Bannockburn South East Precinct Structure Plan– Stormwater Drainage Design

CONCEPT DESIGN REPORT (DRAFT)

March 2025

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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'.

Authors:	Jenny Butcher, Stuart Cleven, Matt Gleeson, Advait Madav
Review:	Stuart Cleven
Approved:	Stuart Cleven
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Contents

1 **Introduction** ... 1

1.1 Location ... 1

1.2 Project background ... 2

1.3 Stakeholders ... 3

1.4 Project scope ... 3

1.5 Strategic context ... 3

1.6 Background information and previous studies ... 4

Bannockburn South West PSP stormwater design (Alluvium, 2019) ... 5

Bannockburn Growth Plan - Bannockburn catchment assessment (Alluvium 2020) ... 6

Bannockburn South East PSP Draft Preliminary IWM Issues and Opportunities Report (Spiire, October 2022) ... 6

2 **Existing conditions** ... 7

2.1 Site visit ... 7

2.2 Land use ... 8

2.3 Topography ... 10

2.4 Catchment context ... 11

2.5 Flooding ... 13

2.6 Existing services and infrastructure ... 14

2.7 Geology ... 17

Geomorphological Management Units (GMU) ... 17

Soils ... 17

Contamination ... 19

2.8 Cultural heritage ... 20

2.9 Ecology ... 21

3 **Post development objectives and conditions** ... 25

3.1 Stormwater drainage requirements ... 25

Stormwater quantity management ... 25

Stormwater conveyance ... 26

Stormwater quality treatment ... 26

General Environmental Duty (GED) and EPAV stormwater guidance ... 26

3.2 Future land use ... 27

4 **Stakeholder input** ... 29

5 **Catchment analysis** ... 32

5.1 Sub-catchments ... 32

6 **Hydrologic analysis** ... 36

6.1 *Hydrologic modelling* ... 36
6.2 *Input parameters* ... 36
6.3 *Pre burst factors* ... 40
6.4 *Results* ... 41
6.5 *Retarding basin design* ... 42
6.6 *Other peak flow rates* ... 44
6.7 *Climate change considerations* ... 46

7 Wetland and sediment basin design ... 47
7.1 *Design arrangement overview* ... 47
7.2 *Stormwater treatment modelling* ... 47
Modelling inputs ... 47
Asset Performance ... 49
7.3 *Sediment Basin sizing* ... 52
7.4 *Wetlands* ... 55
Velocities ... 55
7.5 *Connections* ... 57
Inflow into sediment basins ... 57
Sediment basin to wetland transfer ... 57
Balance pipes ... 57
Wetland outfall ... 57

8 Waterway design ... 58
8.1 *Constructed waterways* ... 58
8.2 *Design objectives* ... 58
8.3 *Design constraints* ... 58
8.4 *Waterway design* ... 58
Design flows ... 59
Longitudinal slope ... 59
Cross-section geometry ... 60
8.5 *Waterway corridors* ... 60
8.6 *Culvert and pipe design* ... 62
Proposed culverts ... 62
Proposed pipe ... 62

9 Concept designs ... 63
9.1 *Concept overview* ... 63
9.2 *Asset details* ... 64

10 Cost estimate ... 75

11 Conclusion ... 76

11.1 Next steps ... 77

12 References ... 78

Appendix A Hydrologic modelling ... 79
Appendix B Treatment modelling ... 82
Appendix C Concept designs with draft Place Based Plan ... 84

Figures

Figure 1. *Bannockburn South East PSP (red outline) within the Western Geelong Growth Area* 1
Figure 2. *Bannockburn Growth Plan – Environment and Water (VPA 2021)* 2
Figure 3. *Bannockburn South West PSP stormwater design (Alluvium, 2019)* 6
Figure 4. *Bannockburn growth investigation area concept assets (Alluvium, 2020)* 6
Figure 5. *Field photos* 8
Figure 6. *Current land use* 9
Figure 7. *Site topography* 10
Figure 8. *Site topography and flow direction* 11
Figure 9. *Catchment context* 12
Figure 10. *Existing flood conditions - 1% AEP (1-in-100 year) flood (Source: Regional Floodplain mapping project (Barwon), 2016)* 13
Figure 11. *Rain on grid mapping showing overland flow paths, Regional Floodplain Mapping Project (2016)* 14
Figure 12. *Existing services and infrastructure* 15
Figure 13. *Culvert details* 16
Figure 14. *Geological unit of the project study area (Source: DELWP/Vicmap, 2020)* 17
Figure 15. *Soils across the project study area (Source: WSP 2022)* 19
Figure 16. *Potential contaminated land across the project study area (Source: WSP 2022)* 20
Figure 17. *Bannockburn SE PSP Cultural and historical heritage values* 21
Figure 18. *Significant flora in the study area* 23
Figure 19. *Significant fauna in the study area* 24
Figure 20. *Draft Bannockburn SE PSP Place Based Plan (June 2024)* 28
Figure 21. *Sub-catchment layout showing flow direction. The urban layout is shown as an underlay.* 34
Figure 22. *Delineated subcatchments for hydrologic modelling – RORB layout* 38
Figure 23. *ARR 2019 loss prediction regions for Victoria* 40
Figure 24. *Concept design overview showing proposed RB locations* 42
Figure 25. *Constructed waterway flow locations* 45
Figure 26. *MUSIC model layout* 48
Figure 27. *Waterway corridor (Reference: Melbourne Water's Waterway Corridor Guidelines).* 60
Figure 28. *Minimum Constructed Waterway corridor requirements (Melbourne Water's Waterway Corridor Guidelines).* 61
Figure 29. *Concept plan overview for Bannockburn SE PSP stormwater drainage design* 64
Figure 30. *WLRB 1 Concept Design* 65
Figure 31. *WLRB 2 Concept Design* 66
Figure 32. *WLRB 3 Concept Design* 67
Figure 33. *WLRB 4 Concept Design* 68

Figure 34. *WLRB 5 Concept Design* 69
Figure 35. *WLRB 6 Concept Design* 70
Figure 36. *WLRB 7 Concept Design* 71
Figure 37. *WLRB 8 Concept Design* 72
Figure 38. *WL 9, WL 10 and RB 9 Concept Design* 73
Figure 39. *Waterway concept design* 74
Figure 40. *Results of RORB model with various kc, compared to rational method calculation* 80
Figure 41. *Existing conditions RORB model* 81
Figure 42. *Developed conditions RORB Model (using Type 2 reaches for establishing 1% AEP flow, storage sizing)* 81
Figure 43. *Simplified MUSIC Method* 83
Figure 44. *WLRB 1 Concept Design (including urban layout in background)* 85
Figure 45. *WLRB 2 Concept Design (including urban layout in background)* 86
Figure 46. *WLRB 3 Concept Design (including urban layout in background)* 87
Figure 47. *WLRB 4 Concept Design (including urban layout in background)* 88
Figure 48. *WLRB 5 Concept Design (including urban layout in background)* 89
Figure 49. *WLRB 6 Concept Design (including urban layout in background)* 90
Figure 50. *WLRB 7 Concept Design (including urban layout in background)* 91
Figure 51. *SBRB 8 Concept Design (including urban layout in background)* 92
Figure 52. *WL 9, WL 10 and RB 9 Concept Design (including urban layout in background)* 93

Tables

Table 1. Adopted fraction impervious values for each proposed land use type 32
Table 2. Developed conditions effective imperviousness area by sub-catchment 35
Table 3. Developed mean annual flow and pollutant loads in each catchment 35
Table 4. Adopted RORB parameters. 37
Table 5. Developed conditions effective imperviousness area by sub-catchment 38
Table 6. Pre burst depth ratios 41
Table 7. 1% AEP RORB modelling results 41
Table 8. Railway culvert details and capacities 43
Table 9. Retarding basin requirements 44
Table 10. Calculated flow rates for waterway design and other calculated flow rates 46
Table 11. Treatment asset parameters for stormwater treatment assets 49
Table 12. Overall PSP MUSIC modelling results 49
Table 13. Wetland 1 treatment results 49
Table 14. Wetland 2 treatment results 50
Table 15. Wetland 3 treatment results 50
Table 16. Wetland 4 treatment results 50
Table 17. Wetland 5 treatment results 50
Table 18. Wetland 6 treatment results 50
Table 19. Wetland 7 treatment results 51
Table 20. Sediment basin 8 treatment results 51
Table 21. Wetland 9 treatment results 51

Table 22. Wetland 10 treatment results 51
Table 23. Sediment basin sizing 53
Table 24. Sediment basin velocity calculations 54
Table 25. Velocity calculations 56
Table 26. Calculated flow rates for waterway design 59
Table 27. Longitudinal slope along low flow channel. 59
Table 28. Waterway cross-section geometry and design parameters. 60
Table 29. Proposed new culvert under Burnside Road 62
Table 30. Proposed new pipe 62
Table 31. Cost estimate summary for the proposed works 75
Table 32. Summary of assets, land take and cost estimates 77

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.

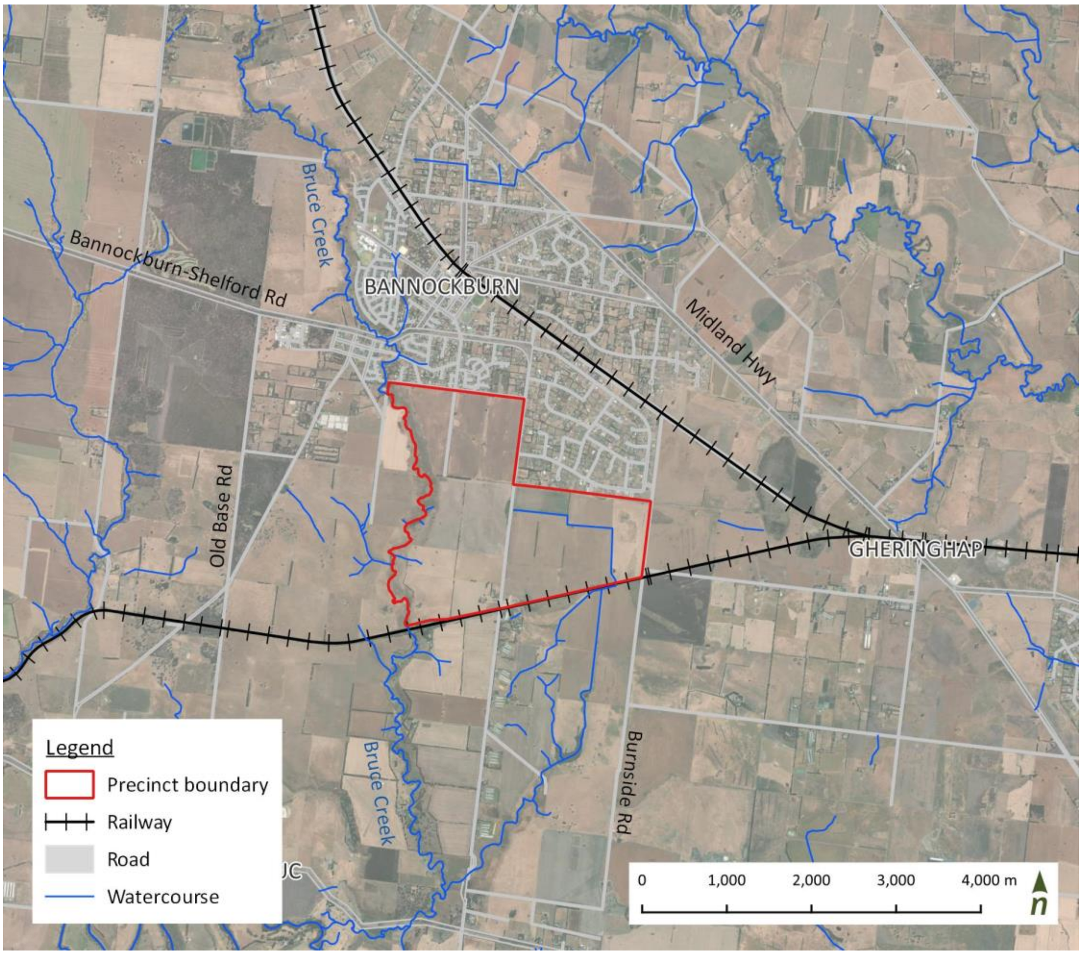


Figure 1. *Bannockburn South East PSP (red outline) within the Western Geelong Growth Area*

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 is shown in Figure 2.

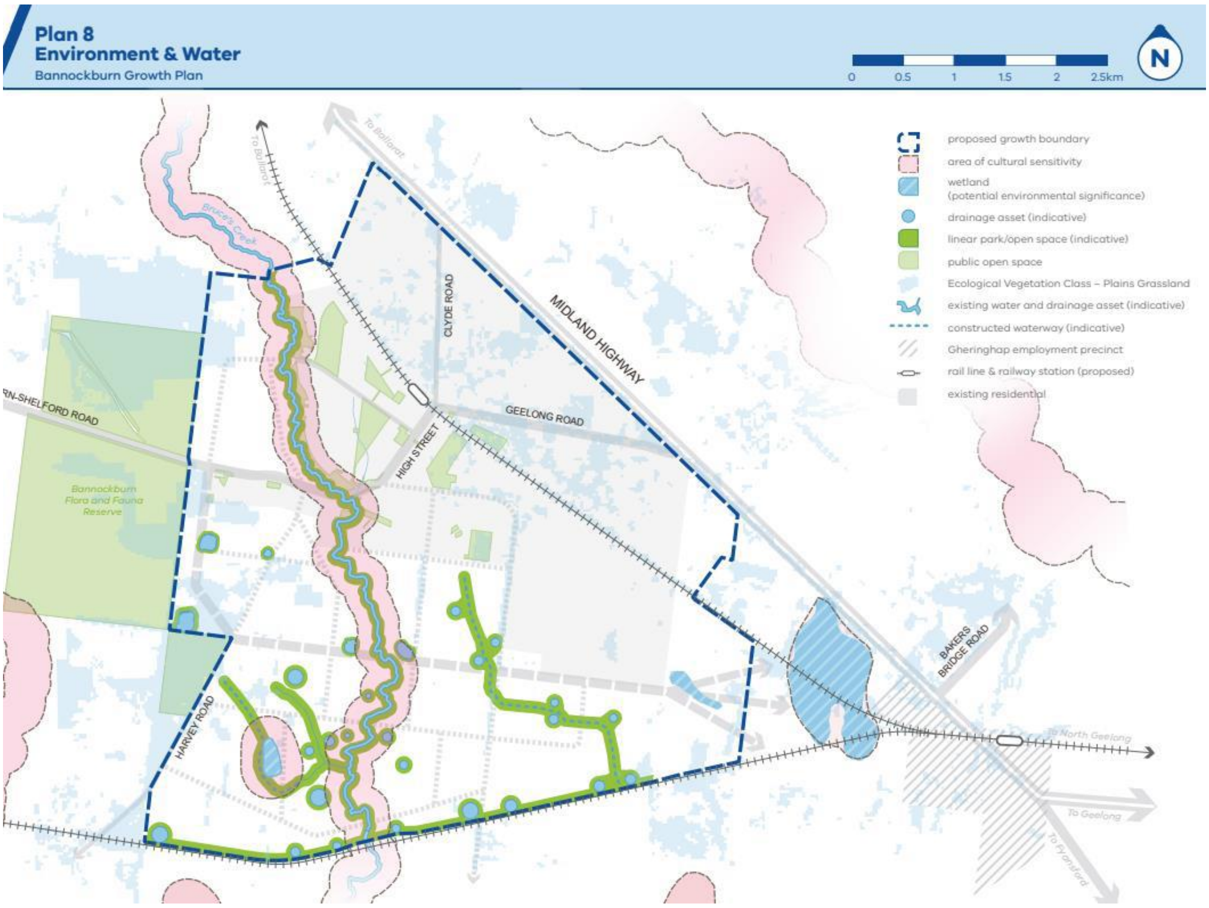


Figure 2. *Bannockburn Growth Plan – Environment and Water (VPA 2021)*

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.

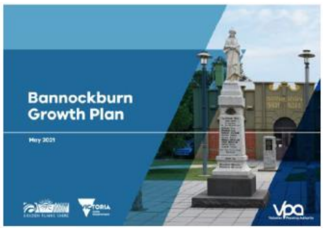
This report details work undertaken up to the conceptual design stage. The functional designs will follow on from final feedback and acceptance of the concept layout by Council and the VPA. The concepts designs presented in this report are relatively detailed concept designs, so to be able to confidently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

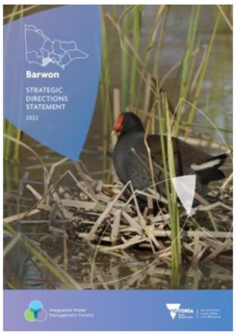
Similarly, the IWM Forum vision for the Barwon has a focus on Working together through sustainable water management to enhance urban landscapes and maximise amenity, environment, and economic outcomes for our communities. In our experience with other IWM plan and PSPs, a clear and shared vision is critical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

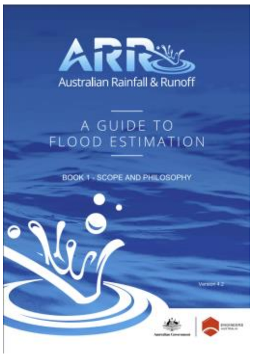
GPS and the VPA developed the Bannockburn Growth Plan to provide a vision and guide the sustainable development of these areas to the year 2050.



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 will be adopted in the functional design phase of the project, when a preferred concept is agreed on.

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)
- 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).
- 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).
  ARR data hub.

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.

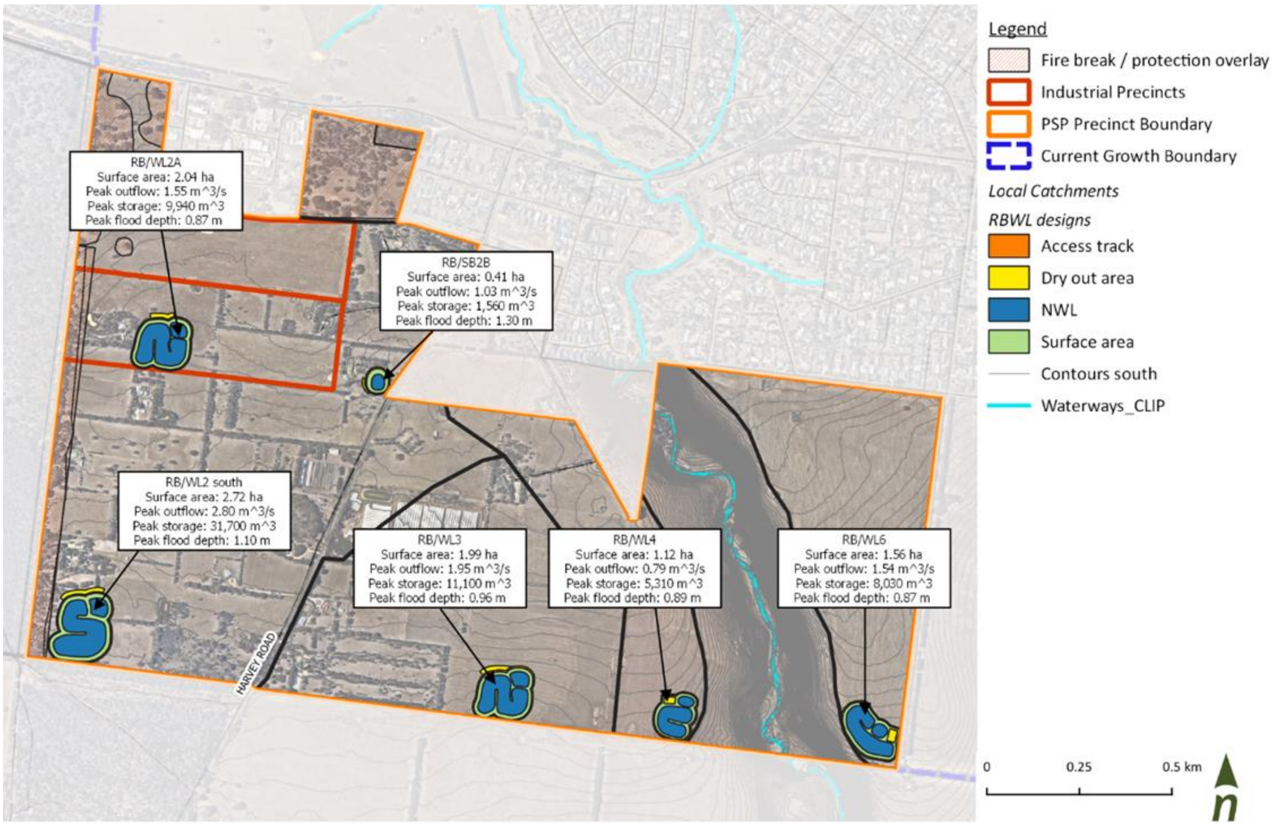


Figure 3. *Bannockburn South West PSP stormwater design (Alluvium, 2019)*

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.

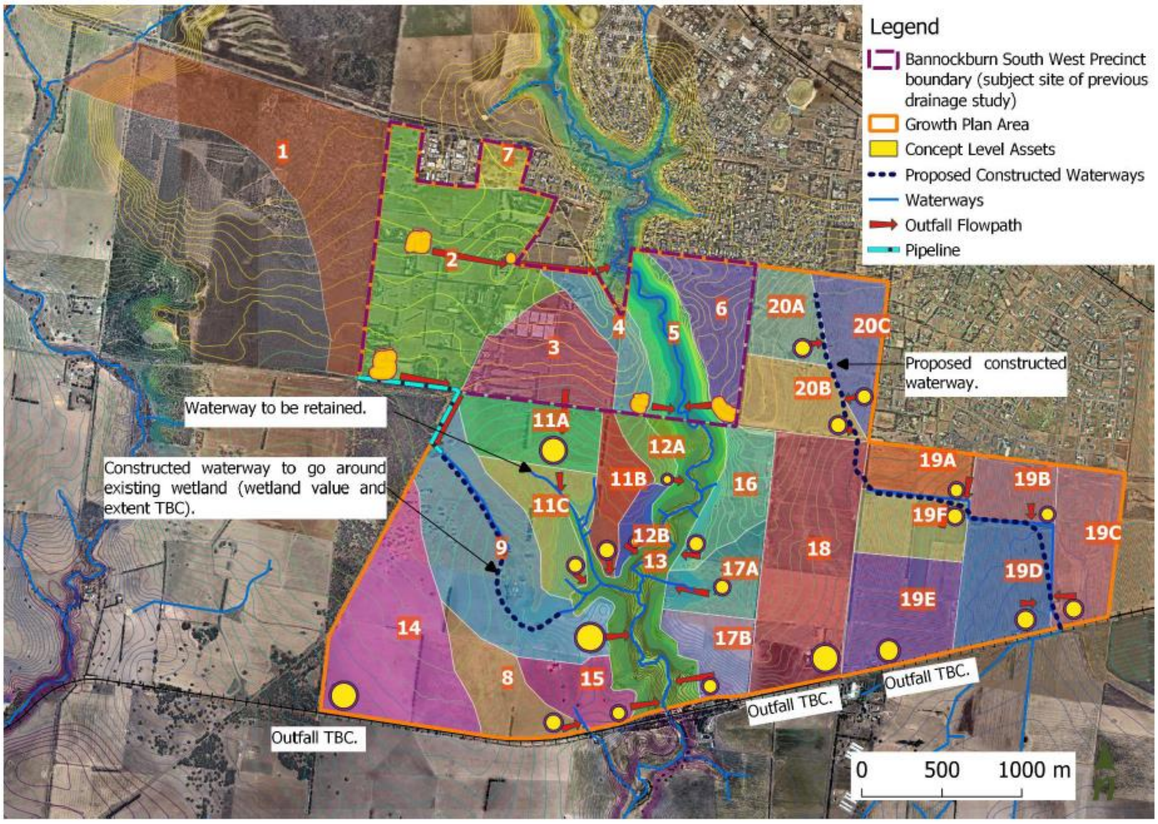


Figure 4. *Bannockburn growth investigation area concept assets (Alluvium, 2020)*

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

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.

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.

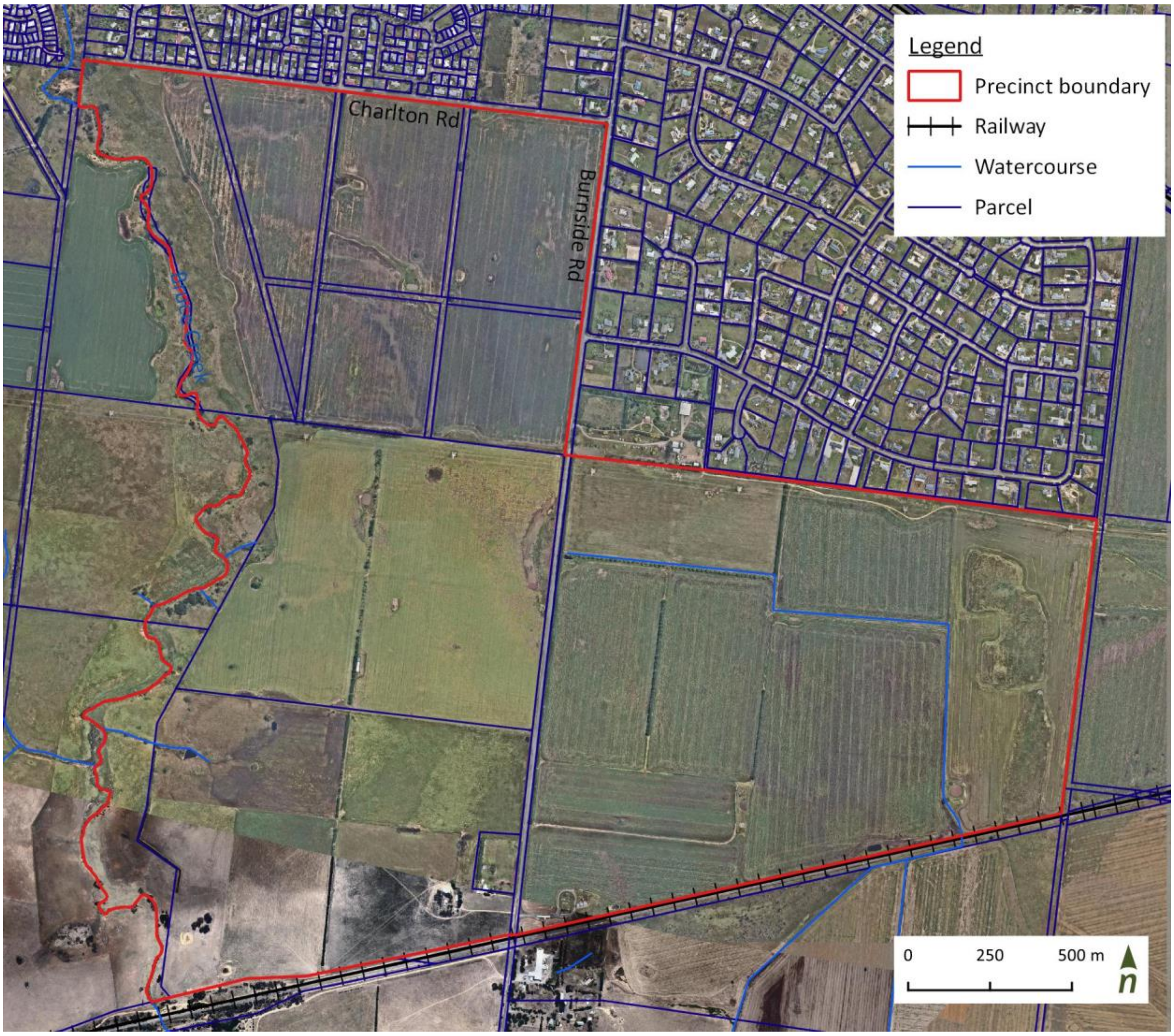


Figure 6. *Current land use*

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 are several smaller catchments which outfall via separate culverts under the railway.

