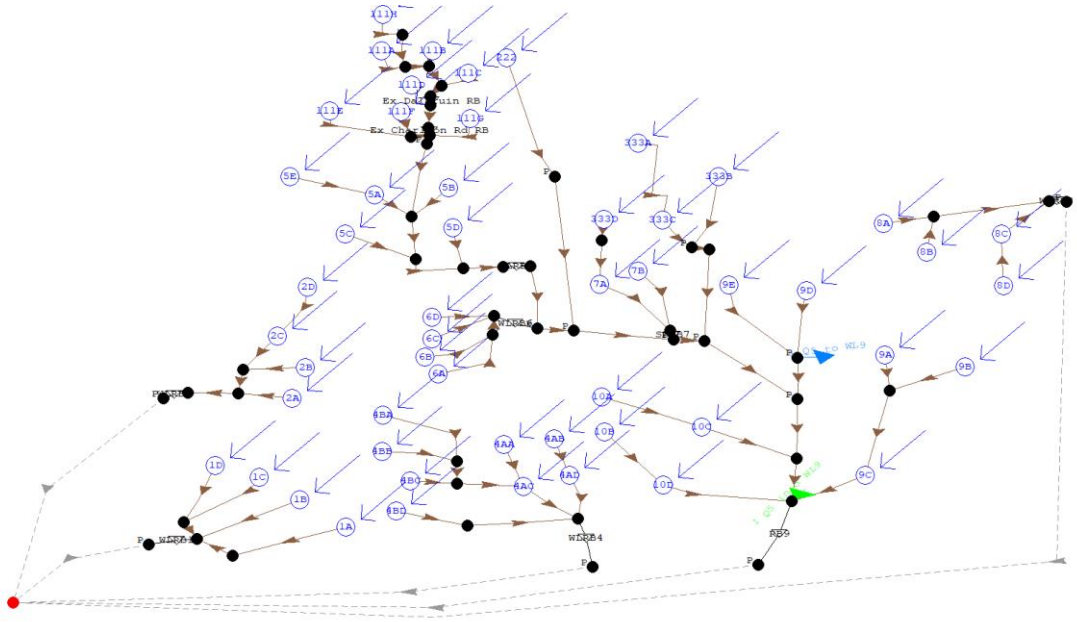


Figure 52. *Developed conditions RORB Model (using Type 2 reaches for establishing 1% AEP flow, storage sizing)*

Appendix B
Treatment modelling

MUSIC Modelling inputs

The MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model that was developed included the following input parameters:

- Melbourne Airport rainfall from 1971-1980. This template has an annual average rainfall of 575mm, and evaporation of 1041 mm/yr.
- MUSIC model run at a 6-minute timestep.
- Fraction impervious values and areas for sub catchments consistent with Table 2.
- Wetlands designed to not exceed 72.0 hours detention time, to prevent terrestrial and aquatic vegetation from 'drowning'.

Figure 53 outlines the iterative process of sizing the treatment infrastructure in MUSIC.

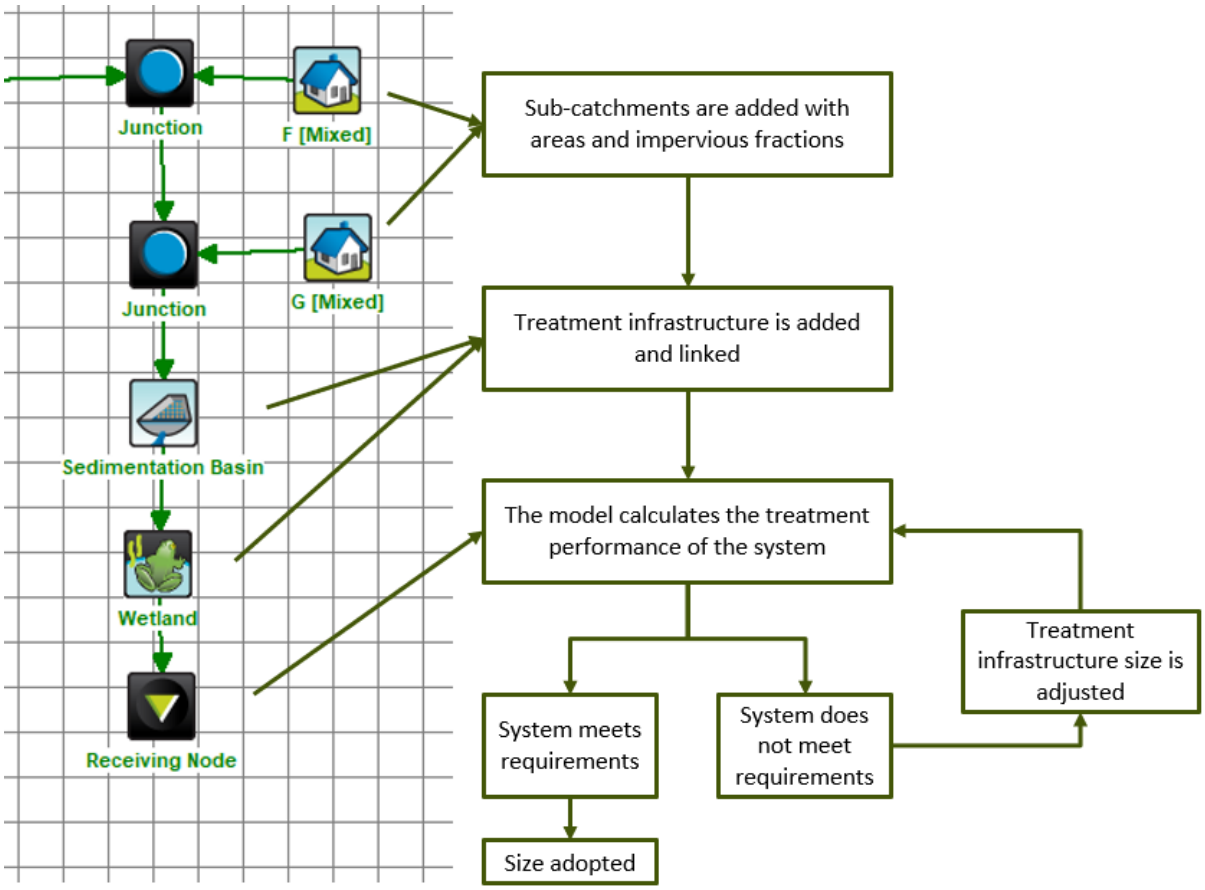


Figure 53. *Simplified MUSIC Method*