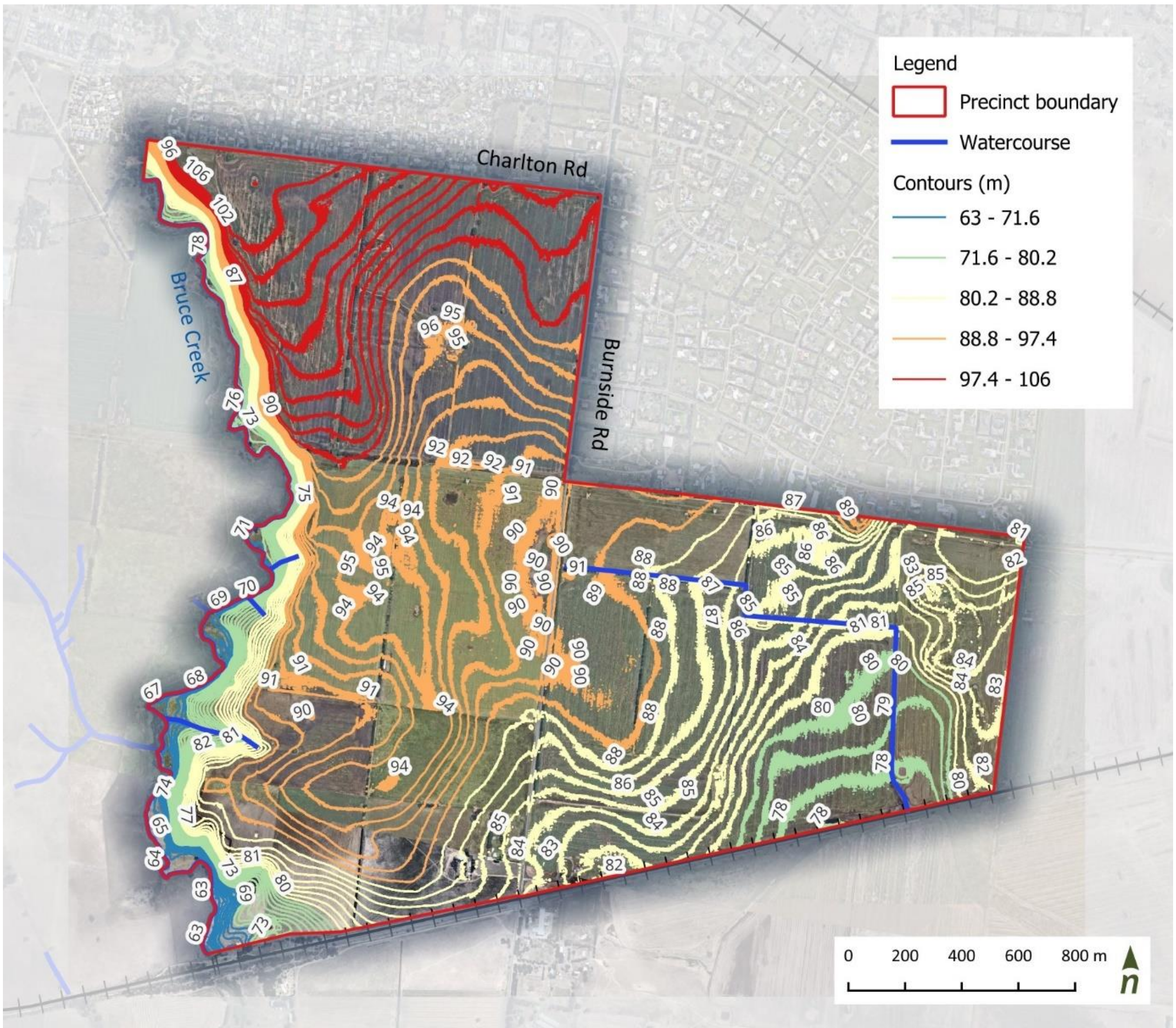


Figure 7. *Site topography*

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

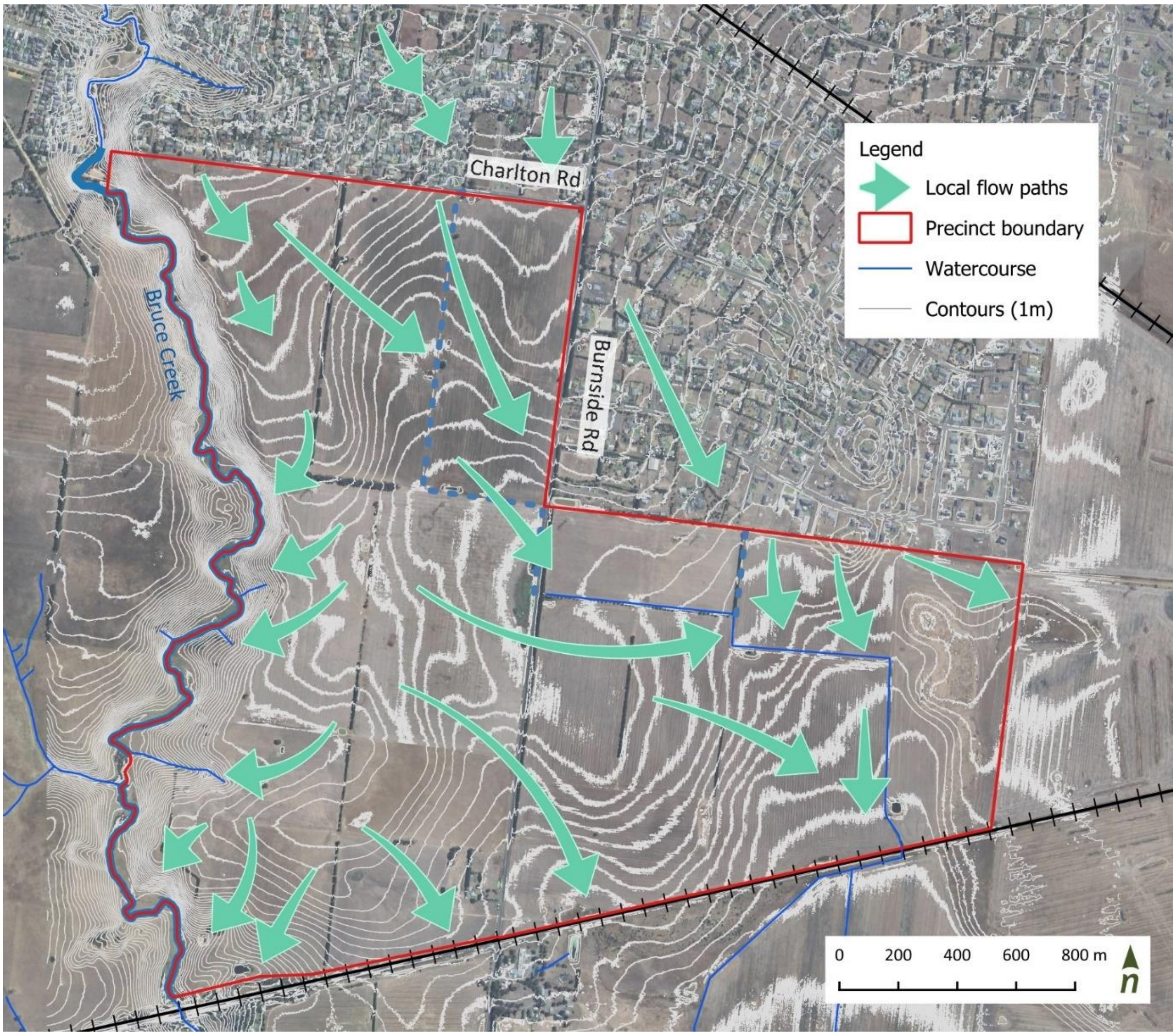


Figure 8. *Site topography and flow direction*

2.4 Catchment context

The site is located within the Barwon River catchment. The unnamed waterway connects with Bruce Creek near the Hamilton Highway. Bruce Creek connects with the Barwon River immediately south of the Hamilton Hwy (Figure 9).

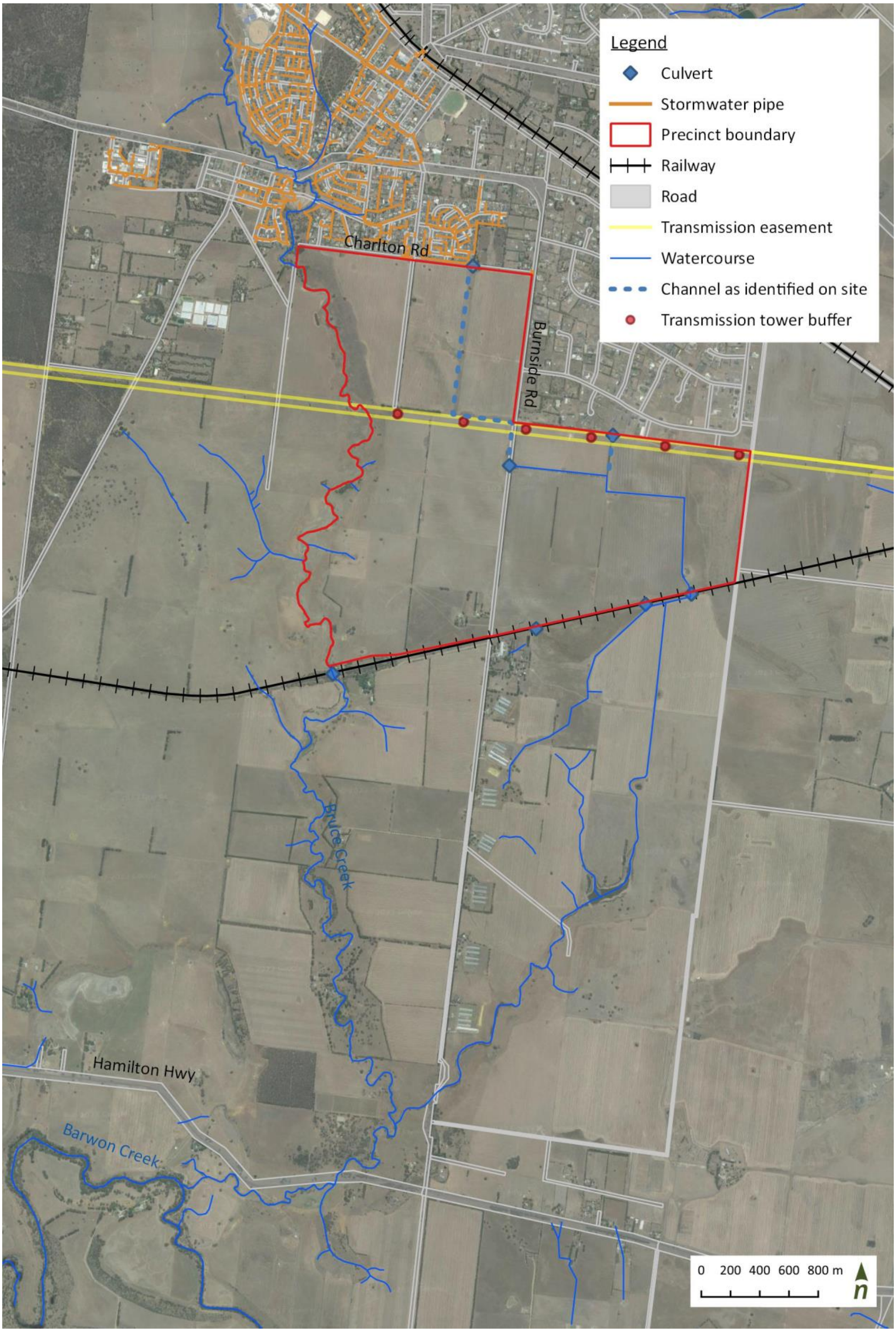


Figure 9. *Catchment context*

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.

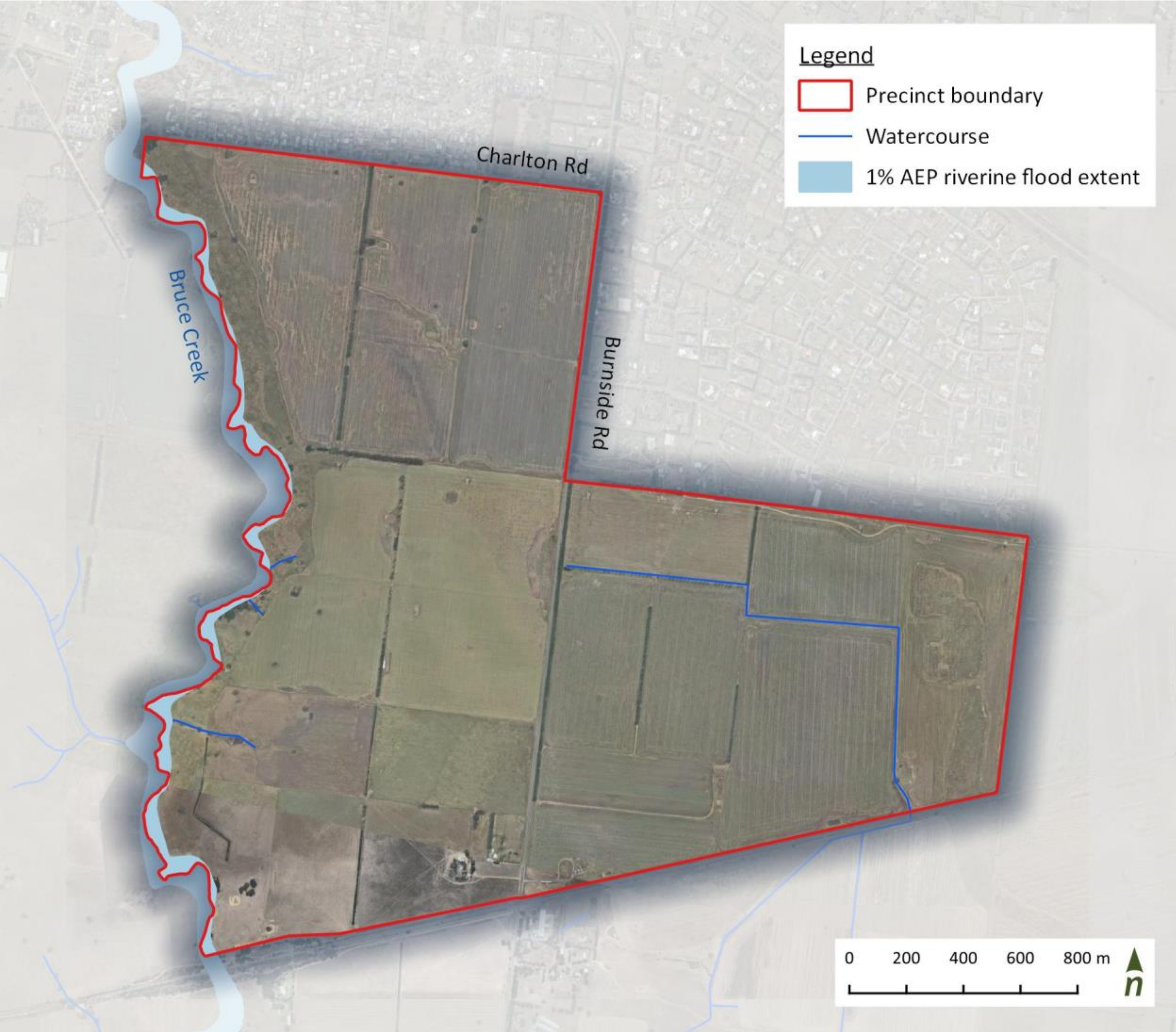


Figure 10. *Existing flood conditions - 1% AEP (1-in-100 year) flood (Source: Regional Floodplain mapping project (Barwon), 2016)*

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 we would expect them 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.

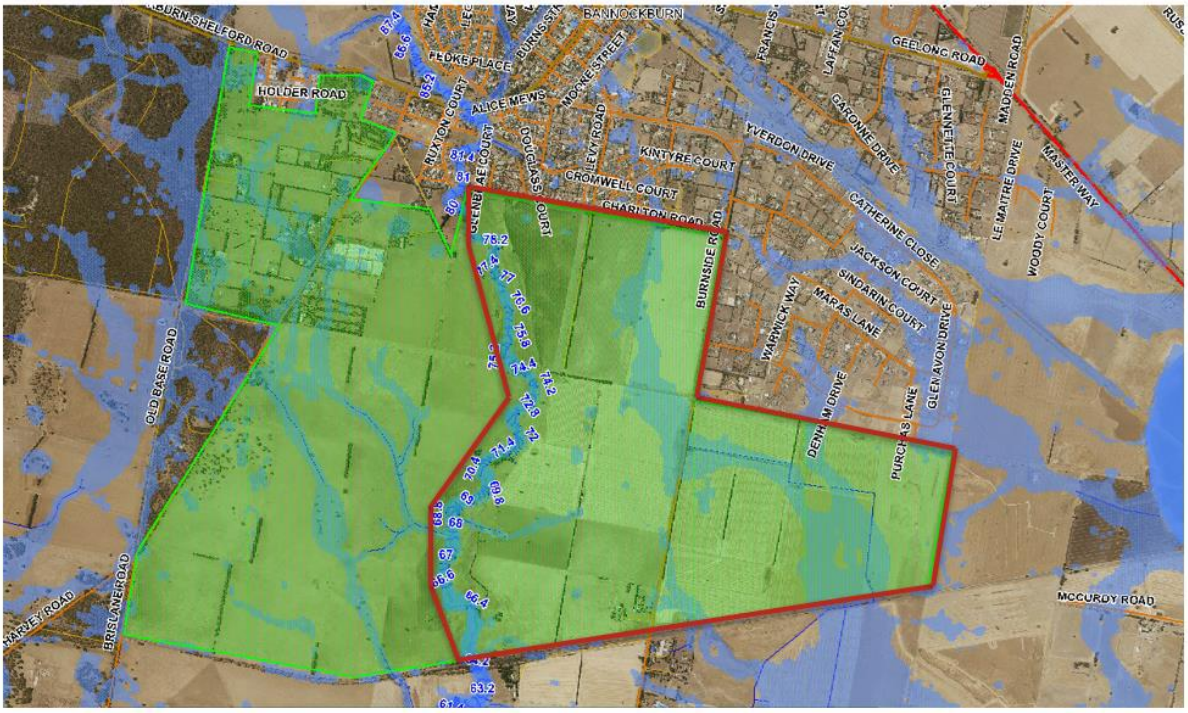


Figure 11. *Rain on grid mapping showing overland flow paths, Regional Floodplain Mapping Project (2016)*

2.6 Existing services and infrastructure

The site contains several channels as shown in Figure 12. 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 and culvert design section (Section 9.3). Existing precinct culvert details are provided in Figure 13, 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.

The site also includes approximately 19ha area of transmission easement located at the centre of the PSP (yellow lines in Figure 12). 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.

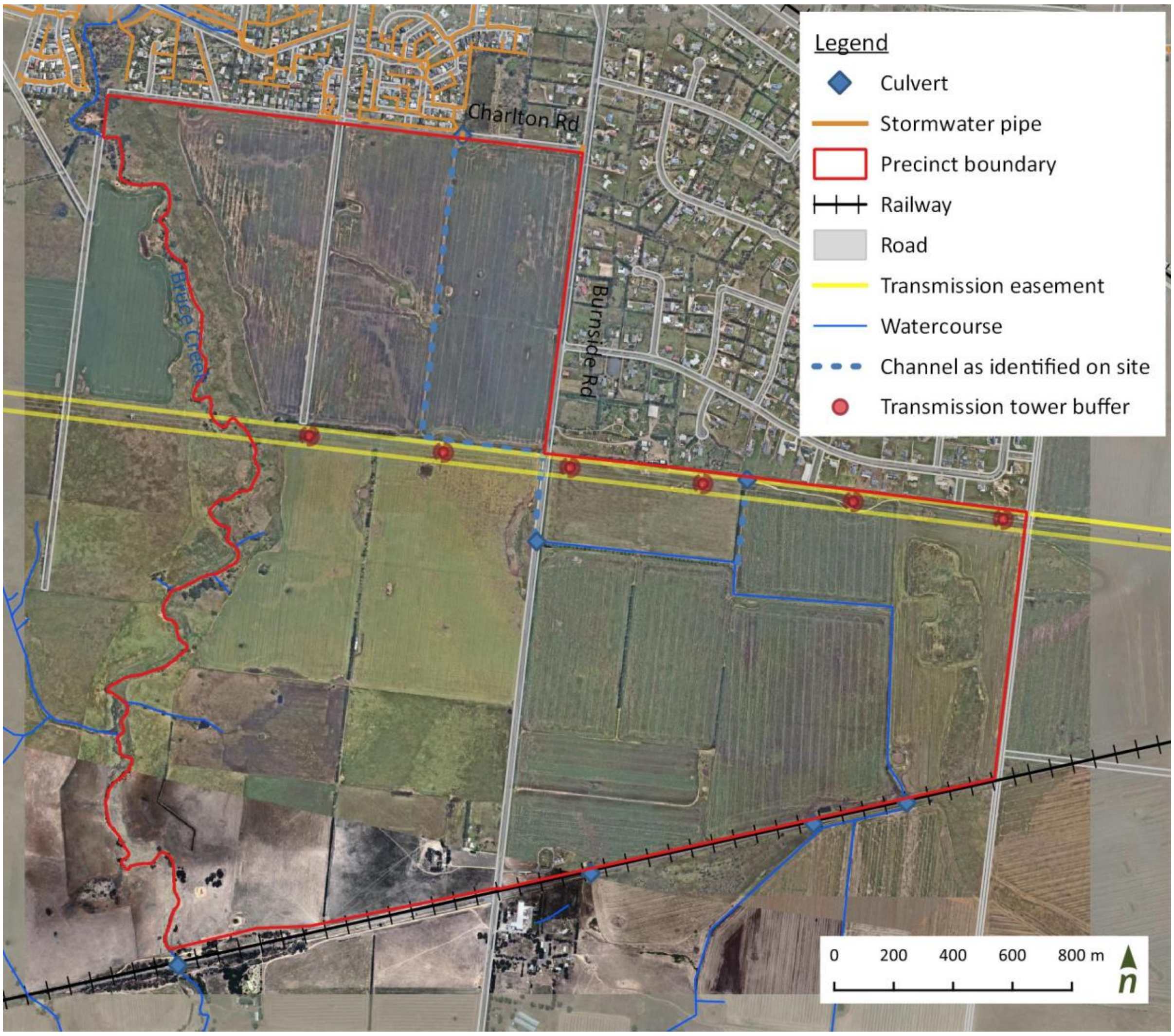


Figure 12. *Existing services and infrastructure*

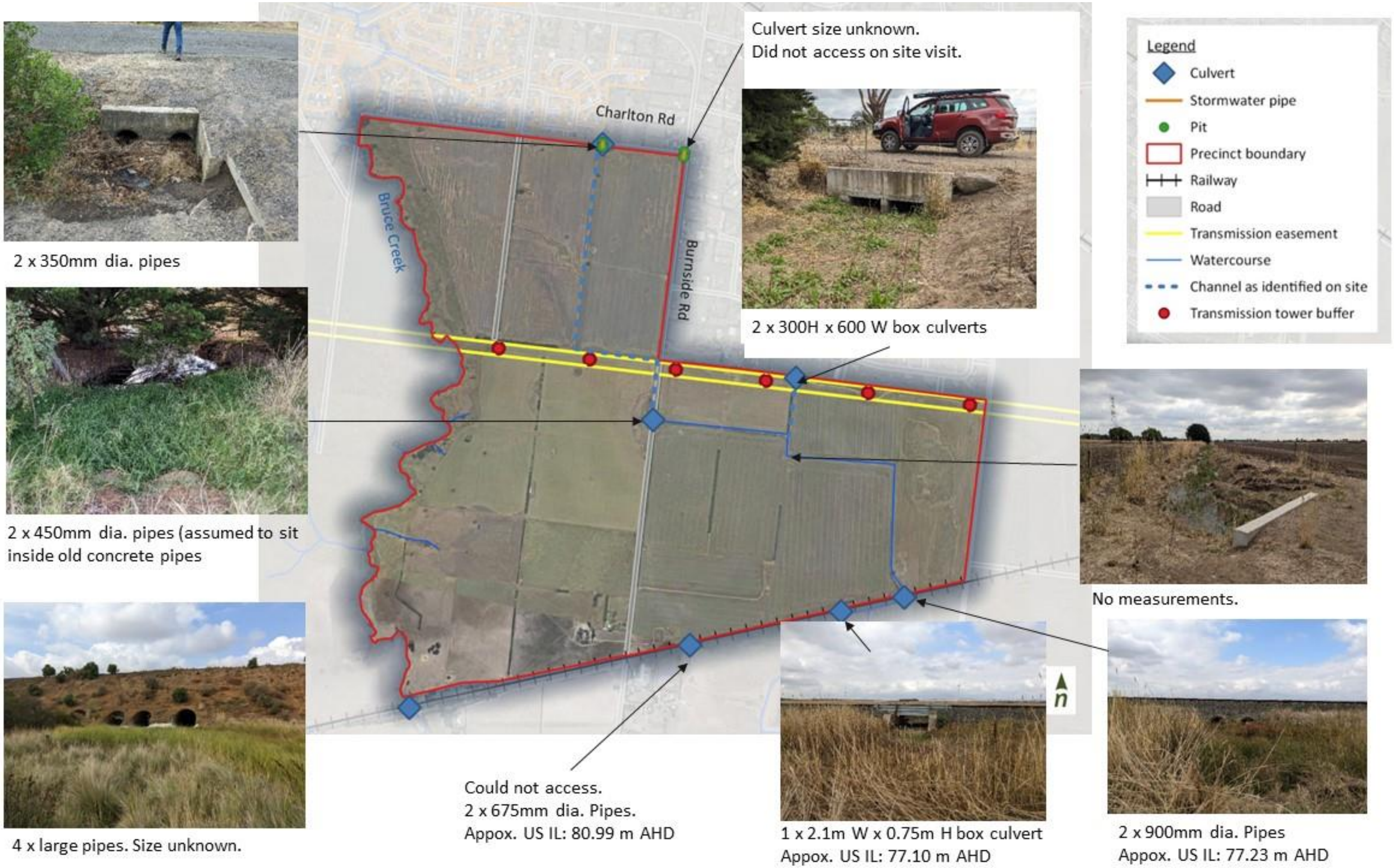


Figure 13. *Culvert details*

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 14.

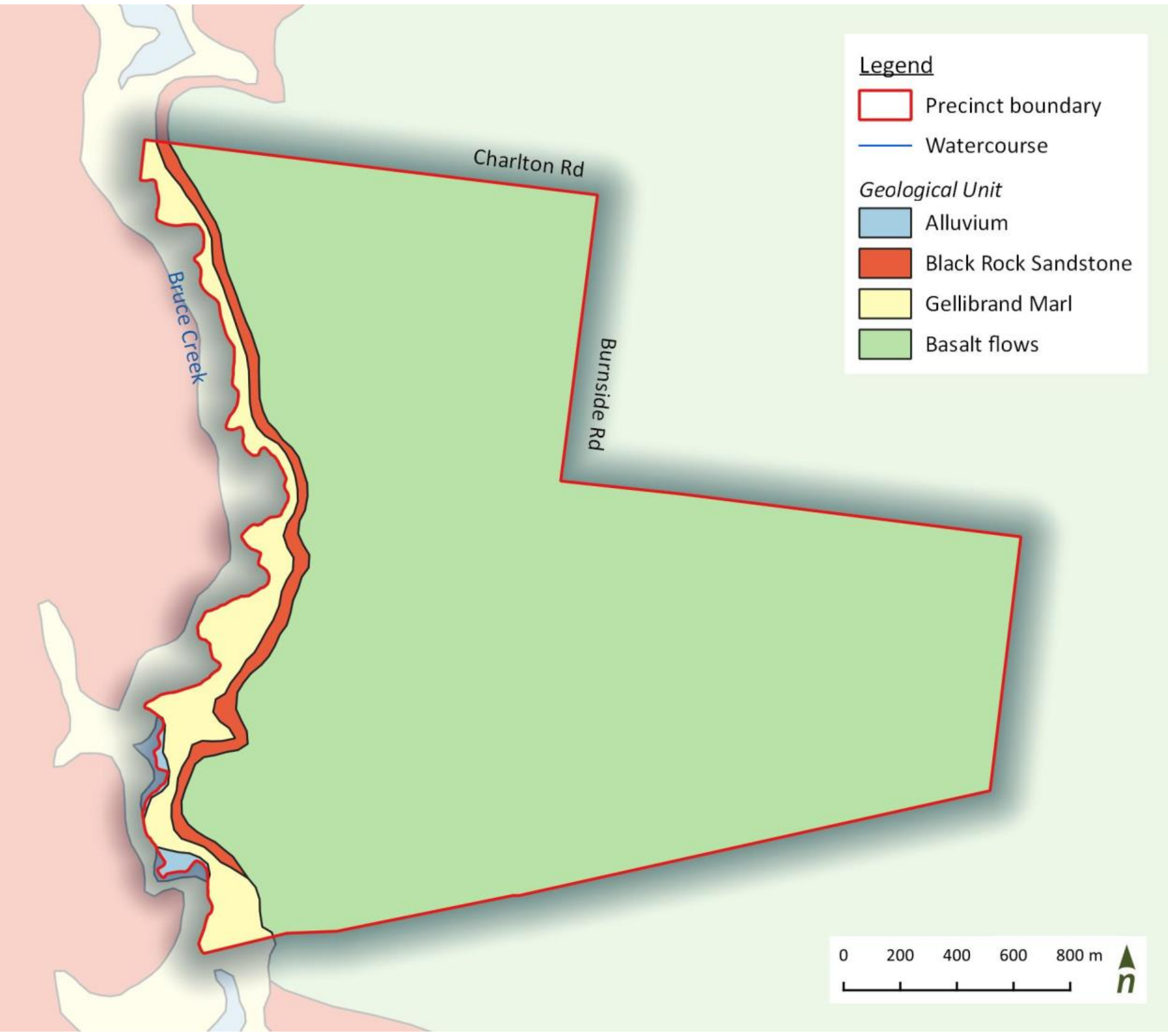


Figure 14. *Geological unit of the project study area (Source: DELWP/Vicmap, 2020)*

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.

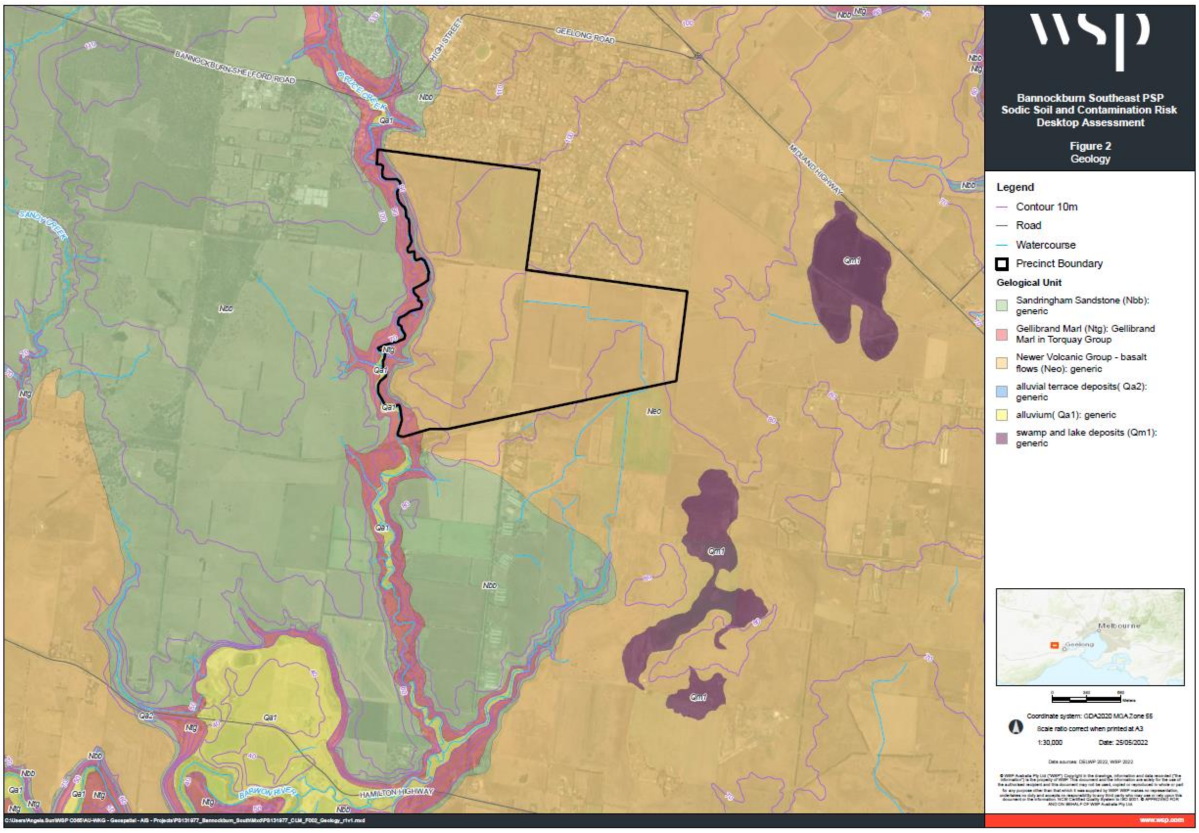


Figure 15. *Soils across the project study area (Source: WSP 2022)*

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

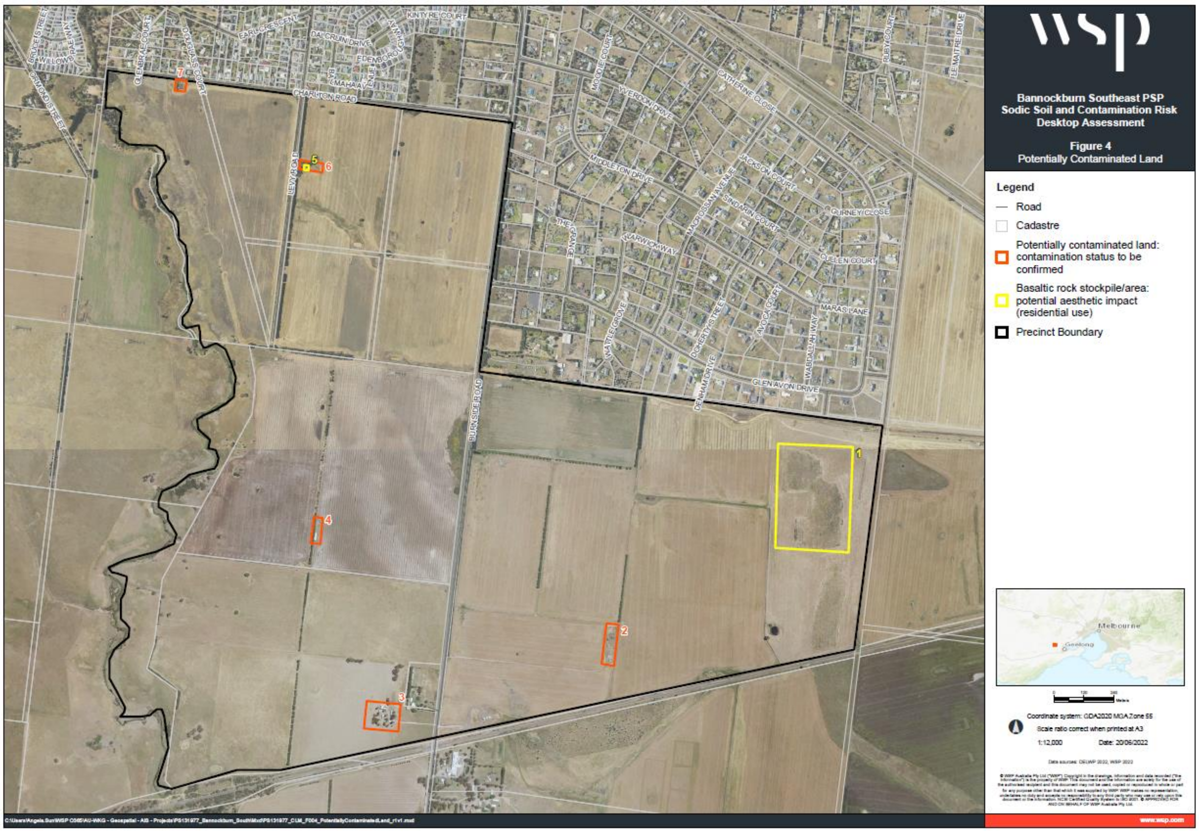


Figure 16. *Potential contaminated land across the project study area (Source: WSP 2022)*

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 17. 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 20). 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.

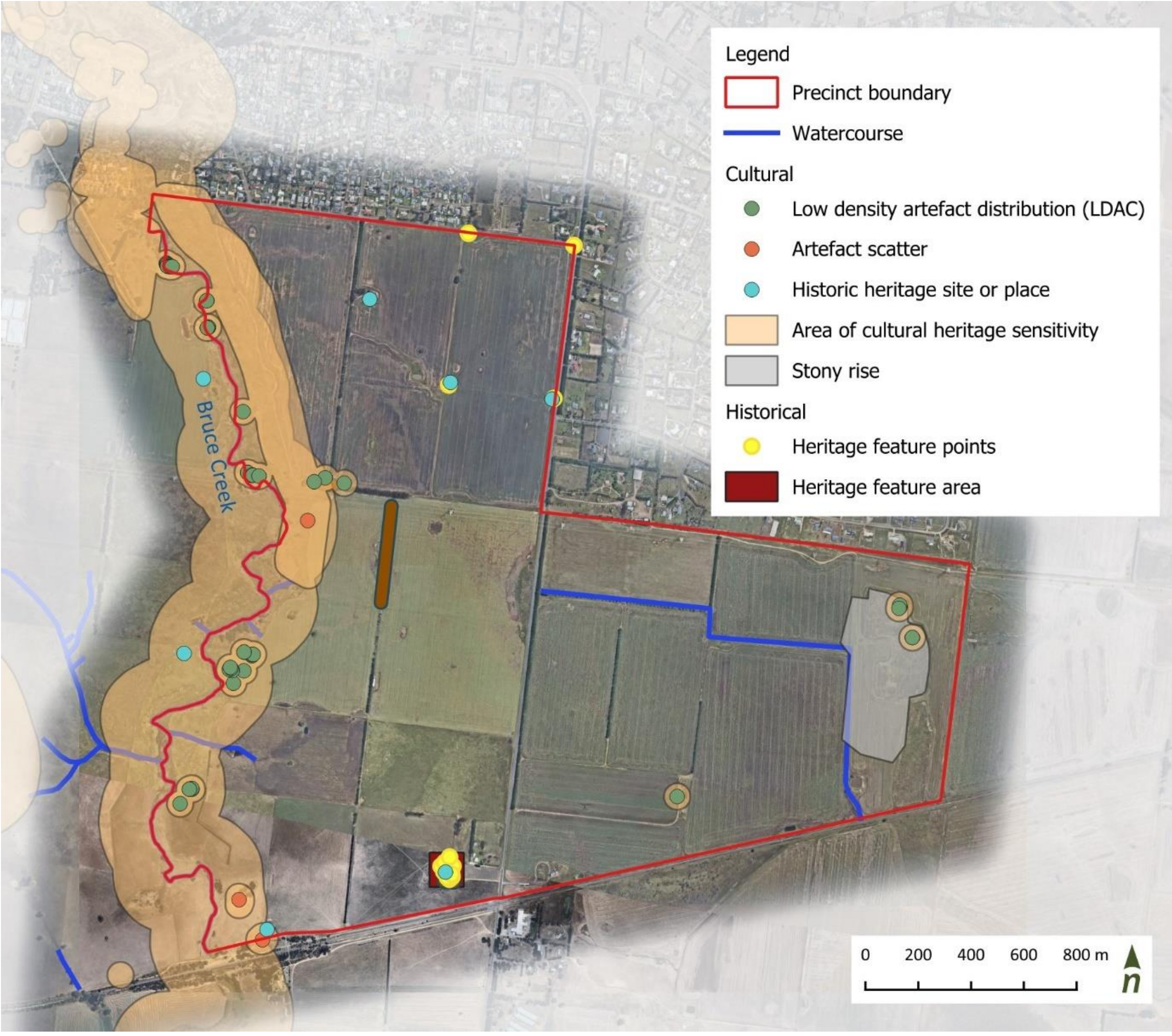


Figure 17. *Bannockburn SE PSP Cultural and historical heritage values*

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 18. Significant fauna mapping is provided in Figure 19. The mapping indicates that along the western side of Bruce Creek is potential Golden Sun Month habitat.

Figure 18. *Significant flora in the study area*

Figure 19. *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 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.

Recent updates to 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.

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, along with reducing potable water consumption, and urban cooling should the water be 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 most recent update of the draft Place Based Plan has been included in Figure 20. 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. 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 it 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.

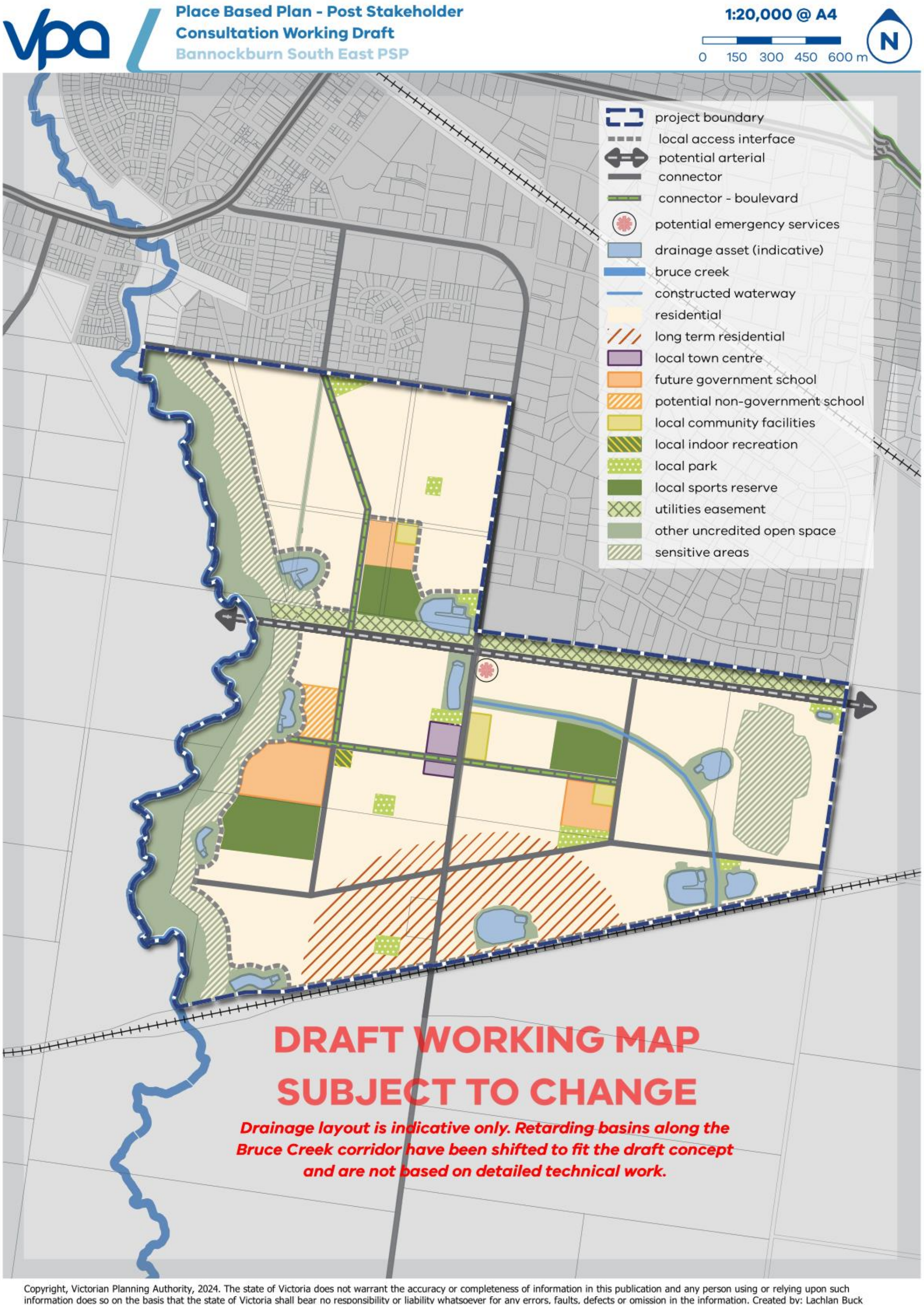


Figure 20. *Draft Bannockburn SE PSP Place Based Plan (June 2024)*

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.

<u>VicTrack and ARTC</u>

- 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.

5 Catchment analysis

Stormwater infrastructure locations are proposed based on existing site conditions, existing flood issues and the proposed urban layout. The site's 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.

It important to map these catchments to better understand the pollutant loads generated from these areas in a post-development scenario. However, for treatment modelling in a developed urban catchment, the road alignments will influence the drainage paths and ultimate catchments. Future road alignments, as per urban layout plans, have been applied in the modelling.

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 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).

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	0.75
Investigation area (Stony Creek)	Fully developed residential area in future	0.75

5.1 Sub-catchments

Based on the existing topography and provided urban layout, the precinct was divided into sub-catchments (Figure 21). 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 transmission easement in north.
- Sub-catchment 3: Bound by Charlton Rd to the north and Levy Rd to the east, falls south and southeast and then toward towards Bruce Creek.
- Sub-catchment 4: Bounded by proposed road and ridge line to the west, a ridge line to the east, the railway to the south. Falls south-easterly to existing culvert under the railway.
- Sub-catchment 5: Bound by Charlton Rd to the north and Levy Rd 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 proposed road in the west and south. Falls eastwards.
- Sub-catchment 7: Bounded by precinct boundary to the north, and proposed waterway to the south. Bounded by ridge line to 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 south-easterly.
- Sub-catchment 9: Bounded by existing/proposed channel to west, precinct boundary to the east, railway to the south. Falls south-westerly to existing culvert under railway.
- Sub-catchment 10: Bounded by existing/proposed channel to north and east, ridge line to the west, and railway to the south. Falls south-easterly to existing culvert under railway.

External catchment:

- Sub-catchment 111: Bounded by Burnside Road to the north and precinct boundary to the south. Bounded by Levy Road to the west and ridge line to the east. Falls south and outfalls into the precinct via a small retarding basin (details and function unknown) and culvert at Charlton Road.
- 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 a culvert at Charlton Road.
- Sub-catchment 333: Bounded by the precinct boundary 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.

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 hydrologic modelling.

Figure 21 shows the catchment layout and flow directions. Table 2 shows the 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.

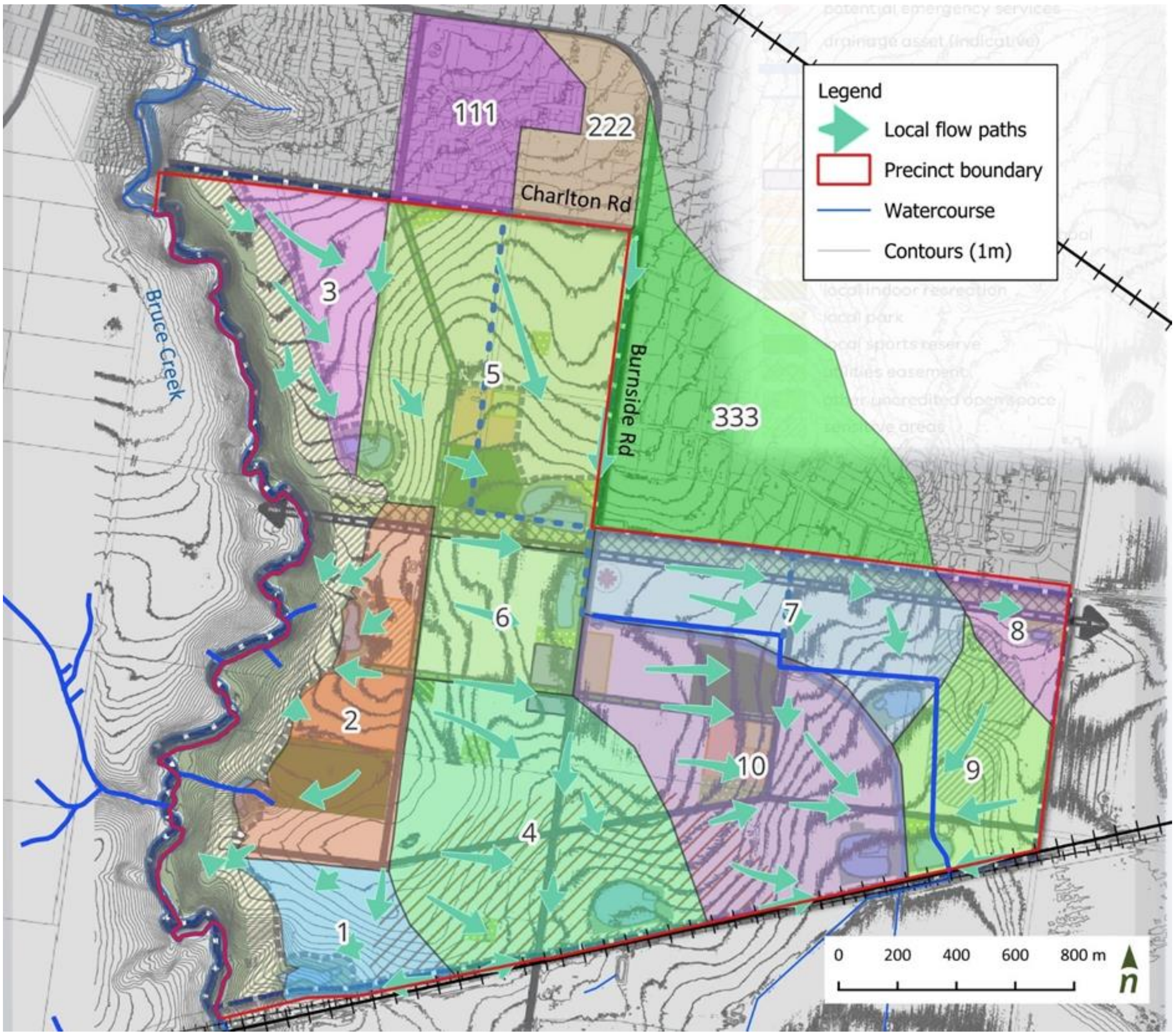


Figure 21. *Sub-catchment layout showing flow direction. The urban layout is shown as an underlay.*

Table 2. Developed conditions effective imperviousness area by sub-catchment

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Catchment 1	20.96	0.72
Catchment 2	43.01	0.55
Catchment 3	23.87	0.73
Catchment 4	78.96	0.72
Catchment 5	87.80	0.65
Catchment 6	26.45	0.70
Catchment 7	48.06	0.60
Catchment 8	12.09	0.54
Catchment 9	30.24	0.72
Catchment 10	74.84	0.65
Total developed area*	446.27	0.66
External catchments		
111	31.55	0.71
222	20.61	0.6
333	85.61	0.6

* Investigation area on Bruce Creek waterway corridor excluded and investigation area for Stony Rise has been considered fully developed.

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	73.7	14700.0	29.8	211.0	2930.0
Catchment 2	122	23200	47.5	345	5010
Catchment 3	84.8	16900	34.4	792.0	3370.0
Catchment 4	277	54600.0	113.0	792.0	11000.0
Catchment 5	284	56300.0	114.0	801.0	11500.0
Catchment 6	90.9	17800.0	36.6	259.0	3630.0
Catchment 7	146	27800.0	57.8	411.0	5950.0
Catchment 8	33.9	6350.0	13.4	96.0	1390.0
Catchment 9	106	21000.0	42.8	301.0	4230.0
Catchment 10	242	46600.0	98.5	693.0	9790.0
Total	1460.3	285250.0	587.8	4701.0	58800.0

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 discharge points for several of the catchments and assets. These are relatively small culverts, with shallow invert levels. Existing culvert capacities have been estimated during this phase to establish the potential discharge limitations, and how this compares with pre-development flow rate discharge requirements.

One approach is to install new, larger, and deeper culverts to enable outfall of the proposed retarding basins and convey pre-development peak flow rates. This would convey more flow downstream of the precinct than is currently conveyed. This approach will ultimately need to ensure no adverse impacts on downstream landholders.

The alternative is to increase the retarding basin sizes so to limit outfall to the existing culvert capacity flows.

The culverts constraints have been raised with Council and the VPA, and the limitations of culvert alterations and downstream (outside of the PSP) works confirmed by them. **As per Council and VPA direction, the strategy presented within this report is to retard back to existing culvert capacity flows.** The intention is that runoff from the precinct will continue to be conveyed through the existing culverts. No works are to occur within the railway culvert.

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.

The RORB models were built by delineating the major catchments into sub-areas based on topography and potential road alignments. This section details the peaks 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 22.

Key inputs into the RORB modelling include:

- The model used an initial loss/continuing loss model with an initial loss of 13mm and a continuing loss of 2.3mm/hr for existing conditions.
- 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 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.
- Catchment areas were further divided into sub-catchments to have at least four sub-catchments upstream of a printing node.

FI values were based on existing conditions and updated to proposed land uses (summarised for each catchment in Figure 22 and Table 5).

- Natural reaches were used in the current condition catchment.
- Reaches were updated to 'unlined channel or drain', in the developed scenario to represent overland flow in the 1%AEP.
- Ensemble simulations were used to determine the critical flows at each flood retention location and determine the appropriate flood storage.

Table 4. Adopted RORB parameters.

Parameter	Existing conditions	Developed conditions
Rainfall Intensity Frequency Duration (IFD)	Obtained from Bureau of Meteorology's IFD tool	Obtained from Bureau of Meteorology's IFD tool
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	13
Continuing loss (CL) (mm/hr)	2.3	2.3

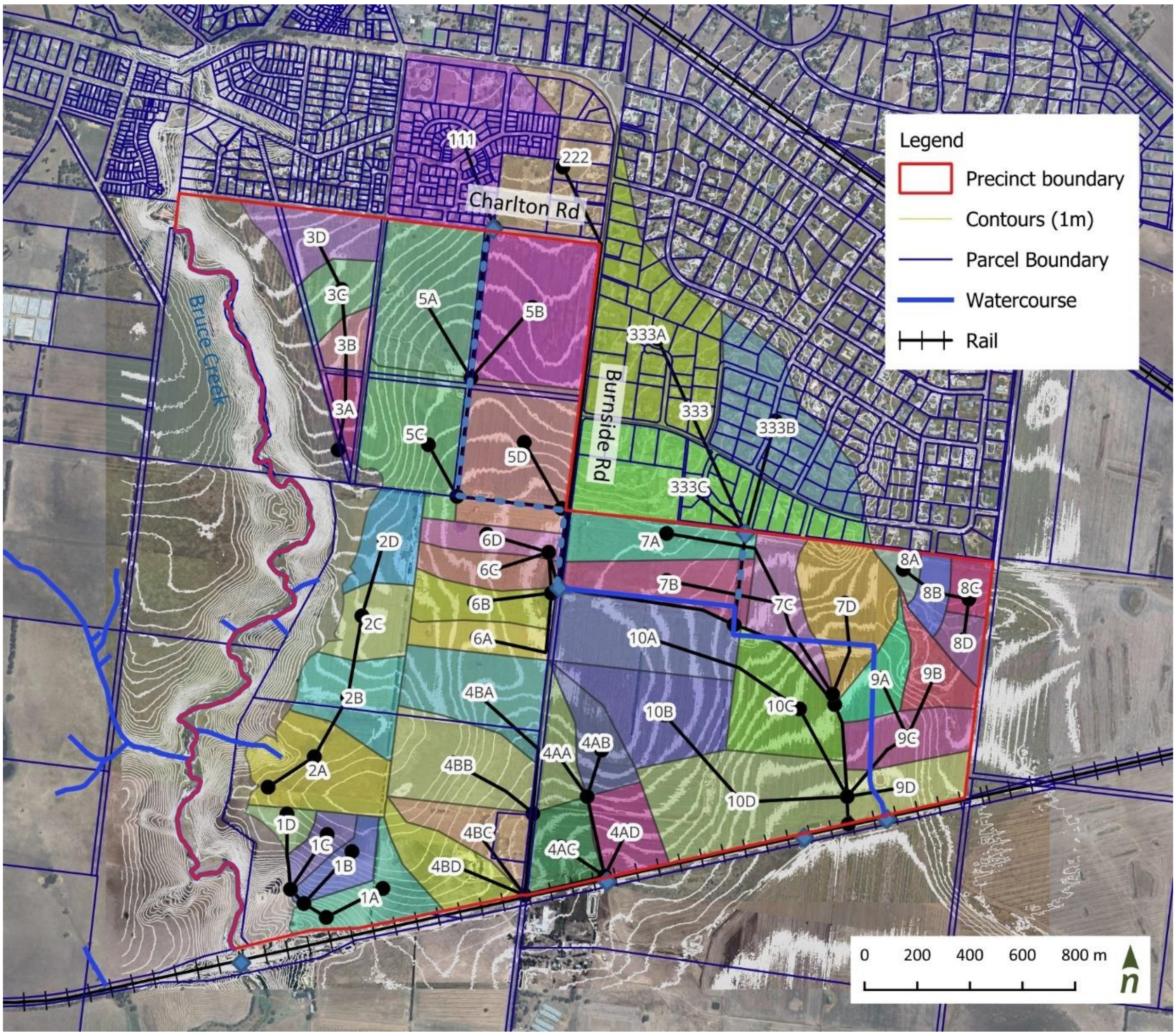


Figure 22. *Delineated subcatchments for hydrologic modelling – RORB layout*

Table 5. Developed conditions effective imperviousness area by sub-catchment

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Sub-catchment 1A	9.41	0.68
Sub-catchment 1B	5.10	0.75
Sub-catchment 1C	3.78	0.75
Sub-catchment 1D	2.67	0.75
Sub-catchment 2A	15.89	0.45
Sub-catchment 2B	11.28	0.52
Sub-catchment 2C	7.70	0.72
Sub-catchment 2D	8.14	0.63
Sub-catchment 3A	3.87	0.67
Sub-catchment 3B	4.04	0.73
Sub-catchment 3C	6.42	0.74
Sub-catchment 3D	9.53	0.75
Sub-catchment 4AA	6.43	0.75

Sub-Catchment	Area (ha)	Fraction Impervious (FI)
Sub-catchment 4AB	6.91	0.75
Sub-catchment 4AC	7.92	0.70
Sub-catchment 4AD	7.61	0.66
Sub-catchment 4BA	15.62	0.72
Sub-catchment 4BB	16.50	0.75
Sub-catchment 4BC	8.48	0.75
Sub-catchment 4BD	9.49	0.69
Sub-catchment 5A	22.09	0.71
Sub-catchment 5B	23.87	0.74
Sub-catchment 5C	18.77	0.63
Sub-catchment 5D	23.06	0.52
Sub-catchment 5E	6.21	0.74
Sub-catchment 6A	7.88	0.67
Sub-catchment 6B	6.79	0.71
Sub-catchment 6C	5.58	0.69
Sub-catchment 6D	6.21	0.74
Sub-catchment 7A	10.83	0.43
Sub-catchment 7B	12.33	0.72
Sub-catchment 7C	9.44	0.62
Sub-catchment 7D	15.47	0.62
Sub-catchment 8A	2.00	0.38
Sub-catchment 8B	3.42	0.58
Sub-catchment 8C	3.26	0.38
Sub-catchment 8D	3.41	0.75
Sub-catchment 9A	6.23	0.74
Sub-catchment 9B	6.32	0.75
Sub-catchment 9C	9.24	0.73
Sub-catchment 9D	8.45	0.66
Sub-catchment 10A	18.13	0.50
Sub-catchment 10B	16.19	0.68
Sub-catchment 10C	15.50	0.72
Sub-catchment 10D	25.03	0.71
Total developed area*	**446.27**	**0.66**

The model extends beyond the precinct to include upstream areas (Catchments 111, 222 and 333). Flows from the upstream areas will be managed outside the precinct, however they will need to be conveyed through or around the precinct. For catchment 111 and 222, it is assumed treated and retarded flows will be conveyed into the precinct via existing culverts. The flows will need to be conveyed via a pipe/road arrangement before they outfall into the proposed waterway. Flows from catchment 333 will be conveyed via the existing culvert near utility easement and outfall into the proposed waterway. Collectively, these flows will be conveyed to the railway culverts to the south of the precinct via the proposed constructed waterway. Details of any retardation within these developed catchments is unknown, and therefore no storages have been included within these catchments in the RORB model.

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 23 indicates the loss region of the subject catchment.

The median pre burst values were derived from the ARR Datahub and 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. ILb – Pre burst depth)

ILs = Storm Initial Loss

Table 6 below provides an overview of the proposed pre burst depth rations applied to the RORB model for the 1% AEP event.

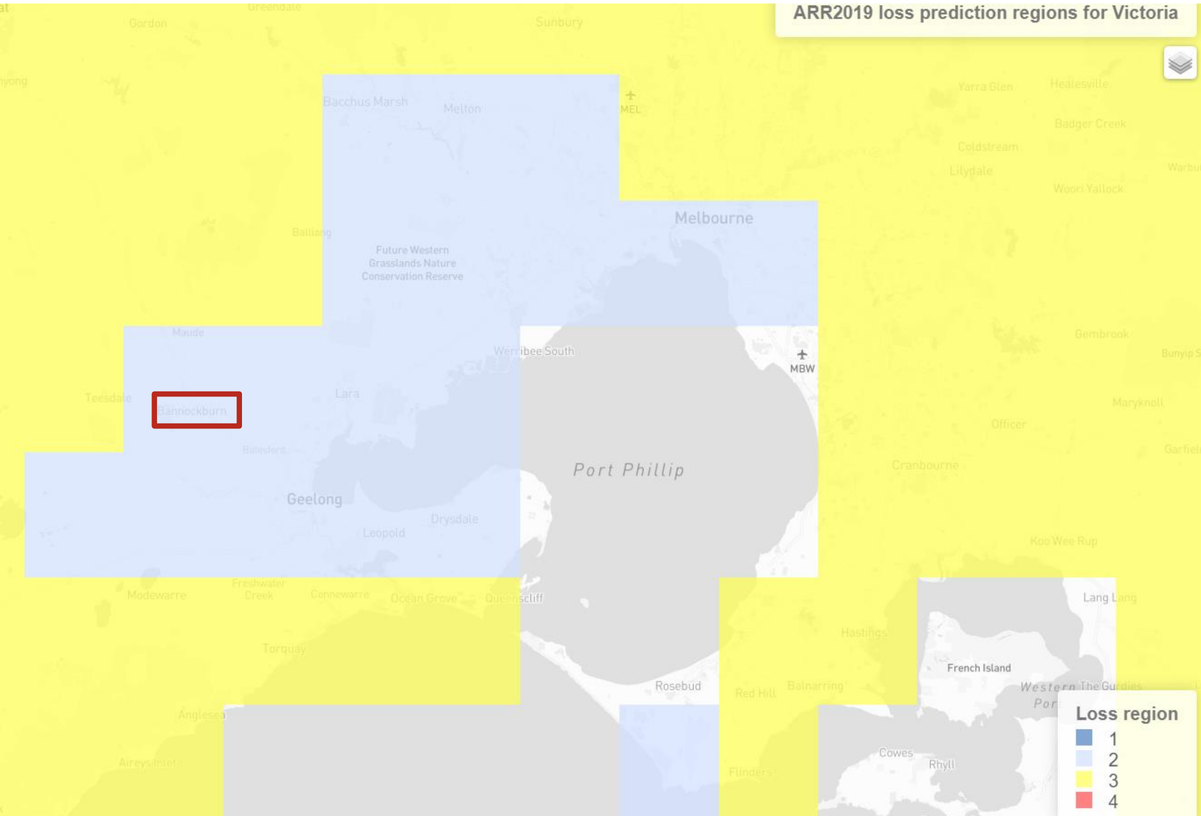


Figure 23. *ARR 2019 loss prediction regions for Victoria*

Table 6. Pre burst depth ratios

Duration	Storm Initial Loss (ILs)	Median Pre burst depth	Burst Initial Loss (ILb)	Pre burst ratio
1 hour	13	3.3	9.7	0.75
1.5 hour	13	2.1	10.9	0.84
2 hour	13	2.6	10.4	0.80
3 hour	13	1.8	11.2	0.86
4.5 hour	13	2.8	10.2	0.78
6 hour	13	2.8	10.2	0.78
9 hour	13	2.8	10.2	0.78
12 hour	13	1	12	0.92
18 hour	13	1.3	11.7	0.90
24 hour	13	0.2	12.8	0.98
30 hour	13	0	13	1.00
36 hour	13	0	13	1.00

6.4 Results

The RORB model was run for the pre 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. For ease of following this section and Section 7, the concept design overview has been provided in Figure 24.

Table 7. 1% AEP RORB modelling results

Asset	Catchment area	Current conditions	Critical duration	Developed conditions	Critical duration
	Ha	Peak flow m³/s	(Current)	Peak flow m³/s	(Developed)
WLRB 1	20.96	2.05	45min (tp26)	5.68	20min (tp26)
WLRB 2	43.01	2.69	45min (tp26)	5.96	20min (tp27)
WLRB 3	23.87	1.15	1.5hr (tp27)	3.03	25min (tp21)
WLRB 4	78.96	3.71	1.5hr (tp28)	10.90	25min (tp21)
WLRB 5	87.80	5.83	1.5hr (tp27)	12.82	25min (tp28)
WLRB 6	26.45	1.78	45min (tp26)	4.37	20min (tp28)
WLRB 7	48.06	2.52	1hr (tp29)	6.84	20min (tp29)
SBRB 8	12.09	1.35	20min (tp27)	2.46	20min (tp24)
WL(9&10)RB9	405.16	13.03	2hr (tp28)	18.97	45min (tp26)

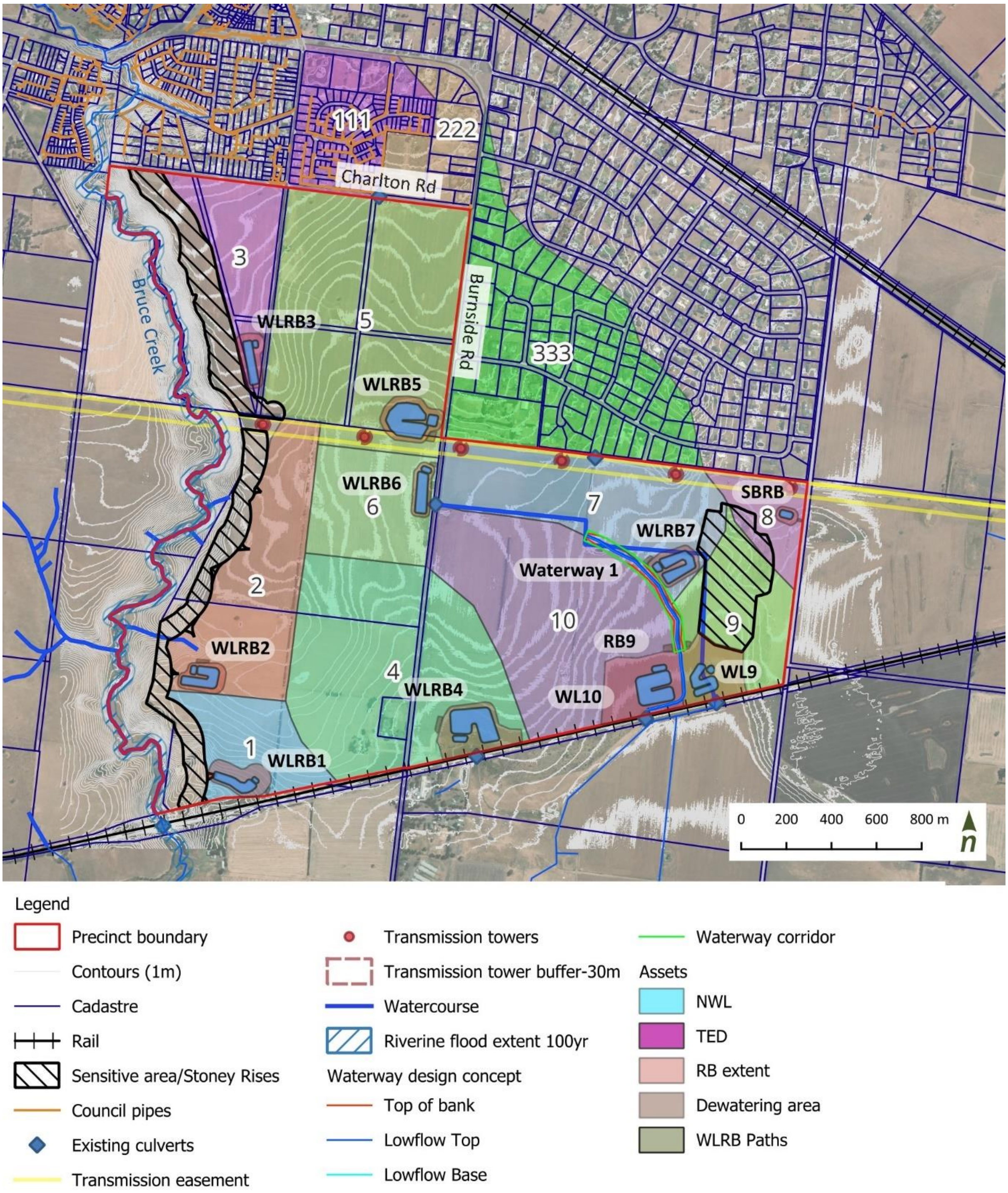


Figure 24. *Concept design overview showing proposed RB locations*

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 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 peak 1% AEP flows to pre development conditions- WLRB1, WLRB2, WLRB3, SBRB8.
2. Retarding peak 1% AEP flows to the railway culvert capacities (less than pre development conditions) – WLRB4 and WL9&10RB9.

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 functional design stage these will be refined further. 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. 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 WL9&10RB9) will require embankments.
- 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, WLRB3, and SBRB8.
- Storage outlet sizes were adjusted until the peak 1% AEP outflows from the RB were equal or less than the existing culvert capacity under the railway line for assets WLRB4 and WL9&10RB9. This requires additional drainage reserve and embankments to contain the flows within the drainage reserve, before conveying flows to the culverts. The culvert capacities were estimated using Culvert Master and are provided in Table 8 below.
- Peak storage volumes and flood heights within the basins were extracted from representative hydrographs runs.

Table 8. Railway culvert details and capacities

Location	Culvert details	Capacity
WL9&10RB9 outfall	900mm X 2 circular culverts 2100mm X 750mm box culvert	Combined capacity: 3.07 m^3/s
WLRB4 outfall	675mm X 2 circular culverts	0.80 m^3/s

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 is being driven by the treatment requirement, resulting in an overall larger storage than the hydrologic modelling indicates is required.

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 limited discharge requirements for WL(9&10)RB9, and the fact that this basin will ultimately receive retarded flows from WLRB5, WLRB6, WLRB7, and external catchments, the use of the storage has been maximised in WLRB5, WLRB6 and WLRB7. 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, whilst still meeting a minimum of 300mm freeboard. Again, this is possible due to the storage being driven by the treatment footprint and minimum 2m NWL depth creating large storages. This approach minimises the collective flow impact on the downstream WL(9&10)RB9.

Table 9. Retarding basin requirements

Asset	Existing Peak flow (m^3/s)	Peak RB outflow (1% AEP) (m^3/s)	Critical duration	Peak RB storage (m^3)	Peak RB flood depth (m)	Freeboard above peak flood depth (mm)*
WLRB1	2.05	1.13	1.5hr (tp26)	6,900	0.8	400
WLRB2	2.69	1.26	3hr (tp29)	10,200	0.83	670
WLRB3	1.15	0.77	1.5hr (tp27)	5,960	0.69	810
WLRB4	3.71	0.79^	24hr (tp26)	42,700	1.5	500
WLRB5	5.83	1.85	9hr (tp25)	45,100	1.65	350
WLRB6	1.78	0.38	24hr (tp26)	9,340	1.03	970
WLRB7	2.52	0.57	24hr (tp26)	17,300	1.26	740
WLRB8	1.35	1.17	45mins (tp26)	15,700	0.81	1190
WL(9&10)RB9	13.03	3.07^	36hr (tp22)	175,000	1.49	360

*To lowest point of RB top of bank.
^ Retarded back to meet existing culvert capacity

6.6 Other peak flow rates

Additional flow rates as established in the developed conditions RORB model are provided in Table 10. Flow locations are shown in Figure 25. 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).

- **Point B –** Flows from external catchment 333 are proposed to outfall into the constructed waterway, as is currently the case with the existing channel. The flow here 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 –** This is the location of the proposed outfall from WLRB7 into the waterway. The flow here 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 D –** Flows from catchments 5, 6, 7, 9,10 and external catchments 111, 222 and 333 will be conveyed through a set of existing culverts. When development occurs upstream, flows will be required to be retarded to the capacity of the existing culverts which is far less than the current peak 1% AEP flows.

- **Point E -** Flows from catchment 4 will be conveyed through an existing railway culvert. When development occurs upstream, flows will be required to be retarded to the capacity of the existing culverts which is far less than the current peak 1% AEP flows.

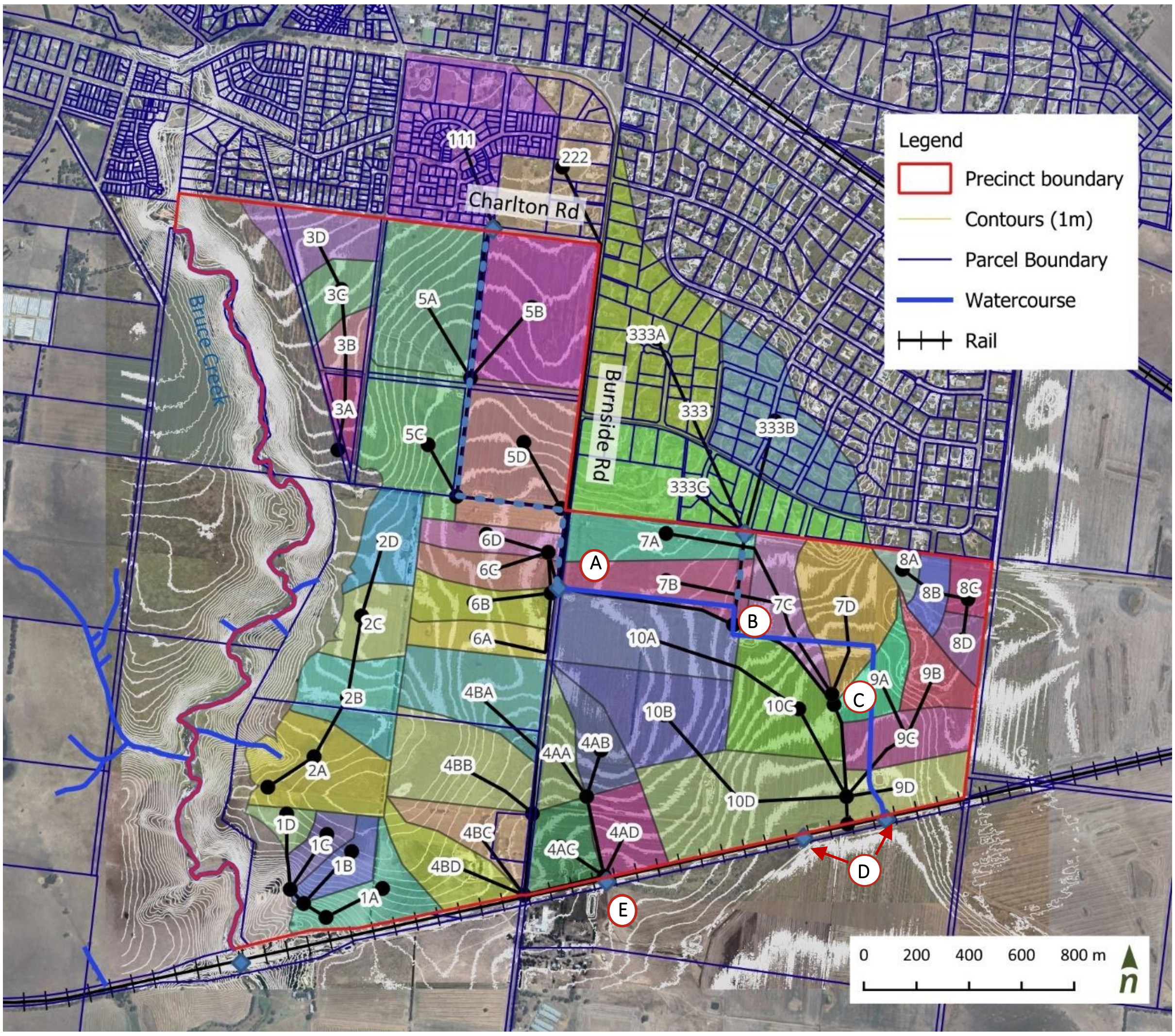


Figure 25. *Constructed waterway flow locations*

Table 10. Calculated flow rates for waterway design and other calculated flow rates

	Existing culvert details – size and capacity (m^3/s) (if applicable)*	Existing conditions peak 1% AEP flows (m^3/s)	Developed conditions peak 1% AEP flows (including RBs) (m^3/s)
Point A (To convey flow from WLRB 5, 6 and external catchment 111 and 222)	-	-	2.70
Point B (location of external catchment 333 outfall)	-	-	12.09
Point C (waterway flows at WLRB7 outfall)	-	-	9.74
Point D (WL9&10RB9 retarded flows in dev. scenario)	900mm X 2 circular culverts. 2100mm X 750mm box culvert. Combined capacity 3.07 m^3/s	13.03	3.07
Point E (WLRB4 retarded flows in dev. scenario)	675mm X 2 circular culverts. Capacity: 0.80 m^3/s	3.71	0.79

*Culvert capacity calculations undertaken in culvert master

The results show that at Point D and E, the peak 1% AEP flows under existing conditions are far higher than the current culvert capacities. This is evident in the flood mapping (Figure 11).

The results indicate that the flows are relatively small at Point A, indicating that a constructed waterway is not appropriate at this location. These flows could be conveyed via a pipe to the start of the constructed waterway. It is proposed that the waterway starts at location B, where the flow magnitude justifies a constructed waterway.

6.7 Climate change considerations

Climate change will be considered in the functional design phase of this project, once a preferred concept is agreed upon by stakeholders. The latest climate change considerations guidance (Chapter 6, Book 1), as provided in ARR: A Guide to Flood Estimate (version 4.2), will be adopted.

7 Wetland and sediment basin design

This section details the analysis, modelling, and results for the treatment assets. Ten wetlands (with associated sediment basins) and one 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.
- The sediment basins have been designed to capture 95% of coarse particles ≥ 125µm diameter entering the system. Basins should have sufficient storage for accumulated sediment.
- The wetlands have been sized based on achieving best practice treatment targets.
- 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.

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 this catchment is therefore required by the other assets. Given this is a relatively small catchment, it is unlikely to have any significant impact on the sizing of 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 26.

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.

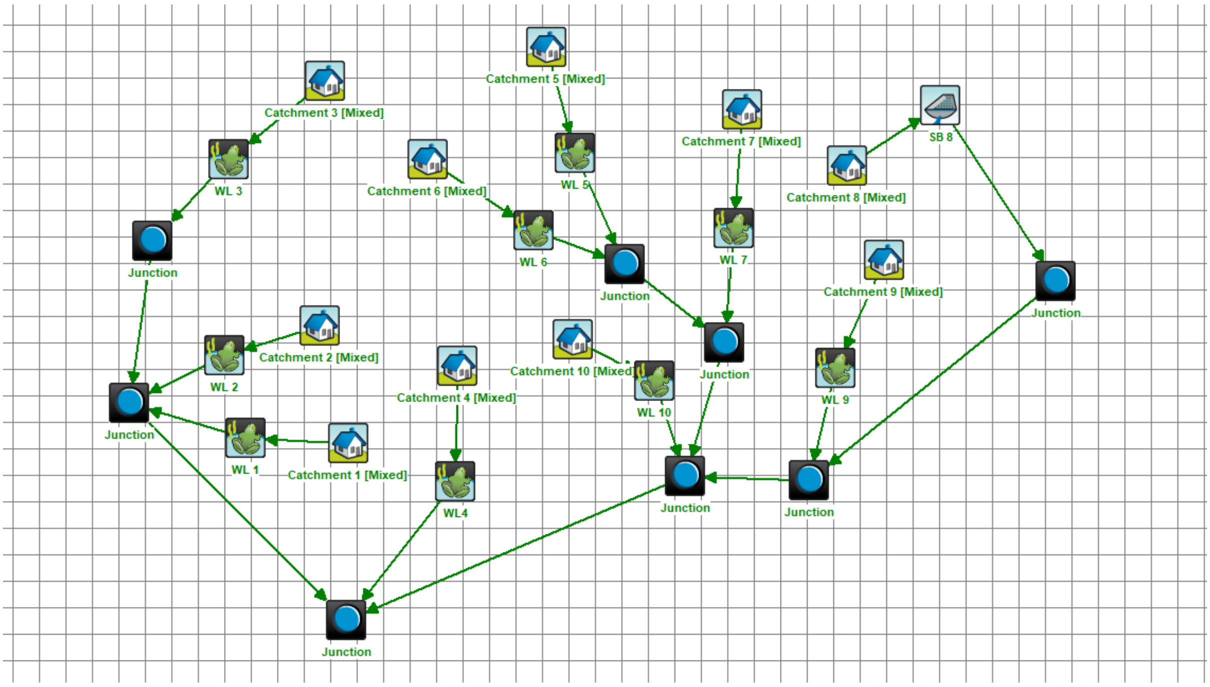


Figure 26. *MUSIC model layout*

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 11.

Table 11. 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)
WLRB1	20.96	7000	320	0.4m	0.35
WLRB2	43.01	9500	600	0.4m	0.35
WLRB3	23.87	7000	400	0.4m	0.35
WLRB4	78.96	21500	1080	0.4m	0.35
WLRB5	87.80	20000	1440	0.4m	0.35
WLRB6	26.45	8000	640	0.4m	0.35
WLRB7	48.06	11000	800	0.4m	0.35
SBRB8	12.09	1500	1200	0.8 (SB)	0.35
WL9	30.24	8500	600	0.4m	0.35
WL10	74.84	18000	1080	0.4m	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 12.

The MUSIC model results for each individual wetland and the sediment basin are provided in subsequent tables. Further refinement of the treatment modelling will occur in the functional design stage, when custom stage storage discharge is included. All wetlands will need to slightly exceed the targets in order to offset the sediment basin, which cannot meet TN targets. This should be done in an equitable manner.

Table 12. Overall PSP MUSIC modelling results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	1,460.0	1,320.0	9.8	
Total Suspended Solids (kg/yr)	285,000.0	55,500.0	80.5	229,500.0
Total Phosphorus (kg/yr)	588.0	176.0	70.0	412.0
Total Nitrogen (kg/yr)	4,150.0	2,070.0	50.3	2,080.0
Gross Pollutants (kg/yr)	58,800.0	-	100.0	58,800.0

Table 13. Wetland 1 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	73.7	64.7	12.2	
Total Suspended Solids (kg/yr)	14,700.0	2,700.0	81.6	12,000.0
Total Phosphorus (kg/yr)	29.8	8.2	72.4	21.6
Total Nitrogen (kg/yr)	211.0	95.8	54.7	115.2
Gross Pollutants (kg/yr)	2,930.0	-	100.0	2,930.0

Table 14. Wetland 2 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	122.0	110.0	9.9	
Total Suspended Solids (kg/yr)	23,200.0	4,640.0	80.0	18,560.0
Total Phosphorus (kg/yr)	47.5	14.3	69.9	33.2
Total Nitrogen (kg/yr)	345.0	166.0	51.9	179.0
Gross Pollutants (kg/yr)	5,010.0	-	100.0	5,010.0

Table 15. Wetland 3 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	84.8	75.9	10.6	
Total Suspended Solids (kg/yr)	16,900.0	3,450.0	79.6	13,450.0
Total Phosphorus (kg/yr)	34.4	10.3	70.1	24.1
Total Nitrogen (kg/yr)	244.0	117.0	52.0	127.0
Gross Pollutants (kg/yr)	3,370.0	-	100.0	3,370.0

Table 16. Wetland 4 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	277.0	250.0	9.9	
Total Suspended Solids (kg/yr)	54,600.0	10,400.0	81.0	44,200.0
Total Phosphorus (kg/yr)	113.0	33.4	70.5	79.6
Total Nitrogen (kg/yr)	792.0	385.0	51.5	407.0
Gross Pollutants (kg/yr)	11,000.0	-	100.0	11,000.0

Table 17. Wetland 5 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	284.0	259.0	9.0	
Total Suspended Solids (kg/yr)	56,300.0	10,800.0	80.8	45,500.0
Total Phosphorus (kg/yr)	114.0	34.9	69.4	79.1
Total Nitrogen (kg/yr)	801.0	399.0	50.1	402.0
Gross Pollutants (kg/yr)	11,500.0	-	100.0	11,500.0

Table 18. Wetland 6 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	90.9	80.6	11.3	
Total Suspended Solids (kg/yr)	17,800.0	3,110.0	82.5	14,690.0
Total Phosphorus (kg/yr)	36.6	10.1	72.5	26.5
Total Nitrogen (kg/yr)	259.0	120.0	53.9	139.0
Gross Pollutants (kg/yr)	3,630.0	-	100.0	3,630.0

Table 19. Wetland 7 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	146.0	132.0	9.6	
Total Suspended Solids (kg/yr)	27,800.0	5,520.0	80.2	22,280.0
Total Phosphorus (kg/yr)	57.8	17.4	69.9	40.4
Total Nitrogen (kg/yr)	411.0	202.0	51.0	209.0
Gross Pollutants (kg/yr)	5,950.0	-	100.0	5,950.0

Table 20. Sediment basin 8 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	33.9	32.7	3.5	
Total Suspended Solids (kg/yr)	6,350.0	1,260.0	80.2	5,090.0
Total Phosphorus (kg/yr)	13.4	5.4	59.7	8.0
Total Nitrogen (kg/yr)	96.0	95.7	0.4	0.3
Gross Pollutants (kg/yr)	1,390.0	-	100.0	1,390.0

Table 21. Wetland 9 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	106.0	95.4	10.2	
Total Suspended Solids (kg/yr)	21,000.0	4,050.0	80.7	16,950.0
Total Phosphorus (kg/yr)	42.8	12.7	70.3	30.1
Total Nitrogen (kg/yr)	301.0	145.0	51.7	156.0
Gross Pollutants (kg/yr)	4,230.0	-	100.0	4,230.0

Table 22. Wetland 10 treatment results

	Source	Residual load	% reduction	kg/yr reduction
Flow (ML/yr)	242.0	219.0	9.5	
Total Suspended Solids (kg/yr)	46,600.0	9,550.0	79.5	37,050.0
Total Phosphorus (kg/yr)	98.5	29.5	70.1	69.0
Total Nitrogen (kg/yr)	693.0	340.0	50.9	353.0
Gross Pollutants (kg/yr)	9,790.0	-	100.0	9,790.0

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 three-month ARI 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 velocity calculations (Table 24) and sediment capture efficiency calculations (Table 23) were performed iteratively to ensure all criteria was met and the sediment basins were sized appropriately. The flows used in these calculations have been obtained from rational method calculations.

Table 23. Sediment basin sizing

	Parameter	WLRB 1	WLRB 2	WLRB 3	WLRB 4	WLRB 5	WLRB 6	WLRB 7	SBRB 8	WLRB 9	WLRB 10
Conditions	Contributing Catchment (ha)	20.96	43.01	23.87	78.96	87.80	26.45	48.06	12.09	30.24	74.84
	Area of Basin (m^2)	400	750	500	1350	1800	800	1000	1500	600	1350
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11	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	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	1.5
	Extended detention depth, de	0.35	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	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	1	1	1	1	1	1	1	1	1	1
	Design Discharge (m^3/s) [4EY]	0.32	0.50	0.36	1.05	1.21	0.43	0.58	0.15	0.49	0.93
	Capture Efficiency	96%	97%	96%	96%	97%	98%	97%	100%	96%	97%
	Check (>95%)	Ok	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	1.6
	Desired clean-out frequency, Fr	5	5	5	5	5	5	5	5	5	5
	Storage volume required, St	161	333	184	607	679	208	374	96	232	579
	Available sediment storage volume	200	375	250	675	900	400	500	750	300	675
	Check (Available storage > required storage)	Ok	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	0.5
	Area required for dewatering (m^2)	322	666	368	1215	1359	417	747	193	464	1157

Table 24. Sediment basin velocity calculations

	Parameter	WLRB 1	WLRB 2	WLRB 3	WLRB 4	WLRB 5	WLRB 6	WLRB 7	SBRB 8	WLRB 9	WLRB 10
Flow conditions	4EY flow (m^3/s)	0.32	0.50	0.36	1.05	1.21	0.43	0.58	0.15	0.49	0.93
	20% AEP flow (m^3/s)	1.62	2.52	1.81	5.26	6.03	2.16	2.91	0.73	2.45	4.65
	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	0.35
Sediment basin	Basin area (m^2)	400	750	500	1350	1800	800	1000	1500	600	1350
	Width at NWL (m)	16	23	18	28	33	16	28	30	16	24.5
	SB top width (m)	20.2	27.2	22.2	32.2	37.2	20.2	32.2	34.2	20.2	28.7
	Average width (m)	18.1	25.1	20.1	30.1	35.1	18.1	30.1	32.1	18.1	26.6
	Flow Area (m^2)	6.3	8.8	7.0	10.5	12.3	6.3	10.5	11.2	6.3	9.3
	Flow Velocity (m/s) (20% AEP)	0.26	0.29	0.26	0.50	0.49	0.34	0.28	0.06	0.39	0.49
	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	< 0.5 OK
	Length to width ratio*	1.56	1.42	1.54	1.72	1.65	3.13	1.28	1.67	2.34	2.25

*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 25.

Table 25. Velocity calculations

	Parameter	WL1	WL2	WL3	WL4	WL5	WL6	WL7	WL9	WL10
NWL area	NWL area (m^2)	7000	9500	7000	21500	20000	8000	11000	8500	18000
Flow conditions	4EY (3 month flow) (m^3/s) (rational calc)	0.32	0.50	0.36	1.05	1.21	0.43	0.58	0.49	0.93
	Flow depth (m)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Wetland	Width at NWL (m)	35	40	41	73	67	44	35	28	60
	Width at top (m)	39.2	44.2	45.2	77.2	71.2	48.2	39.2	32.2	64.2
	Average width (m)	37	42	43	75	69	46	37	30	62
	Flow Area (m^2)	13	15	15	26	24	16	13	11	22
	Flow Velocity (m/s) (4EY)	0.025	0.034	0.024	0.040	0.050	0.03	0.04	0.05	0.04
	Check	< 0.05 OK	< 0.05 OK	< 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	4.16	4.03	4.46	4.13	8.98	10.34	5.00

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 AEP (3 month ARI) 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).

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

8.1 Constructed waterways

A constructed waterway (Waterway 1) is proposed downstream of Burnside Road, 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.

8.2 Design objectives

The design objectives for waterway design are as follows:

- Safely convey large flood events 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.
- 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 will need to end at the railway corridor edge
- Minimise excavation to reduce costs and land take.

8.4 Waterway design

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 the 4EY flow. All designs of the waterways are in accordance with Melbourne Water's Constructed Waterway Design Manual (2019).

The constructed waterway is proposed to begin where the flows from external catchment 333 currently outfall into the existing channel. No constructed waterway is proposed upstream of this due to the small flows, as discussed in Section 6.6. The flows upstream of this point are proposed to be piped into the start of the constructed waterway. The culvert under Burnside Road and the pipe details are provided in Section 8.6.

The constructed waterway will be aligned to go through RB9. It is proposed that the flow channel will continue through the base of the RB, before outfalling into the railway culvert (remaining outside of the railway reserve). There will be no high flow channel within the basin. In larger events, when the culvert capacity and low flow channel capacity is exceeded, the basin 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, including storage design (Table 26). 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 largest flow is at the start of the waterway.

Table 26. Calculated flow rates for waterway design

Storm event	Flow rate (m^3/s)
1% AEP	12.09
4EY	1.09

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. 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 WLRB6, WLRB7, WL9 and WL10. This includes the ability to gravity drain the wetlands within the RBs. 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.

Table 27 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 27. 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)
Waterway	83.8 m AHD	77.1	1088	200

* Driven by downstream invert of proposed pipe conveying flows from Catchment 5,6, 111,222, as well as ability to outfall external catchment 333.

**Driven by need to connect into existing railway culvert invert level.

Cross-section geometry

The cross-sectional geometry should be designed to accommodate the 4EY to 1EY flows in the low flow channel and the 1% AEP flows in the full compound channel. These flows are determined using RORB modelling as discussed in the hydrologic modelling section. The minimum proposed channel cross section of the waterway is provided in Table 28. Waterway has been designed with a minimum of 300mm freeboard above the 1% AEP peak flow levels. The waterway bed depth will also be dictated by the need to enable stormwater outfall. This may 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.

Table 28. Waterway cross-section geometry and design parameters.

Parameter	Low flow channel	High flow channel
Base width (m)*	2.0	6.0 m
Channel depth minimum (m)	0.5 m	0.9 m
Side slope	1 in 3	1 in 5
Top width (m)	5.0 m	18.0 m
Manning's n (assumed)**	0.05 (vegetated)	0.05 (vegetated)
Capacity	1.10 m^3/s	13.2 m^3/s
Hydraulic width (m)	-	15 m
Waterway corridor	-	50. m^

*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

8.5 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

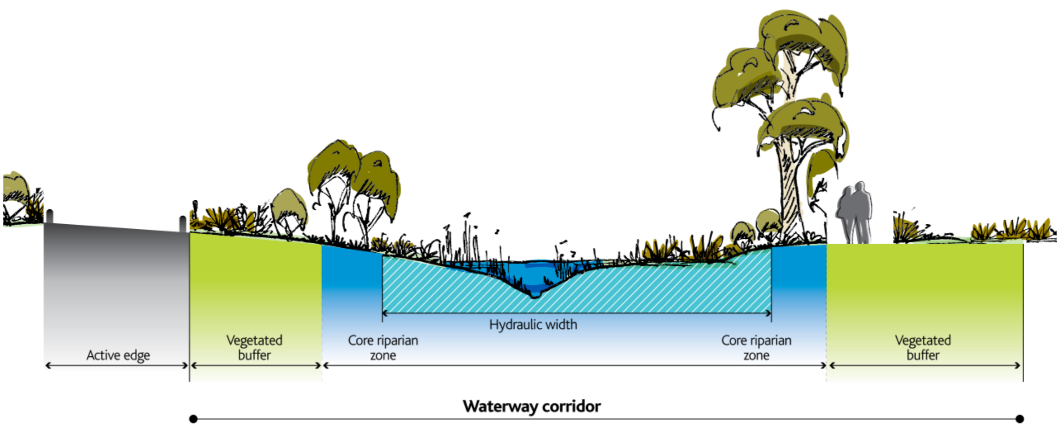


Figure 27. *Waterway corridor (Reference: Melbourne Water's Waterway Corridor Guidelines).*

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 28. The waterway corridor width, as per the established hydraulic widths, is 45m. However, due to the required waterway depths to enable outfall from the basins, the overall waterway top width at times exceeds 40m. Therefore, a 50m wide waterway corridor may be more appropriate. This should be confirmed with the relevant authorities. A 50m corridor has been shown in the concept maps.

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

8.6 Culvert and pipe design

Proposed culverts

One new culvert is proposed to enable outfall from the proposed drainage assets. Other culverts will be required where proposed roads cross the proposed pipe and constructed waterway – these have not been considered as part of the drainage strategy assessment.

The proposed culvert arrangement, based on preliminary calculations, is provided in Table 29.

Table 29. Proposed new culvert under Burnside Road

	Upstream invert	Downstream invert	Length	Required capacity	Size	Culvert capacity
Under Burnside Rd (flows from WLRB5, WLRB6, 111 and 222)	86.2	86.1*	36m	2.70 m^3/s	1 x 1500mm W x 1200mm H	3.01 m^3/s

*Start of new proposed pipe

Proposed pipe

A new pipe is proposed to enable retarded flows from WLRB5, WLRB6 and external catchments 111 and 222 to the start of constructed waterway, where external catchment 333 flows outfall.

The proposed pipe arrangement, based on preliminary calculations, is provided in Table 30.

Table 30. Proposed new pipe

	Upstream invert	Downstream invert	Length	Required capacity	Size	Pipe capacity
From culvert under Burnside Rd to start constructed waterway	86.1	83.8*	684	2.70 m^3/s	1350 mm	3.05 m^3/s

*Into the start of the new constructed waterway

The proposed culvert and pipe have been included in the cost estimate, under the waterway design.

9 Concept designs

The concept design development was an iterative process including:

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

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 the specific arrangements and infrastructure have not yet been finalised, they 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 takes).

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 looking at 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), 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.

An overview of the concept plan for the PSP drainage assets is provided in Figure 29.

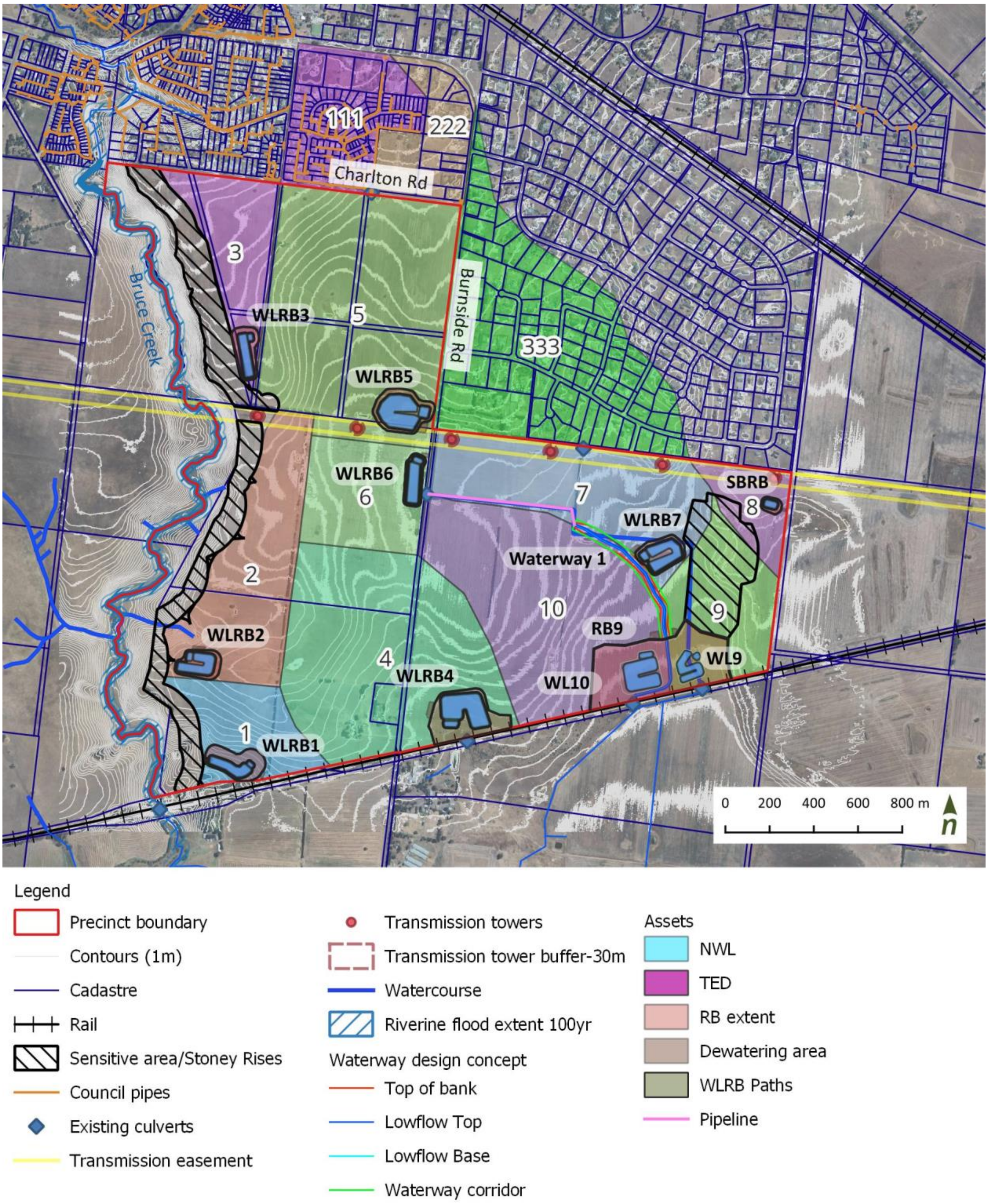


Figure 29. *Concept plan overview for Bannockburn SE PSP stormwater drainage design*

9.2 Asset details

The following pages outline the key parameters and conceptual layouts for each catchment and asset. These will be refined during subsequent design stages. The concept designs with the draft Place Based Plan in the background are provided in Appendix C.

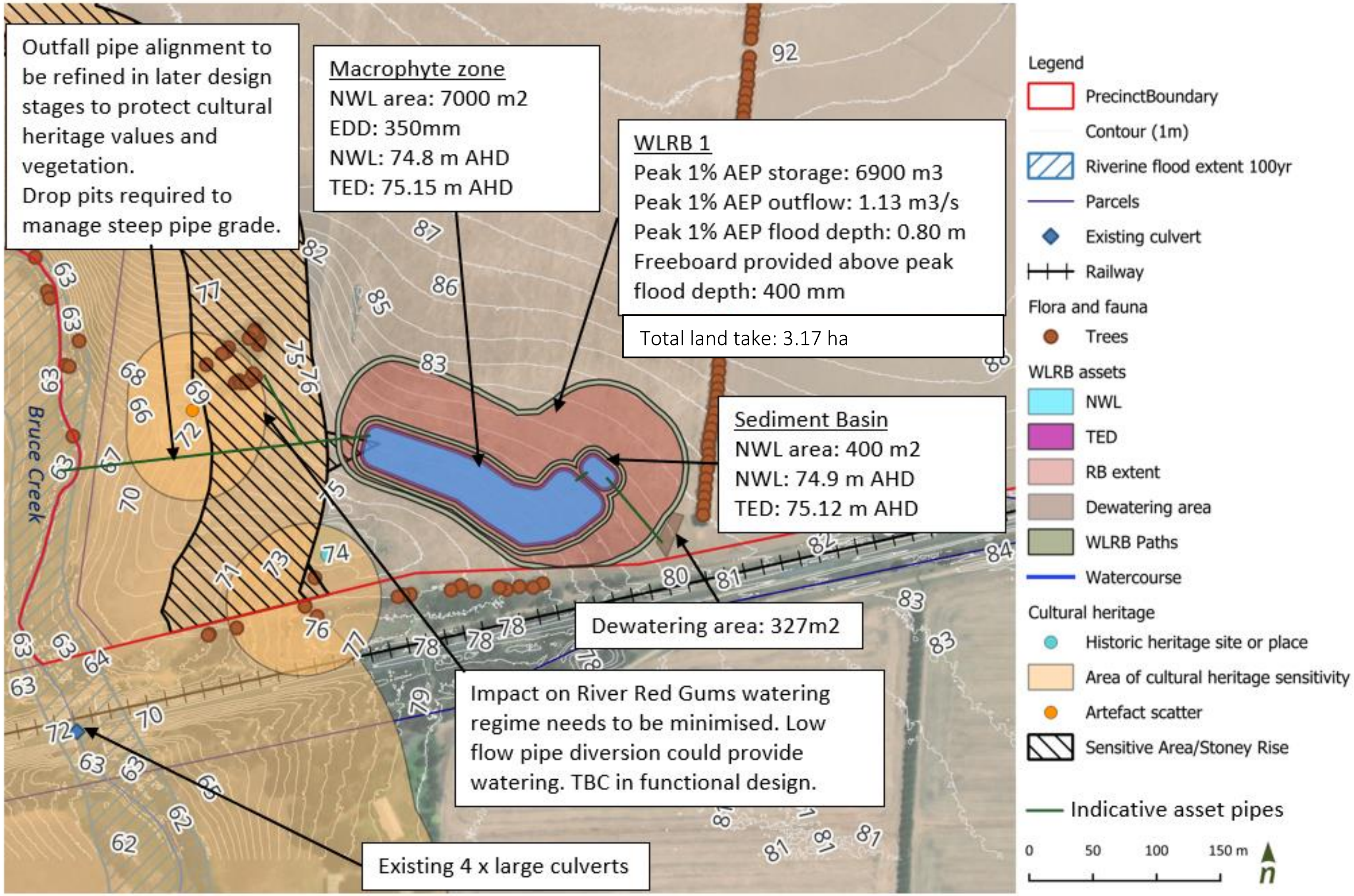


Figure 30. *WLRB 1 Concept Design*

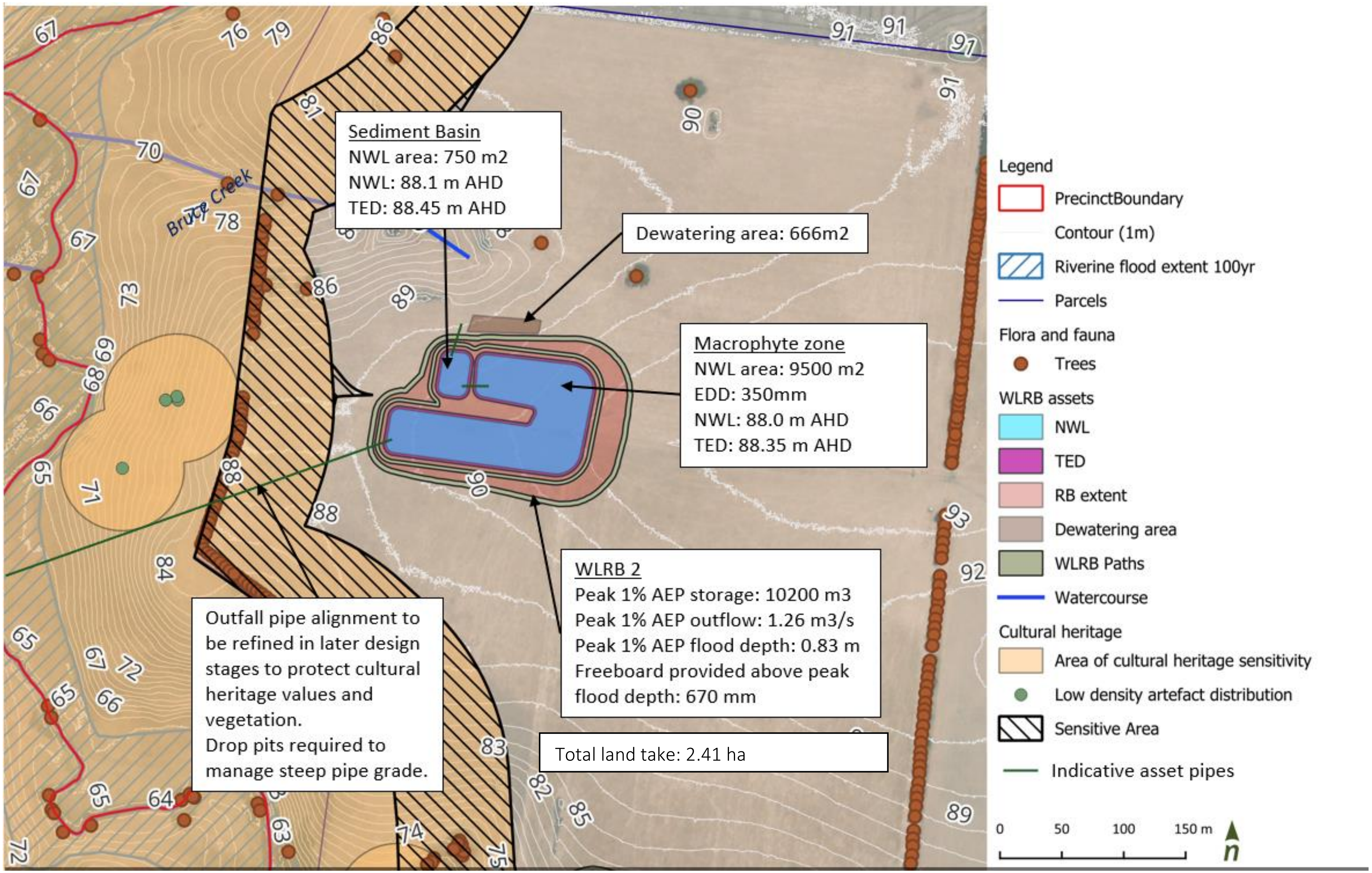


Figure 31. *WLRB 2 Concept Design*

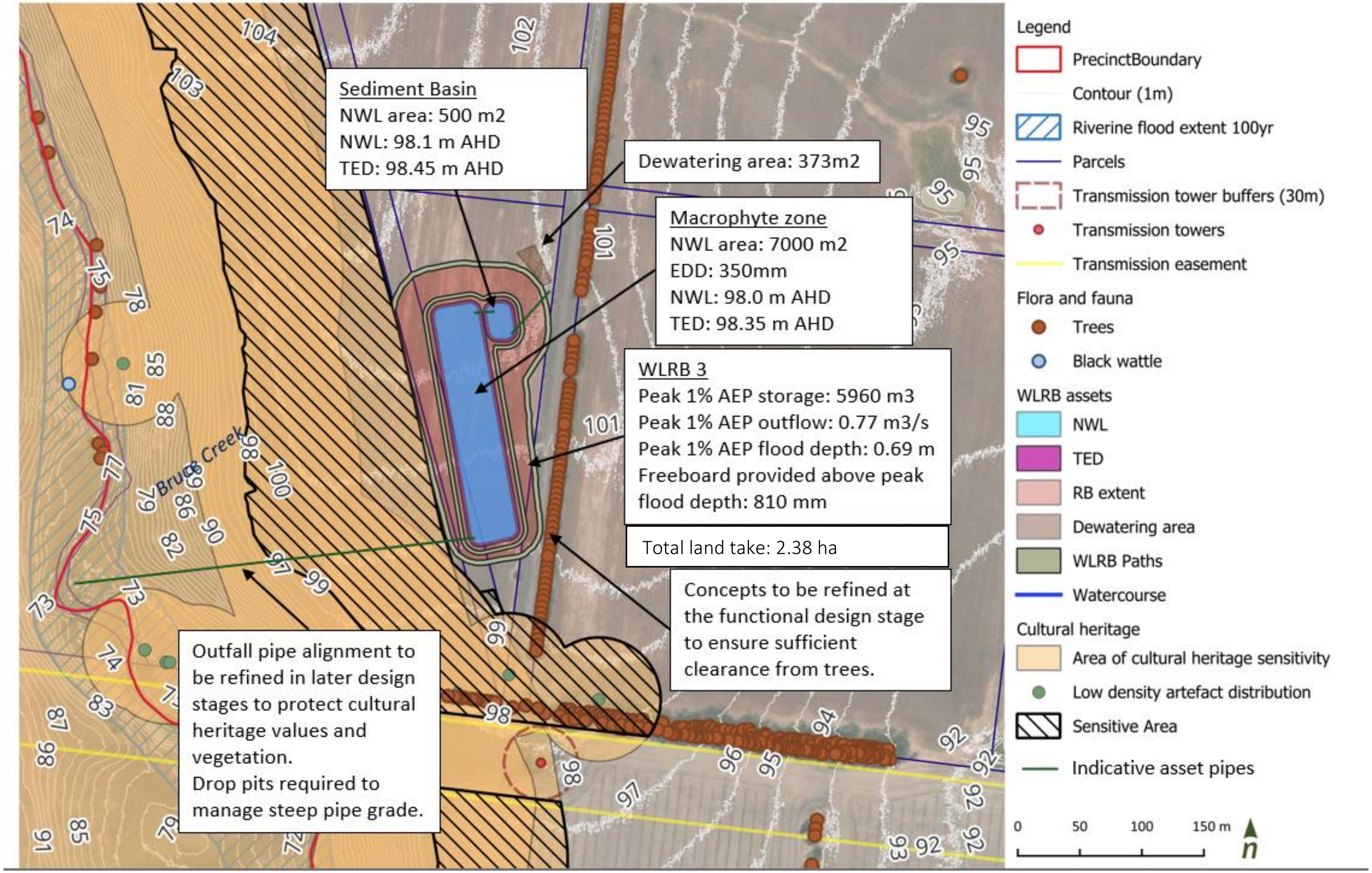


Figure 32. *WLRB 3 Concept Design*

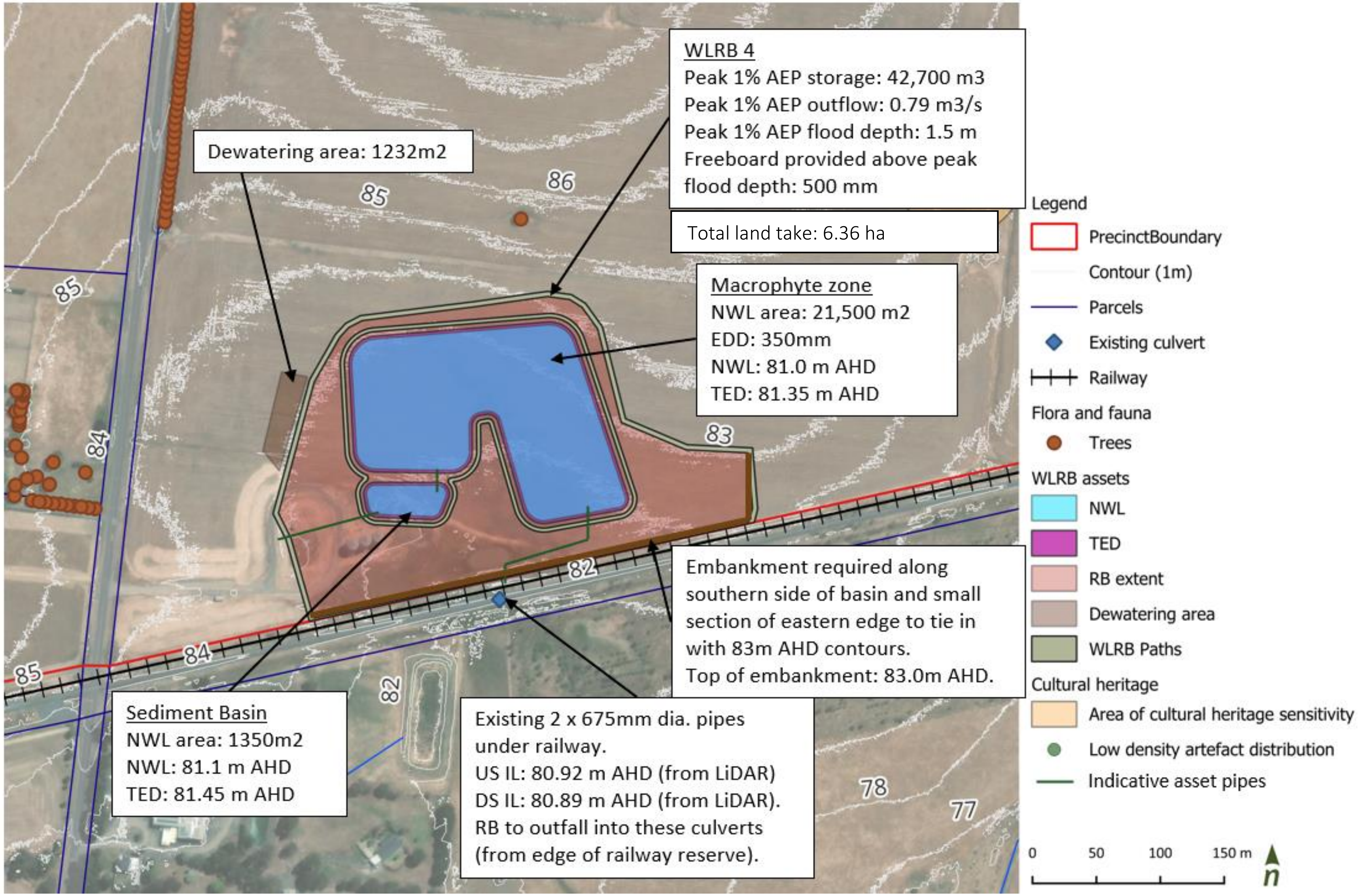


Figure 33. *WLRB 4 Concept Design*

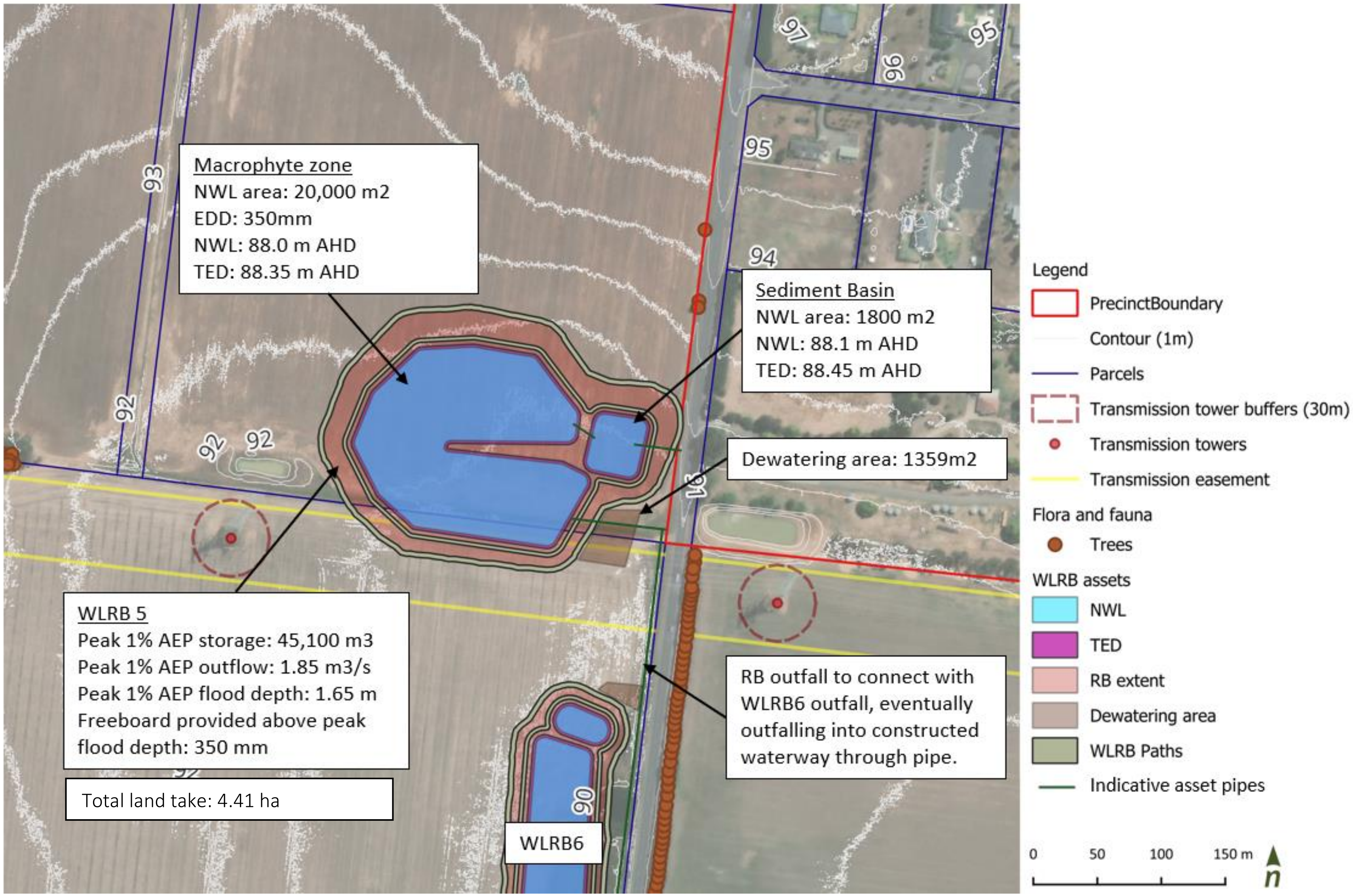


Figure 34. *WLRB 5 Concept Design*

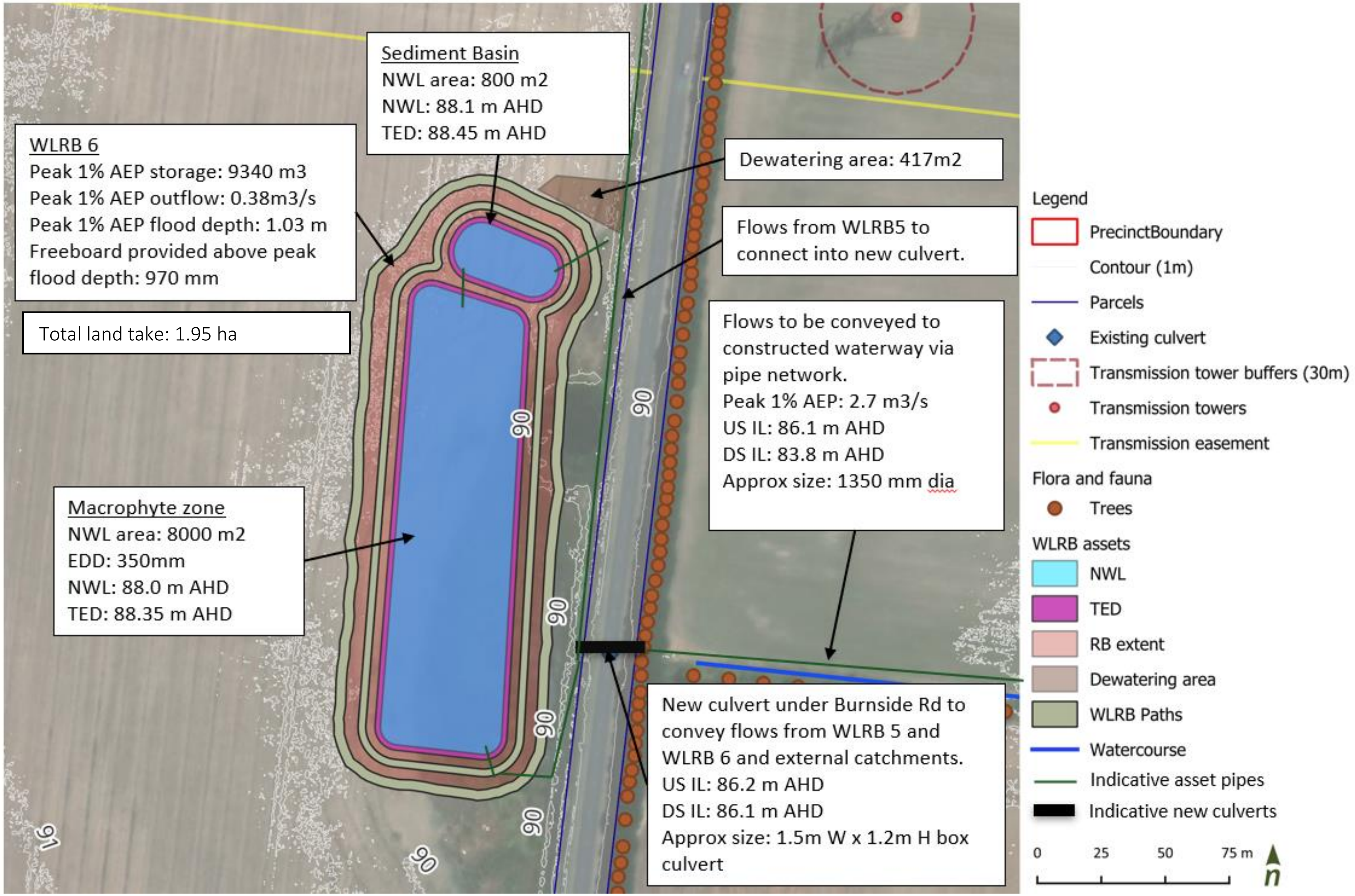


Figure 35. *WLRB 6 Concept Design*

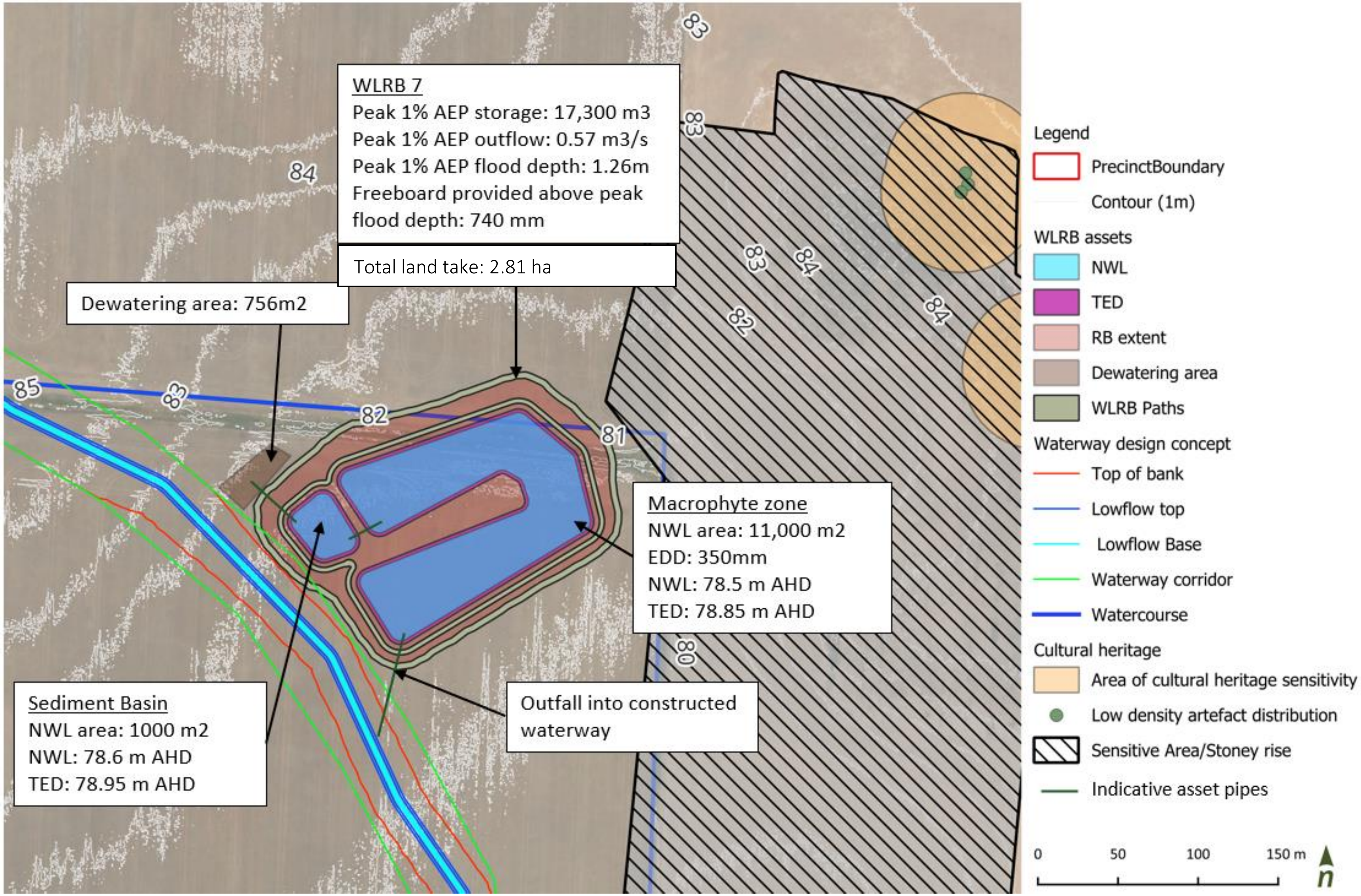


Figure 36. *WLRB 7 Concept Design*

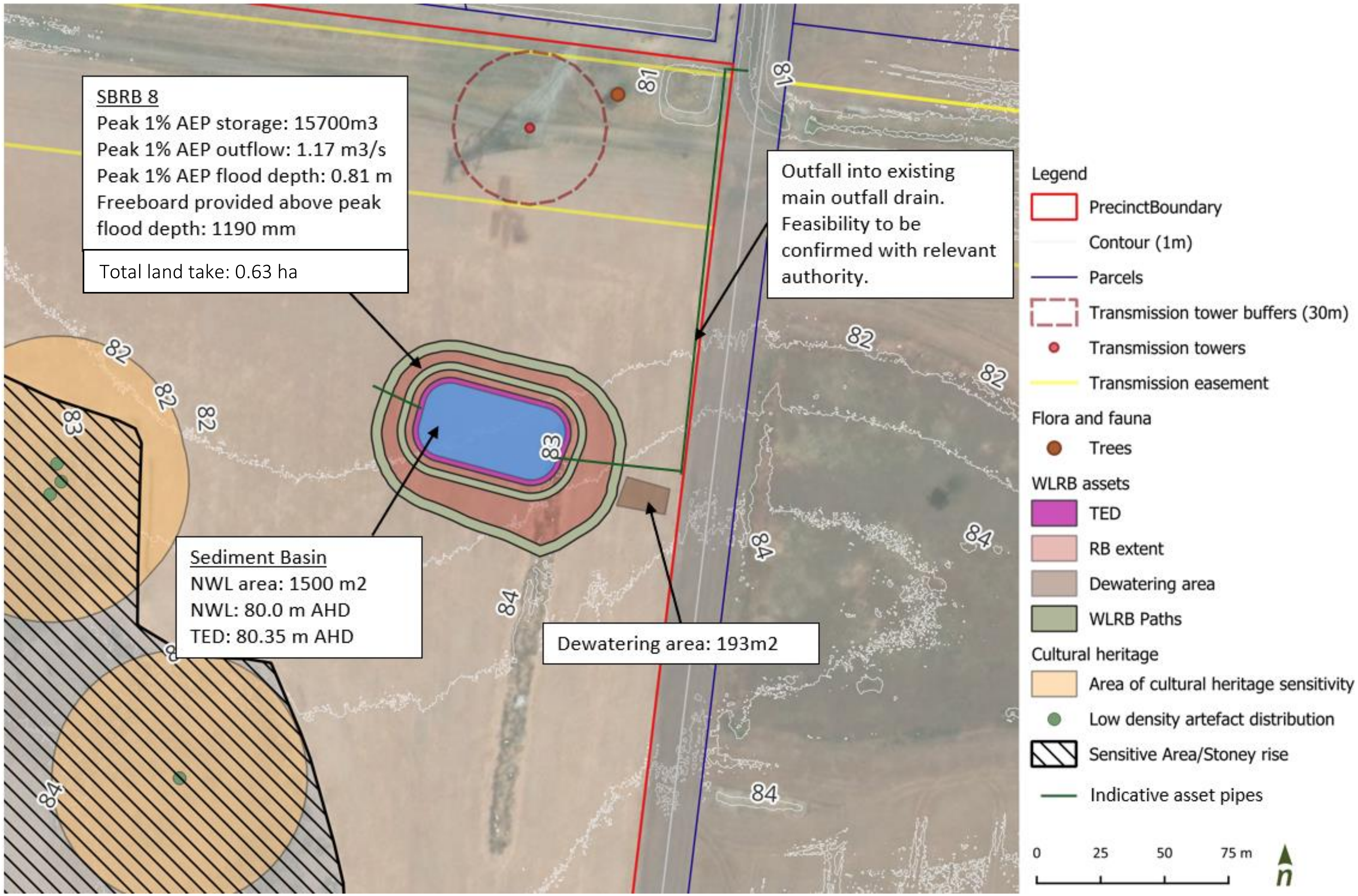


Figure 37. *WLRB 8 Concept Design*

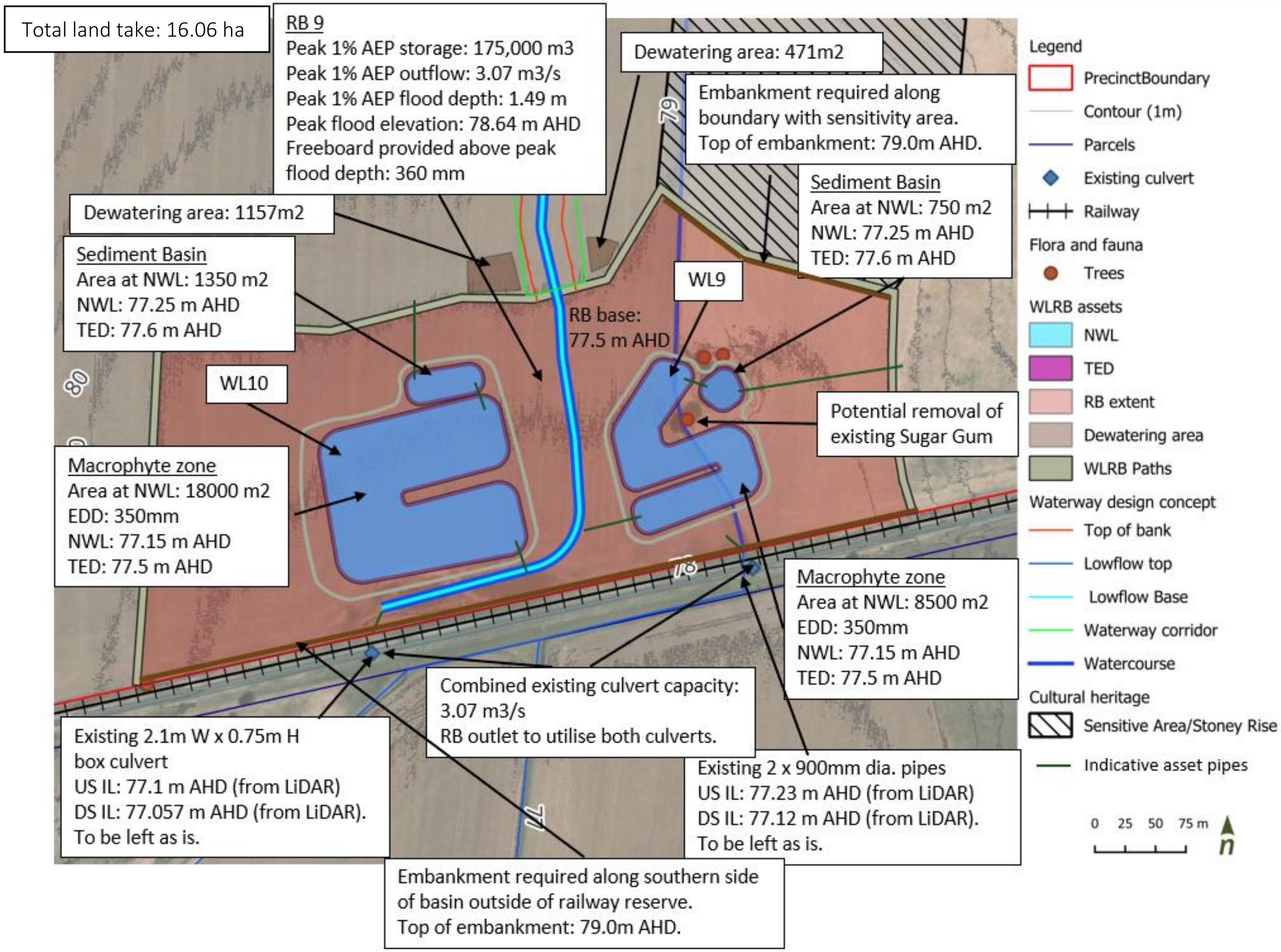


Figure 38. *WL 9, WL 10 and RB 9 Concept Design*

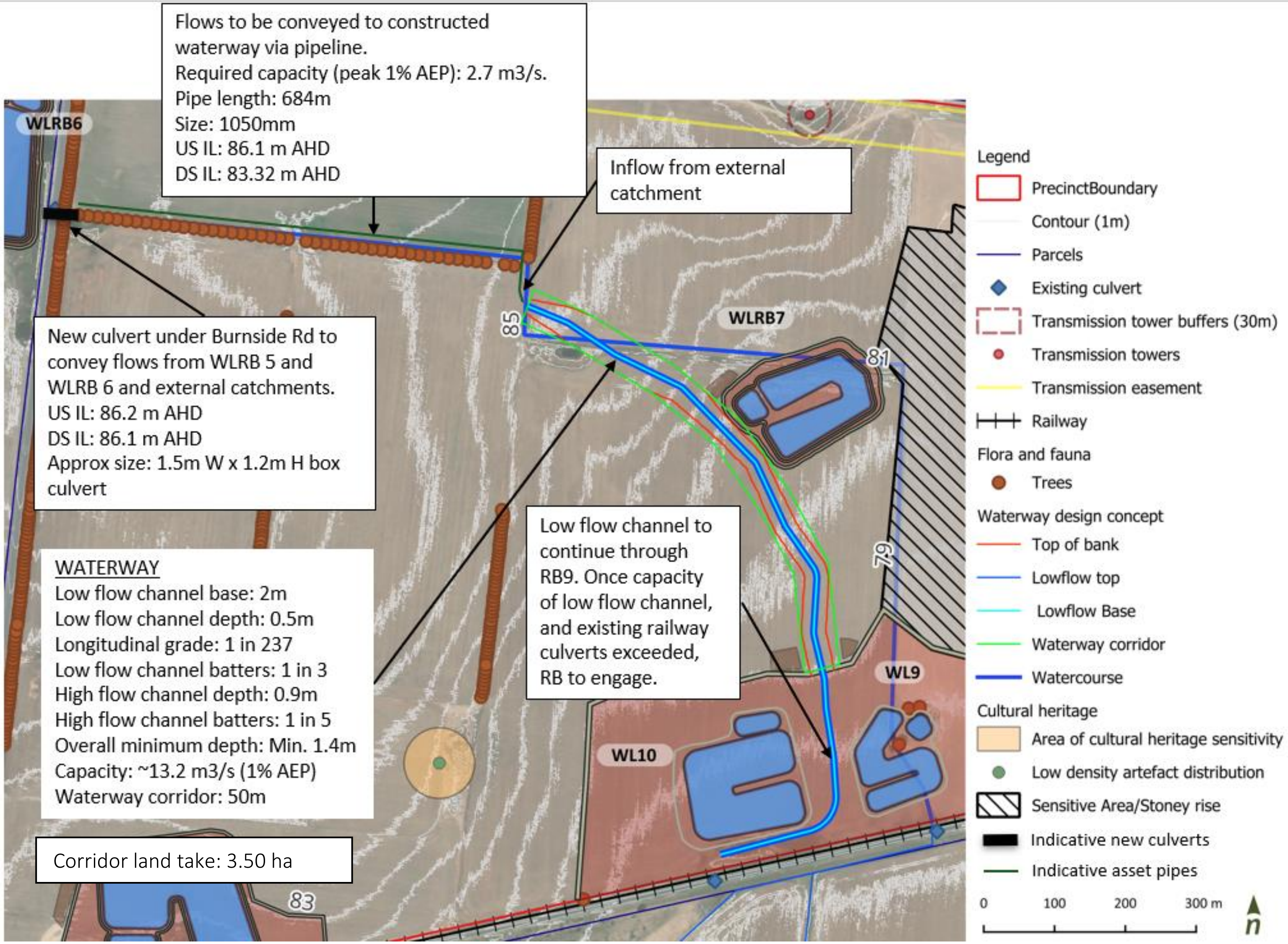


Figure 39. *Waterway concept design*

10 Cost estimate

Cost estimate summaries for each asset are provided in Table 31 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, 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. This 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 in the Waterway 1 costing.

Table 31. Cost estimate summary for the proposed works

Item	Description	WLRB1	WLRB2	WLRB3	WLRB4	WLRB5	WLRB6	WLRB7	SBRB8	WL9&10/RB9	Waterway 1	ALL ASSETS
1	SITEWORKS AND EARTHWORKS	$3,007,679.2	$1,832,986.0	$1,977,211.2	$2,086,571.3	$3,927,989.3	$1,029,450.2	$1,902,786.4	$ 78,210.5	$4,111,496.2	$2,006,685.6	$21,961,065.9
2	DRAINAGE	$ 468,699.0	$ 627,085.2	$ 547,496.2	$ 514,765.5	$ 681,947.9	$ 468,239.5	$ 478,415.8	$ 201,338.3	$ 730,057.8	$ 792,721.1	$ 5,510,766.3
3	ROCK WORKS	$ 39,100.0	$ 39,100.0	$ 39,100.0	$ 71,100.0	$ 16,600.0	$ 16,600.0	$ 16,600.0	$ 5,100.0	$ 86,700.0	$ 109,080.0	$ 439,080.0
4	CLAY LINER	$ 173,740.2	$ 237,208.6	$ 177,073.2	$ 499,808.6	$ 480,133.8	$ 202,646.4	$ 278,194.4	$ 38,036.6	$ 649,147.2	$ -	$ 2,735,989.0
5	TOPSOIL	$ 89,365.7	$ 63,683.7	$ 64,004.2	$ 184,719.2	$ 118,970.0	$ 49,350.5	$ 74,842.4	$ 13,472.3	$ 493,288.0	$ 115,500.0	$ 1,267,195.7
6	AQUATIC PLANTING	$ 472,032.3	$ 338,825.9	$ 342,892.6	$ 933,925.1	$ 602,367.0	$ 266,141.5	$ 395,129.8	$ 72,902.2	$2,529,854.0	$ 384,430.0	$ 6,338,500.1
7	PUMPING	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
8	LANDSCAPE	$ 231,298.2	$ 194,699.8	$ 209,559.7	$ 251,872.8	$ 258,668.6	$ 199,507.4	$ 208,475.2	$ 87,354.2	$ 396,902.6	$ 116,062.5	$ 2,154,401.0
9	MISCELLANEOUS	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 70,900.0	$ 60,900.0	$ 141,800.0	$ 64,800.0	$ 763,800.0
10	OTHER	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUB-TOTAL WORKS	$4,552,814.5	$3,404,489.2	$3,428,237.0	$4,613,662.4	$6,157,576.5	$2,302,835.5	$3,425,343.9	$ 557,314.0	$9,139,245.8	$3,589,279.2	$41,170,798.0
11	DELIVERY (inc. 35% contingency)	$2,788,598.9	$2,085,249.6	$2,099,795.2	$2,825,868.2	$3,771,515.6	$1,410,486.7	$2,098,023.1	$ 557,314.0	$5,597,788.1	$2,198,433.5	$25,433,073.0
12	TOTAL ESTIMATED COST	$ 7,341,413	$ 5,489,739	$ 5,528,032	$ 7,439,531	$ 9,929,092	$ 3,713,322	$ 5,523,367	$ 898,669	$ 14,737,034	$ 5,787,713	$66,387,911.8

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 or railway culvert capacity discharge constraints.
- Velocity and sediment capture efficiency calculations
- Earthworks modelling
- Stakeholder feedback on preliminary concept designs.

Ten wetland/retarding basin assets, one waterways, and a sediment basin/retarding basin were developed up:

- WLRB1, outfalling into the Bruce Creek
- WLRB2, outfalling into the Bruce Creek
- WLRB3, outfalling into the Bruce Creek
- WLRB4, outfalling into the railway culvert
- WLRB5, outfalling into the constructed waterway via pipe network
- WLRB6, outfalling into the constructed waterway via pipe network
- WLRB7, outfalling into the constructed waterway
- SBRB8, outfalling into the existing drainage channel
- WL9 (within RB9), outfalling into the waterway
- WL10 (within RB9), outfalling into the waterway
- WL9&10/RB9, outfalling into the railway culverts
- Constructed waterway, outfalling into the railway culvert.

A summary of the assets, land take and cost estimates are provided in Table 32. The land take includes

Table 32. Summary of assets, land take and cost estimates

Asset	Cost (inc. 35% contingency)	Land take (ha)^
WLRB1	$7,341,413	3.17
WLRB2	$5,489,739	2.41
WLRB3	$5,528,032	2.38
WLRB4	$7,439,531	6.36
WLRB5	$9,929,092	4.41
WLRB6	$3,713,322	1.95
WLRB7	$5,523,367	2.81
SBRB8	$898,669	0.63
WL9&10/RB9	$14,737,034	16.06
Constructed waterway*	$5,787,713	3.50

* Corridor area, up to RB9.
^Includes perimeter paths and sediment dewatering areas.

11.1 Next steps

Project next steps are outlined below:

- Refine strategy as per stakeholder input
- Refine modelling, including climate change hydrologic modelling.
- Functional designs (drawings and costings).

12 References

Alluvium (2019). Bannockburn South West precinct – Stormwater Drainage Assessment.

Alluvium (2020). Bannockburn Catchment Assessment.

Cardno (2022). Bannockburn Industrial Estate Infrastructure Servicing Assessment.

Commonwealth of Australia (Geoscience Australia) (2019). Australian Rainfall and Runoff (ARR): A guide to flood estimation

Corangamite CMA (2020). Flood Advice Request – Bannockburn Growth Plan.

EPA Victoria (2021). Urban stormwater management guidelines.

ENSPEC (2021). Arboriculture Assessment - Bannockburn South East PSP.

Local Government Infrastructure Design Association (2022). Infrastructure Design Manual (version 5.40).

Melbourne Water (2005). WSUD Engineering Procedures: Stormwater.

Melbourne Water (2013). Waterway corridors: guidelines for greenfield development areas within the Port Phillip and Westernport Region.

Melbourne Water (2019). Constructed Waterway Design Manual.

Melbourne Water (2020). Wetland Design Manual.

Melbourne Water (2024). MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Guideline.

Spiire (2023). Draft Preliminary IWM issues and opportunities report . Report for VICTORIAN PLANNING AUTHORITY.

Victorian Stormwater Committee (1999). Urban Stormwater - Best Practice Environmental Management Guidelines.

Victorian Planning Authority (2024). Bannockburn South East Precinct Structure Plan Place Based Plan.

Wadawurrung Traditional Owners Aboriginal Corporation (2020). Paleert Tjaara Dja Let's make Country good together 2020-2030 -Wadawurrung Country Plan

WSP (2022). Soil Desktop assessment – Sodic/ Dispersive soils and contamination risk Bannockburn South-East Precinct.

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 40.

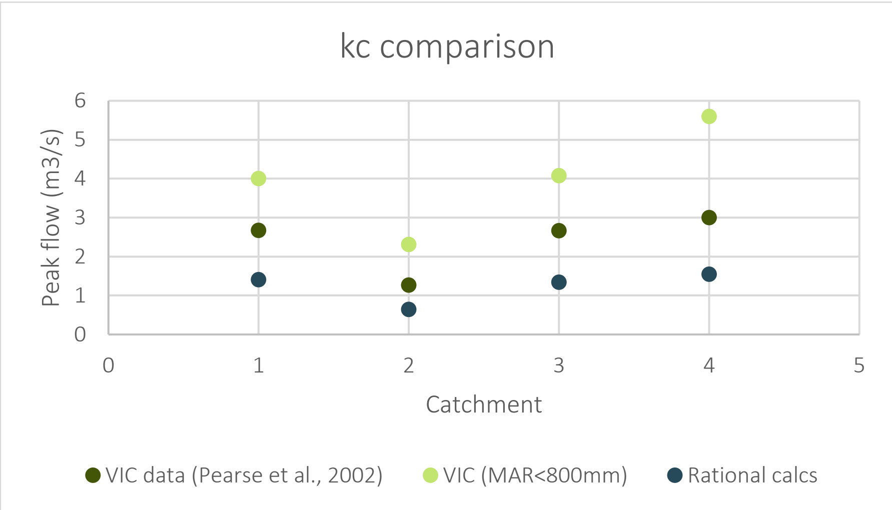


Figure 40. *Results of RORB model with various kc, compared to rational method calculation*

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

RORB models

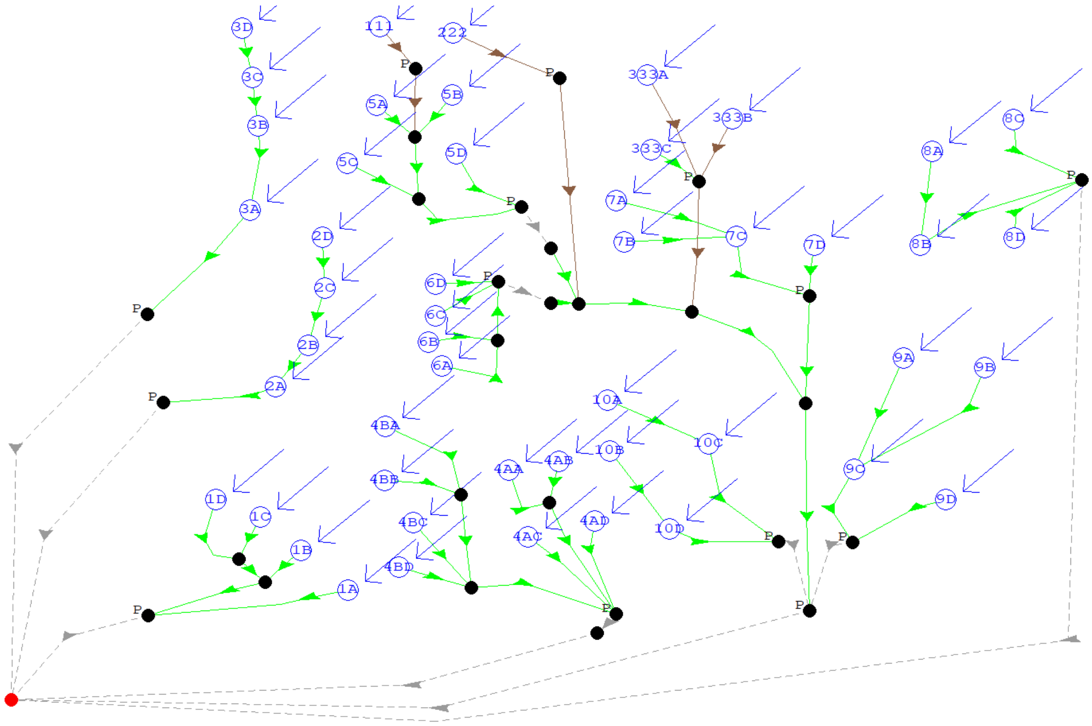


Figure 41. *Existing conditions RORB model*

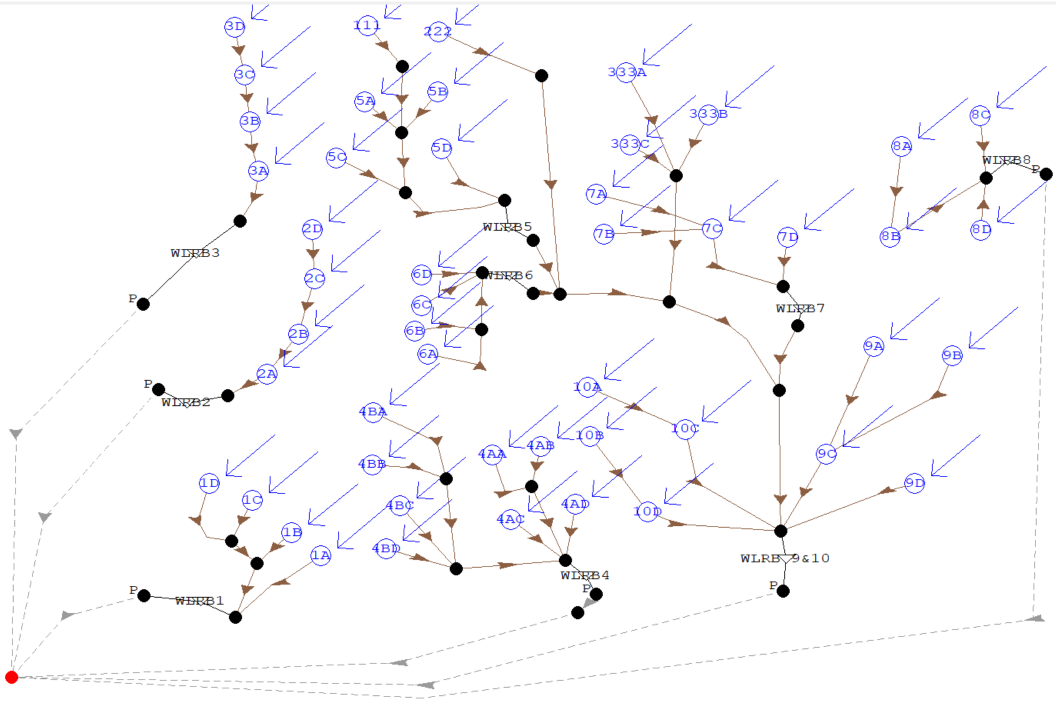


Figure 42. *Developed conditions RORB Model (using Type 2 reaches for establishing 1% AEP flow, storage sizing)*

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 43 outlines the iterative process of sizing the treatment infrastructure in MUSIC.

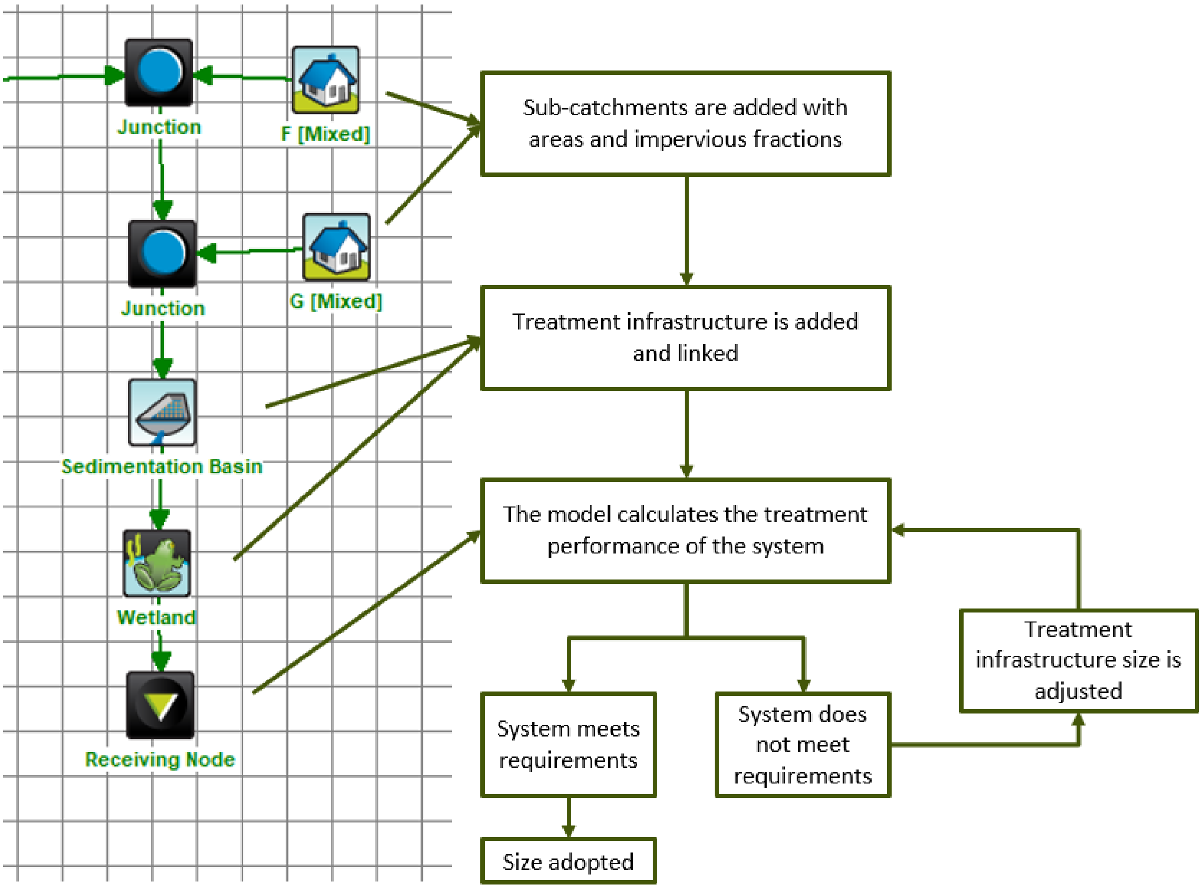


Figure 43. *Simplified MUSIC Method*

Appendix C
Concept designs with draft Place Based Plan

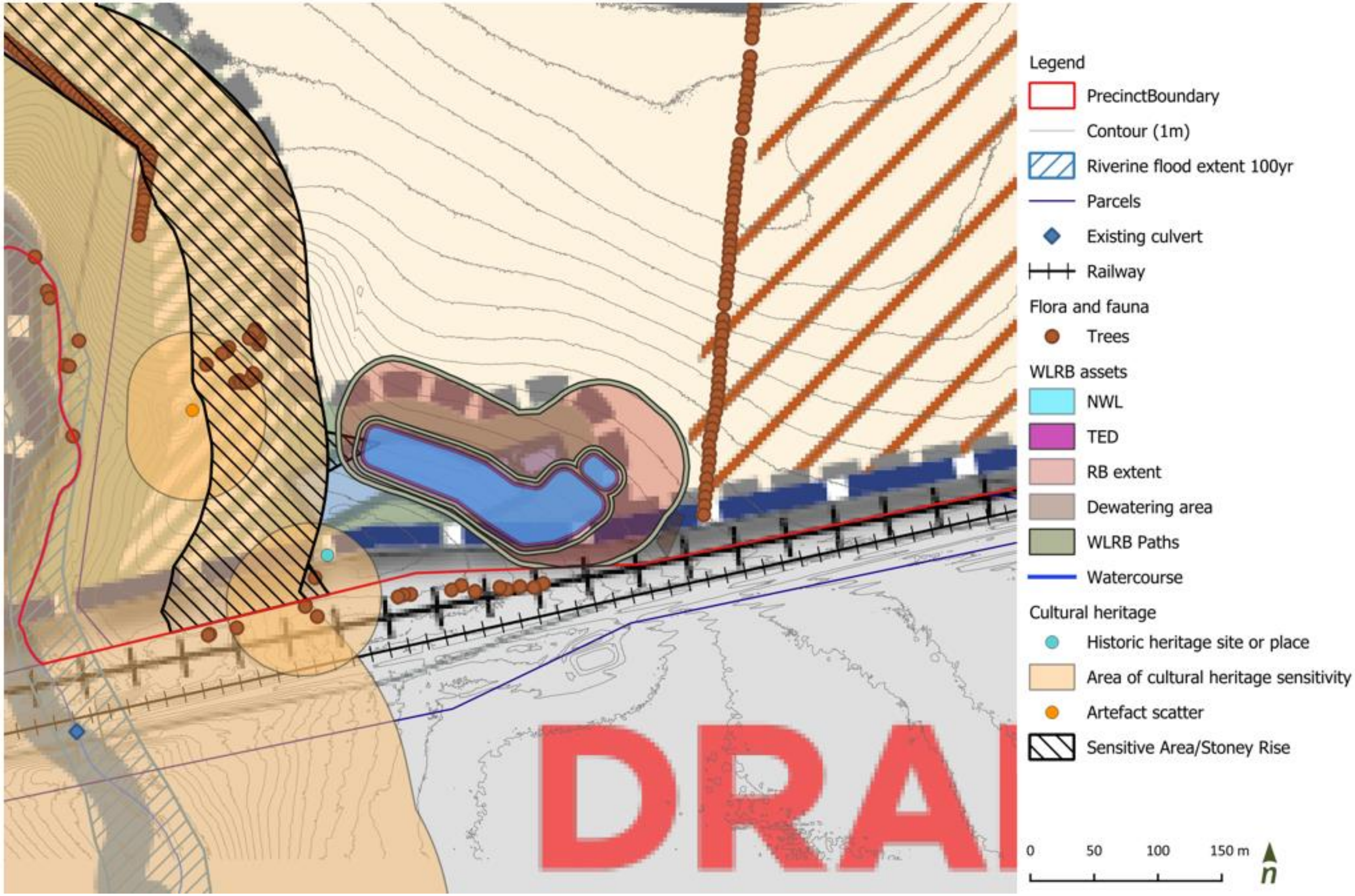


Figure 44. *WLRB 1 Concept Design (including urban layout in background)*

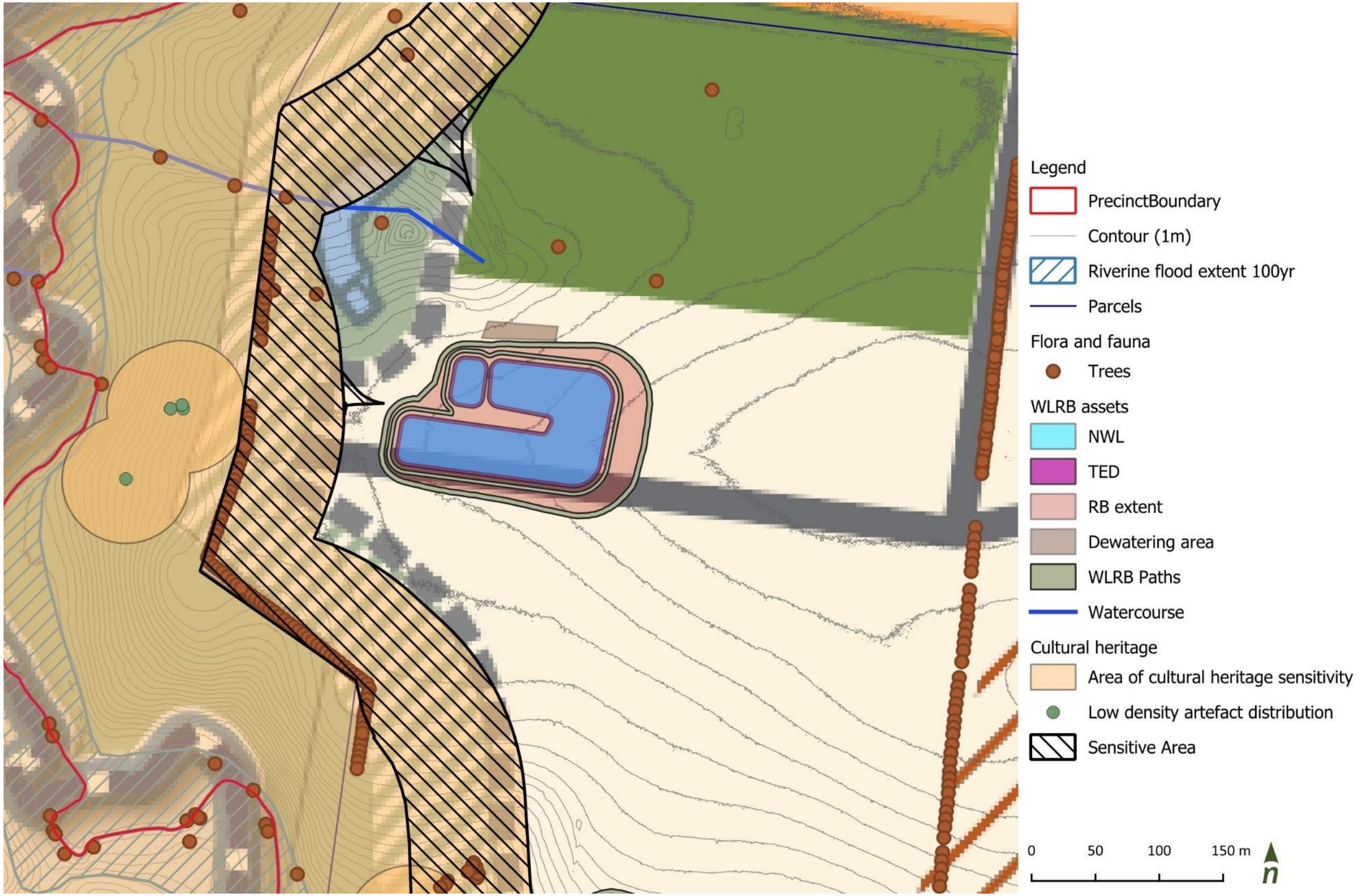


Figure 45. *WLRB 2 Concept Design (including urban layout in background)*

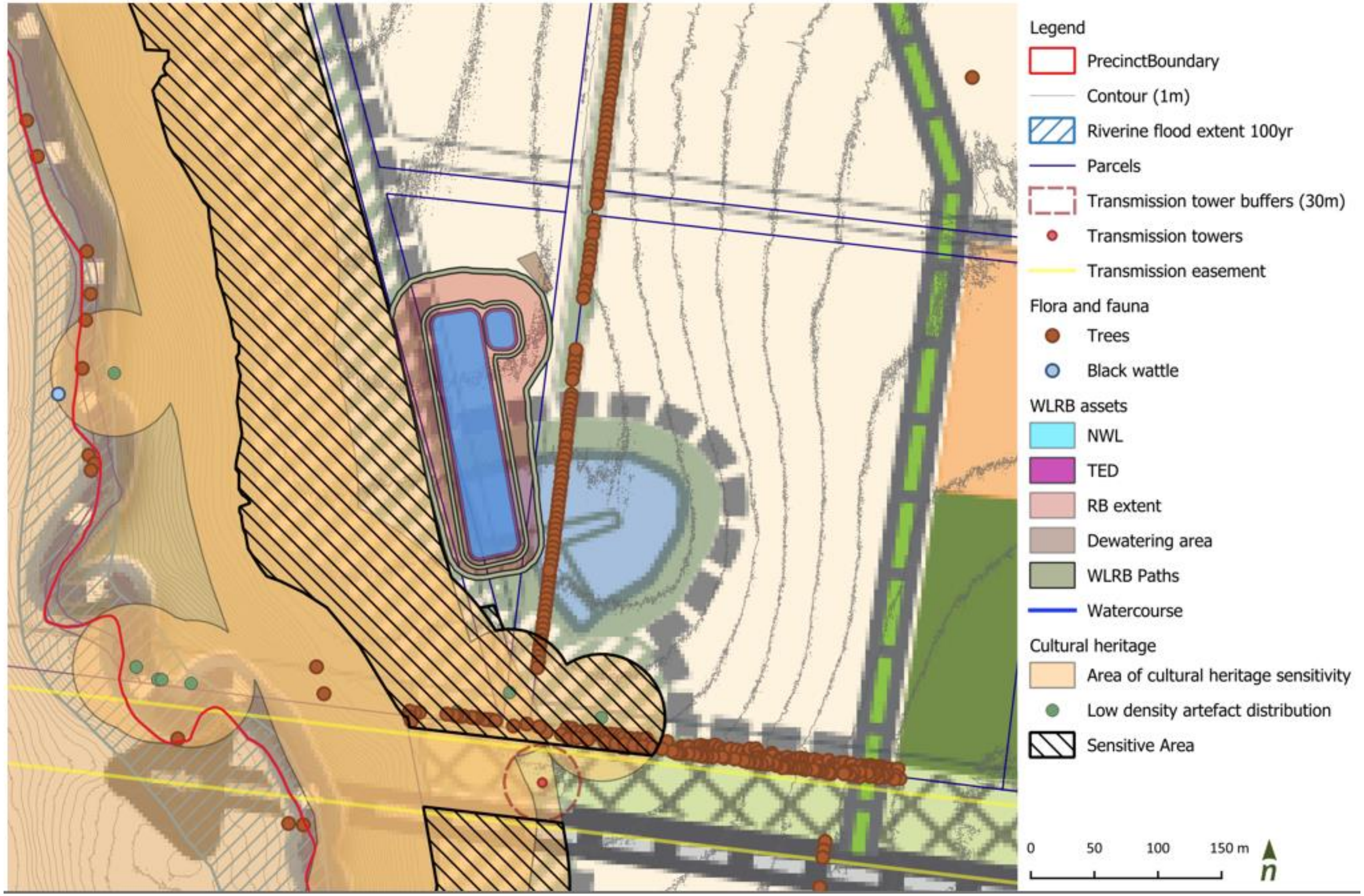


Figure 46. *WLRB 3 Concept Design (including urban layout in background)*

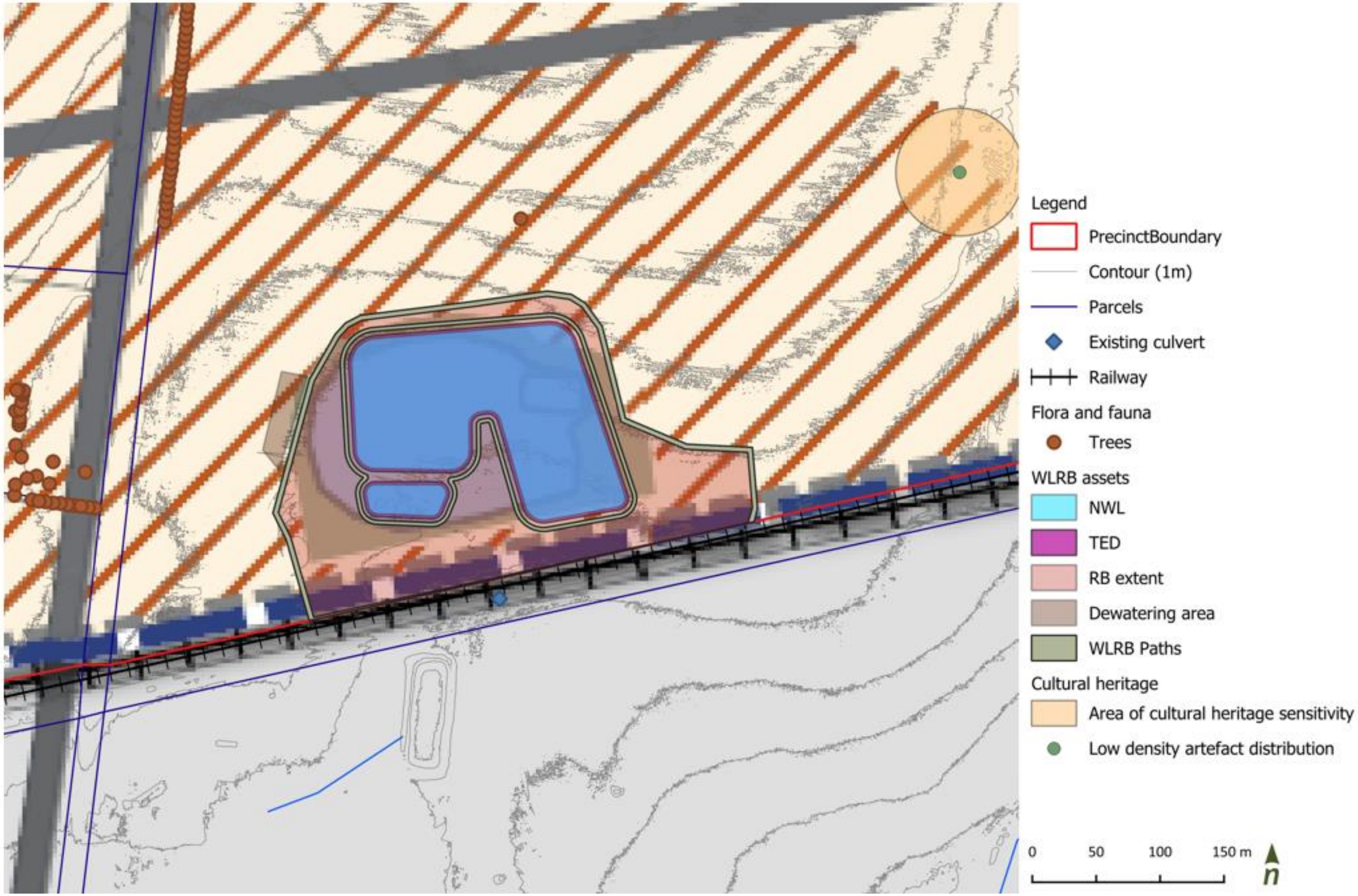


Figure 47. *WLRB 4 Concept Design (including urban layout in background)*

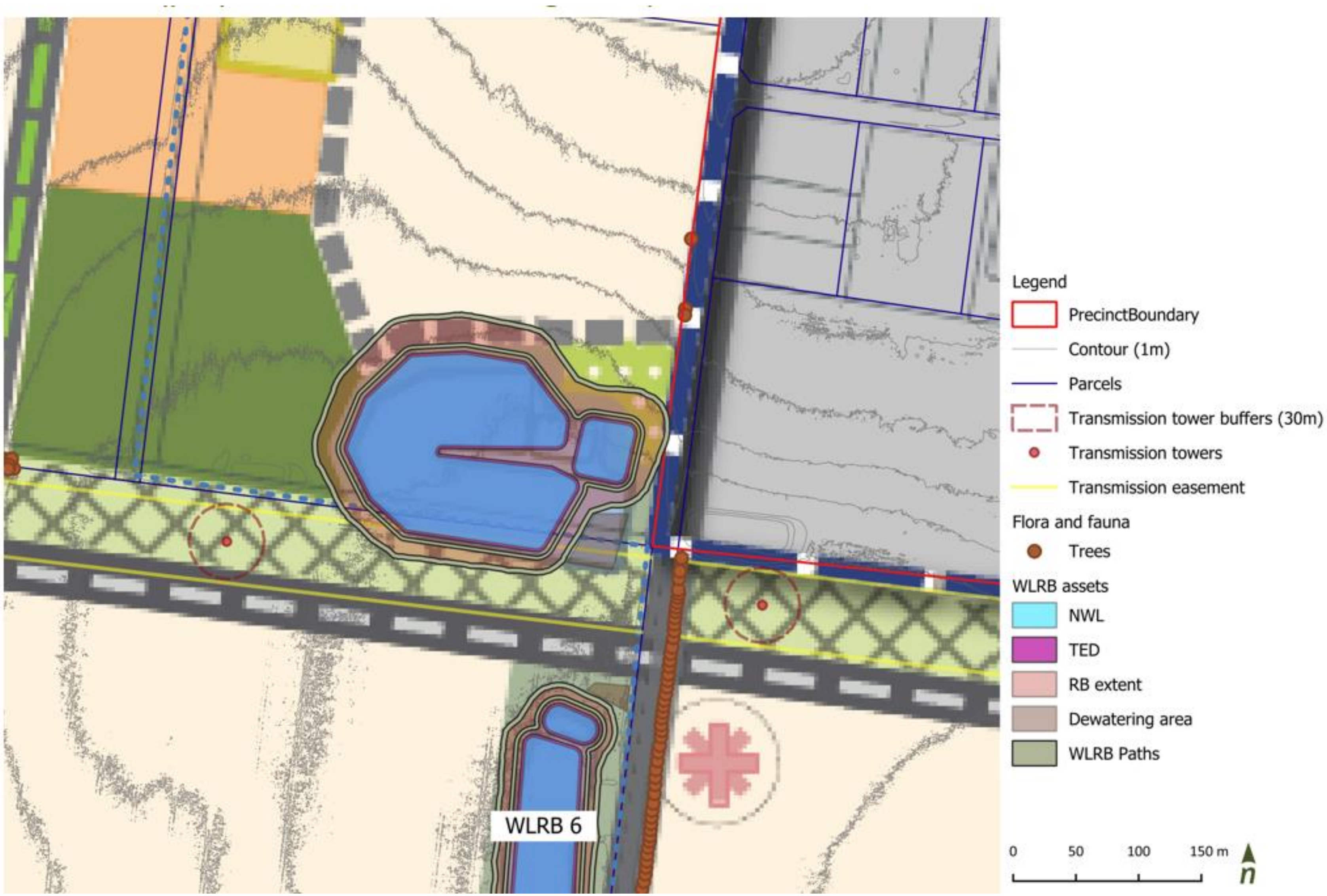


Figure 48. *WLRB 5 Concept Design (including urban layout in background)*

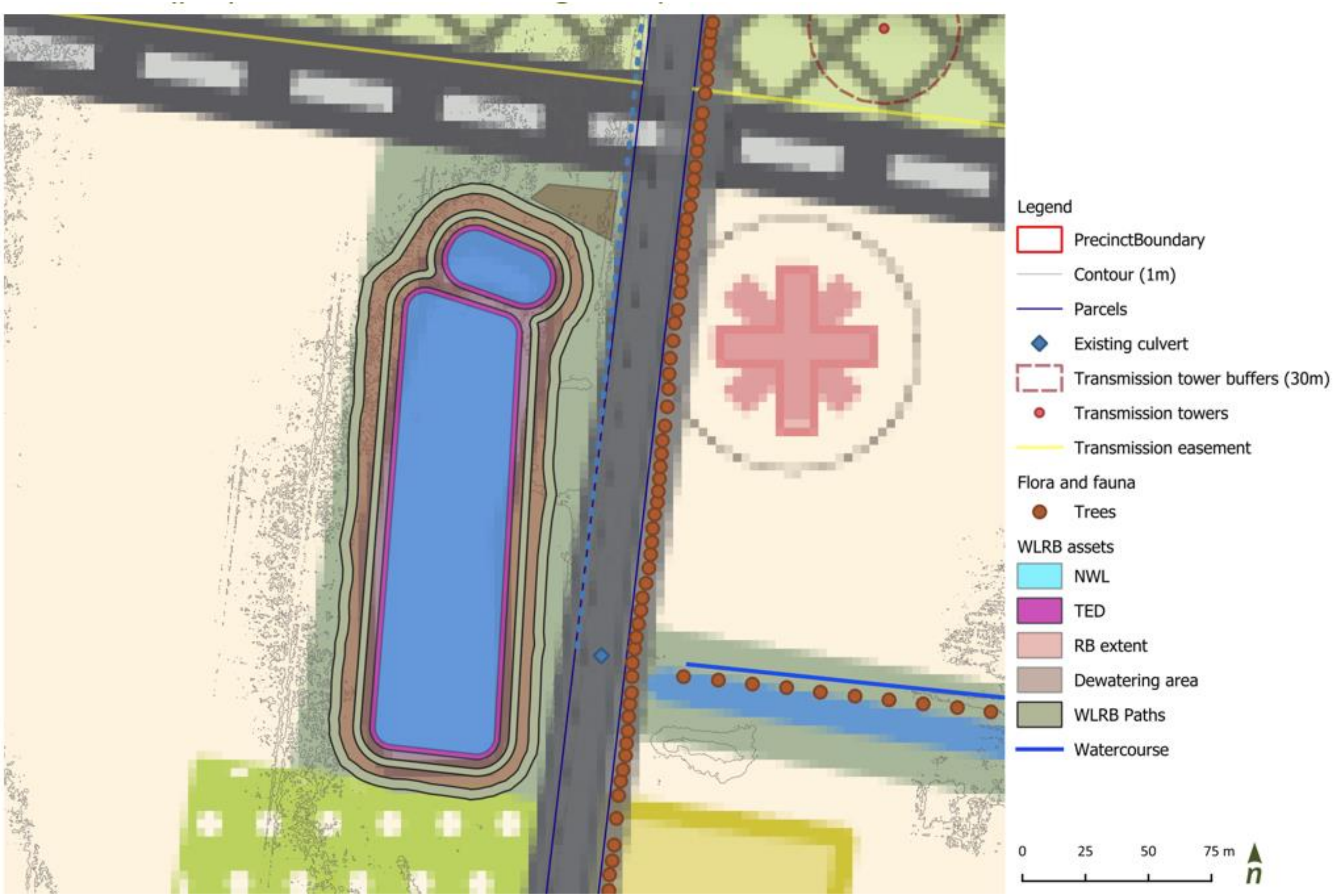


Figure 49. *WLRB 6 Concept Design (including urban layout in background)*

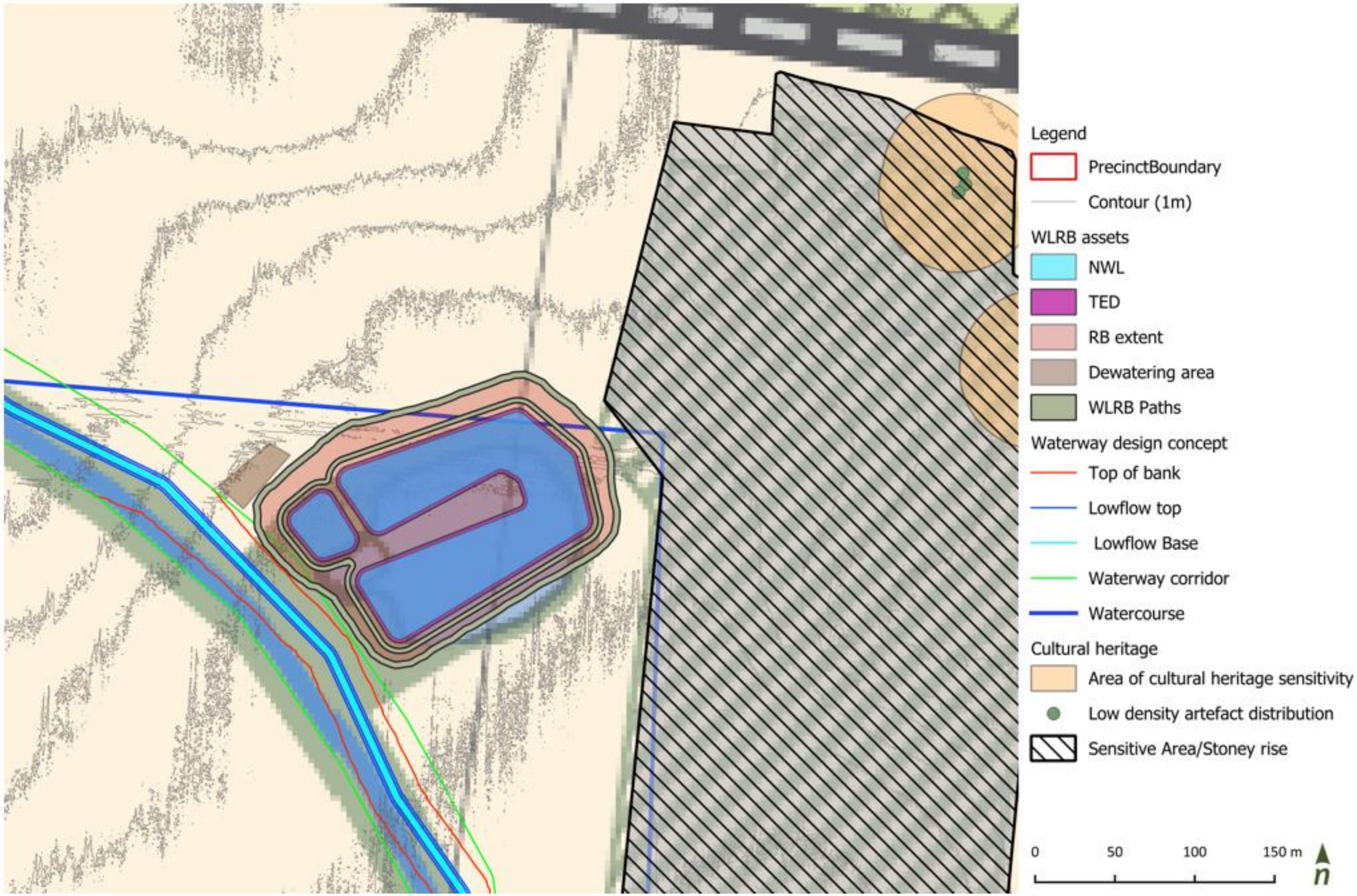


Figure 50. *WLRB 7 Concept Design (including urban layout in background)*

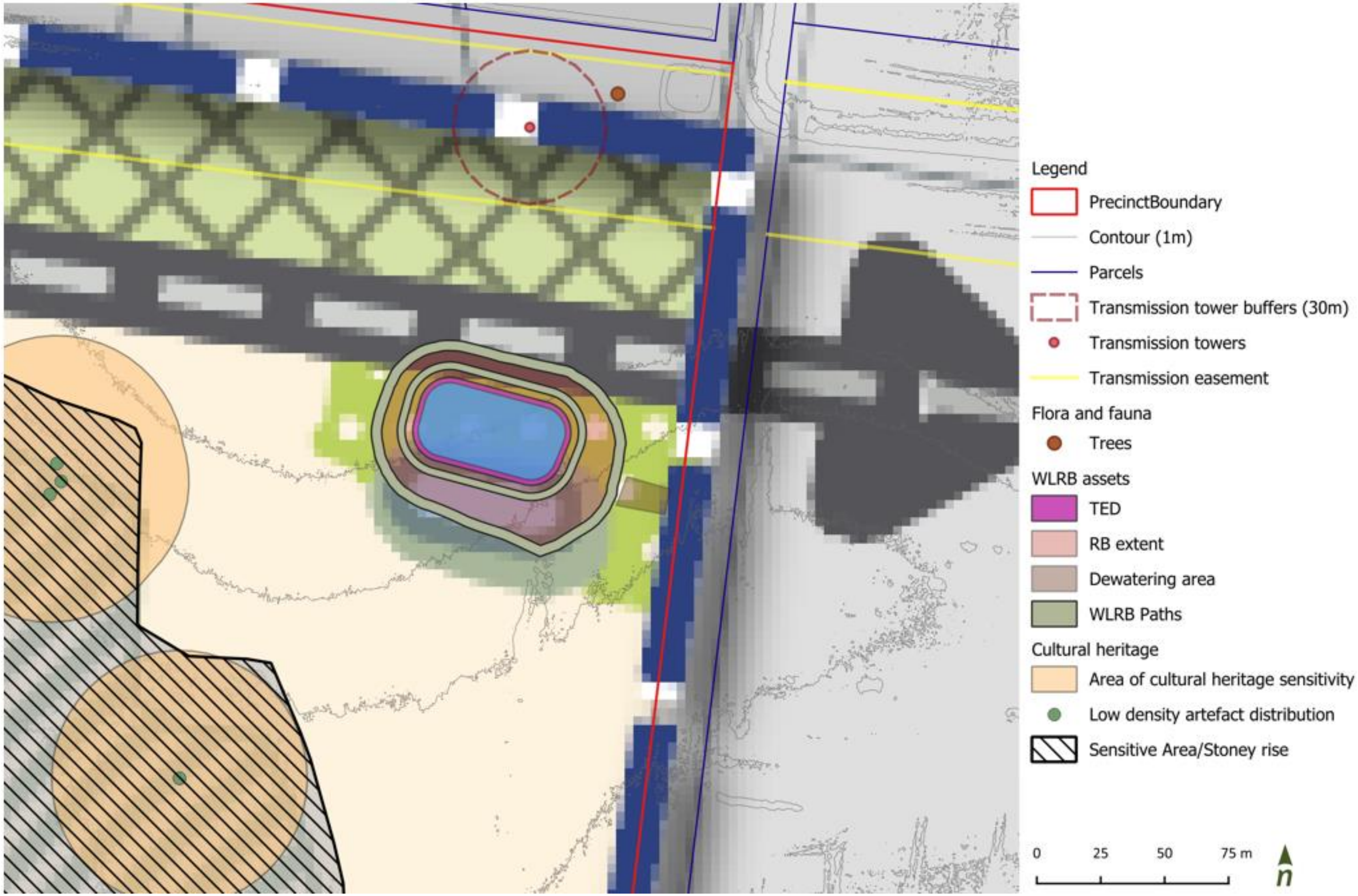


Figure 51. *SBRB 8 Concept Design (including urban layout in background)*

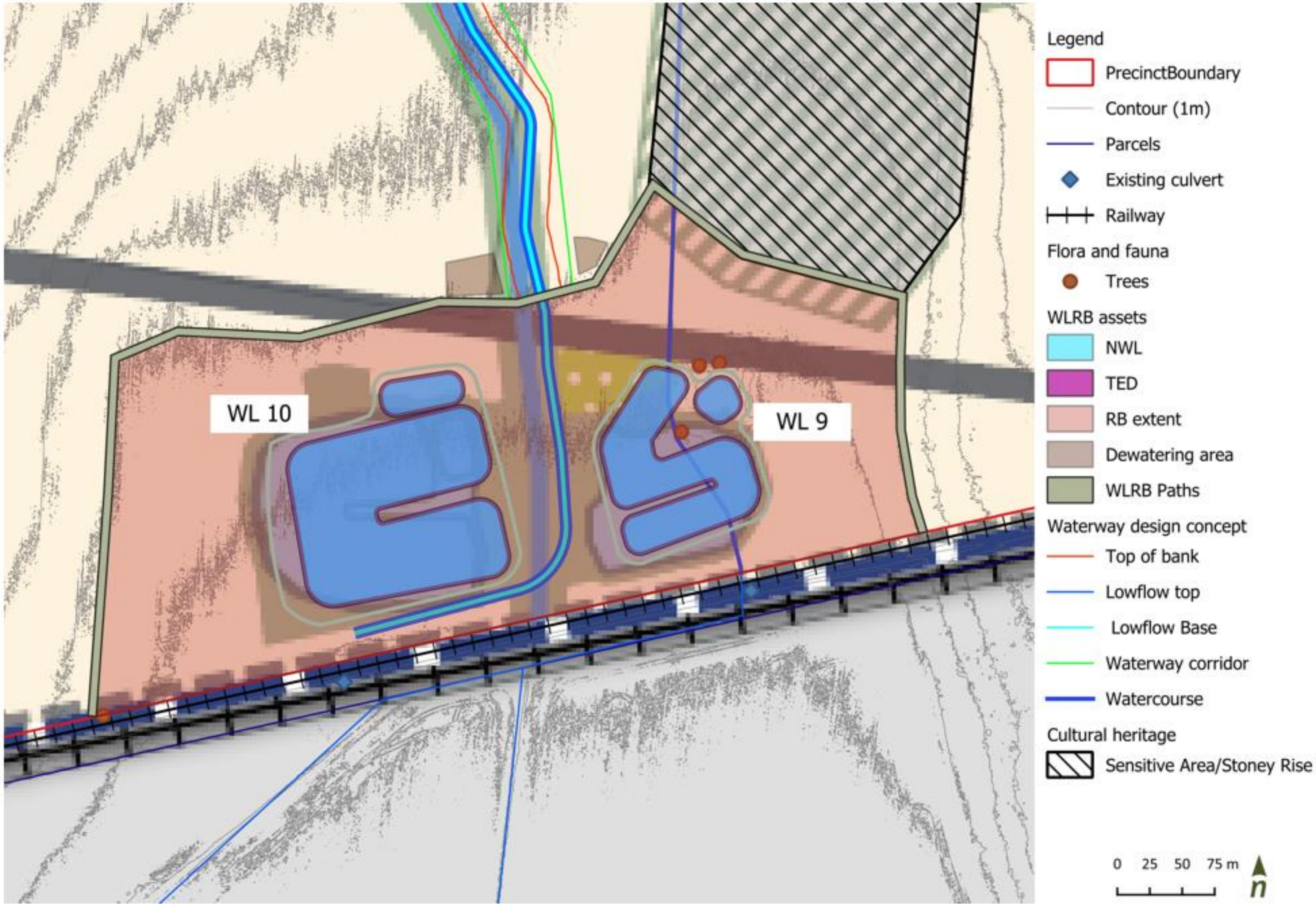


Figure 52. *WL 9, WL 10 and RB 9 Concept Design (including urban layout in background)*